5,000 Years of Aboriginal Land Use in the Western Phoenix Basin

The Luke Air Force Base Solar Project

Volume 2: Analyses and Interpretations

Edited by
Robert M. Wegener and John D. Hall

Statistical Research
Technical Series 95

5,000 Years of Aboriginal Land Use in the Western Phoenix Basin

The Luke Air Force Base Solar Project

Volume 2: Analyses and Interpretations

Edited by
Robert M. Wegener and John D. Hall

With contributions by
Karen R. Adams, Z. Nahide Aydin, Jesse A. M. Ballenger, David E. Doyel,
William M. Graves, Janet L. Griffitts, John D. Hall, Michael P. Heilen,
Jeffrey A. Homburg, Mitchell A. Keur, Eric Eugene Klucas, Stacey Lengyel,
Heather J. Miljour, Amelia M. Natoli, Matthew C. Pailes, M. Steven Shackley,
Susan J. Smith, Karen K. Swope, Rein Vanderpot, Robert M. Wegener,
Jason D. Windingstad, and Atticus W. Zavelle

Statistical Research
Technical Series 95

2017

CONTENTS

Appendixes on CD-ROM

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This document is the second of two volumes and presents the results of analyses and interpretations for the Luke Air Force Base (LAFB) Solar-Power Array Archaeological Data Recovery Project (Luke Solar project). The Luke Solar project was conducted in advance of a planned 107-acre, 17-megawatt solar-power array to be constructed on an undeveloped portion of LAFB, near the town of Glendale, Arizona. This research was carried out for LAFB under Contract No. W9126G-10-D-0023, Task Order 003, sponsored by the U.S. Army Corps of Engineers, Fort Worth District; Aerostar Environmental Services, Inc.; and Statistical Research, Inc. Four prehistoric sites were included in the analyses: Falcon Landing (AZ T:7:419 [ASM]), AZ T:7:68 (ASM), AZ T:7:423 (ASM), and AZ T:7:437 (ASM). AZ T:7:423 (ASM) and AZ T:7:437 (ASM) are located entirely within LAFB property. Falcon Landing and AZ T:7:68 (ASM) both extend beyond the boundaries of LAFB; unknown portions of those sites exist outside the project area and therefore outside the scope of this investigation. In addition, a Historical period site, Rancho La Loma Well (AZ T:7:424 [ASM]) was investigated as part of the Luke Solar project; the results of archival research and field studies for that site were presented in Volume 1 of this series.

A detailed geomorphological analysis of the project area was conducted, including radiocarbon analysis of select features and natural deposits. The geomorphological and radiocarbon analysis allowed for the dating of the natural stratigraphy, and in turn, nearly all the cultural features identified at the project sites were placed into a project geochronology. The project area is characterized as a slowly aggrading lower-*bajada* landscape located in the western Phoenix Basin. The natural sediments within the project area represent late Quaternary alluvial deposition from ephemeral-fan drainage networks originating from the nearby White Tank Mountains, about 7 km to the west. A geologic feature unique to that landscape has been credited as a major factor for the prehistoric occupation of the Luke Solar project area: the Luke Salt Body, a large salt dome buried several hundred feet below the surface, has uplifted the local basin-fill deposits, creating an elevated water table and a possible mesquite bosque immediately south of LAFB. The mesquite bosque would have attracted prehistoric groups to the lower-*bajada* location, where a variety of plant and animal species thrived in an otherwise-poor resource zone. The chapters that follow present the detailed analyses of material culture and ecofacts excavated from the four sites on LAFB. The final chapter of this volume incorporates the information from the analysis chapters and synthesizes the data, using the project research themes.

Over 3,000 features were identified at the four prehistoric sites, about 98 percent of them located at Falcon Landing. As a result, the majority of the analyses and interpretations discussed in this volume focused on Falcon Landing. The features identified at the Luke Solar project sites represented a palimpsest of prehistoric occupation in a lower-*bajada* environment. Feature types included predominantly small, basin-shaped, nonthermal “processing” pits; bell-shaped “storage” pits; thermal “fire” pits; house-in-pit structures; fire-affected-rock concentrations; activity areas; charcoal/ash lenses; middens; and a possible reservoir. Cultural components represented in the project area included Early, Middle, and Late Archaic period; Early Ceramic period; Hohokam; and Protohistoric period occupations. The most intense occupation of the project area began during the Chiricahua phase of the Middle Archaic period (ca. 3500–1200 B.C.), followed by the San Pedro (ca. 1200–800 B.C.) and Cienega (ca. 800 B.C.–A.D. 50) phases of the Late Archaic period and the Red Mountain phase (ca. A.D. 50–400) of the Early Ceramic period. In general, these occupations were characterized by residential groups who visited the project area intermittently during the spring and summer months for the procurement and processing of wild-plant resources, particularly mesquite. Later, Hohokam and Protohistoric period or Historical period Native American occupations of the project area were much less intense than earlier, Archaic period occupations and likely represented logistical task groups who visited the project area for similar plant-food-processing activities. The nearby Agua Fria River, about 5 km east of the

project area, represents a nearly inexhaustible supply of raw lithic materials, particularly volcanic materials, such as rhyolite and basalt. These materials were imported to the project area for use in a specialized ground stone technology, as well as for the manufacture of bifacial tools. Many of the ground stone tools were left in place or cached for anticipated reuse. Interestingly, the bifacial tools were not regularly used or left within the project area but were likely maintained in the project area and transported elsewhere, in anticipation of hunting and animal processing. Animal-resource procurement and processing within the project area was likely an outcome of opportunistic encounters and was clearly a secondary activity that was focused almost exclusively on leporids and other rabbit-sized mammals. The processing of mesquite and other wild-plant food has been identified as the main subsistence pursuit at the Luke Solar project sites; it was an embedded activity with an associated stone-artifact technology that persisted relatively unchanged for nearly 5,000 years.

The results of this volume indicate that Falcon Landing represents the largest Middle and Late Archaic period site in southern Arizona investigated to date. Archaic period groups in the western Phoenix Basin were attracted to the location, visiting the site for mesquite processing as part of their seasonal round between upland and lowland environmental zones. Over time, the Hohokam culture emerged in southern Arizona, distinguished by elaborate material culture, monumental architecture, and a reliance on agriculture, including the largest prehistoric irrigation network known in North America. During that cultural and economic development, the activities at Falcon Landing remained unchanged. Although the intensity of occupation at Falcon Landing significantly declined during the Hohokam pre-Classic period, the technology and methods for processing mesquite persisted over millennia. In fact, ethnographic accounts have shown that the mesquite-processing technology identified at Falcon Landing as early as 3300 B.C. continued to be used by contemporary Native American groups, such as the Piman and Yuman people of southern Arizona, southern California, and northwestern Mexico.

ACKNOWLEDGMENTS

The Luke Air Force Base Solar-Power Array Archaeological Data Recovery Project (Luke Solar project) was a monumental effort that involved many individuals and several government agencies. Without the concerted efforts of these people, the project would not have been a success. We would like to take this opportunity to extend our thanks to this extraordinary team.

The Luke Solar project was located on Luke Air Force Base (LAFB) and was therefore under the direct supervision of Mr. Jeff Rothrock, U.S. Air Force Air Education and Training Command, 56th Civil Engineer Squadron Natural Resources Management. In coordination with LAFB, the Arizona Public Service Company (APS) planned the development and construction of the solar-power-array, and Mr. Jon Shumaker, APS archaeologist, was instrumental to the project's success. Jon tirelessly and expertly supported the successful completion of all needed Section 106 consultation requirements. As such, Jon was also instrumental in guiding the project scoping and resolving numerous complex challenges. He was an invaluable asset and team member. Many of the project's successes are undoubtedly a direct result of his unwavering dedication.

Multiple contracts through multiple organizations supported the Luke Solar project. Weston Solutions, Inc., held the initial contract with LAFB for Phase 1 testing, and the work of Mr. Rick Logsdon, Mr. Michael Barone, and Mr. Robert Pozorski helped obtain and implement the Storm Water Pollution Prevention Plan (SWPPP) and dust-control permits throughout the course of the project. For the first phase of data recovery, Statistical Research, Inc. (SRI), maintained a contract with LAFB under the direction of Mr. Rothrock. Aerostar Environmental Services, Inc. (Aerostar), was contracted through the U.S. Army Corps of Engineers (USACE), Fort Worth District, to complete the second phase of data recovery as well as this volume. Mr. Jay Newman was the contracting officer's representative and point of contact for the USACE, and Ms. Tiffany Seibt was the Aerostar project manager. Mr. Rothrock, Mr. Newman, and Ms. Seibt worked tirelessly to keep the project moving, from a contract-management perspective. We also wish to thank Ms. Ann Howard and Ms. Kris Dobschuetz from the Arizona State Historic Preservation Office for reviewing the Historic Properties Treatment Plan (HPTP) as well as participating in multiple consultations that helped to structure the project approach.

We extend our sincere gratitude to the members of the Salt River Pima-Maricopa Indian Community (SRPMIC), the Gila River Indian Community (GRIC), the Tohono O'odham Nation (TON), the Ak-Chin Indian Community, the Fort McDowell Yavapai Nation, the Yavapai-Apache Nation, the Yavapai-Prescott Indian Tribe, and the Colorado River Indian Tribes for their cooperation and assistance throughout the entire project. Tribal representatives who visited the project area, examined the treatment plan and excavations, and provided their important insights included Mr. Shane Antone, Ms. Angela Garcia-Lewis, Mr. Jacob Butler, and Mr. Thomas Wright of the SRPMIC; Mr. Barnaby Lewis, Ms. Semana Thompson, and Mr. Larry Benallie of the GRIC; Mr. Joseph Joaquin of the TON; Ms. Caroline Antone of the Ak-Chin Indian Community; and Mr. Scott Kwiatkowski of the Yavapai-Prescott Indian Tribe. Thanks especially to Mr. Lewis and Ms. Thompson, who visited the project to perform blessings of the burial feature.

The enormous number of buried features uncovered during the Luke Solar project required a significant amount of heavy machinery. The initial test trenching and SWPPP installation was performed by Red J Environmental Corp. The remainder of the testing and data recovery phases, including the mechanical stripping of more than 45 acres, was mightily executed by Casey's Backhoe Service, operated by Mr. Keith Tanko. Mr. David Thompson ran one of the trackhoes for the entire project, and Mr. Greg Albertson ran the second trackhoe for the last phase of data recovery. Mr. Roger Lane, Mr. Kenneth Hogan, and Mr. Mark Kear ran backhoes intermittently throughout the project. Mr. Kevin Delaney, Mr. Steve Desautel, Mr. Kear, Mr. David Lambert, and Mr. Scott Hilliard ran front-end loaders nonstop, to keep the trackhoes moving, as well as water trucks to comply with the dust-control permits. The quality of the work performed by Casey's Backhoe Service cannot be overemphasized.

The importance of the Luke Solar project is evidenced in the number of people who contributed to this long and complicated undertaking. Successfully navigating a project of this magnitude required the talents of many. Dr. Jeffrey H. Altschul, SRI's cofounder and principal, worked closely with the project staff to help guide us through a complex contractual and regulatory environment. Dr. Teresita Majewski, SRI's Vice President, supported SRI Principal Investigator Mr. Robert Wegener in the management of the Air Force, Aerostar, and Weston Solutions, Inc., contracts. All day-to-day aspects of the Luke Solar project were directly supervised by Mr. Robert M. Wegener, who served as principal investigator through the entirety of the project. Mr. Wegener was supported by Mr. John D. Hall, who served as senior project director in all stages of research, from developing the testing and data recovery plans and directing all phases of fieldwork to preparing this volume. Mr. Hall was assisted in these tasks by two co-project directors, Mr. Mitchell A. Keur and Dr. Jesse A. M. Ballenger. Both Mr. Keur and Dr. Ballenger were instrumental in maintaining the project momentum and coordinating the multitude of tasks required to run a large project. Mr. Hall, Mr. Keur, and Dr. Ballenger had much help from assistant project directors Ms. Heather J. Miljour, Ms. Amelia M. Natoli, Mr. James Marsh, and Mr. Steven Ditschler. Ms. Natoli spent many months supervising the mechanical excavations, which ultimately led to uncovering nearly 46 acres of cultural resources and more than 3,000 features. Ms. Natoli had help from several other archaeological monitors, including Mr. Marsh, Mr. Ditschler, Mr. Jeffrey Charest, Ms. Jessica South, Ms. Cannon Daughtrey, Dr. Ballenger, and Mr. Wegener. Ms. Miljour kept a constant vigil over the feature excavations and field paperwork, ensuring consistent and quality work during all stages of fieldwork. Ms. Karry Blake also provided assistance to the field team from SRI's Tucson office. Ms. Miljour and Ms. Natoli also had the support of several assistant crew chiefs over the course of fieldwork, including Mr. Charest, Ms. Daughtrey, Ms. Lauren Jelinek, Ms. Dorothy Ohman, Mr. Donovan Quam, Ms. South, and Ms. Meaghan Trowbridge. The efforts of these assistant crew chiefs were vital to the field effort; they assigned provenience numbers and supervised the feature excavations.

The individuals who labored through the heat and cold of the Sonoran Desert, as well as under the ever-present roar of F-16 Fighting Falcon jet engines, are particularly deserving of praise for doing such an excellent job during the field effort. As the challenging pace and schedule of the Luke Solar project evolved, the crew responded with the utmost diligence. They include Ms. Shannon Acothley, Mr. Franco Boggle, Mr. Blayne Brown, Mr. Tanachy Bruhns, Mr. Peter Byler, Dr. Janet Griffitts, Mr. Nicholas Hlatky, Dr. Jeffrey Homburg, Mr. Brian Medchill, Mr. Brandon McIntosh, Mr. Geoff Morley, Ms. Ashley Morton, Ms. Bonnie Regenhardt, Mr. Justin Rego, Ms. Rachelle Robinson, Mr. Robert "Reuven" Sinensky, Mr. George Tinseth, Mr. David Unruh, Mr. William A. White III, and Mr. William G. White. During the second phase of data recovery, several Aerostar crew members joined the effort, including Mr. Christopher Ferguson, Mr. Patrick McDermott, Ms. Kathy Mowrer, Mr. Jonathan Paklaian, and Mr. William Turpin, as well as Aerostar's technical representative in the field, Ms. Marilyn Hess. Mr. Jason Windingstad, SRI's geomorphologist, spent many weeks investigating the site soils and stratigraphy. The geologic model developed by Mr. Windingstad is one of the most important contributions to this project and helped place nearly 3,000 features into chronologic groups. Mr. Windingstad was aided in this effort by Dr. Homburg, Dr. Ballenger, and Dr. Stacey Lengyel. Archaeomagnetic samples were collected in the field by Mr. Charest, Ms. Miljour, and Ms. Ohman, under the guidance of Dr. Lengyel. Mr. Scott Thompson, head of SRI's Historic Program, conducted archival research for the historical component of the project, including Rancho La Loma Well, and Dr. Karen Swope analyzed the Historical period materials from the project sites.

Over the course of the long field effort, numerous individuals visited the site and provided both labor and their expertise in southwestern archaeology. These individuals include Dr. Karen Adams, Dr. Richard Ciolek-Torello, Dr. John Douglass, Dr. David Doyel, Dr. William Graves, Dr. Donn Grenda, Dr. Bruce Huckell, Dr. Edgar Huber, Dr. Eric Klucas, Dr. Jonathan Mabry, Ms. Adrianne Rankin, Dr. Seetha Reddy, Ms. Susan Smith, and Dr. Bradley Vierra. The insights and analyses provided by those in this impressive list of experts have greatly increased our understanding of this important project. In particular, the authors would like to thank Dr. Huckell, Dr. Mabry, and Mr. Ben Resnick who served as the project peer review panel. Their comments for this volume were very beneficial and much appreciated. Dr. Ciolek-Torello, SRI's Research Director, also provided an internal review of the first draft of this volume and offered many helpful comments.

The project maps and cartographic data were generated by Ms. Z. Nahide Aydin, Dr. Stephen McElroy, Mr. Daniel Perez, Ms. Rita Sulkosky, Ms. Meredith Wismer-Lanoë, and Mr. Atticus Zavelle. Mr. Jim Lofaro, Mr. Carey Tilden, and Mr. James Bayer created and updated SRI's intricate database, responding to the ever-changing demands of analysts, authors, and curation staff.

Many individuals were involved with laboratory processing and initial curation preparation. These individuals included Ms. Jody Holmes, Ms. Olivia Charest, Mr. Hlatky, Ms. Ohman, Ms. Erica Young, and Aerostar laboratory technicians Ms. Rachel Hessick and Ms. Ginger Thompson. Special thanks go to Ms. Holmes for obtaining the necessary permits, supervising the laboratory and curation effort, and negotiating the curation process with LAFB.

Ms. Maria Molina coordinated all the production efforts for the HPTP and the preliminary reports, as well as this volume. Ms. Molina was ably assisted by Mr. John Cafiero. Ms. Jacquelyn Dominguez, Mr. Andrew Saiz, Mr. Luke Wisner, and Ms. Peg Robbins produced many of the excellent report illustrations, formatted the digital photographs, and scanned the original field maps. Ms. Beth Bishop and Mr. Grant Klein edited the draft version of this volume. Mr. Jason Pitts, Ms. Linda Wooden, and Ms. KeAndra Begay assisted with the layout of the text and tables. Ms. April Moles, Ms. Cory McKean, and Ms. Sandra Lindblad also provided vital administrative assistance for the project.

Ms. Janet Grenda and Ms. Nicole Torstvet provided administrative support during the course of this project. They assisted the principal investigator in preparing budgets for each phase of the work and prepared timely and accurate financial statements to help us manage the project. Ms. Trish Craig and Ms. Kelly Davern in SRI's Human Resources department also greatly contributed to the success of the project and the well-being of SRI's personnel.

Finally, we extend our sincere appreciation to all those associated with this project, and we apologize to any that we may have inadvertently omitted.

CHAPTER 1

Introduction

John D. Hall

This document is the second of two volumes reporting the results of the Luke Air Force Base Solar-Power Array Archaeological Project (Luke Solar project). The Luke Solar project was a multiphase data recovery project conducted by Statistical Research, Inc. (SRI) on Luke Air Force Base (LAFB). LAFB is located in the western Phoenix Basin, surrounded by the town of Glendale, Arizona. The Luke Solar project was conducted in support of a proposed 107-acre solar-power array planned for construction on LAFB. The 107-acre area of potential effect (APE) was the focus of SRI's investigations (Figure 1). The APE is divided by Strike Eagle Street; the 42-acre portion north of Strike Eagle Street was designated Area A, and the 65-acre portion south of Strike Eagle Street was designated Area B (see Figure 1). Volume 1 of this series presents the Luke Solar project background, the natural and cultural setting, history of previous research, the project research design, as well as descriptions of all the sites and features investigated as part of this project. The following chapters of Volume 2 present the results of the artifact and ecofact analyses conducted for the Luke Solar project, as well as interpretations of the project data and how these data help to answer the research questions presented in Volume 1.

Project Summary

In September of 2010, SRI, in consultation with LAFB and the Arizona State Historical Preservation Office (AZSHPO), obtained Arizona State Museum (ASM) site numbers for five previously recorded archaeological sites within the current APE that were previously identified with a "Luke 03A" prefix, originally recorded by Tagg (2008) and Tagg et al. (2007) (Table 1). These sites are AZ T:7:419 (ASM), AZ T:7:420 (ASM), AZ T:7:421 (ASM), AZ T:7:422 (ASM), and AZ T:7:423 (ASM). The project area had been previously surveyed by Adams (1991) and Slawson and Maldonado (1990), and Adams (1991) had identified a single site, AZ T:7:68 (ASM). With the exception of its extreme-northern portion, AZ T:7:68 (ASM) is located south of the current Luke Solar project APE (see Chapter 5, Volume 1). During Phase 1, SRI obtained another ASM site number, AZ T:7:424 (ASM), for the Historical period well and water-conveyance system associated with the Rancho La Loma residence. This Historical period site, named Rancho La Loma Well, is located outside the project area (see Chapter 8, Volume 1), but portions of the water-conveyance system associated with the well traverse the project APE. In the remainder of this volume, site numbers are abbreviated using only the final set of digits of the ASM site designations. For example, AZ T:7:68 (ASM) is referred to hereafter as Site 68.

Table 1. Luke Solar Site Number Concordance

Luke Site No.	ASM Site No.
Luke 03A-02	AZ T:7:419 (ASM)
Luke 03A-03	AZ T:7:420 (ASM)
Luke 03A-04	AZ T:7:421 (ASM)
Luke 03A-05	AZ T:7:422 (ASM)
Luke 03A-06	AZ T:7:423 (ASM)
La Loma Well	AZ T:7:424 (ASM)

Between November 3 and December 2, 2010, SRI conducted Phase 1 archaeological investigations in the Luke Solar project area. The Phase 1 investigations included the survey and reevaluation of each site and its boundary; the identification of all surface features; and locating, mapping, and collecting all surface artifacts at Sites 68, 419, 420, 421, 422, and 423 within the project APE. Following the surface artifact collection, 45 backhoe trenches, totaling 3,180 m,

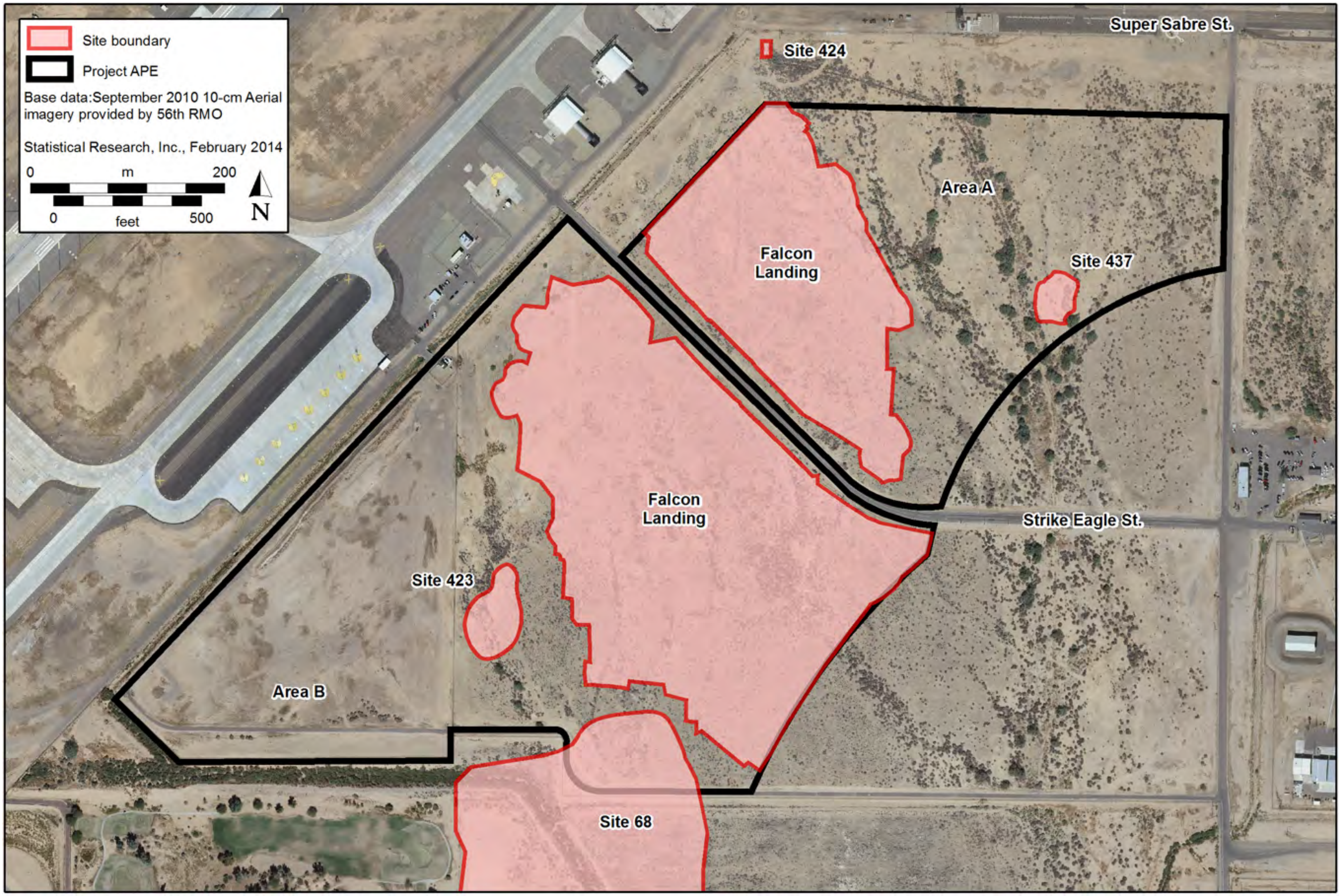


Figure 1. Overview of the Luke Solar Project APE showing Falcon Landing (AZ T:7:419 [ASM]), AZ T:7:68 (ASM), AZ T:7:423 (ASM), AZ T:7:437 (ASM), and Rancho La Loma Well (AZ T:7:424 [ASM]).

were excavated among all six archaeological sites. A limited amount of mechanical stripping was also conducted at Sites 419, 421, and 422, totaling about 2 acres (Figure 2). Additionally, the La Loma Well (Site 424) was documented via archival research and field recordation.

An additional intersite testing program for those areas between previously defined archaeological site boundaries within the project APE was conducted between May 23 and June 9, 2011 (Hall and Wegener 2011). This intersite testing consisted of an additional 83 backhoe trenches, totaling 2,166 m, placed outside of previously recorded site boundaries and distributed evenly throughout the APE (Figure 3). A new archaeological site, AZ T:7:437 (ASM), was identified as a result of the intersite trenching; this site was located across a small drainage to the east of Site 419 (see Figure 1). Based on the results of SRI's Phase 1 investigations and intersite testing (discussed in Chapter 4, Volume 1), Sites 419, 420, 421, and 422 were combined into one large prehistoric site, named AZ T:7:419 (ASM).

On September 19, 2011, SRI began Phase 2 data recovery on the Luke Solar project. The data recovery phase consisted of large-scale mechanical stripping and intensive excavation of features. On February 9, 2012, the project was temporarily suspended because of the expiration of the contract with LAFB. SRI resumed data recovery efforts on November 5, 2012, as a subconsultant to Aerostar Environmental Services, Inc. (Aerostar), and this work concluded on April 25, 2013. At the conclusion of Phase 2 data recovery, SRI successfully completed the archaeological field investigations of Sites 68, 419, 423, 424, and 437 (Table 2 and Figure 4). As a part of our subsequent analysis and reporting, Site 419 was given the name Falcon Landing.

Falcon Landing (AZ T:7:419 [ASM])

Falcon Landing is an extensive, multicomponent prehistoric and Historical period site. The portion of Falcon Landing preserved within the APE consisted of ca. 44 contiguous acres of buried cultural resources (see Chapter 4, Volume 1). About 98 percent of the features identified and artifacts collected during the Luke Solar project came from Falcon Landing. As a result, Falcon Landing is the main focus of both Volumes 1 and 2. A total of 3,006 cultural features were identified at Falcon Landing (see Table 2), including 48 structures and possible structures, 14 activity areas (including 1 activity surface), 2,738 extramural pits, 19 caches, 65 charcoal/ash lenses, 109 FAR concentrations, 9 postholes, 2 middens, a possible reservoir, and a human burial (see Chapter 4, Volume 1).

The vast majority of features at Falcon Landing were assigned to chronological groups based on a relatively limited number of radiocarbon dates as well as the natural stratigraphy of the site. Dating the natural stratigraphy involved a complex sequence of analyzing the radiocarbon dates from feature and nonfeature contexts, coupled with correlating the sequences of deposition across the APE. The resulting geochronology allowed for the assignment of nearly every feature at Falcon Landing to a chronologic group (see Chapter 2), totaling 33 chronologic groups (Table 3) (see discussion below). The chronologic groups correspond to the cultural history defined in Chapter 2 of Volume 1, including the Cochise cultural sequence developed by Sayles and Antevs (1941) for the Archaic-aged features and the sequence developed by Dean (1991) for the Hohokam Ceramic period occupation of the project area. Hundreds of features at Falcon Landing were assigned to particular cultural phases and therefore could be used to analyze contemporaneous feature groups and associated material culture in the following chapters.

Spatial and temporal analyses of Falcon Landing revealed that discrete clusters of spatially associated and likely contemporaneous features were located throughout the site (see Chapter 10). Important chronologic groups represented by multiple features included the Chiricahua, San Pedro, Cienega, and Red Mountain phases. The presence of numerous contemporaneous features belonging to these chronologic groups indicated a continuity of occupation from the Middle Archaic through the Early Ceramic period at Falcon Landing. Furthermore, these discrete clusters of structures and associated extramural features indicated some of these occupations represented multiple activities and perhaps short-term, temporary encampments. In sum, Falcon Landing can be characterized as an occupational palimpsest of intermittent, seasonal occupations, the evidence of which was periodically buried under natural sediments and subsequent reoccupations in later periods.

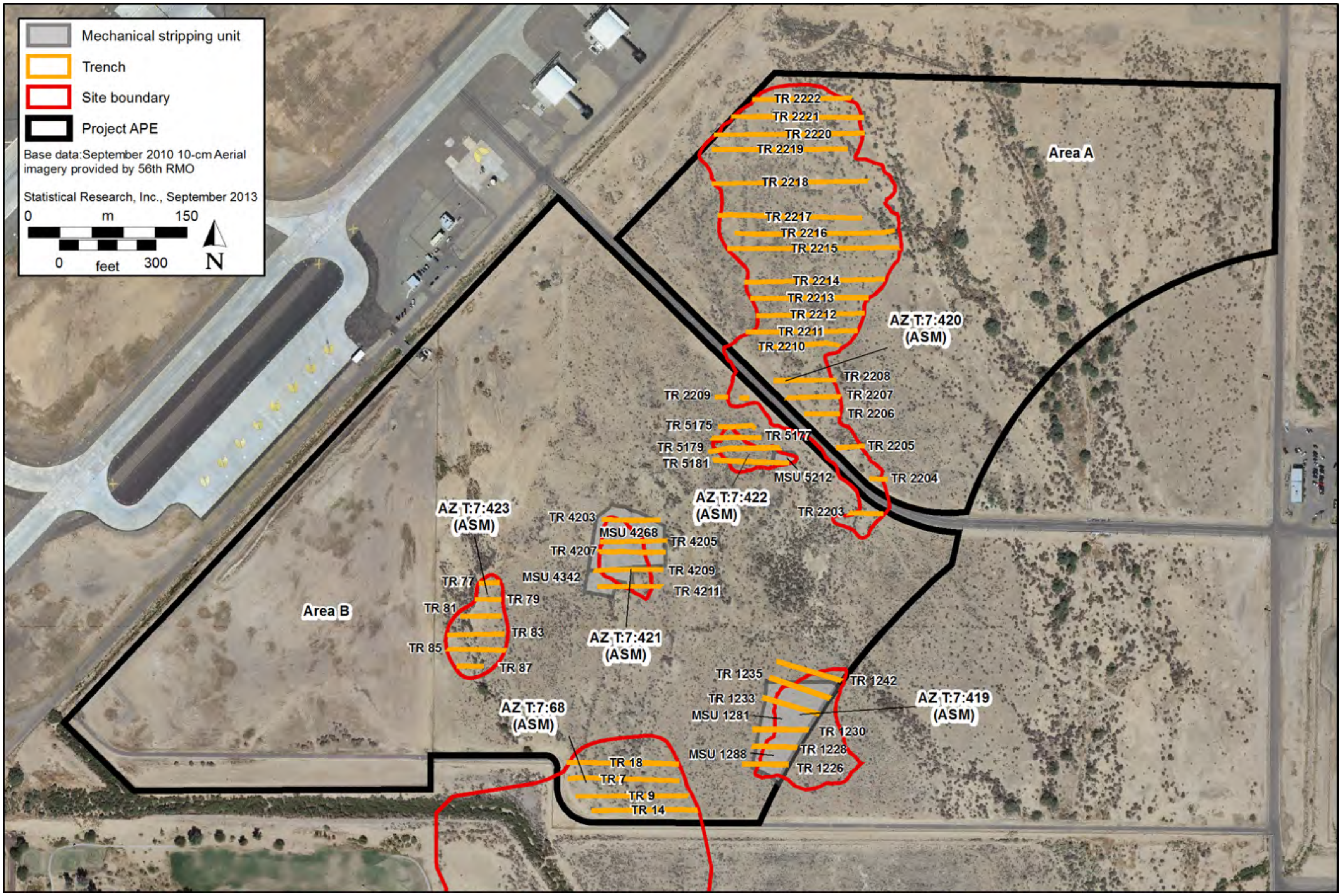


Figure 2. Locations of trenches and MSUs excavated during Phase 1.

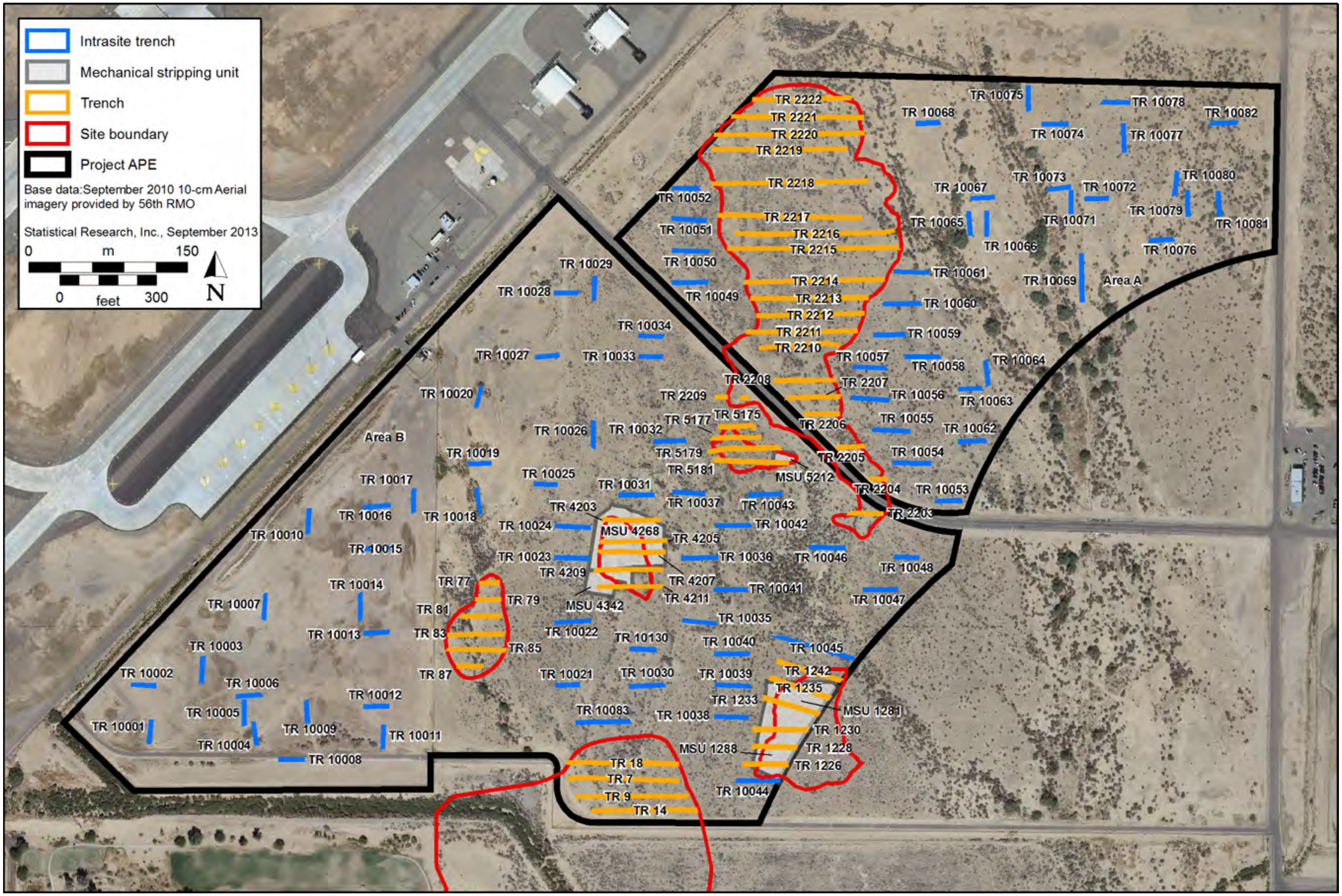


Figure 3. Locations of trenches excavated during the intersite trenching phase.

Table 2. Features Identified at Luke Solar Project and Excavation Level of Effort

Site Name	Feature Type	Level of Effort				Total
		Examined	Complete	Partial	Sampled	
Falcon Landing (AZ T:7:419 [ASM])	activity area[a]	—	8	6	—	14
	burial	—	1	—	—	1
	cache	—	14	3	2	19
	charcoal/ash lens	8	3	33	21	65
	FAR concentration	17	13	44	35	109
	house-in-pit	—	40	—	—	40
	midden	—	—	2	—	2
	nonthermal pit	1,275	106	443	549	2,373
	nonthermal pit (bell shaped)	8	9	7	1	25
	posthole	—	6	—	3	9
	reservoir	—	—	1	—	1
	structure (possible)	1	—	—	3	4
	surface structure	—	4	—	—	4
	thermal pit	58	139	78	55	330
	thermal pit (bell shaped)	1	6	2	1	10
Subtotal, Falcon Landing		1,368	349	619	670	3,006
AZ T:7:68 (ASM)	artifact concentration	—	1	—	—	1
	burial	—	1	—	—	1
	house-in-pit	—	2	—	—	2
	nonthermal pit	13	6	11	2	32
	nonthermal pit (bell shaped)	—	1	—	—	1
Subtotal, AZ T:7:68 (ASM)		13	11	11	2	37
AZ T:7:423 (ASM)	FAR concentration	—	—	1	—	1
	nonthermal pit	—	—	2	—	2
	nonthermal pit (bell shaped)	—	—	1	—	1
Subtotal, AZ T:7:423 (ASM)		—	—	4	—	4
AZ T:7:437 (ASM)	FAR concentration	1	—	—	—	1
	nonthermal pit	4	—	11	—	15
	thermal pit	1	1		—	2
Subtotal, AZ T:7:437 (ASM)		6	1	11	—	18
Rancho La Loma Well (AZ T:7:424 [ASM])		—	1	—	—	1
Total		1,387	362	645	672	3,066

[a] Includes one activity surface.

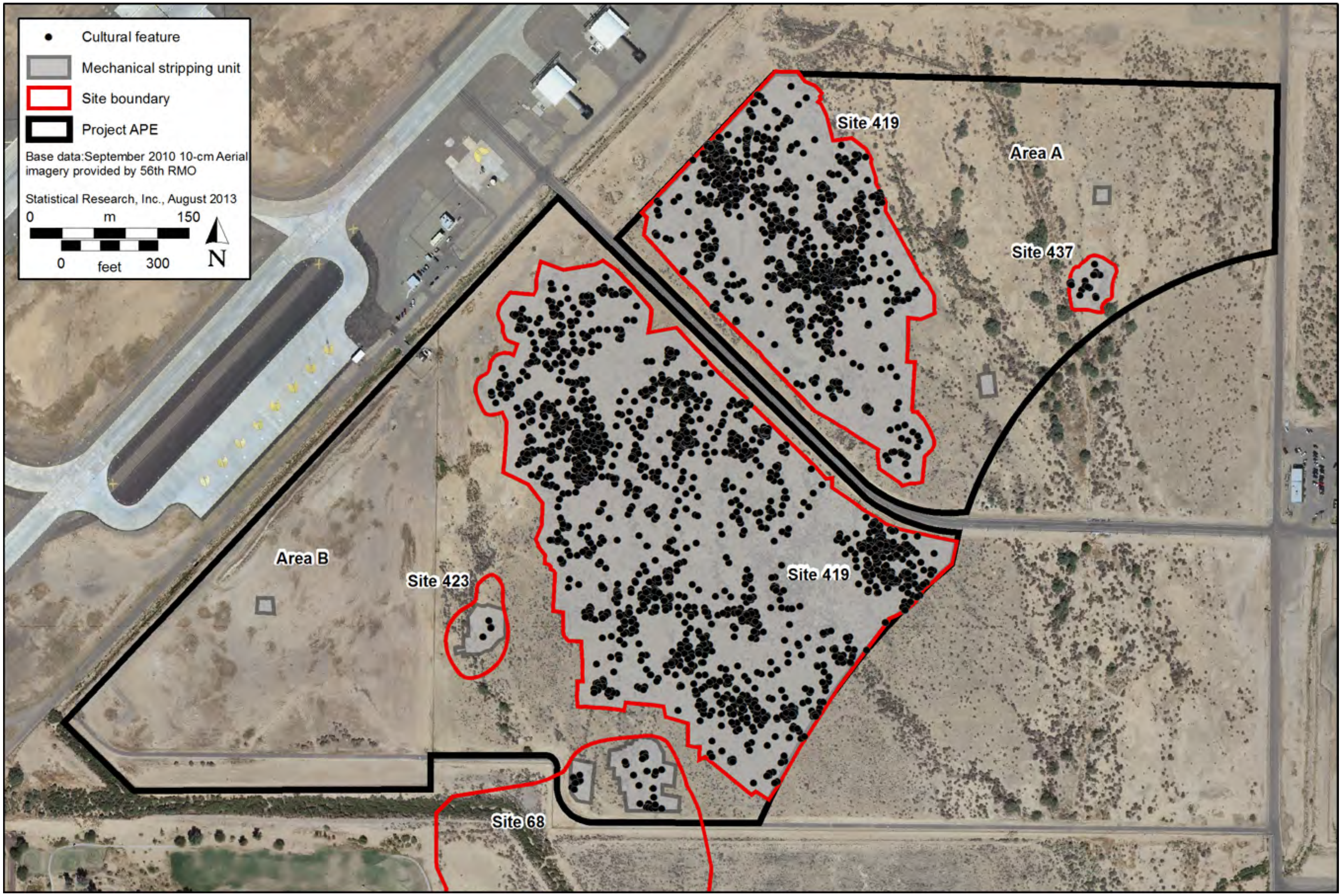


Figure 4. Map showing completed Phase 2 excavations.

Table 3. Number of Features per each Chronologic Component Defined for the Luke Solar Sites

Site Name	Chronologic Components	Calibrated Date Range	Feature Total
Falcon Landing			
	Early Archaic to Middle Archaic	9500–1200 B.C.	108
	Early Archaic to Late Archaic	9500 B.C.–A.D. 50	181
	Early Archaic to Pioneer	9500 B.C.–A.D. 400	98
	Early Archaic to Protohistoric	9500 B.C.–A.D. 1800	1
	Chiricahua	3500–2100 B.C.	710
	Middle Archaic to Late Archaic	3500 B.C.–A.D. 50	614
	Middle Archaic to Pioneer	3500 B.C.–A.D. 750	262
	Middle Archaic to Protohistoric	3500 B.C.–A.D. 1800	155
	Late Chiricahua	2100–1200 B.C.	7
	San Pedro	1200–800 B.C.	20
	Late Archaic	1200 B.C.–A.D. 50	6
	Late Archaic to Pioneer	1200 B.C.–A.D. 750	155
	Late Archaic to Classic	1200 B.C.–A.D. 1450	2
	Late Archaic to Protohistoric	1200 B.C.–A.D. 1800	97
	Early Cienega	800–400 B.C.	6
	Cienega	800 B.C.–A.D. 50	64
	Late Cienega	400 B.C.–A.D. 50	2
	Late Cienega to Red Mountain	400 B.C.–A.D. 400	183
	Red Mountain	A.D. 50–400	3
	Early Ceramic to Pioneer	A.D. 50–750	5
	Early Ceramic to Protohistoric	A.D. 50–1800	42
	Pioneer	A.D. 400–750	1
	Pioneer to Classic	A.D. 400–1450	100
	Snaketown	A.D. 650–750	4
	Sacaton	A.D. 1000–1150	4
	Sedentary to Classic	A.D. 1000–1450	1
	Soho/Civano	A.D. 1150–1450	2
	Classic to Protohistoric	A.D. 1150–1800	28
	Protohistoric	A.D. 1450–1800	2
	post-Middle Archaic	post 3500 B.C.	39
	post-Late Archaic	post 1200 B.C.	90
	post-Soho	post A.D. 1150	9
	post-early Historic	post A.D. 1700	5
Subtotal, Falcon Landing			3,006
Site 68			
	Early Archaic to Middle Archaic	9500–1200 B.C.	5
	Middle Archaic to Late Archaic	3500 B.C.–A.D. 50	15
	Late Archaic to Protohistoric	1200 B.C.–A.D. 1800	15
	Snaketown	A.D. 650–750	2
Subtotal, Site 68			37

Site Name	Chronologic Components	Calibrated Date Range	Feature Total
Site 423			
	Early Archaic to Late Archaic	9500 B.C.–A.D. 50	1
	Late Archaic to Classic	1200 B.C.–A.D. 1450	2
	Late Cienega to Red Mountain	400 B.C.–A.D. 400	1
Subtotal, Site 423			4
Site 437			
	Sulphur Spring	9500–3500 B.C.	1
	Chiricahua	3500–2100 B.C.	2
	Middle Archaic to Late Archaic	3500 B.C.–A.D. 50	8
	Late Archaic to Pioneer	1200 B.C.–A.D. 750	5
	Cienega	800 B.C.–A.D. 50	1
	Pioneer to Classic	A.D. 400–1450	1
Subtotal, Site 437			18
Total[a]			3,065

[a] Does not include Site 424 (La Loma Well).

AZ T:7:68 (ASM)

Site 68 is a large prehistoric archaeological site, however, only about 3 percent of the northern portion of this previously recorded site was within the APE (Adams 1991; Hall et al. 2011). Site 68 is immediately south of Falcon Landing and extends several hundred meters south of LAFB. Phase 1 and 2 data recovery efforts in the portion of Site 68 within the APE resulted in the identification of 37 buried cultural features (see Table 2) including 2 house-in-pit structures, 1 human burial, 1 artifact concentration, and 33 extramural pits (see Chapter 5, Volume 1). The Site 68 features were grouped into three chronologic components based on stratigraphic position and one component based on radiocarbon dating. Thirty-five features of Site 68 had stratigraphic dates, including Early Archaic to Middle Archaic (n = 5), Middle Archaic to Late Archaic (n = 15), and Late Archaic to Protohistoric (n = 15) (see Table 3). Unfortunately, the stratigraphic dates were generally very broad and made temporal associations difficult within and among the chronologic groups. The Middle to Late Archaic group, however, had an associated date range of 1380–920 cal B.C., and corresponds to the Chiricahua/San Pedro temporal component discussed below. Spanning approximately 400 years across the age ranges defined for the Middle and Late Archaic periods, the Chiricahua/San Pedro component included a structure, a human burial (secondary cremation), and 13 nonthermal pits (including one large bell-shaped pit). Radiocarbon-dated features at Site 68 (cal A.D. 650–780) included one structure and one extramural pit, both dating to the Snaketown phase. The data suggest that the portion of Site 68 within the APE was occupied intermittently from the Middle Archaic through the Hohokam Pioneer period. Activities at Site 68 likely included plant processing and storage, as evidenced by the large bell-shaped pit and numerous possible processing features. The presence of 2 ephemeral house-in-pit structures suggests individuals or a small group of people visited the site for a duration long enough to require shelter. The secondary cremation also suggests a slightly longer occupation.

AZ T:7:423 (ASM)

Site 423 was a small, limited-activity site located to the southwest of Falcon Landing. Phase 1 and 2 data recovery efforts at Site 423 resulted in the identification of four prehistoric features (see Table 2), including three extramural pits and an FAR concentration (see Chapter 6, Volume 1). The features at Site 423 were grouped into two chronologic components based on stratigraphic position and one component derived from a radiocarbon date. A single nonthermal bell-shaped pit was assigned to the Early to Late Archaic period, and two nonthermal pits were assigned to the Late Archaic to Classic period. A single FAR concentration was radiocarbon dated to the Red Mountain phase (cal A.D. 10–130). The small number of features at Site 423 suggests the site was a limited-activity resource-procurement, staging, and processing locale.

AZ T:7:437 (ASM)

Site 437 was a small, limited-activity resource procurement and processing locale, located about 130 m east of Falcon Landing, across a small drainage (see Chapter 7, Volume 1). Site 437 was originally identified as a single buried feature, recognized during the intersite trenching phase. Subsequent Phase 2 mechanical stripping uncovered an additional 17 buried features (see Table 2), including 16 extramural pits and an FAR concentration. The original feature identified during intersite trenching was a thermal pit radiocarbon dated to 7040–6690 cal B.C. (Sulphur Spring phase) of the Early Archaic period, and it represents the oldest dated feature in the project area.

Rancho La Loma Well (AZ T:7:424 [ASM])

The Rancho La Loma Well is a Historical-period well and water-conveyance system (see Chapter 8, Volume 1). The main well pad and associated features are approximately 50 m north of the APE (see Figure 1). Portions of the underground water line and aboveground utility line, leading to and from the well, cross the APE. The well was built in 1952 to provide nonpotable water to the Rancho La Loma residence (owned by Mr. and Mrs. P. W. Litchfield), located about 1 mile to the southeast from the well. The Rancho La Loma property, and by extension the well and associated distribution-system easement, has since changed ownership, and is now operated by Sun Health Properties, Inc.

Research Themes

Historic contexts and research themes were presented in the original treatment plan (Hall and Wegener 2011; Hall et al. 2011; Hall, Ciolek-Torrello, et al. 2010), and the updated version is presented in Chapter 2, Volume 1. Several research themes were identified in the treatment plan, each of which can be related to a number of general research questions. Themes relevant to the Luke Solar project included chronology, prehistoric cultural affiliation, and land-use patterns. Each of the research themes subsumes several research questions, and each analysis in this volume examined the data with respect to these themes. Stone artifacts, faunal remains, and macrobotanical and pollen remains were analyzed to address questions of subsistence, for example, and the age of the cultural features and the natural site sediments related to the theme of chronology. The aboriginal use of the project area through time was a particularly salient aspect of the project; contemporaneous groups of features were identified to address questions of land use, mobility, seasonality, and the intensity and duration of site occupations.

Data collected from the Luke Solar project sites also helped to improve the regional culture history. Falcon Landing is the largest Middle Archaic occupation identified to date in the Phoenix Basin. Information from Falcon Landing will likely add to our growing body of knowledge about the Middle Archaic period in southern Arizona, including the use of the distinctive lower-*bajada* landscape. Prior to this study, much of the evidence for these time periods was derived from riverine sites. Falcon Landing also has provided important information on subsequent Late Archaic and Early Ceramic period occupations in this region.

A Note on the Luke Solar Chronology

The establishment of temporal control was a fundamental goal during the Luke Solar project. The chronologic placement of individual features and the dating of the natural stratigraphy was perhaps the greatest methodological challenge of this project. A complicated multistep process using different analytical approaches was used to assign ages of varying precision to particular features, as well as to identify temporally defined groups of features (Figure 5). This process ultimately was responsible for the assignment of over 3,000 features into a temporal framework, and also strived to obtain the most precise or analytically meaningful dates possible. Four frameworks were devised to investigate chronology at the Luke Solar sites, including chronologic components, analytical groups, temporal components, and occupational episodes. The following summarizes the process involved in interpreting the Luke Solar chronology and how this chronology was applied to the project sites, features, and material culture in the following chapters.

Chronological Components

In total, 34 chronologic components were defined for the Luke Solar sites, extending from the Early Archaic to the Historical period (see Table 3). The chronologic components were defined by a combination of radiocarbon dates and geoarchaeological analysis of the natural sediments within project area. In Chapter 4, Volume 1, the geochronologic model was introduced, and the basis of this model is extensively described in Chapter 2 of this volume. Basically, the geochronologic model correlated the natural alluvial deposition across the site using radiocarbon analysis to determine the age of stratigraphic units. The result was the definition and age-bracketing of five major stratigraphic units (Units I–V) in the Luke Solar project area. Using the age ranges for natural stratigraphic units, nearly every feature in the project area was assigned to a chronological component (see Table 3). Assigning features to chronologic components required several steps. Features were assigned a date range based on a series of five methods, or cases, each requiring a specific set of data, and each decreasing in precision (see Figure 5). First, features that were individually radiocarbon dated (Case 1) had a specific and precise age range obtained from the radiocarbon analysis. This radiocarbon date was preferable over all other dating methods for its ability to assign a direct date to an individual cultural feature. Second, features were dated stratigraphically, using the geochronologic model that was developed by directly or indirectly dating the natural stratigraphy. If a feature was not radiocarbon dated, then it was given the age range of its associated natural stratum (Units I–V). In some cases, a feature was coeval (Case 2) with a natural stratum (i.e., a feature wholly contained within a single stratum) and was assigned a bracketing age range for that particular stratum. Other features intruded into the upper surface of a stratum, with a younger stratum overlying the surface, creating an unconformity (Case 3). In the case of an unconformity, the feature was assigned the latest date for the stratum it intruded into and the earliest date for the overlying stratum. Sometimes this unconformity date range was quite long, making the age assigned to a particular feature very broad. In rare instances, a feature intruded into the surface of a stratum and did not have an overlying stratum (Case 4) or the overlying stratum was not determined in the field (Case 5); therefore, these features were considered to postdate the stratum into which they intruded. Features with a precise date range were assigned to a specific cultural phase, based on the culture history defined in Chapter 2, Volume 1. Features that crossed multiple phases were assigned to the next most precise cultural period. For example, a feature with a date range that crossed both the San Pedro and Cienega phases would be assigned to the Late Archaic period. Features that crossed multiple periods were assigned to the earliest and latest periods encompassed by the date range. For example, a feature date range that began sometime in the Early Archaic period and ended in the Late Archaic period would be assigned to the Early to Late Archaic period component. All feature descriptions presented in Volume 1 are arranged by these chronological components.

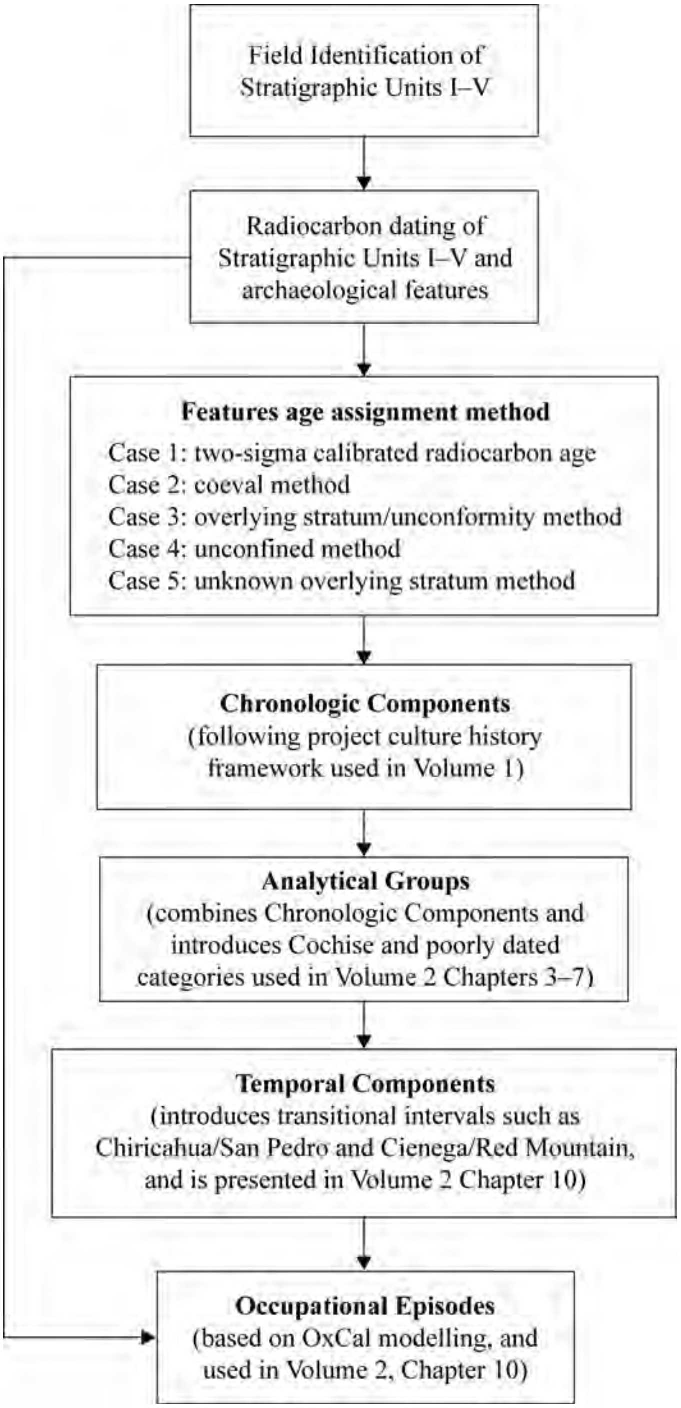


Figure 5. Flowchart showing the process of establishing the Luke Solar chronology.

Analytical Group

The artifact and ecofact analyses presented in this volume used an abbreviated version of the original chronology components introduced in Volume 1. Many of the 34 chronologic components used in Volume 1 were too imprecise to be analytically useful. In other words, chronologic comparisons could not be made with feature dates that extended over multiple cultural phases or periods. As an example, a nonthermal pit on Falcon Landing (Feature 14624) was intrusive to the surface of Unit I, with Unit V alluvium overlying the feature. This stratigraphic position provided a geochronologic date of 5320 cal B.C.–cal A.D. 1520, corresponding to the Early Archaic to Protohistoric period. This date range spans nearly the entire Luke Solar project chronology. Obviously, a feature with such a broad date range is not analytically useful when studying culture change over time. In order to resolve this type of temporal conundrum, the chronologic components from Volume 1 were revised to provide more-meaningful temporal groups. These new categories were called analytical groups (Table 4). The first step in creating the new analytical groups was to recategorize the components into fewer groups and eliminate the number of components with long date ranges. As a result, 13 analytical groups were established, a marked decrease from the previous 34 chronological components. Chronologic components with similar date ranges were lumped together, and poorly dated features were placed into two broad categories. For example, features originally assigned to the Snaketown and Sacaton phases, or the Pioneer period, were combined into the analytical group “pre-Classic” (A.D. 400–1150). In other cases, features with long date ranges such as Early Archaic to Protohistoric, Middle Archaic to Pioneer, or Late Archaic to Classic, were categorized as “poorly dated,” and were excluded from further analysis. An additional category of “Cochise” was used to encompass all features that had broad date ranges but still fell within the established span of the Archaic period, such as the Early to Middle Archaic and Middle to Late Archaic components. The Chiricahua phase of the Middle Archaic was also divided into early and late phases in this schema to represent the beginning of the Early Agricultural period. Following Huckell (1995), the Early Agricultural period is defined by the introduction and slow development of agricultural practices in southern Arizona around 2100 B.C. Despite the lack of agricultural signatures in the Luke Solar sites, the ability to compare contemporaneous occupations at Luke Solar with those in the Tucson Basin, or elsewhere in the U.S. Southwest where early agriculture was practiced, seemed prudent. As such, the addition of the early and late Chiricahua phases should be considered a simple heuristic device, allowing the comparison of early (3500–2100 cal. B.C.) and late (2100–1200 cal. B.C.) Chiricahua phase contexts. The span of the late Chiricahua phase used here has been reported from several Middle and Late Archaic/Early Agricultural sites in the Tucson Basin, such as the “unnamed interval” by Mabry (2005:Table 1.1), as well as the Silverbell phase by Whittlesey et al. (2010:6). The material culture and ecofact analyses presented in Chapters 3–7 of this volume follow the analytical group schema. Importantly, these analytical groups represent mutually exclusive temporal categories that were investigated by the analysts, the results of which are directly comparable to each other as well as the chronological components presented in Volume 1.

Temporal Components

During the course of analysis, it was recognized that large groups of features with relatively precise age ranges had been lumped into the Cochise category. These groups represented features stratigraphically dated, but their age ranges overlapped more than one cultural phase. As an example, nearly 200 features at Falcon Landing and Site 68 had age ranges than straddled the accepted Chiricahua (ca. 3500–1200 B.C.) to San Pedro (ca. 1200–800 B.C.) transition date. Features stratigraphically dated to ca. 1380–920 B.C. represented a significant occupation in the Luke Solar project area; however, the previously defined cut-off date of 1200 B.C. for the end of the Middle Archaic and beginning of the Late Archaic period masked potentially important occupations during the Chiricahua/San Pedro transition at Luke Solar. Other transitional date ranges identified in the Luke Solar chronology included the San Pedro/Cienega phases, Cienega/Red Mountain phases, and Classic/Protohistoric periods. Features in these categories were not included in the analytical groups because they overlapped more than one group; therefore, redundant and/or nonmutually exclusive temporal

Table 4. Number of Features per Analytical Group

Site Name	Analytical Groups	Calibrated Date Range	Feature Total
Falcon Landing			
	early Chiricahua	3500–2100 B.C.	710
	late Chiricahua	2100–1200 B.C.	7
	San Pedro	1200–800 B.C.	20
	Cienega	800 B.C.–A.D. 50	72
	Red Mountain	A.D. 50–400	5
	pre-Classic	A.D. 400–1150	9
	Classic	A.D. 1150–1450	2
	Protohistoric	A.D. 1450–1800	2
	Historical	post A.D. 1700	5
	Cochise	9500 B.C.–A.D. 50	1,090
	poorly dated		1,084
Subtotal, Falcon Landing			3,006
Site 68			
	pre-Classic	A.D. 650–750	2
	Cochise	9500 B.C.–A.D. 50	20
	poorly dated		15
Subtotal, Site 68			37
Site 423			
	Red Mountain	400 B.C.–A.D. 400	1
	Cochise	9500 B.C.–A.D. 50	1
	poorly dated	1200 B.C.–A.D. 1450	2
Subtotal, Site 423			4
Site 437			
	Sulphur Spring	9500–3500 B.C.	1
	early Chiricahua	3500–2100 B.C.	2
	Cienega	800 B.C.–A.D. 50	1
	Cochise	3500 B.C.–A.D. 50	8
	poorly dated		6
Subtotal, Site 437			18
Total[a]			3,065

[a] Does not include Site 424 (La Loma Well).

categories were avoided in the material culture analysis. A new framework was established that included these "transitional" occupations, called temporal components (Table 5). In total, 11 temporal components were defined, including a category of "not applicable" (n/a) for poorly dated features. The temporal components basically mirrored the analytical groups presented above, with the exception of including the transitional groups. Therefore fewer features were included in poorly dated categories. Furthermore, the early and late Chiricahua phase contexts defined in the analytical groups (above) were collapsed to include only the Chiricahua phase. Temporal components were used in the spatial and aspatial analyses of Chapter 10. In the Chapter 10 discussion, the transitional categories were considered with the same weight as the other mutually exclusive categories despite the slight overlap with age ranges. These transitional categories demonstrate how some of the Luke Solar occupations do not fit neatly within the established cultural historical frameworks developed for southern Arizona.

Table 5. Number of Features per Each Temporal Component Defined at Luke Solar

Site Name	Temporal Components	Calibrated Date Range	Feature Total
Falcon Landing	Chiricahua	3500–1200 B.C.	717
	Chiricahua/San Pedro	1380–920 B.C.	189
	San Pedro	1200–800 B.C.	20
	San Pedro/Cienega	920–720 B.C.	6
	Cienega	800 B.C.–A.D. 50	72
	Cienega/Red Mountain	160 B.C.–A.D. 340	183
	Red Mountain	A.D. 50–400	3
	pre-Classic	A.D. 400–1150	14
	Classic	A.D. 1150–1450	2
	Classic/Protohistoric	A.D. 1220–1520	28
	n/a		1,772
Subtotal, Falcon Landing			3,006
Site 68	Chiricahua/San Pedro	1380–920 B.C.	15
	pre-Classic	A.D. 400–1150	2
	n/a		20
Subtotal, Site 68			37
Site 423	Cienega/Red Mountain	160 B.C.–A.D. 340	1
	n/a		3
Subtotal, Site 423			4
Site 437	Chiricahua	3500–1200 B.C.	2
	Cienega	800 B.C.–A.D. 50	1
	n/a		15
Subtotal, Site 437			18
Total[a]			3,065

[a] Does not include Site 424 (La Loma Well).

Occupational Episodes

Finally, a fourth chronologic framework was devised for Luke Solar using radiocarbon-dated features. The analysis of the individually radiocarbon dated features using the OxCal program resulted in the definition of 10 radiometrically discrete occupational episodes (0–9), as defined in Chapter 2, this volume. A revised version of the occupational episodes was used in Chapter 10, which focuses on a subset of features from the original OxCal model (Table 6). Each of the nine episodes used in Chapter 10 was given an alpha-designation (A–I) and corresponds to the previous temporal frameworks and age ranges. A significant aspect of the occupational episodes was that all features within a single episode were determined to be statistically contemporaneous: a feature in Occupational Episode A, for instance, corresponds to the earliest portion of the Chiricahua phase defined for the Luke Solar project, or 3340–2890 cal B.C. (see Table 6). If the age of a particular feature spanned multiple occupational episodes, then the feature was assigned an alpha-designation for each episode it crossed. For example, Feature 14624 (described above) has a geochronologic date of Early Archaic to Protohistoric (5320 cal B.C.–cal A.D. 1520). This geochronologic date would correspond to Occupational Episode A–I. Obviously, the more letters assigned to a particular feature, the less precise the date range. Understandably, the well-dated occupational episodes (i.e., those features with only a single alpha-designation), included only a very small sample of the features identified at the project sites. The process involved in the OxCal modeling and defining of the occupational episodes is discussed in greater detail in Chapter 2, and the spatial and aspatial analyses of features and material culture within these episodes are presented in Chapter 10.

Table 6. Occupational Episodes Defined at Falcon Landing

Occupational Episodes				Cultural Phase
OxCal Model[a]	2σ Date Range	Revised[b]	2σ Date Range	
0	7040–6690 cal B.C.	n/a	n/a	Sulphur Spring
1	3340–2890 cal B.C.	A	3340–2890 cal B.C.	early Chiricahua
2	2890–2490 cal B.C.	B	2860–2620 cal B.C.	early Chiricahua
3	2570–2340 cal B.C.	C	2570–2460 cal B.C.	early Chiricahua
4	2200–1310 cal B.C.	D	2200–1310 cal B.C.	late Chiricahua
5	1390–800 cal B.C.	E	1390–800 cal B.C.	San Pedro
6	790–160 cal B.C.	F	790–540 cal B.C.	Cienega
7	cal A.D. 10–250	G	cal A.D. 10–120	Red Mountain
8	cal A.D. 610–780	H	cal A.D. 610–780	pre-Classic
9	cal A.D. 980–1270	I	cal A.D. 980–1270	pre-Classic/Classic

[a] Occupational episode dates derived from OxCal Model (Chapter 2, this volume).

[b] Revised occupational episode dates used for analysis in Chapter 10, this volume.

Volume 2 Overview

The following chapters present the results of analyses and interpretations for the Luke Solar project. Chapter 2 begins with a thorough study of the geoarchaeology and paleoenvironment of the project area. The environmental reconstruction sets the stage for subsequent analyses in this volume and has broader implications for how and when Archaic foragers used this lower-*bajada* landscape. Chapter 2 also provides a complete summary of the radiocarbon analysis conducted for the project. Radiocarbon dating was the fundamental method for interpreting the periods of deposition across the APE, which in turn allowed for the chronological placement of each stratigraphic unit defined within the project area. Cultural features without direct radiocarbon dates were indirectly dated via the stratigraphy. Placing individual features into chronological groups was a major milestone for the Luke Solar project and facilitated the subsequent study of how the project area was occupied over time.

The analysis of all flaked and ground stone artifacts recovered from the Luke Solar project is discussed in Chapter 3. Stone artifacts made up over 75 percent of the project artifact collection, and this collection was a key tool in understanding aboriginal technology, subsistence, and land use as it pertains to the Luke Solar project area. Important items of the stone artifact collection included numerous Archaic-style projectile points and evidence of a predominantly bifacial-reduction technology. A diverse and unique ground stone technology points to a major focus on processing locally available plants throughout the Middle and Late Archaic periods, and continuing into the Ceramic period.

Chapter 4 presents the results of the faunal bone and shell analyses. Leporids and rabbit-sized mammals made up the majority of animal remains recovered in the project area, and the diversity of animal taxa was generally very low. The faunal remains identified in the Luke Solar project indicate hunting was likely not the primary activity during the Archaic and Early Ceramic periods. Procuring and processing animal resources was clearly a secondary activity, likely an outcome of opportunistic encounters, and at select times, a more logistically organized procurement mode. Large numbers of marine shell beads recovered from Falcon Landing point to long-distance exchange networks. Interestingly, over a third of the faunal collection was recovered from a single Historical-period feature, providing a glimpse into an early-twentieth-century rabbit drive.

The analysis and interpretation of the prehistoric ceramic artifacts are presented in Chapter 5. The small ceramic collection from the Luke Solar sites represented mostly occasional use of ceramic vessels in the project area, to fulfill short-term liquid or dry storage needs and/or for use in cooking. The majority of the ceramics were associated with the Hohokam Ceramic tradition (ca. A.D. 50–1450). However, two untempered plainware sherds recovered from Late Archaic contexts (ca. 1200–200 B.C.) provide some clues to the very earliest stage of the development of ceramic technology in the Phoenix Basin.

Charred plant material analyzed from the Luke Solar project is discussed in Chapter 6. Preserved plant material from flotation and macrobotanical samples provided a relatively limited record of aboriginal plant use. Economic plant resources included the fruit and/or seeds of saltbush (*Atriplex*), cheno-am, grass (*Panicum*), plantain (*Plantago*), purslane (*Portulaca*), horse purslane (*Trianthema portulacastrum*), and mesquite (*Prosopis*). No evidence of domesticated plants was identified in the macrobotanical record. Charred nonreproductive plant parts (stem fragments, twigs, and wood) of saltbush, saguaro (*Carnegiea gigantea*), ocotillo (*Fouquieria splendens*), creosote bush (*Larrea*), grass (Poaceae), and mesquite likely represented fuel, construction timbers, tools, and other nonsubsistence uses.

Preserved pollen remains identified and analyzed from the Luke Solar project are discussed in Chapter 7. Pollen concentrations were moderately high, though the richness, or diversity, of plant taxa was generally low. Most abundant was cheno-am pollen. Other economic plants identified by pollen analysis included mesquite, palo verde (*Parkinsonia* [*Cercidium*]), plantain (aka Indianwheat), hackberry (*Celtis*), and wolfberry (*Lycium*). A single maize pollen grain was identified from the floor of a Late Archaic structure, and it is the only evidence of a domesticated plant in the project area. Other rare but economically important pollen signatures included prickly pear (*Opuntia* [*Platyopuntia*]), cattail (*Typha*), cottonwood (*Populus*), ocotillo, silktassel (*Garrya*), as well as possibly *Erodium*, and the pea family (Fabaceae). Evidence from both the pollen and macrobotanical records indicated that generally, aboriginal groups occupied the Luke Solar project area primarily during the spring and summer, with infrequent evidence of late-winter and early-fall visitations, in order to benefit from the available wild-plant resources.

Chapter 8 presents the results of the bioarchaeological analysis for the Luke Solar sites. Only two human burials were identified in the Luke Solar project area. In accordance with the project NAGPRA Plan of Action, all human remains and associated mortuary items recovered from the Luke Solar project area were repatriated to the Salt River Pima-Maricopa Indian Community on June 28, 2013. The rarity of burials in the project area relative to other Archaic period sites in southern Arizona is likely related to the aboriginal land-use strategies practiced in the project area. Foraging groups visiting the project area were unlikely to inter the deceased, perhaps preferring to relocate their loved ones to another location or base camp. Chapter 8 also includes an overview of Archaic and Early Ceramic period burials from elsewhere in southern Arizona and compares these data to the mortuary behavior documented in the project area.

Chapter 9 discusses the evidence for archaeological signatures of subsistence activities. The chapter begins with a discussion of the environmental context of the Sonoran Desert as well as a thorough review of the available plant and animal resources and ethnographic examples of food-processing technologies. Using these ethnographic examples, the chapter discusses the different tools and methods used to process plant and animal resources as well as how these tools and behaviors might manifest themselves into the archaeological record, particularly in regards to the features and artifacts documented at the Luke Solar sites.

Chapter 10 organizes and discusses the tremendous amount of feature, artifact, ecofact, spatial, and temporal data collected for the Luke Solar project. First, the extramural-pit analysis presented in Chapter 4, Volume 1, is revisited, and this analysis is furthered by assigning these pits into functional categories. Second, an aspatial analysis of features and feature artifact content is discussed, with a focus on assessing the intensity of occupations over time. The aspatial analysis used the analytical groups and occupational episodes discussed above. Thirdly, spatially associated clusters of contemporaneous features are defined through statistical Geographic Information Systems (GIS) analysis, and this study identified several significant spatial and temporal patterns of occupation within the Luke Solar project area.

Chapter 11 concludes Volume 2 by addressing the research questions and synthesizing the project results. In particular, the artifact and ecofact analyses presented in Chapters 3–7 are revisited and used to answer the research themes presented in Chapter 2, Volume 1. Subsistence data discussed in Chapter 9 and the spatial and temporal analysis in Chapter 10 are also used to address the research themes of land use, cultural affiliation and chronology. In the last section, avenues of potential future research are described, including furthering the chronometric data through additional radiocarbon analysis as well as processing and analyzing the archaeomagnetic samples collected during fieldwork. It is also noted that the archaeobotanical record for Luke Solar could be strengthened by the analysis of additional pollen and flotation samples. Finally, a predictive geological model is introduced that estimates the location of potential buried Middle Archaic cultural resources in the vicinity of LAFB based on soil survey data.

As part of conveying information pertinent to the analyses presented in the previous chapters, Appendixes 1.1–9.1 accompany Volume 2 on a DVD. Table 7 lists these appendixes. One of the most challenging aspects of the Luke Solar project was the physical scale of the excavations. Because of this scale, it was difficult to adequately portray the entire project area on one map. An interactive portable document format (pdf) file (Appendix 1.1) was created to help the reader by presenting the project map in a digital format. This interactive pdf file is searchable and contains multiple layers that are independently selectable. Volume 1 of this series contains a similar interactive pdf file; however, the Volume 1 interactive pdf includes only the results of SRI's fieldwork, including all features, excavations units, etc. The interactive pdf file provided in this volume includes the same content as the Volume 1 interactive pdf, but also contains the subsequent results of temporal and geologic analyses. Features in Appendix 1.1 are arranged by temporal component, allowing the reader to explore the changes in prehistoric occupation over time. Also included in Appendix 1.1 are layers that depict the natural surface geology of the project area, the geology of the mechanically stripped surface, and natural channels defined within the project area. A step-by-step user's guide for the interactive pdf, Appendix 1.2, is also provided on the accompanying DVD.

Table 7. Table of Appendixes

Appendix No.	Description
1.1	Interactive PDF
1.2	Interactive PDF How-To Guide
2.1	Phosphorus Analysis of Structures
2.2	Radiocarbon Analysis
2.3	Geologic Profile Descriptions
2.4	Geochronology Model
3.1	EDXRF Analysis of Obsidian
3.2	Flaked Stone Data Table
3.3	Ground Stone Data Table
3.4	Expedient Use Data Table
4.1	Archaeological and Excavation Context and Faunal Taxon, Element, and Taphonomy Data
4.2	Ages of Features and Nonfeature Proveniences with Faunal Remains, by Site
4.3	Shell Artifacts from the Luke Solar Project
5.1	Ceramic-Attribute Recording
6.1	Analyzed Luke Solar Project Flotation and Macrobotanical Samples
6.2	Luke Solar Project Flotation-Sample Data, by Site
6.3	Luke Solar Project Macrobotanical Sample Data, by Site
7.1	Proveniences of Luke Solar Project Pollen Samples
7.2	Raw Counts of Pollen Data for the Luke Solar Project
9.1	Basketry at Falcon Landing: (A Study of What Once Was)
10.1	Interactive PDF: Spatio-Temporal GIS Analysis Layers
10.2	Spatio-Temporal GIS Analysis Layers How-To Guide

CHAPTER 2

Geoarchaeology and Archaeological Chronology

Jason D. Windingstad, Stacey Lengyel, John D. Hall, Matthew C. Pailes,
Jeffrey A. Homburg, and Robert M. Wegener

Introduction and Research Goals

The Luke Solar project provided a unique opportunity to investigate the geomorphic history and prehistoric cultural use of a 46-acre excavated footprint on a Sonoran Desert *bajada*. The archaeological record preserved over 5,000 years of episodic but pervasive use beginning with the Middle Archaic and lasting through the Hohokam Classic period. From a modern landscape perspective, LAFB does not appear to have been an attractive area for prehistoric settlement. In regional Archaic settlement models, *bajada* settings are considered part of the Sonoran landscape that was traveled across but not extensively occupied because access to water was severely limited (Roth and Freeman 2008). Understanding how the distal *bajada* evolved over time and how changes relate to the occupational history of the site(s) is a critical step in explaining why prehistoric groups repeatedly came to this area.

This chapter presents the findings of the geoarchaeological and chronological research conducted at Falcon Landing (AZ T:7:419 [ASM]) and adjacent sites between 2011 and 2013. Geoarchaeological investigations focused on documenting and interpreting the natural site stratigraphy, geochronology, and prehistoric landscape context. Defining the site stratigraphy and constructing a geochronological model was an important research goal because very few of the cultural features uncovered during excavation could be radiocarbon dated. Placing the remaining features in a well-defined stratigraphic sequence was the only viable way to assign a temporal context to most of the archaeological record. Fortunately, many of the stratigraphic units were deposited over a large portion of the project area during a relatively short period of geologic time, which made them very useful for stratigraphic dating. By correlating the units across space via radiocarbon dating, many features could be assigned an absolute age. Because of the lateral complexity of the stratigraphy, however, some age assignments were either not possible or were simply too broad to be useful. The project geochronology also served as the foundation for modeling the radiocarbon data set by placing temporal/stratigraphic constraints on the radiometrically dated features. In many cases, these constraints resulted in more-refined age estimates by requiring one set of features to be older (or younger) than another, thus truncating the probability distributions of the unmodeled calibrated radiocarbon dates.

Background

The following provides critical background information for the study. This includes information on local geology, soils, landforms, geomorphic processes, regional paleoenvironments, and modeling of radiocarbon data sets.

Physiography and General Geologic Contexts

Regionally, the project area is situated in the western Phoenix Basin (hereafter referred to as the Luke Basin), a Cenozoic basin in the south-central part of the Basin and Range tectonic province (Gootee 2013). The Luke Basin initially developed during the middle Tertiary (21–17 million years ago [Ma]) when crustal deformation resulted in extensive faulting across what is now the Basin and Range Province (Reynolds 1985). At this time, extension of the earth's crust along low-angle detachment faults created the early White Tank and South Mountains (footwall, uplifted block) and the Luke Basin (hanging wall, down-dropped block). A second pulse of tectonic activity during the Basin and Range disturbance (15–8 Ma) may have supported additional Luke Basin subsidence via high-angle normal faults (Menges and Pearthree 1989). During and following major periods of basin subsidence, the basins began to accumulate sediment derived from the adjacent uplifted mountain ranges. Initially, the basins were hydrologically closed and contained large ephemeral lakes or playas. By the late Pliocene, basin fills had aggraded up to the elevation of the basin drainage divides, and external drainage networks developed. In the Luke Basin, the internally drained streams were captured by the Gila River drainage network (Gootee 2013).

The Luke Basin is bound to the west by the White Tank Mountains, to the south by the Sierra Estrella Mountains, to the southeast by South Mountains, to the east by the Phoenix Mountains, to the northeast by Union Hills, and to the north-northwest by the Hieroglyphic Mountains. External drainage is accommodated by the Gila River along the basin's southern margin. Major tributaries of the Gila that flow through Luke Basin include the Salt, Agua Fria, and New Rivers. More locally, LAFB is situated on the lower eastern piedmont of the White Tank Mountains, a setting now occupied by the western fringe of the Phoenix metropolitan area. The White Tank Mountains are a mid-Tertiary metamorphic core complex composed of Proterozoic metamorphic and plutonic rocks, several Late Cretaceous to early Tertiary granitic plutons, and some mid-Tertiary plutonic, volcanic, and sedimentary rocks (Reynolds et al. 2002). The rocks along the eastern flank of the White Tank Mountains are almost entirely early Proterozoic and Cretaceous to early Tertiary granites (Reynolds et al. 2002; Richard et al. 2000). Ultimately, nearly all of the piedmont alluvium on the east side of the White Tank Mountains was derived from these granitic rocks. The range has a maximum elevation of just over 1,240 m (4,068 feet) above mean sea level (AMSL) and is surrounded by an extensive, gently sloping piedmont capped primarily with Quaternary alluvial deposits. The eastern and southern piedmont of the White Tank Mountains is drained by the lower Agua Fria River and the middle Gila River, respectively. The Agua Fria–Gila River confluence is located approximately 15 km (9.3 miles) south of LAFB.

The project area sits at an elevation of 325 m AMSL (1,066 feet) and is located 11 km (6.8 miles) east of the eastern flank of the White Tank Mountains and 6 km (3.7 miles) west of the modern Agua Fria River channel. The alluvial plain surrounding LAFB slopes gently (less than 0.5 percent slope) to the southeast and is characterized by very low topographic relief. The only topographic break is a pair of conspicuous hills located immediately east of LAFB and just west of the New River–Agua Fria River confluence. As discussed in more detail below, these hills likely represent the surface expression of minor upward plastic flow of the Luke Salt Body, a 3,600–4,400-m (11,800–14,440-foot)-thick deposit of rock salt that underlies the central Luke Basin (Eaton et al. 1972; Peirce 1984). Alternatively, the hills could be the result of differential compaction of basin fills over a high spot in the salt dome. In either case, there is a causal link between the formation of these landforms and the underlying salt body; therefore, the hills will be referred to as salt domes throughout the chapter.

White Tank Piedmont Soils and Landforms

The primary landscape element of the White Tank Mountains piedmont is the alluvial fan and its associated discontinuous ephemeral-fan drainage system. An alluvial fan is an aggradational sedimentary deposit in the shape of a cone that radiates downslope from a point where a drainage channel changes from confined to unconfined flow (Bull 1977; Drew 1873). Put more simply, an alluvial fan will form where there is a source of sediment and sufficient water to carry it to a wide place suitable for deposition (Vincent et al. 2004).

Because alluvial fans form in many different environments, no single criterion can be used to define a fan (Bull 1984). For instance, many fans are not cone or fan shaped because they are constrained by older adjacent fans. This is particularly true on middle to upper *bajadas*. Additionally, alluvial fans in a classic sense have mountainous catchments, but most middle and lower piedmont fan drainages in southern Arizona have their catchments on middle to upper piedmont surfaces (relict fans) and are disconnected to the mountains hydrologically (Field and Pearthree 1991).

The piedmont as a whole is a depositional plain composed of many coalescing alluvial fans of differing age and size (*bajada*). In general, Holocene alluvial surfaces become more extensive on the medial and distal White Tank *bajada* where active or recently active alluvial fans begin to merge with terraces of the Agua Fria River. Conversely, relict alluvial fans dating to the Pleistocene and late Tertiary generally increase in spatial extent on the proximal piedmont where they form topographically elevated surfaces with incised dendritic drainage networks (Field and Pearthree 1991). Such a landform sequence is indicative of a tectonically stable basin that has experienced basinwide erosion throughout the late Quaternary (Bull 1984).

Geologic mapping of the White Tank Mountains piedmont by Field and Pearthree (1991) indicates much of the piedmont west of LAFB is covered with undifferentiated fan alluvium dating to the Holocene from 10,000 years ago to the present (Figure 6). These areas are prone to occasional to frequent flooding. In the project area, late to middle Pleistocene (1,000–10 thousand years before present [ka]) fan deposits form islands surrounded by younger Holocene alluvium (see Figure 6). The undifferentiated late and middle Pleistocene M12 or M1 mapping units are used primarily in agricultural or disturbed areas where natural surface characteristics were destroyed. Unfortunately, the 1:24,000 geologic maps (Field and Pearthree 1991) did not extend east of LAFB and so the salt domes were not mapped. The *Geologic Map of Quaternary and Upper Tertiary Alluvium in the Phoenix North 30' x 60' Quadrangle, Arizona*, however, indicates the domes are early Pleistocene and late Pliocene landforms (greater than 1,000 ka) (Demsey 1988).

Maricopa County soil survey maps reveal a pattern similar to the geologic maps in that most of the medial piedmont is covered by young alluvium with weakly developed soils, and the proximal and distal piedmont are characterized by relict landforms with strongly developed soils (Figure 7). This is not surprising because the geologic maps are partially based on soil survey data. Immediately west of LAFB, most of the soils are mapped as Torrifluvents, which are Entisols (young, weakly developed soils that lack subsurface diagnostic horizons, i.e., A–C horizonation) with an irregular decrease in organic carbon with depth (Soil Survey Staff 2010). The irregular distribution of organic carbon signifies the presence of stratified alluvium and/or the presence of buried surface horizons. The Torrifluvents mark active or recently active (late Holocene) discontinuous ephemeral-fan networks on the White Tank Mountains piedmont. At present, most of the medial piedmont Torrifluvents are being used for agricultural purposes.

On the proximal and distal piedmont, soils with diagnostic subsurface horizons identify older landform (see Figure 7). These soils are classified as Aridisols, that is, soils in an aridic soil moisture regime with one or more of the following diagnostic subsurface horizons: cambic (Bw), argillic (Bt), calcic (Bk), petrocalcic (Bkm), natric (Btn), salic (Bz), gypsic (By), petrogypsic (Bym), or duripan (Bqm) (Buol et al. 2003; Soil Survey Staff 2010). Although many of these relict soils are capped by younger alluvium, particularly on the distal piedmont, diagnostic subsurface horizons are close enough to the modern surface (within 100 cm) to influence soil classification. Many Aridisols on the White Tank Mountains piedmont represent late Pleistocene or older landforms; however, soils mapped as Haplocambids (Aridisols with a Bw horizon), Haplocalcids (those with a Bk horizon), or Natrargids (those with a Btn horizon) could date to the Holocene. Haplocambids and Natrargids require less time for development and have been radiometrically dated to the late and middle Holocene in south-central Arizona (Huckleberry 1997). Soils with calcic horizons (must be at least 15 cm thick and contain 15 percent more calcium carbonate [$CaCO_3$] by volume than the underlying horizon) in the fine-grained low-carbonate alluvium of the White Tank Mountains piedmont are probably at least early Holocene in age (Gile 1975). Some Haplocalcids in south-central Arizona have been dated to the middle Holocene (Huckleberry 1997), but these have likely formed in coarse-textured or high-carbonate alluvium. The development of true calcic horizons requires less time in these parent materials (Birkeland 1999; Gile 1975; Gile et al. 1981; Machette 1985; McFadden and Tinsley 1985).

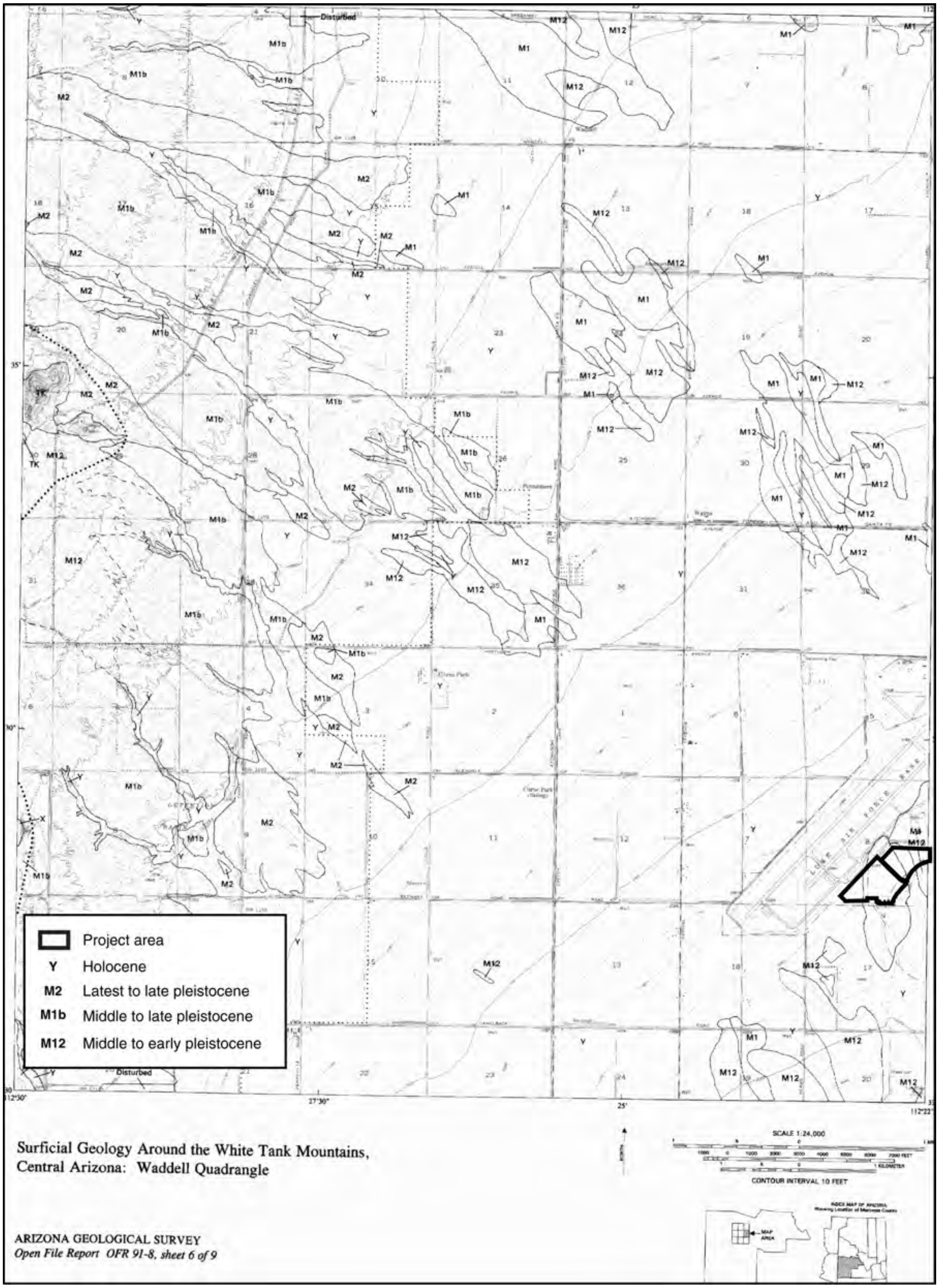
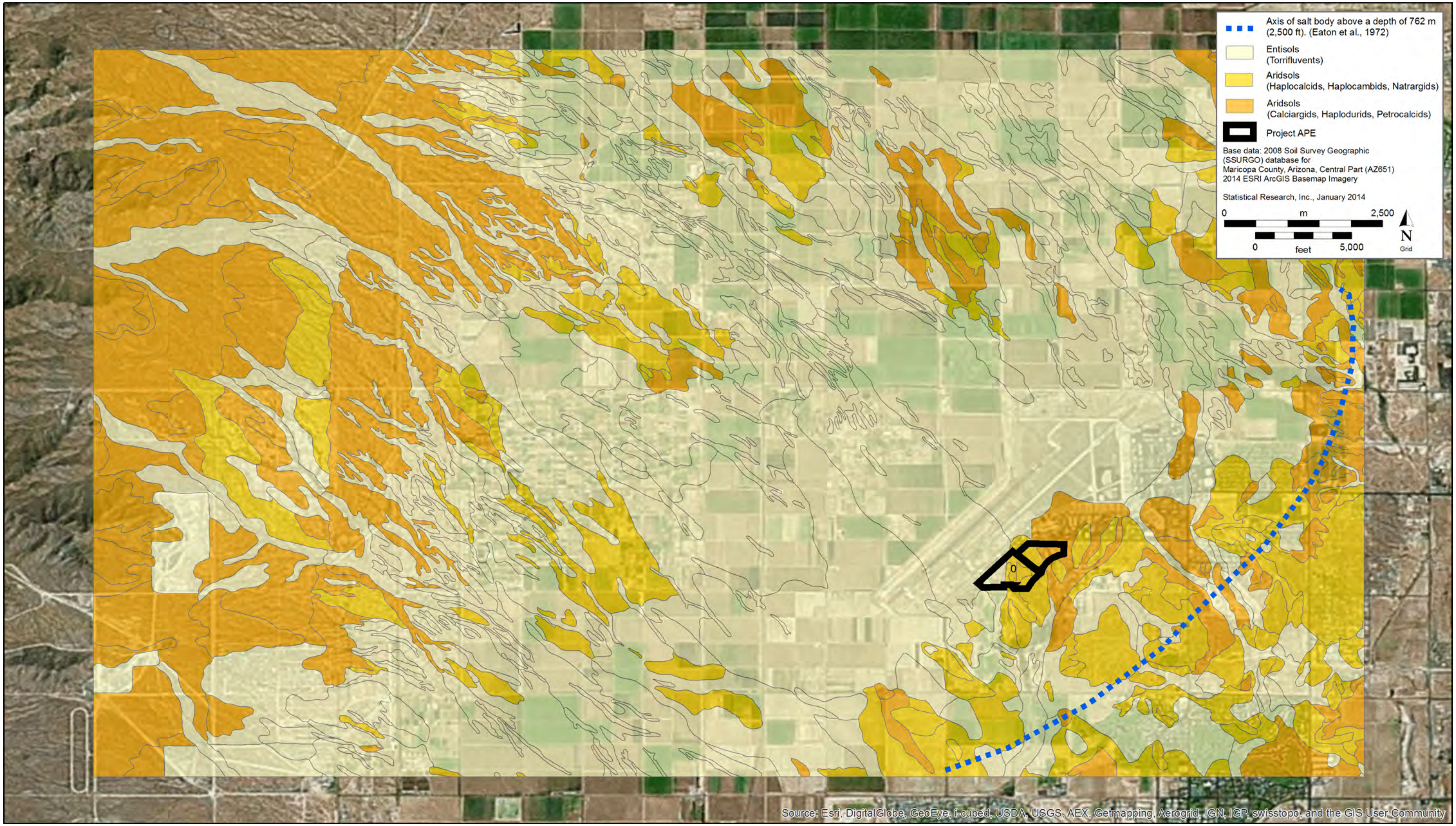


Figure 6. Geologic map of the Eastern White Tank Mountains piedmont (modified from Field and Pearthree 1991).



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7. Soil map showing distribution of Aridisols and Entisols on the Eastern White Tank Mountains piedmont.

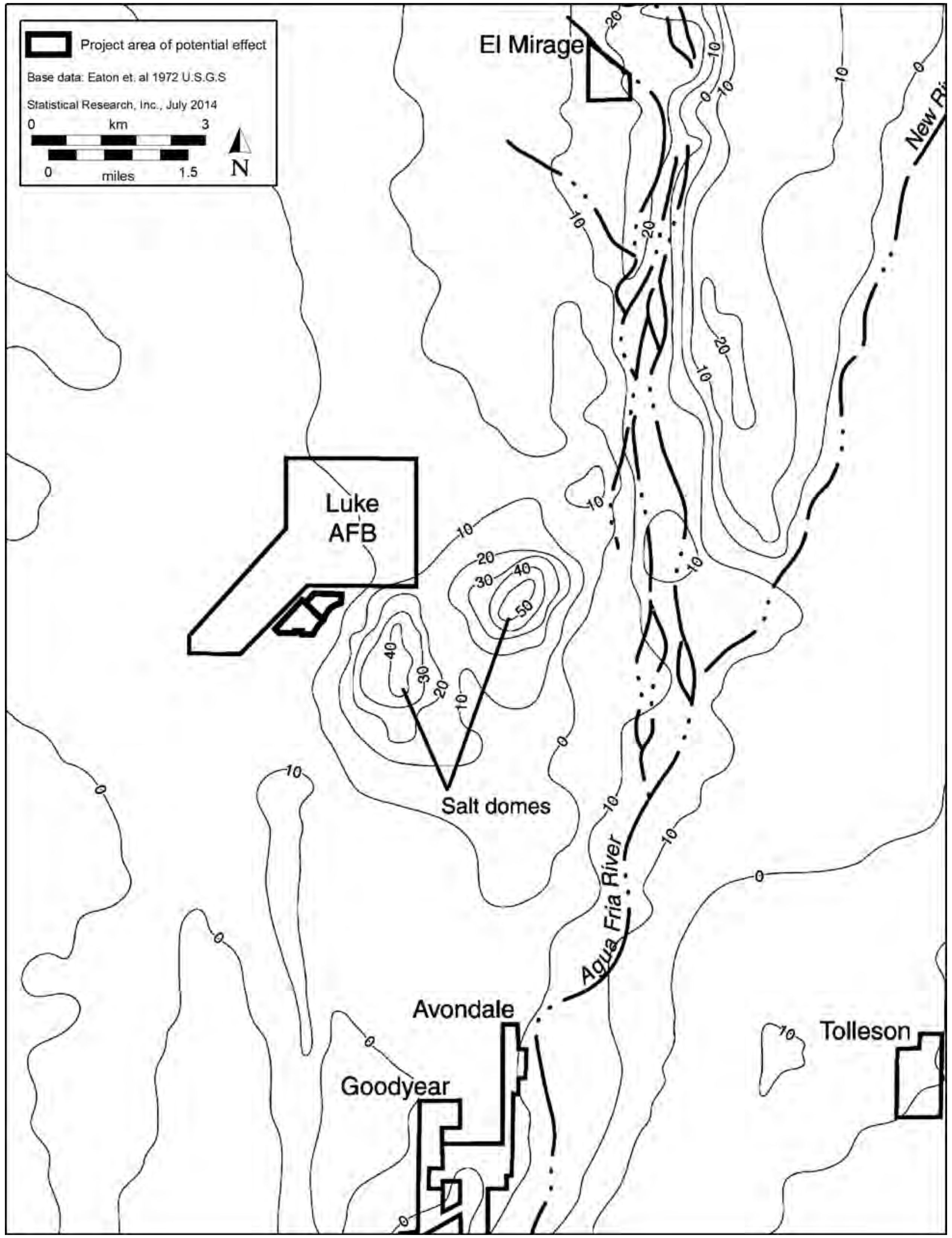


Figure 8. Location of salt domes east of Luke AFB.

The salt domes are mapped as Aridisols with calcic, petrocalcic, or duripan subsurface soil horizons (see Figure 7). Relict middle to late Pleistocene landforms are often buried by Holocene alluvium on much of distal piedmonts. The presence of these relict soil horizons near the modern surface (within 100 cm) on and adjacent to the salt domes suggests these deposits were uplifted by the rise of the underlying Luke Salt Body. Because salt bodies are lighter than surrounding rock, they are buoyant and rise toward the surface in the earth's crust. Indurated soil horizons have very low permeability, so they have the potential to perch local water tables. The La Palma soil series is mapped in multiple areas adjacent to the salt domes. The official soil series description notes the presence of a relict perched water table in the B horizons above the petrocalcic horizon (https://soilseries.sc.egov.usda.gov/osdname.asp, accessed August 2013).

The salt domes themselves are 14–17 m (45–55 feet) in height, semicircular in shape, and have a diameter of about 3 km (1.9 miles) at their base (Figure 8). A quasi-radial drainage pattern is visible in aerial imagery on both of the domes, and a small drainage net has developed between them. A comprehensive description of the unconsolidated deposits forming the salt domes does not currently exist, but they were briefly examined by geologist M. E. Cooley (Eaton et al. 1972:2):

> The deposits comprising the hills are divisible into two units—a younger gravel and an older silt to silty sand. The gravel is thin and is not present on the summits of all the hills. Where it is present, it has the appearance of a terrace deposit, which tends to mask the presence of the underlying unit. The gravel unconformably overlies the older unit and has a maximum observed thickness of 6 feet. It consists mainly of rounded to subrounded pebbles composed of volcanic, granite-gneiss, and other silicic types. In places there are also a few rounded cobbles and small boulders as much as 16 inches in the long dimension. In its overall appearance, the gravel is similar to that transported by the nearby Agua Fria River and dissimilar to the well-rounded to rounded quartzitic and hard silicic pebbly to cobbly gravel exposed in terraces along the Salt River. The imbrication or arrangement of the gravel indicates that it was deposited chiefly by southwestward-moving water, but the range of individual measurements is from the southwest, through south, to west-northwest.
>
> The older unit is composed principally of buff silt and some thin layers of silty sand and sand. It is weakly cemented by limey materials. Some thin beds contain more than 75 percent of porous limestone (or caliche). At one exposure, the silt has been crumpled somewhat and is interlaced with very thin calcite veins, which dip at different angles and trend in different directions. In general, the deposit resembles silt-sand beds exposed near the lower Hassayampa River to the west and other fine-grained deposits in Arizona that are considered to be of late Tertiary (chiefly Pliocene) age.

At the Morton Salt facility located 4 km (2.5 miles) northeast of the project area, well logs indicate the top of the salt body is 268 m (880 feet) deep and extends to a maximum depth of 3,600+ m (11,810 feet) (Gootee 2013). The depth to the top of the salt body below the salt domes is estimated to be 150 m (490 feet) (Figure 9). Approximately 1.6 km (1 mile) east of LAFB, an exploratory test hole drilled in 1968 by the Arizona Salt Company and El Paso Natural Gas Company penetrated the salt body at a depth of 241 m (790 feet) (Eaton et al. 1972).

The origin of this massive salt body is not well understood. Bromide content indicates it was deposited in a lacustrine (freshwater) environment, but such a large volume of salt has not been documented in a freshwater setting in the western United States (Eaton et al. 1972). A possible explanation is that the Luke Basin is at the lowest point of a series of playas that runs along the Gila Low, a geologic subprovince in south-central Arizona that includes the Luke, Picacho, Paradise, and Higley Basins (Peirce 1984). The age of the salt is not well constrained; however, a basalt flow overlying the Luke Salt Body was dated to 10 million years ago (Ma) and this is interpreted to be a minimum age for the lower Luke Basin fills, including the salt deposits (Eberly and Stanley 1978).

Several groundwater studies conducted adjacent to LAFB have identified an area of low groundwater transmissivity (or permeability) in the upper 150 m (490 feet) of valley fill immediately south-southeast of the base (Anderson 1968; Stulik and Twenter 1964). This area appears to be associated with fine-grained alluvium that may have been compacted and partially cemented by the buoyant rise of the Luke Salt Body (Eaton et al. 1972).

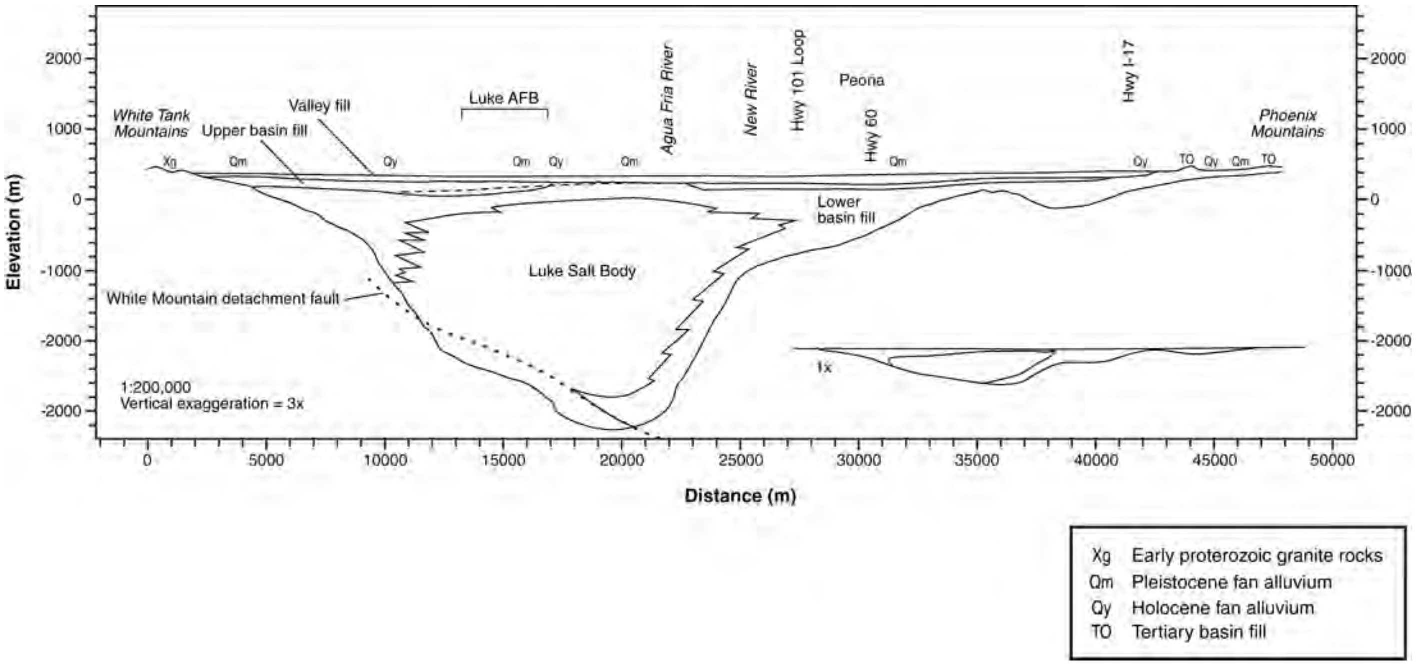


Figure 9. Cross section of the Luke Basin showing distribution of the Luke Salt Body (modified from Gootee 2013).

White Tank Mountains Piedmont Geomorphic Processes and Taphonomic Implications

The primary mechanism of erosion, sediment transport, and deposition on the White Tank Mountains piedmont is the discontinuous ephemeral-fan drainage system. All discontinuous ephemeral streams contain a repetitive sequence of three main reaches: the headcut tributaries, the master stream, and the alluvial-fan reach (Bull 1997; Leopold et al. 1964; Packard 1974; Schumm and Hadley 1957) (Figure 10). One complete headcut–master stream–alluvial-fan sequence can be repeated at intervals ranging from less than 15 m (ca. 50 feet) in small drainage networks to over 10 km (6.2 miles) along major streams (Bull 1997). In both large- and small-order streams, the positions of the main reaches are not constant; they evolve over time in response to a number of internal and external geomorphic forcing mechanisms. Reach migration over timescales ranging from a single storm event to several millennia produces a complex stratigraphic sequence that is very difficult, if not impossible, to reconstruct without multiple lines of geologic evidence. The following text reviews the geomorphic characteristics and geoarchaeological implications of each individual reach in a discontinuous ephemeral stream system.

The headcut-tributaries reach in the upper drainage marks the beginning of channelized surface flow (Leopold et al. 1964) (see Figure 10). Typically, many small tributary channels emerge from a series of headcuts incised in the fan toe of the upstream alluvial-fan reach. These channels converge downstream to form the head of the master channel reach. Headcut retreat occurs at the knickpoint (vertical face of the headcut) and is typically caused by water seeping out of the vertical face after heavy precipitation events (Leopold et al. 1964). Viewed in stratigraphic profile, the headcut tributaries are incised, or inset, into older fan alluvium and are filled with poorly sorted channel deposits. Channelized flow along the tributary channels can have a negative impact on archaeological deposits by displacing and transporting artifacts long distances downstream. Additionally, deflation of the surface between tributaries via rill and sheet erosion commonly concentrates stratified cultural occupations onto a single erosional surface.

The point where the headcut tributaries converge is the start of the master channel reach (see Figure 10). The master channel consists of a single gully that contains both narrow, deeply incised chutes and wider braided segments. Like the tributaries reach, the master channel is incised into older alluvial deposits. The depth of the master channel decreases downstream until stream discharge overflows from the channel and intersects the surface (Leopold et al. 1964; Packard 1974). This intersection point marks the fan head or proximal part of the alluvial-fan reach (see Figure 10). In stratigraphic sections, master channel deposits consist of sandy and/or gravelly channel alluvium contained either within a single channel or multiple closely spaced channels. Fine-grained sheet-flood deposits (overbank flood deposits) coeval with the channel alluvium may be present adjacent to the master channel. Because of the higher energy associated with channelized flow, archaeological remains recovered from master channel deposits are commonly displaced from their primary contexts (Waters 1992). Preexisting stratified cultural occupations within the older alluvium exposed along the gully walls are also subjected to erosion via bank undercutting and slump. Cultural occupations within the master channel reach, however, can be quickly buried by channel alluvium and well preserved in primary context.

The alluvial-fan reach of a discontinuous ephemeral stream begins at the intersection point. The fan reach can be further subdivided into three primary components: the fan head, the middle fan, and the fan toe (see Figure 10). At the fan head, flow spreads out laterally from the intersection point along shallow diverging channels. On some fans, large peak-flow events have incised and extended the master channel into the upper fan to create a fan-head trench. On the middle fan, the bifurcating fan-head channels quickly lose definition and grade into small depositional lobes (Schuster 1990). The middle fan is often characterized by a combination of channelized and unchannelized flow that results in a complex stratigraphic sequence of bedded channel lenses and massive sheet-flood deposits (Packard 1974). Finally, the fan toe is characterized by a complete loss of channelized flow, and the deposition of suspended sediment load (silts and clays) in shallow deposits that form a broad sheetwash plain (Schuster 1990).

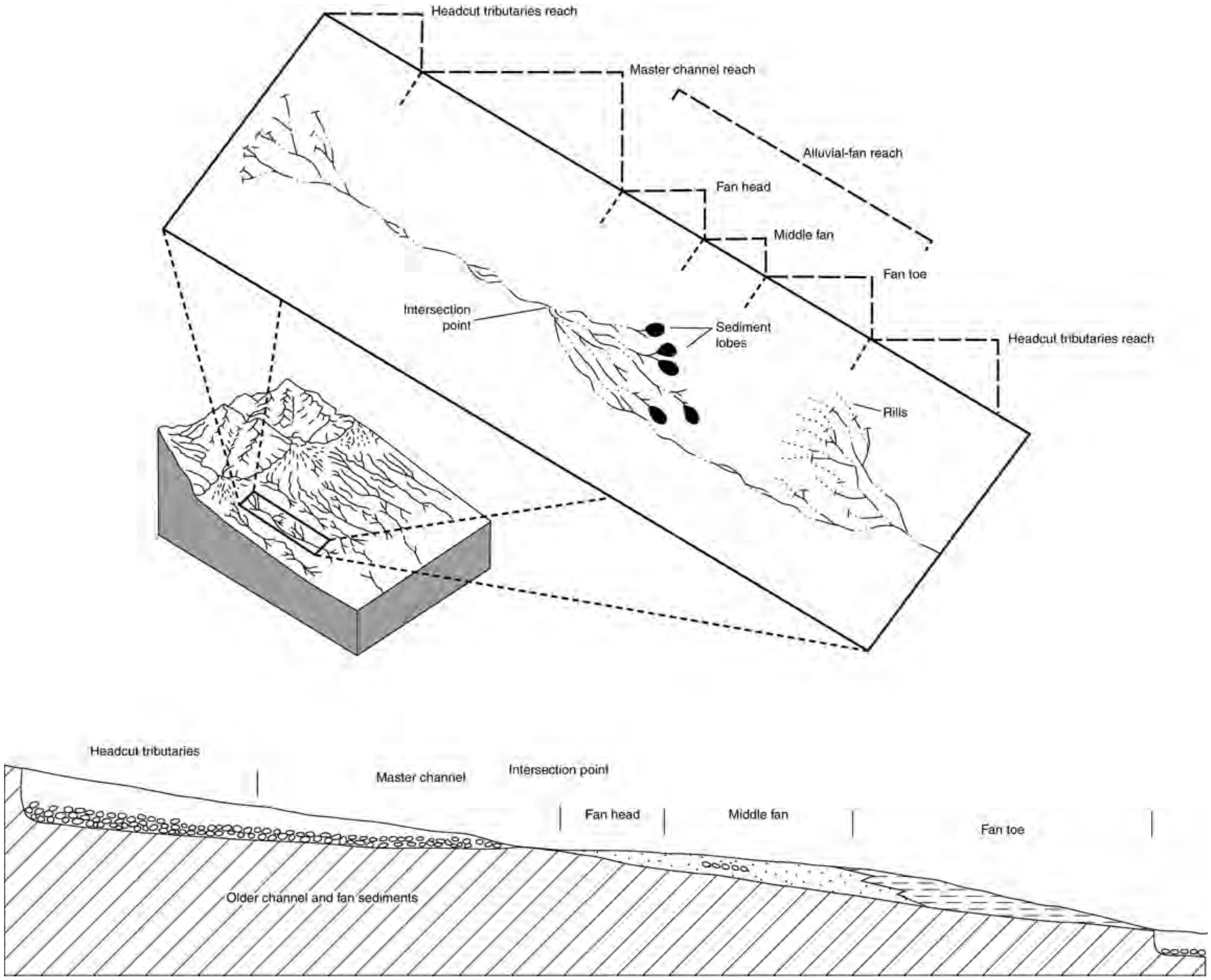


Figure 10. Schematic diagram of a discontinuous ephemeral stream network (modified from Schuster 1990).

Buried archaeological sites are commonly found in the alluvial-fan reaches of ephemeral streams in southern Arizona (Phillips et al. 2001; Rice 1987; Schuster 1990; Waters 1987; Waters and Field 1986). Many of these sites have contained intact house floors and activity areas that were minimally disturbed by superimposed sheet-flood deposits (Schuster 1990; Waters and Field 1986) because sheetwash has a low-tractive force that is unlikely to entrain and redeposit artifacts over significant distances (Waters 1992). However, sheetwash often forms a shallow blanket of fine-textured alluvium over preexisting bar-and-swale fan surfaces. Prehistoric occupations on the topographically higher bars will be shallowly buried and subsequently subjected to more-intense pedoturbation processes. Conversely, more-deeply buried cultural materials in swales will be partially or completely removed from the active zone of pedogenesis and are therefore more likely to remain in primary context. Additionally, the upstream migration of the headcut tributaries reach will impact buried archaeological deposits in the fan toe.

A complete fan drainage contains multiple headcut tributary–master channel–alluvial-fan segments that make up a discontinuous gully system (Schuster 1990; Waters 1992). The general pattern of reach migration is in an upstream direction. Headcuts move and expand upstream, thereby generating larger volumes of sediment that aggrade onto the alluvial-fan reach. Continued aggradation on the fan eventually begins to bury the lower end of the master channel reach. The result is a system in which each individual reach migrates upstream over the adjacent reach (Schuster 1990). Over time, this produces a stratigraphic sequence of stratified and interfingering facies. A complete stratigraphic section recording the succession of stream reaches upstream is rarely encountered. Rather, discontinuous streams usually migrate laterally via channel avulsion to cause adjacent fan systems to overlap and grade into one another (Field 2001). This produces a stratigraphic section that can include deposits from a single alluvial fan or from multiple adjacent alluvial fans.

In summary, because of the complex alluvial architecture associated with ephemeral drainage networks, contemporary archaeological resources will be simultaneously exposed on the surface and buried at variable depths in different parts of the same alluvial-fan/ephemeral drainage system. This introduces variable levels of taphonomic bias into the archaeological record that can only be recognized if the geologic context of the site is well understood. This is particularly challenging in alluvial-fan environments because fan deposits generally cannot be correlated across space without independent age control.

Geochronology and Paleoclimatic Significance of Sonoran and Eastern Mojave Desert Alluvial Fans

Geomorphic studies focused on mapping and dating alluvial fans have identified a rough regional synchronicity in periods of active fan deposition in the Sonoran and eastern Mojave Deserts (Bull 1977, 1984, 1991; McDonald et al. 2003; McFadden et al. 1989; Wells et al. 1987). These studies cite climate change, particularly wet to dry phase changes during the Pleistocene–Holocene transition, as the driving mechanism behind synchronous episodes of alluvial-fan aggradation (Bull 1991; McDonald et al. 2003). Few studies, however, have concentrated on the linkage between Holocene climate variability and alluvial-fan activity. Soil geomorphic characteristics of *bajada* surfaces, along with a handful of radiocarbon dates, indicate that Holocene alluvial fans are extensive on middle to lower piedmonts in southern Arizona (Bacon et al. 2010; Bull 1991; Field and Pearthree 1991). As Bacon et al. (2010) note, many of these fans grade into larger stream systems that are known to contain extensive Holocene alluvial and archaeological records (Huckleberry et al. 2013; Waters 2008). The following text summarizes relevant fan-climate studies for the Sonoran and eastern Mojave Deserts. In the following text, calibrated radiocarbon dates are presented as calendar years before present (cal B.P.), uncalibrated dates as radiocarbon years before present (^{14}C yr B.P.), and the geomorphic surfaces of Bull (1991) and uranium-series (U-series) dates from speleothems as thousands of years before present (ka). The ka dates are comparable to calendar years. An approximate calibrated radiocarbon date is provided for uncalibrated dates in calendar years before present (cal B.P.).

Studies of Quaternary alluvial geomorphic surfaces in the lower Colorado River drainage (southern Arizona, southeastern California, and southern Nevada) have identified nine generations of alluvial fans and stream terraces based on their topographic features, pedogenic characteristics, and desert-pavement and varnish development (Bull 1991:Table 2.2). Because of their regional extent, Bull considered these surfaces to be the result of climate change rather than geomorphic variables intrinsic to individual drainage systems. Within the context of past human occupation, five of these alluvial fans (Q4a and b; Q3a, b, and c) aggraded while indigenous and/or historical-period groups occupied the Sonoran landscape. The remaining four (Q2c, b, a, and Q1) were already present when human populations first arrived in the latest Pleistocene.

The Q3 surfaces (Q3a, b, and c) represent *bajada* deposition during the Holocene (12–2 ka). Q3 surfaces have been stable long enough to develop desert pavements but remain largely undissected by on-fan drainages. As noted previously, these surfaces commonly are more extensive on middle to lower piedmonts where they bury older fan deposits. Because Q3 surfaces have not been subjected to long periods of erosion, some original constructional bar-and-swale topography is usually preserved. This gives Q3 surfaces a distinctive plumose appearance in aerial imagery. Soil development in Q3 is limited to the formation of 15–20-cm-thick Bk horizons with Stage I calcium carbonate morphology (that is, fine filaments or thin coatings on the underside of gravels). However, early Holocene fans (Q3a) may contain Stage II nodules or weakly developed argillic horizons (Bt horizons marked by significant accumulations of clay that have been translocated from above) (Bull 1991:Table 2.2). The youngest surfaces, Q4a and b, represent gravelly bars and channels along active or recently abandoned streams. These surfaces are characterized by a lack of desert pavement and either incipient or complete lack of rock varnish. On the middle to upper piedmont, Q4 surfaces are confined to narrow incised channels and are subject to modification by flooding. On distal piedmonts, small Q4 fans are often inset below Q3 surfaces. Soil formation in Q4 deposits is generally absent or only very weakly expressed.

Holocene piedmont surfaces of the lower Colorado River drainage have been assigned relatives ages based mainly on soil development and topographic characteristics, but several studies have systematically dated Holocene deposits using absolute-dating techniques (e.g., Bacon et al. 2010; Cerling et al. 1999; Clark 1994; Liu, Phillips, Pohl, and Campbell 1996; McDonald et al. 2003; Miller et al. 2010; Phillips et al. 2001; Wells et al. 1987; Wells et al. 1990). Early Holocene alluvial fans, Q3a (12–8 ka) of Bull (1991), are not well dated in Arizona. Several studies in the eastern Mojave Desert bracket latest Pleistocene to early Holocene fan deposition between 14,000 and 9400 cal B.P. on the Soda Mountains (Wells et al. 1987) and 12,500–10,400 cal B.P. on piedmonts of the Providence Mountains (Clark 1994). These dates span the Pleistocene–Holocene transition, a time in the desert Southwest when increased summer storm (monsoon) activity may have promoted channel incision, fan-head entrenchment, and fan aggradation (Bull 1991; Harvey et al. 1999; Wells et al. 1987). This interpretation is largely based on a late Pleistocene–early Holocene increase in succulents and grasses in pack-rat middens across the eastern Mojave and Sonoran Deserts (Spaulding 1985; Spaulding and Graumilch 1986; Van Devender 1990). However, an increase in extreme storm events associated with late-season Pacific frontal storms and late-summer tropical cyclones may also have played an important role (McAuliffe and Van Devender 1998; McDonald et al. 2003; Van Devender et al. 1987). A high stand of Paleolake Cochise (McDonald et al. 2003) in southeastern Arizona and the presence of early Holocene lake clays at Montezuma Well (Davis and Shafer 1992) in central Arizona further suggest an early Holocene pluvial period supported by increased summer precipitation.

At the end of the early Holocene, an episode of significant and rapid global climate change has been documented in numerous paleoclimatic records between 9000 and 8000 cal B.P. (Alley et al. 1997; Mayewski et al. 2004). The catastrophic drainage of glacial lakes between 8400 and 8000 cal B.P. and the subsequent disruption of ocean circulation is cited as the primary cause (Barber et al. 1999). At lower latitudes, this global event was characterized by a period of increased aridity in a generally wet, early Holocene, along with a shift in precipitation regimes (deMenocal et al. 2000). At Montezuma Well, lower lake levels were marked by a transition from lake muds to peat around 8000 ^{14}C yr B.P. (approximately 7000 cal B.C.) and a pronounced increase in charcoal at 7300 ^{14}C yr B.P. (approximately 6000 cal B.C.), which suggests burning of the marsh surrounding the lake (Davis and Shafer 1992). The resolution of existing alluvial-fan and pack-rat-midden chronologies is generally not sufficient to identify this global event.

By 8 ka, the present climatic and vegetational regimes across much of the Southwest had been established (Van Devender 1990). Antevs (1955) originally defined the middle Holocene from approximately 7–4.5 ka as the Altithermal period. First identified in the winter precipitation–dominated Great Basin, this warm period has been extended to include other areas of the Southwest that predominantly receive summer precipitation during the North American Monsoon (NAM) (Van Devender and Spaulding 1979). However, atmospheric circulation patterns that result in dry conditions in the Great Basin are unlikely to produce the same result in the Sonoran or eastern Mojave Deserts. This is evident in the fossil pollen record of the Murray Springs and Double Adobe sites where pollen data indicate a period of greater effective moisture and a shift in vegetational zones downward in elevation by 300 m (980 feet) (Martin 1963; Mehringer et al. 1967). Sonoran Desert pack-rat-midden chronologies also reveal an increase in summer-rainfall-obligate plant species during the middle Holocene (Van Devender 1990). Van Devender and Spaulding (1979) argue that areas characterized by summer monsoons actually had increased summer rainfall due to warmer global temperatures favoring the development of the Bermuda High. By contrast, the lacustrine record of Paleolake Cochise in the Willcox Basin indicates that a lake was absent during the Altithermal from 7–5 ka and did not fill again until the end of this period (5–4 ka) (Waters 1989). Bull (1991) and Miller et al. (2010) suggest that increases in warm-season high-intensity storms favor hillslope erosion and alluvial aggradation and that periods with increased cool-season frontal storms cause major flooding and the expansion of ephemeral lakes. Interestingly, very few alluvial-fan deposits have been directly dated to the middle Holocene, especially between 8000 and 6000 cal B.P. (Miller et al. 2010:54), which contradicts this idea of fan aggradation in response to increased warm-season precipitation. Because there are few geochronological studies focused on dating Holocene fan deposits, it is difficult to determine if this was a regional trend.

The latter half of the Holocene is characterized by climatic conditions similar to the present, namely, hot and dry, but some significant fluctuations have been documented. Numerous studies of alluvial and lacustrine records in the southwestern United States cite an increase in the frequency and strength of El Niño-Southern Oscillation (ENSO) in the late Holocene as the cause of significant changes observed in terrestrial records (Bacon et al. 2010; Liu et al. 2000). This idea is supported by historical climate records that correlate El Niño climatic patterns with increased winter North Pacific frontal storms and Pacific tropical cyclones that track into the Southwest and stimulate increased winter and spring precipitation (Andrade and Sellers 1988). Some of these events (e.g., tropical storm Nora in 1997) promoted substantial erosion and deposition on southern Arizona piedmonts (Pearthree et al. 2004). Although it is widely accepted that ENSO climatic patterns are responsible for major shifts in precipitation during the late Holocene, the type of atmospheric conditions and the hydrologic processes responsible for these changes are poorly understood (Bacon et al. 2010; Scuderi et al. 2010).

Paleoflood chronologies spanning the last 6,000 years reconstructed for rivers in Arizona and southern Utah indicate that floods are divided into distinct time periods (Ely 1997; Harden et al. 2010). Although sampling bias may have influenced the development of these chronologies (Ballenger and Mabry 2011), they still document significant periods of aggradation along major drainages. Evidence indicates high-magnitude floods along bedrock reaches from 5000 to 3600 ^{14}C yr B.P. (5800–4200 cal B.P.) and again between 1100 and 900 ^{14}C yr B.P. and after 500 ^{14}C yr B.P. (approximately 1050–950, 910–750, and 540–510 cal B.P., 2σ range) (Ely 1997). Harden et al. (2010) documented episodes of significant flooding along bedrock and alluvial reaches at 6700–5700, 5600–4820, 4550–3320, and 2000–0 cal B.P., with major peaks at 6300, 5380, 3850, and 1310 cal B.P. Increases in cool-season storms during the negative phase of the Southern Oscillation Index (El Niño conditions) are considered responsible for the increased frequency of flooding during these times (Ely 1997).

Although El Niño conditions are well correlated with cool-season precipitation and flooding along major streams, ENSO impacts on alluvial-fan activity are more difficult to determine. What is known, however, is that after 6000 cal B.P. there was a significant increase in alluvial-fan aggradation across much of the eastern Mojave and Sonoran Deserts (Bacon et al. 2010; Cerling et al. 1999; Liu, Phillips, Pohl, and Campbell 1996; McDonald et al. 2003; Miller et al. 2010; Phillips et al. 2001; Wells et al. 1987). These studies indicate that alluvium underlying the Q3b and c (8000–2000 yr B.P.) mapping units of Bull (1991) commonly date between 6000 and 2000 cal B.P., with a prominent peak between 6000 and 3000 cal B.P. in the Mojave and eastern Sonoran Deserts and between 3200 and 2300 cal B.P. in the southwestern Sonoran Desert. These date ranges are interesting because they put alluvial-fan aggradation out of phase with the warm and dry middle

Holocene (8–4 ka) and increasingly wet and cool late Holocene (4–0 ka) paradigm espoused by southwestern researchers (e.g., Antevs 1955; Bull 1991). Rather than correlating with broad changes in average temperature and mean annual precipitation, these episodes of fan aggradation appear to be more closely linked to periods of rapid global climate change dated between 6000 and 2500 cal B.P. and enhanced ENSO climatic patterns (Bacon et al. 2010; Mayewski et al. 2004; Miller et al. 2010).

The first of these periods of global climate change took place between approximately 6000 and 5000 cal B.P. (Mayewski et al. 2004) and corresponds very closely to an abrupt increase in sea surface temperatures in the Gulf of California as detected in microfauna proxy data at 6200 cal B.P. (Barron et al. 2005; Miller et al. 2010). This was deemed significant because an increase in NAM activity has been closely correlated to increased sea-surface temperatures in the Gulf of California (Mitchell et al. 2003). Miller et al. (2010) suggest that more-intense NAM events after 6200 cal B.P. triggered sediment transport on slopes that resulted in widespread alluvial-fan aggradation between 6000 and 3000 cal B.P. A U-series–dated speleothem record from the Cave of Bells located on the eastern side of the Santa Rita Mountains in southeastern Arizona also suggests dry and warm winters and a stronger summer monsoon between 6.9 and 3.5 ka (Wagner 2006). In south-central Arizona, the geoarchaeological study of an Archaic occupation in a *bajada*/alluvial-fan setting located 10 km (6.2 miles) east of the McDowell Mountains in the northern Luke Basin (Last Ditch site [AZ U:5:33 ASM]) documented Archaic occupations in association with alluvial-fan deposits that began to aggrade around 5000 cal B.P. (Phillips et al. 2001). Archaic occupations were largely coeval with aggradation of the fan between approximately 5000 and 3800 cal B.P. If widespread alluvial-fan aggradation is related to an increase in high-intensity warm-season precipitation events after 6000 cal B.P., it is possible that fan aggradation here was also triggered by ENSO-intensified NAM activity.

Late Holocene Q3c alluvial-fan deposits have been dated between 3200 and 2300 cal B.P. in several areas of southern Arizona and the Colorado Plateau. These fans correlate with a period of rapid global climate change between 3500 and 2500 cal B.P. and a pronounced El Niño climatic pattern from 3200 to 2800 cal B.P. (Mayewski et al. 2004; Sandweiss et al. 2001). Atmospheric conditions created by an intensified ENSO cycle after 3300 cal B.P. favored regional alluvial-fan aggradation between 3200 and 2950 cal B.P. near Yuma, Arizona (Bacon et al. 2010), between 2750 and 2350 cal B.P. in the Ajo Mountains (Liu, Phillips, and Campbell 1996), sometime between 3500 and 1000 cal B.P. in the Phoenix Basin (Rogge and Phillips 2009a), and between 3300 and 2200 cal B.P. on the Colorado Plateau (Cerling et al. 1999). Regionally, paleoclimatic proxies indicate unusually wet conditions over this same time period, supporting the idea that fan aggradation was caused by climate change. Periods of increased precipitation were dated to 3.3–2.7 ka (U-series dates) in the speleothem record of Carlsbad Caverns and Hidden Cave in the Guadalupe Mountains of New Mexico (Asmerom et al. 2007; Polyak and Asmerom 2001). Sediment cores from the Gulf of California also have identified two significant ocean-cooling events centered around 3400 and 2700 cal B.P. (Pérez-Cruz 2006). These cooling events were separated by a 700-year period of increased ocean temperatures indicative of periodic El Niño sea-surface conditions. Alluvial chronologies in the Gila River watershed further point to multiple episodes of synchronous arroyo cut-and-fill cycles after 4500 cal B.P. (Waters and Haynes 2001). A major period of aggradation along both the Santa Cruz and San Pedro Rivers was documented between 4000 and 2500 ^{14}C yr B.P. (Haynes 1987; McDonald et al. 2003).

Latest Holocene alluvial fans (less than 2 ka, Q4 of Bull [(1991]) are not extensively dated in the Sonoran or eastern Mojave Deserts. Over the last 2,000 years, episodes of rapid climate change have been documented around 1200–1000 and 600–150 cal B.P. (Mayewski et al. 2004), both in regional and global paleoclimatic proxy records. Arroyo formation and periods of increased flooding correlate to these events along southwestern drainages, but the impact on desert piedmonts is not as clear (Ely 1997; Huckleberry et al. 2013; Waters 2008; Waters and Haynes 2001). On the piedmont of the western Tortolita Mountains north of Tucson, late period Hohokam agricultural settlements dating between 1000 and 650 ^{14}C yr B.P. were associated with Q4 fans. Cultural features were stratified within alluvial-fan deposits, thereby indicating occupation during periods of fan aggradation. These occupations were associated with small seasonally active fans. People apparently avoided placing their settlements on larger dynamic fans (Waters and Field 1986). It is possible that the occupations between 1000 and 650^{14}C yr B.P. correspond with a period of lower-energy fan deposition. Larger climatically driven fan aggradation at 1200–1000 and 650–150 cal B.P. was poorly suited for *ak chin* agriculture, which requires low-energy non-erosive sheetwash (Schuster 1990; Waters and Field 1986). Whether this pattern corresponds to any regional trend remains unknown.

Modeling of Radiocarbon Data Sets

Over the last few decades, large radiocarbon data sets have become more common in archaeological and earth science research (Kerr and McCormick 2014). The most common methods employed for presenting these data are sum probability curves and/or Bayesian age-depth models generated in OxCal or Calib radiocarbon calibration software. Sum of probability curves, or cumulative probability density functions (CPDFs), are xy plots with probability density on the y axis and calibrated age on the x axis. Such frequency distributions are often cited as evidence for the rise and fall of prehistoric human populations (Kerr and McCormick 2014; Surovell et al. 2009). This technique, however, is subject to certain caveats. Each radiocarbon date represents a specific moment in time, but the calibrated date gives a spread of possible dates with a definite margin of error. The quality of the material dated and the shape of the calibration curve influence the range or spread of possible younger and older dates on each side of the actual date (Baillie 1991; Wiener 2012). This "smearing" effect is particularly problematic on flat areas of the calibration curve, such as the 800–400 B.C. plateau, or where the curve oscillates enough to produce several intercepts (Wiener 2012). As a consequence, the calibrated ages can artificially flatten or peak the probability distribution giving an anomalous population proxy for those time periods (Williams 2012).

The Baysian approach incorporates a priori knowledge of the stratigraphic relationship between radiocarbon dates in the data set. Bronk Ramsey (2011) considers the Baysian age-depth approach to be a more reliable indicator of past events than CPDFs. In OxCal modeling software, the "Sequence" code is used to constrain a group of dates to a chronologically controlled stratigraphic unit. The geochronological framework can then be used to identify periods of site occupation and place temporal constraints on these occupational episodes. OxCal software then uses the constraints introduced by this structure to calculate the modeled posterior density estimate of each feature's calendar age and to assess the integrity of the overall model. In many cases, these constraints result in more-refined age estimates by requiring one set of features to be older (or younger) than another, thus truncating the probability distributions of the unmodeled calibrated radiocarbon dates. Of course, this method is most successful where a well-defined stratigraphic sequence has been previously constructed (Kerr and McCormick 2014).

Taphonomic, sampling, and discovery biases are also important factors that influence both temporal frequency distributions and Bayesian a priori models (Ballenger and Mabry 2011; Surovell et al. 2009). Taphonomic bias is introduced by processes that destroy the fossil record (Allison and Bottjer 2011). Like the archaeological record, radiocarbon chronologies are limited by the completeness and integrity of the geologic record (Waters and Kuehn 1996). It is not possible to radiocarbon date the absence of alluvium; only the sediment preserved in the geologic record can be directly dated (Ballenger and Mabry 2011). This introduces taphonomic bias because older deposits are often more extensively eroded and are therefore not fully represented in the chronology. A similar form of taphonomic bias is introduced when organic material suitable for radiocarbon dating is not well preserved or was never deposited. In this case, the sediment in question has not been eroded but the absence of suitable material makes it impossible to radiocarbon date.

Alluvial chronologies, particularly in the Southwest, also suffer from discovery bias because only the sediment exposed along natural cuts (arroyos) is sampled. Nearby unincised deposits often remain unsampled because they are not easily uncovered for analysis. Finally, sampling or scientific bias can be introduced when certain samples are preferentially targeted based on preconceived research goals or sampling strategies. Overall, the missing time in radiocarbon chronologies can be attributed to many factors, including poor preservation of datable materials, discovery bias, sampling bias, or taphonomic loss (erosion) and may not accurately reflect prehistoric populations or geomorphic events (Ballenger and Mabry 2011).

Methods

The following section reviews the geoarchaeological and chronological methods. It is divided into two sections, field and postfield methods. Discussion of the field methods includes how the stratigraphy in trenches and excavation units was described, how the site stratigraphy was delineated, and how features were assigned to a specific stratigraphic unit. The discussion of postfield methods describes the chemical and physical laboratory analyses performed on soil/sediment samples, the radiocarbon-sample selection procedure, and elaborates on how the OxCal Bayesian model was constructed.

Field Methods

Trench walls were described using standard methods outlined in Schoeneberger et al. (2002), Soil Survey Staff (1993), and Birkeland (1999). Soil and sediment descriptions included the following observations: horizon boundary depth below modern surface; horizon designation (i.e., A, Bk, Bw, Bt); moist and dry Munsell colors; texture (by the ribbon method); gravel content, approximated by volume; soil structure; ped coatings (i.e., clay and organic films); consistence; secondary carbonate morphology (along with other concentrations such as iron, etc.); pores and voids; and horizon boundary characteristics. Additional notes were taken concerning the landscape context, including slope shape and gradient, vegetation, and signs of recent disturbance. Pedogenic features such as secondary carbonate accumulation, rubification (reddening), soil structure, and clay films along ped surfaces provided an estimate of the relative age of deposits (Birkeland 1999; Bull 1991; Gile 1975; Gile et al. 1981; Machette 1985; McFadden and Tinsley 1985). Intact bedding features, clast characteristics (shape, size, and orientation), and particle size were used to draw interpretations of sedimentary facies, that is, bodies of sediment formed in response to a particular sedimentary environment (Boggs 1987:307).

In total, 180 profile descriptions were made in backhoe trenches (Figure 11) and more than 40 descriptions along the edges of mechanical stripping units. Numerous shallow shovel tests were also excavated throughout the project area during mechanical excavation. By the end of the project, well over 300 stratigraphic observations were made across the project area.

The Luke Solar stratigraphic sequence was defined using an allostratigraphic model. Although the concept of the allostratigraphic unit was first introduced and defined in the 1983 *North American Stratigraphic Code*, Quaternary stratigraphers have long used bounding disconformities to define stratigraphic units (Haynes and Huckell 2007:30; Holliday 2004:76). As defined by the North American Commission on Stratigraphic Nomenclature (NACSN) (2005:1578), the allostratigraphic unit is "a mappable body of rock (or unconsolidated sediment) defined and identified on the basis of its bounding discontinuities." Allostratigraphic units are particularly useful for mapping sediments that are lithologically similar but clearly separated by disconformities (Birkeland 1999; Donovan 1996; Holliday 2004; Rinck 2014). The discontinuities can be erosional or pedogenic and can formally link geomorphic surfaces to discrete packages of sedimentary deposits across the landscape (the unconformity can be traced laterally). An allostratigraphic unit is defined as a depositional unit, not a soil, but a soil can be used to define the bounding unconformities. A properly defined allostratigraphic unit is a set of landforms and depositional sequences (including multiple facies) formed during a discrete period of time in response to a specific set of environmental conditions (Heinrich 1993:138). In a discontinuous ephemeral-stream setting, each allostratigraphic unit contains deposits from all of the major facies: headcut tributaries, master channel, and alluvial fan. This could include superimposed facies created via reach migration from a single stream system or interfingering facies from adjacent fans. The unconformities separating the Luke Solar stratigraphic units are the result of adjustments in the ephemeral drainage network(s) that ultimately limited alluvial deposition in the project area. Whether this was related to localized changes in the fan drainage network (i.e., reach migration or channel avulsion), or external forcing via climatic change, is something that is not easily discerned and is a major topic of discussion in the later parts of this chapter.

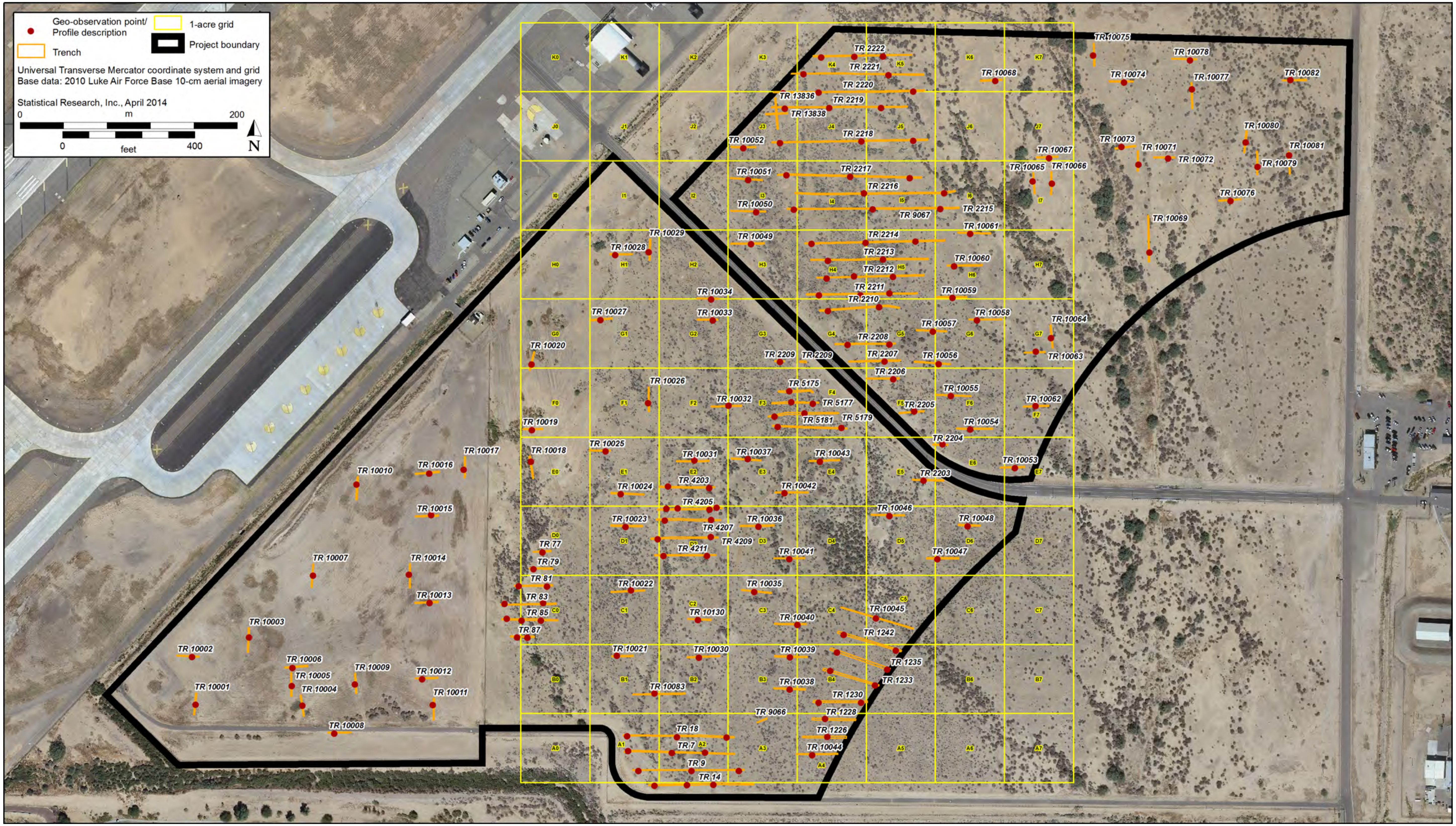


Figure 11. Luke Solar APE trench and profile locations.

In the following text, the primary Holocene units, Units I, II, III, IV, and V (oldest to youngest), are considered alloformations while Units IIA, IIs/sf, III1, III2, and III2cf are considered allomembers of the Unit II and Unit III alloformations. However, to facilitate discussion and because the terms alloformation and allomember are somewhat unwieldy, each unit, including the allomembers, is discussed individually and references to formation and member are rarely made.

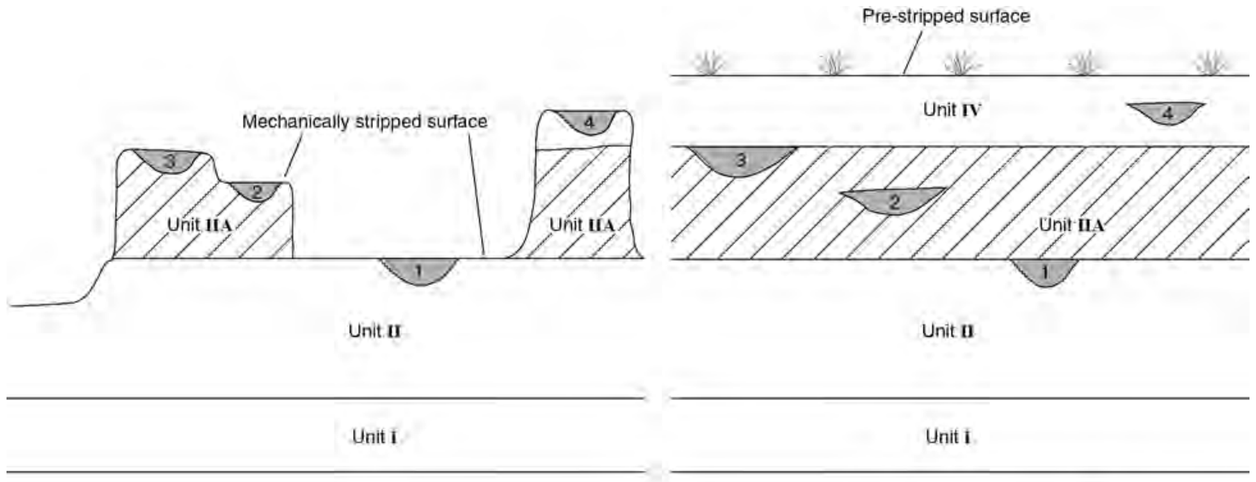
The alluvial deposits were divided into stratigraphic units based on their bounding disconformities using three main field criteria: soil development, stratigraphic position, and to a lesser degree, particle size and intact bedding features (i.e., facies assignments). Once the primary units were identified, some rudimentary correlations across short distances could be made in the field. Owing to the lateral complexity inherent in *bajada* settings, however, independent age control (radiocarbon dating) was necessary before a stratigraphic model could be constructed for the entire mechanically stripped area.

During the initial phases of fieldwork, the deposits were coarsely divided into Units I–IV (oldest to youngest), later amended to add a Unit V. These divisions were based primarily on soil development, namely pedogenic carbonate morphology. The presence of visible pedogenic carbonates was considered to be the most useful age-stratigraphic indicator because many of the deposits had very similar soil parent materials, specifically, silt loam alluvium derived from a noncalcareous granitic bedrock source. Additionally, in arid climates secondary carbonate accumulation typically occurs within the upper 10–20 cm of the soil surface (Birkeland 1999; Gile et al. 1981; Machette 1985; McFadden and Tinsley 1985). Although climatic perturbations have certainly occurred in the past, the overall climate has been arid and hyperthermic during the Holocene (Davis and Shafer 1992; Holmgren et al. 2003; Van Devender et al. 1987). This indicates that the zone of carbonate accumulation has likely been near the soil surface for at least the last 10,000 years. Although pedogenic carbonates can form deeper in the soil profile in arid environments, the presence of a buried accumulation of pedogenic carbonates typically marks a significant unconformity.

Unfortunately, soil development did not always provide a reliable means of correlation because deposits of the same age were both buried and exposed at or near the modern surface and therefore had very different pedogenic characteristics. However, the Litchfield Ranch (LR) Formation and Unit IIA were distinctive enough that they could be used as reliable stratigraphic markers. The LR Formation almost always had Stage II carbonates with some gypsum accumulations, and Unit IIA was a dark thick ABk horizon with abundant insect burrows and few Stage I carbonates. Additionally, the latest Holocene deposits, Units III–V, typically did not have visible pedogenic carbonates and were located stratigraphically above Units I and II in alluvial-fan reaches and inset (incised) into these same units along entrenched channels (headcut tributaries or master channel reaches).

As the excavations expanded during the course of fieldwork, the initial Unit I–IV sequence was amended to accommodate newly discovered deposits/unconformities. The biggest change occurred when a deposit that was thought to be a Unit II–IIA sequence was found to be an older deposit between Units I and II. Rather than renumber the entire sequence, this deposit became Unit I and the previous Unit I became the LR Formation. The other amendments resulted in the basic units being subdivided into members (allomembers). For example, the radiocarbon results indicated that Unit III should be divided into the allomembers III1, III2, and III2cf. These deposits were separated spatially and were rarely stratified at a single location, which is why they were not subdivided in the field. Additionally, swale fills and sheet-flood deposits on the Unit IIA surface began accumulating immediately after Unit IIA deposition and therefore were identified as Unit IIs (swale) or IIsf (sheetflood). Unit IIs/sf was the product of secondary fan processes acting on the surface of Unit IIA and Unit I over a long period of time. It therefore did not fit neatly into the old to young Unit I–V sequence of primary fan deposition.

Because geologic time has been accounted for in the stratigraphic sequence, the feature-stratum assignments provided a geologic age for many of the undated features. Considerable effort was made to maintain stratigraphic control during mechanical stripping. Each of the 3,400 features was individually inspected by examining the stratigraphy exposed in the feature pedestal if the surrounding mechanical-stripping unit (MSU) was stripped to a deeper depth, or in small shovel tests if the feature was level with the base of the stripping unit. These stratigraphic observations were then correlated with the nearest detailed profile description made during initial trenching of the project area. Commonly the feature could be reliably assigned to



	Geologic Age
Feature 1	Hiatus between II and IIA
Feature 2	Coeval with IIA deposition
Feature 3	Hiatus between IIA and IV
Feature 4	Coeval with IV deposition

Figure 12. Diagram showing possible geologic contexts of Luke Solar features.

a stratigraphic unit in the field, particularly in the northern and western portions of the project area where Units I, II, and IIA continued laterally for some distance. However, the complexity of the stratigraphic sequence increased to the south and east, making stratigraphic assignments difficult. In some cases, there was simply not enough information to assign the feature to a specific stratigraphic unit.

Features could be dated geologically in one of two ways. The feature either originated within an allostratigraphic unit, in which case it was coeval with deposition of that unit, or the feature originated at the surface of a unit, in which case it dated to the depositional hiatus (unconformity) between the unit the feature intruded into and the overlying unit (Figure 12). In some instances, the stratigraphic context of the feature could be assigned in the field because there was a clear stratification of adjacent features within a single stratigraphic unit. On most occasions, however, the stratification was too subtle and it was unclear whether the feature originated within or on the surface of the unit. In these cases, the elevation of the feature was compared to the elevation of the unconformities in the nearest profile description. If the feature originated at least 10–15 cm below the elevation of the unconformity it was assigned a coeval date. This buffer was used because it is likely that the upper part of some features was removed during mechanical stripping. If the feature was within 10 cm of the unconformity it was dated to the hiatus. In many instances, the field description, combined with the feature's elevation in relation to a nearby radiocarbon-dated profile, provided a reliable stratigraphic assignment. In some cases, the nearest profile was too far away and the stratigraphy too complex to accurately assign a feature to a specific stratigraphic unit.

Geologic mapping of the 46-acre stripped area was accomplished by examining high-resolution historical aerial photographs, modern satellite imagery, and by comparison of these images with field observations. The constructional topography of the latest Holocene units was visible in aerial imagery and could be easily delineated on the modern ground surface. Specifically, entrenched channel sections and the bar-and-swale topography inherent to distributary flow networks were clearly visible for most of the Unit III (Units III1, III2 and III2cf), Unit IV, and Unit V drainage networks. Mapping of Units I, II, and IIA was based largely on field observations because these units were buried by younger deposits and typically not visible in the aerial imagery. The LR Formation was not exposed on the modern ground surface or on the excavated surfaces of the mechanically stripped areas (Figure 13).

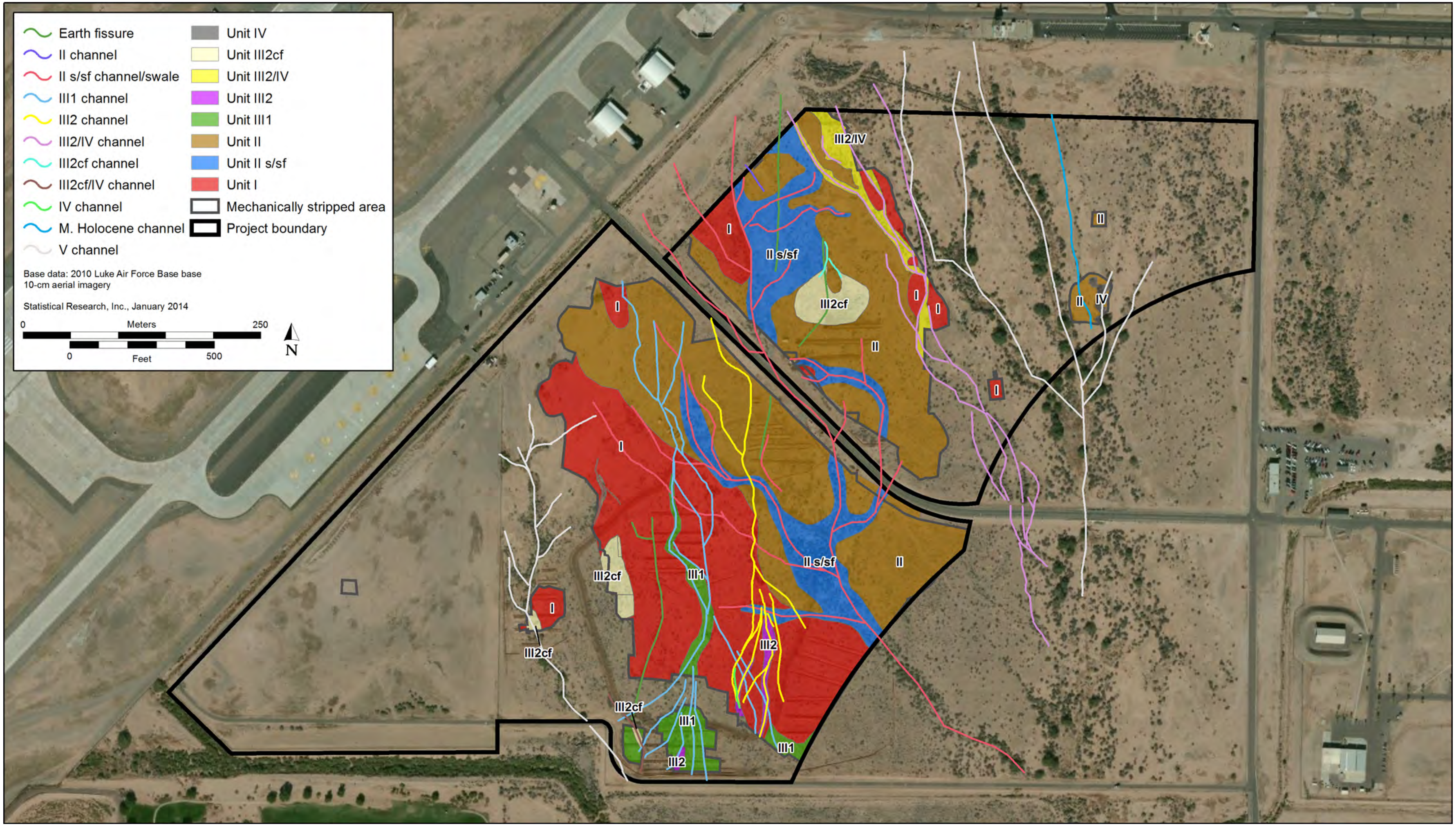


Figure 13. Geologic map of the mechanically stripped surface.

Postfield Analysis

A suite of chemical and physical analyses was required in order to fully characterize the soils and sedimentary deposits of the project area. Particle size was the only physical analysis performed on project samples, and it was determined via laser diffractometry (Malvern Mastersizer 2000) at the University of Kansas Soils and Geomorphology Laboratory under the direction of Dr. Daniel Hirmas. Particle-size analysis provides critical information on depositional sedimentary environments (facies) and certain soil-formation processes (Birkeland 1999; Miller et al. 1988). Closely sampled particle-size data can also help identify lithological unconformities (abrupt shifts in the depositional environment) in the soil profile.

Chemical analysis of soil/sediment samples provided the following data: organic carbon (OC) content, calcium carbonate ($CaCO_3$) content, pH, electrical conductivity (EC), available phosphorus (P), and $\delta^{13}C$ values of soil organic matter (SOM). Organic carbon was measured via CO_2 evolution in a dry combustion carbon analyzer (Method 4H2, Soil Survey Staff 2004), and available P was determined using the Mehlich-3 extraction procedure (Method 4D6, Soil Survey Staff 2004). The OC and available P typically increase at or near the soil surface as plants become established and begin biocycling plant-essential nutrients. Over time, as plants incorporate atmospheric C from CO_2 into their biomass during photosynthesis, extract P from the soil parent material, and complete their lifecycles, these elements begin to accumulate on the soil surface during microbial decomposition. These analyses can therefore aid in identifying the presence of buried soil surfaces or further validate buried surfaces previously identified in the field. Available P is also a persistent indicator of past human activity (Holliday and Gartner 2007). Anthropogenic P originates from human waste, organic refuse (e.g., bone, meat, and plants), and ash from fires (Eidt 1984). Once in the soil, P quickly bonds with iron (Fe) or aluminum (Al) in acidic soils or calcium (Ca) in alkaline soils to form stable inorganic phosphate minerals and organic phosphate (Proudfoot 1976). These forms of P are resistant to oxidation, reduction, and soil leaching processes. As humans add P to the soil it tends to accumulate at the site of deposition (Holliday and Gartner 2007) (Appendix 2.1). Spikes in OC and available P, above natural levels in association with buried surface horizons, may indicate more-intensive cultural use of the surface.

Calcium carbonate content, pH, and EC are important indicators of the presence and concentration of soluble salts in the soil profile. $CaCO_3$ content was determined by applying 1 N (normal) HCl (hydrochloric acid) to the sample and measuring the evolved CO_2 manometrically (a manometer is an instrument used to measure the pressure of gases) (Soil Survey Staff 2004). Soil pH and EC were measured in a 1:1 soil-water slurry of distilled and deionized water. All soil chemical analyses were performed at the Iowa State University Soil and Plant Analysis Laboratory. The time-transgressive accumulation of $CaCO_3$ in desert soils is fundamental in assigning relative ages to geomorphic surfaces and locating pedogenic unconformities in stratigraphic sections (Birkeland 1999; Gile et al. 1981; Machette 1985). The presence of salts more soluble than $CaCO_3$, including sodium and gypsum, can have implications for plant growth and landscape/paleoenvironmental reconstructions. Soil pH levels also dictate the potential of the local soil environment to preserve organic archaeological materials such as basketry and faunal or human bone.

Finally, plants with different photosynthetic pathways have unique stable-carbon-isotope (stable C) values ($\delta^{13}C$) that are not significantly altered during decomposition (Boutton et al. 1998). The $\delta^{13}C$ value of SOM therefore reflects the proportions of C3, C4, and Crassulacean acid metabolism (CAM) plants that contribute organic matter to the soil (Nordt 2001). On average, $\delta^{13}C$ differs by about 13 between modern C3 (~22.6 to 26.8‰) and C4 (~9.2 to 17.7‰) grass species (Nelson et al. 2006). Over 90 percent of all plant species use C3 exclusively and include most tree, shrub, forb, and cool-season grass species. In the Sonoran Desert, common C3 plants include mesquite (*Prosopis* spp.), ironwood (*Olneya tesota*), foothills palo verde (*Parkinsonia microphylla*), blue palo verde (*Parkinsonia florida*), creosote bush (*Larrea tridentata*), bursage (*Ambrosia* spp.), and wolfberry (*Lycium* spp.). C4 plants use carbon dioxide more efficiently and lose less water through transpiration and are therefore better suited to hot sunny environments. Common C4 plants in the Sonoran Desert include warm-season grasses (sideoats grama [*Bouteloua curtipendula*], Rothrock grama [*Bouteloua barbata* var. *rothrockii*], and Plains bristlegrass [*Setaria leucopila*]), perennial halophytes (*Atriplex* spp.), and weedy annuals (pigweed [*Amaranthus* spp.], summer spurges [*Euphorbia* spp.], and devils claw [*Proboscidea althaeifolia*]) (Ehleringer 1989). CAM plants have a photosynthetic pathway similar to

C4, but facultative CAM plants (that is, ones that have the ability to switch from C3 to CAM photosynthesis when water availability decreases) can produce $\delta^{13}C$ values that span the entire spectrum of $\delta^{13}C$ values produced during C3 and C4 photosynthesis (Nordt 2001). In the Sonoran Desert, succulents are the primary CAM species (Ehleringer and Cooper 1988). The $\delta^{13}C$ value of SOM in well-dated stratified deposits can provide valuable insight into past vegetation communities (Liu, Phillips, Pohl, and Campbell 1996; Nordt et al. 1994). Although $\delta^{13}C$ values of SOM are most informative in semiarid climates that have experienced pronounced shifts in C3 to C4 plant communities, stable C data from deserts can still provide some insight into vegetational shifts, particularly when paired with fossil pollen or macrobotanical analyses. Stable C analysis has proven useful in the northern Chihuahuan Desert of south-central New Mexico and the Ajo Mountains of southern Arizona (Buck and Monger 1999; Liu, Phillips, and Campbell 1996; Monger 1995). At Luke Solar, increases in saltbush (*Atriplex* spp.) and weedy annuals should produce a less negative $\delta^{13}C$ value while increases in woody C3 species should yield a more negative $\delta^{13}C$ signal. The presence of CAM succulents could be a confounding factor because they produce $\delta^{13}C$ values that span the C3–C4 pathway; although it is important to note that no or very few succulents are present at the site today. The stable C abundance is expressed as a ratio of the two most-abundant isotopes in the sample ($^{13}C/^{12}C$) compared to the same ratio in an international standard (Vienna Pee Dee Belemnite [VPDB] international standard originates from the Cretaceous Pee Dee Formation in South Carolina). The deviation from the standard is expressed as parts per thousand or per mil (‰). Stable C analysis was performed at the University of Kansas Soils and Geomorphology Laboratory.

Radiocarbon Sampling Methods

According to the Historic Properties Treatment Plan (HPTP) (Hall et al. 2011:42), chronology is one of the critical research themes in the Luke Solar data recovery plan. Placing individual features and artifacts into their proper temporal context is a crucial step towards making meaningful inferences of diachronic cultural change. The Luke Solar project contained a rich record of buried cultural features spanning over 5,000 calendar years, so assigning individual features to chronological groups remained a high priority throughout the project. The primary dating technique used for the Luke Solar project was radiocarbon dating, specifically accelerator mass spectrometer (AMS) analysis. All charcoal samples selected for radiocarbon analysis were first analyzed by Dr. Karen Adams to determine their taxonomic classification (see Chapter 6, this volume). With a limited budget for radiocarbon dates, individual features and contexts were carefully chosen to provide the most meaningful information to the overall project. In total, 120 radiocarbon dates were obtained for the Luke Solar project, with 97 features chosen for radiocarbon analysis and 23 nonfeature (geologic) contexts (Table 8. Appendix 2.2). During Phase 1, 44 flotation samples were collected from the fill of unexcavated features. Carbonized plant material from 16 of these flotation samples and another 8 point-located charcoal samples were submitted for AMS analysis (see Chapter 4, Volume 1). These 24 dates provided the project team with a preliminary indication of the temporal variability within the APE. As noted previously, 23 of these Phase 1 dates were from unexcavated features. As a result of the subsequent excavation of features, several of the original feature interpretations changed during Phase 2 data recovery. During Phase 2 fieldwork, 23 geological samples were submitted for radiocarbon dating to help construct the geochronological model. Select depositional contexts were chosen for dating based on the presence of charcoal at stratigraphic boundaries or within specific strata.

Once Phase 2 fieldwork was complete, the project team focused on which feature and stratigraphic contexts would be most meaningful for dating. Several factors were used to determine which features were selected for radiocarbon dating. One of the first priorities was dating architectural features (structures). Thirty-three of the 50 structures identified in the APE were radiocarbon dated. This obvious bias towards structures was intentional because structures can provide the most useful information toward understanding the land use, cultural affinity, and domestic organization of a particular site (see Hall et al. 2011:51). Individual structures were chosen based on the presence or absence of carbonized material, as well as their level of preservation, artifact content, stratigraphic position, and spatial association with other structures

Table 8. Radiocarbon Dates Obtained for the Luke Solar Project, by Phase and Aeon Lab Number

Aeon No.	Site No.	Feature No.	Subfeature No.	Feature Type/ Context	Stratigraphic Unit	Plant Specimen	^{14}C B.P.	Error	2δ Calibrated Range	Chronologic Component	δ^{13}C
Phase 1											
674	Falcon Landing	1349		nonthermal pit	III2 surface	*Prosopis* wood	1365	20	cal A.D. 640–670	Snaketown	- 24.3
675	Falcon Landing			Trench (TR) 2215 profile	II (detrital charcoal)	*Prosopis* wood	4115	15	2860–2580 cal BC	Early Chiricahua	- 20.3
676	Falcon Landing	4235		nonthermal pit	I surface	*Prosopis* wood	4490	15	3340–3090 cal BC	Early Chiricahua	- 23.1
677	Falcon Landing	4287		nonthermal pit	III1 lower	*Prosopis* wood	2835	15	1010–920 cal B.C.	San Pedro	- 21
678	Falcon Landing	4302		house-in-pit	III1	*Prosopis* wood	2885	15	1130–1000 cal B.C.	San Pedro	- 22.7
679	Falcon Landing	1290		house-in-pit	III2 surface	*Atriplex* wood	1390	15	cal A.D. 640–670	Snaketown	- 10.2
680	Falcon Landing	1303		activity area	I surface	unknown ID	3915	15	2480–2340 cal BC	Early Chiricahua	- 20.9
681	Falcon Landing	1244		house-in-pit	I surface	*Atriplex* wood	3030	20	1390–1210 cal BC	Late Chiricahua	- 10.6
735	Falcon Landing	5213		thermal pit	IIs/sf surface	*Atriplex* seed	595	25	cal A.D. 1290–1410	Soho/Civano	- 12.7
736	Falcon Landing	2486		noncultural charcoal lens	IIA (detrital charcoal)	*Prosopis* wood	4055	20	2840–2490 cal B.C.	Early Chiricahua	- 26.2
737	Falcon Landing	2602		house-in-pit	IIA surface	*Atriplex* twig	3975	20	2560–2460 cal BC	Early Chiricahua	- 14.6
738	Falcon Landing	2605		house-in-pit	IIA surface	*Prosopis* wood	3955	20	2560–2460 cal B.C.	Early Chiricahua	- 25.6
739	Falcon Landing	2630		structure – possible	IV surface	*Prosopis* wood[a]	270	20	cal A.D. 1520–1800	Protohistoric	- 22.3
740	Falcon Landing	2627		house-in-pit	IIs/sf surface	*Prosopis* wood	2655	15	840–800 cal B.C.	San Pedro	- 24.8
741	Falcon Landing	2622		house-in-pit	IIA surface	*Atriplex* wood	3970	15	2560–2460 cal B.C.	Early Chiricahua	- 14.8
742	Falcon Landing	2628		house-in-pit	IIs/sf surface	*Atriplex* wood	2685	15	840–800 cal B.C.	San Pedro	- 14.0
743	Falcon Landing	1343		nonthermal pit	III2 surface	*Prosopis* wood	815	15	cal A.D. 1180–1270	Soho/Civano	- 23.8
744	Falcon Landing	1315		thermal pit	I surface	*Prosopis* wood	2500	15	770–540 cal B.C.	Early Cienega	- 25.7
745	Falcon Landing	1307		nonthermal pit	I surface	*Prosopis* wood	2755	20	980–830 cal B.C.	San Pedro	- 25.5
746	Falcon Landing	4409		noncultural pit	III1 surface	*Portulaca* seed[a]	400	45	cal A.D. 1420–1640	Classic–Protohistoric	- 46.9
747	Falcon Landing	4388		house-in-pit	I surface	*Prosopis* seed	4320	20	3020–2890 cal B.C.	Early Chiricahua	- 22.9
748	Falcon Landing	4308		house-in-pit	III1 surface	*Prosopis* wood	2805	15	1010–920 cal B.C.	San Pedro	- 26.1
749	Falcon Landing	4343		thermal pit	III1 lower	*Prosopis* seed	2835	15	1050–920 cal B.C.	San Pedro	- 23.8
750	Falcon Landing	4355		nonthermal pit	IIs/sf upper	*Prosopis* wood	2860	15	1110–1000 cal B.C.	San Pedro	- 25.8

continued on next page

Aeon No.	Site No.	Feature No.	Subfeature No.	Feature Type/ Context	Stratigraphic Unit	Plant Specimen	^{14}C B.P.	Error	2δ Calibrated Range	Chronologic Component	δ^{13}C
Phase 2											
1339	nonsite			TR 10073 profile	III2 channel base (detrital charcoal)	*Prosopis* wood	2380	25	540–390 cal B.C.	Cienega	-23.5
1340	nonsite			TR 10067 profile	IIs/sf base (detrital charcoal)	*Prosopis* wood	3910	20	2480–2300 cal B.C.	Early Chiricahua	-24.9
1341	nonsite			TR 10075 profile	IV (detrital charcoal)	*Prosopis* wood	1300	20	cal A.D. 660–780	Snaketown	-23.2
1342	nonsite			TR 10083 profile	I sand lens (detrital charcoal)	*Prosopis* wood	7695	30	6600–6460 cal B.C.	Sulphur Spring	-24.4
1343	Falcon Landing			TR 10130 profile	I sand lens (detrital charcoal)	*Prosopis* wood	7740	30	6650–6490 cal B.C.	Sulphur Spring	-24.9
1344	Falcon Landing			TR 10031 profile	IIs/sf upper (detrital charcoal)	*Prosopis* wood	2985	20	1310–1120 cal B.C.	Middle Archaic–Late Archaic	-25.1
1345	Falcon Landing			TR 10040 profile	IIs/sf lower (detrital charcoal)	*Prosopis* wood	3940	20	2560–2340 cal B.C.	Early Chiricahua	-25.4
1346	Falcon Landing			MSU 11429	I near surface (detrital charcoal)	*Prosopis* wood	4375	25	3090–2910 cal B.C.	Early Chiricahua	-25.4
1394	Falcon Landing			TR 2219 profile	II s/sf lower (detrital charcoal)	*Prosopis* wood	3670	20	2140–1970 cal B.C.	Late Chiricahua	-25.5
1395	Falcon Landing			TR 2218 profile	II (detrital charcoal)	*Prosopis* wood	4200	20	2900–2760 cal B.C.	Early Chiricahua	-26.6
1396	Falcon Landing			TR 9066 profile	III2 lower (detrital charcoal)	*Prosopis* wood	2230	15	390–200 cal B.C.	Late Cienega	-23.7
1397	Falcon Landing			TR 4211 profile	I upper (detrital charcoal)	*Prosopis* wood	7060	20	6000–5890 cal B.C.	Sulphur Spring	-25.2
1398	Falcon Landing			TR 2211 profile	IIA (detrital charcoal)	*Prosopis* wood	4135	20	2820–2600 cal B.C.	Early Chiricahua	-25.4
1399	Site 437			TR 10069 profile	middle Holocene channel (detrital charcoal)	*Prosopis* wood	6405	20	5470–5320 cal B.C.	Sulphur Spring	-27.4
1400	Site 68			TR 14 profile	III1 lower (detrital charcoal)	*Prosopis* wood	2950	20	1270–1050 cal B.C.	Middle Archaic–Late Archaic	-24.6
1401	Falcon Landing			MSU 11075 shovel test	IIs/sf lower (detrital charcoal)	*Prosopis* wood	3875	20	2470–2290 cal B.C.	Early Chiricahua	-25.7
1402	Falcon Landing			TR 2216 profile	IIA (detrital charcoal)	*Atriplex* wood	4055	20	2840–2490 cal B.C.	Early Chiricahua	-24
1403	nonsite			TR 10006 profile	I lower (detrital charcoal)	*Prosopis* wood	7945	30	7030–6690 cal B.C.	Sulphur Spring	-26

Aeon No.	Site No.	Feature No.	Subfeature No.	Feature Type/ Context	Stratigraphic Unit	Plant Specimen	^{14}C B.P.	Error	2δ Calibrated Range	Chronologic Component	δ^{13}C
1404	Falcon Landing	20378		drainage	IIA base (detrital charcoal)	*Prosopis* wood	4130	20	2820–2580 cal B.C.	Early Chiricahua	-25.5
1405	Falcon Landing	20378		drainage	II charcoal lens (detrital charcoal)	*Atriplex* wood	4190	20	2890–2690 cal B.C.	Early Chiricahua	-16.4
1406	Falcon Landing	20378		drainage	II lower (detrital charcoal)	*Prosopis* wood	4180	20	2890–2760 cal B.C.	Early Chiricahua	-25
1407	Falcon Landing	20378		drainage	I (detrital charcoal)	*Prosopis* wood	7295	25	6230–6080 cal B.C.	Sulphur Spring	-25.2
1408	Falcon Landing	2967		house-in-pit	III1	Unknown wood	2870	20	1110–1000 cal B.C.	San Pedro	-23.3
1415	Falcon Landing			TR 9067 profile	II lower (detrital charcoal)	Unknown wood	4335	20	2970–2890 cal B.C.	Early Chiricahua	-26.2
1436	Falcon Landing	2602	7757	house-in-pit	IIA surface	*Trianthema* seed[b]	800	20	cal. A.D. 1210–1270	Early Chiricahua	-11.7
1437	Falcon Landing	3521	6311	house-in-pit	I surface	*Prosopis* wood	2990	20	1310–1120 cal B.C.	Middle Archaic–Late Archaic	-24.6
1438	Falcon Landing	1334		nonthermal pit	I surface	*Prosopis* wood	3105	20	1440–1310 cal B.C.	Late Chiricahua	-22.8
1439	Falcon Landing	11181	12245	house-in-pit	I surface	*Prosopis* wood	2875	20	1110–1000 cal B.C.	San Pedro	-24.8
1440	Falcon Landing	11229		house-in-pit	I surface	*Prosopis* wood	3025	20	1380–1210 cal B.C.	Late Chiricahua	-24.4
1441	Falcon Landing	10114		house-in-pit	I surface	*Prosopis* seed	3020	20	1380–1210 cal B.C.	Late Chiricahua	-21.4
1442	Falcon Landing	7998		thermal pit	IIA	unknown seed	3985	20	2570–2460 cal B.C.	Early Chiricahua	-20.8
1443	Falcon Landing	4387		house-in-pit	I surface	*Prosopis* wood	4205	20	2890–2690 cal B.C.	Early Chiricahua	-24.5
1444	Falcon Landing	1498	6666	house-in-pit	I surface	too small to ID	3450	20	1880–1690 cal B.C.	Late Chiricahua	-22.8
1445	Falcon Landing	2642		house-in-pit	IIA surface	*Prosopis* wood	3720	20	2200–2030 cal B.C.	Late Chiricahua	-22.5
1446	Falcon Landing	2629	6798	house-in-pit	IIs/sf surface	*Prosopis* wood	2805	25	1030–890 cal B.C.	San Pedro	-24.7
1447	Falcon Landing	3963	8019	house-in-pit	III1 surface	*Prosopis* wood	1790	20	cal A.D. 130–330	Red Mountain	-24.2
1481	Falcon Landing	1523		thermal pit	I surface	*Prosopis* wood	4145	20	2870–2630 cal B.C.	Early Chiricahua	-23.4
1482	Falcon Landing	2529		house-in-pit	III2cf	*Prosopis* wood	1960	20	20 cal B.C. – cal A.D. 120	Late Cienega–Red Mountain	-24.1
1483	Falcon Landing	3256		midden	IIA surface	*Prosopis* wood	2875	30	1200–930 cal B.C.	San Pedro	-25.5
1484	Falcon Landing	4621	6828	surface structure	IIA surface	*Prosopis* wood	2230	20	390–200 cal B.C.	Late Cienega	-23.2
1485	Falcon Landing	10278		reservoir	I surface	*Prosopis* wood	2865	20	1120–1000 cal B.C.	San Pedro	-25
1486	Falcon Landing	10849		house-in-pit	III2cf surface	*Prosopis* wood	1665	20	cal A.D. 260–430	Red Mountain	-24.1

continued on next page

Aeon No.	Site No.	Feature No.	Subfeature No.	Feature Type/ Context	Stratigraphic Unit	Plant Specimen	^{14}C B.P.	Error	2δ Calibrated Range	Chronologic Component	δ^{13}C
1487	Falcon Landing	13071	16970	house-in-pit	IIs/sf surface	*Prosopis* wood	2750	20	970–830 cal B.C.	San Pedro	-24.3
1488	Falcon Landing	14613		house-in-pit	I surface	*Prosopis* wood	4060	20	2840–2490 cal B.C.	Early Chiricahua	-24.1
1489	Falcon Landing	14702		house-in-pit	III2cf	*Prosopis* wood	1920	20	cal A.D. 20–120	Late Cienega–Red Mountain	-24.1
1490	Falcon Landing	14755		nonthermal pit	IIs/sf upper	*Prosopis* wood	2945	20	1260–1050 cal B.C.	Middle Archaic–Late Archaic	-24.5
1491	Falcon Landing	15173		nonthermal pit	IIs/sf upper	*Prosopis* wood	2950	20	1270–1050 cal B.C.	Middle Archaic–Late Archaic	-23.1
1492	Falcon Landing	17908	20285	house-in-pit	III2cf	Cheno–am seed	1890	100	160 cal B.C. – cal A.D. 330	Late Cienega–Red Mountain	-16.3
1493	Falcon Landing	18192		house-in-pit	IIA surface	*Prosopis* wood	2720	20	910–810 cal B.C.	San Pedro	-24.2
1494	Falcon Landing	18887	20321	house-in-pit	IIs/sf surface	*Prosopis* wood	2890	20	1120–1000 cal B.C.	San Pedro	-23.8
1495	Falcon Landing	3321		house-in-pit	IV	*Prosopis* wood	1300	20	cal A.D. 650–770	Snaketown	-25
1496	Falcon Landing	4370		nonthermal pit	III1	*Prosopis* wood	3005	25	1380–1120 cal B.C.	Middle Archaic–Late Archaic	-24.8
1497	Falcon Landing	4626		thermal pit	IV surface	*Prosopis* wood	1000	20	cal A.D. 980–1150	Sacaton	-22.7
1498	Falcon Landing	10514		thermal pit	IV surface	*Prosopis* wood	875	20	cal A.D. 1050–1220	Sedentary–Classic	-24.4
1499	Falcon Landing	14959		nonthermal pit	IIs/sf lower	*Prosopis* wood	3645	20	2130–1940 cal B.C.	Late Chiricahua	-24.4
1500	Falcon Landing	15482		thermal pit	IIs/sf surface	*Prosopis* wood	2895	20	1200–1000 cal B.C.	San Pedro	-25.4
1501	Falcon Landing	19067		nonthermal pit	IV	*Prosopis* wood	1400	20	cal A.D. 610–670	Pioneer	-25.7
1502	Falcon Landing	18880		nonthermal pit	IIs/sf upper	*Atriplex* wood	2930	20	1260–1040 cal B.C.	Middle Archaic–Late Archaic	-10.4
1503	Falcon Landing	11284		thermal pit	IIA surface	*Prosopis* wood	2980	20	1300–1120 cal B.C.	Middle Archaic–Late Archaic	-24
1504	Falcon Landing	11106		nonthermal pit	IIA surface	*Prosopis* wood?	2505	30	790–550 cal B.C.	Early Cienega	-23.7
1505	Falcon Landing	18254		thermal pit	IIA surface	*Prosopis* wood	2895	20	1200–1000 cal B.C.	San Pedro	-24.2
1506	Falcon Landing	18250		nonthermal pit	IIA	*Prosopis* wood	4190	20	2890–2670 cal B.C.	Early Chiricahua	-24.7
1507	Falcon Landing	18237		thermal pit	IIA surface	*Prosopis* seed	2975	25	1310–1120 cal B.C.	Middle Archaic–Late Archaic	-21
1508	Falcon Landing	14839		nonthermal pit	I surface	*Prosopis* wood	4100	25	2840–2500 cal B.C.	Early Chiricahua	-25.2
1509	Falcon Landing	3600		nonthermal pit	III2 lower	*Prosopis* wood	2410	20	720–400 cal B.C.	Early Cienega	-24.8
1510	Falcon Landing	11389		nonthermal pit	III2cf	*Prosopis* wood	2965	20	1270–1110 cal B.C.	Middle Archaic–Late Archaic	-24.9

Aeon No.	Site No.	Feature No.	Subfeature No.	Feature Type/ Context	Stratigraphic Unit	Plant Specimen	^{14}C B.P.	Error	2δ Calibrated Range	Chronologic Component	δ^{13}C
1511	Falcon Landing	14765		nonthermal pit	III2	*Prosopis* wood	2180	30	370–160 cal B.C.	Late Cienega	-23.8
1512	Falcon Landing	11088		nonthermal pit	IIA surface	*Prosopis* wood	2435	25	750–400 cal B.C.	Early Cienega	-23.2
1513	Falcon Landing	3372		cache	IIA surface	*Prosopis* wood	1340	25	cal A.D. 650–770	Snaketown	-24.9
1514	Falcon Landing	11025		nonthermal pit	IIA surface	*Fouquieria* wood	3945	35	2570–2340 cal B.C.	Early Chiricahua	-25.4
1515	Falcon Landing	3508		nonthermal pit	III1 surface	*Atriplex* twig (1 ring)	2490	30	770–540 cal B.C.	Early Cienega	-24.7
1516	Falcon Landing	14656		charcoal/ash lens	III2cf (detrital charcoal)	*Prosopis* wood	1840	40	cal A.D. 70–250	Red Mountain	-23.4
1517	Falcon Landing				III2cf (detrital charcoal)	*Prosopis* wood	1840	30	cal A.D. 80–250	Late Cienega–Red Mountain	-23.8
1518	Falcon Landing				III2cf (detrital charcoal)	*Fouquieria* wood	1915	35	cal A.D. 1–210	Late Cienega–Red Mountain	-24.6
1519	Falcon Landing	15096		nonthermal pit	IIs/sf surface	*Atriplex* twig (1 ring)	1005	25	cal A.D. 980–1150	Sacaton	-25
1520	Falcon Landing	15142		nonthermal pit	II surface	*Prosopis* wood	4170	30	2880–2630 cal B.C.	Early Chiricahua	-24.8
1521	Falcon Landing	15191		nonthermal pit	IIs/sf surface	*Prosopis* wood	2960	20	1270–1110 cal B.C.	Middle Archaic–Late Archaic	-10.7
1522	Falcon Landing	15197		thermal pit	IIs/sf upper	*Fouquieria* wood	3005	20	1380–1130 cal B.C.	Middle Archaic–Late Archaic	-23.7
1523	Falcon Landing	18028		thermal pit	IIs/sf surface	*Atriplex* twig (1 ring)	2830	20	1050–920 cal B.C.	San Pedro	-22.3
1524	Falcon Landing	15457		thermal pit	IIA	*Prosopis* wood	4210	30	2900–2670 cal B.C.	Early Chiricahua	-25.5
1525	Falcon Landing	15317		thermal pit	I surface	*Prosopis* wood	4490	30	3340–3030 cal B.C.	Early Chiricahua	-11.4
1526	Falcon Landing	15319		nonthermal pit	II	*Fouquieria* wood	4140	25	2870–2620 cal B.C.	Early Chiricahua	-23.6
1527	Falcon Landing	11130		nonthermal pit (bell-shaped)	IIA surface	*Atriplex* twig (1 ring)	2550	30	790–550 cal B.C.	Early Cienega	-24.3
1532	Falcon Landing	11156		nonthermal pit	II surface	*Prosopis* wood	4300	20	2930–2880 cal B.C.	Early Chiricahua	-24.4
1533	Falcon Landing	10925		nonthermal pit	IIA surface	*Prosopis* wood	4110	25	2860–2580 cal B.C.	Early Chiricahua	-26.1
1534	Falcon Landing	18439		thermal pit	IIA	*Fouquieria* wood	4135	25	2860–2580 cal B.C.	Early Chiricahua	-10.3

continued on next page

Aeon No.	Site No.	Feature No.	Subfeature No.	Feature Type/ Context	Stratigraphic Unit	Plant Specimen	^{14}C B.P.	Error	2δ Calibrated Range	Chronologic Component	δ^{13}C
1535	Falcon Landing	18468		nonthermal pit	IIA	*Atriplex* twig (1 ring)	4085	25	2850–2490 cal B.C.	Early Chiricahua	-23.4
1536	Falcon Landing	14655		nonthermal pit	IV surface	*Prosopis* wood	970	25	cal A.D. 1010–1160	Sacaton	-25.6
1537	Falcon Landing	11072		thermal pit	IV surface	*Atriplex* wood	975	25	cal A.D. 1010–1160	Sacaton	-10.9
1538	Falcon Landing	15256		nonthermal pit	II surface	*Prosopis* wood	2685	30	900–800 cal B.C.	San Pedro	-24.8
1539	Falcon Landing	2602	7742	thermal pit	IIA surface	*Atriplex* wood	4040	25	2830–2470 cal B.C.	Earl;y Chiricahua	-10.5
1543	Site 68	97		nonthermal pit	III1 surface	*Prosopis* wood	1280	20	cal A.D. 660–780	Snaketown	-25.1
1546	Site 68	13		house-in-pit	III1 surface	*Prosopis* wood	1315	35	cal A.D. 660–780	Snaketown	-23.9
1547	Site 423	131		FAR concentration	I surface	*Prosopis* wood	1930	25	cal A.D. 10–130	Late Cienega–Red Mountain	-23.5
1548	Site 437	10307		thermal pit	I	*Prosopis* wood	7950	30	7040–6690 cal B.C.	Sulphur Spring	-25.2
1549	Falcon Landing			TR 9066 profile	Litchfield Ranch	bulk sediment (insoluable fraction)	15150	70	16,680–16,080 cal B.C.		-24.3

Key: FAR = fire-affected rock.

[a] Dates obtained from unburned plant material, may not reflect cultural activity.

[b] Determined to be intrusive into feature.

and extramural features. Structures that were not well preserved, contained few artifacts, and were not associated with other features were considered poor candidates for dating. Once the sample of structures was finalized, charcoal from the most appropriate context was submitted for dating. Structure contexts considered the most informative included, in descending order, subfeatures (postholes or intramural pits), floor contact, floor fill, and upper structure fill.

Following structures, extramural features were the next most commonly dated context. Two main criteria were used to select extramural features for dating. The first criterion was the feature's stratigraphic position. Because the stratigraphy of the APE was subtle and horizontally complicated, numerous dates were required to date the stratigraphy. Dating features within strata or at stratigraphic boundaries functioned as a proxy for obtaining depositional dates from the natural stratigraphy. The ubiquity of features in the APE allowed for this strategy of bracketing the natural stratigraphy via dating cultural features. Following the geomorphological analysis of the project area, features were assigned to a stratigraphic unit. In some cases, a pair of spatially associated features was identified that existed at important stratigraphic boundaries. Table 9 shows a list of 12 extramural pit features that were radiocarbon dated based on their stratigraphic position. For instance, Features 15096 and 15142 were located in MSU 15070 approximately 20 m apart (see Appendix A, Volume 1). Feature 15096 was pedestalled during mechanical stripping, meaning the feature was identified, marked by the archaeological monitor, and the sediments surrounding the feature were mechanically excavated deeper to search for additional features. Approximately 20 m away, Feature 15142 was identified stratigraphically lower relative to Feature 15096. Feature 15096 was located at the surface of Unit IIs/sf, and Feature 15142 was located at the surface of Unit II. Both Features 15096 and 15142 contained ample charred plant material so charcoal samples from both features were submitted for radiocarbon dating. The rest of the features listed in Table 10 follows the same logic. In general, the resulting 2σ calibrated dates confirm the relative stratigraphic position (i.e., stratigraphically lower features were older than stratigraphically higher features). The second criterion used to select an extramural feature for dating was the content of the feature. Table 10 shows 10 features that were specifically chosen to be radiocarbon dated because of their content. For example, Features 1523, 14702, 14755, 15173, and 17908 all contained diagnostic projectile points. Features 4626, 10514, and 15482 contained ceramic artifacts, one of which was a possible incipient plainware sherd (see Chapter 5, this volume).

Overall, the selection of radiocarbon samples for analysis was predicated on the best-available carbonized material and the most-meaningful contexts. Owing to the difficulty of correlating alluvial-fan deposits across space, the fundamental goal of the radiocarbon analysis was to help build the geochronologic model. In other words, interpreting and dating the natural stratigraphy was of paramount importance. Once the chronology and sequence of deposition was known within the APE, all features could be assigned a calendar date based upon each feature's assigned stratigraphic unit. As a result, 120 radiocarbon dates allowed for the temporal assignment of over 3,400 features. Because of lateral variability of the geologic column, however, some dates were more meaningful than others.

OxCal Modeling

The geochronology framework was used to identify periods of occupation at the site and to place temporal constraints on these occupational episodes. To do this, a site chronology model was constructed in the analysis program OxCal 4.2 (Bronk Ramsey 2009), using the site stratigraphy to order and group radiocarbon-dated features into stratigraphically coeval groups, or phases. Thus, radiocarbon dates from features with similar stratigraphic unit assignments were grouped together in a phase, and the phases were ordered according to the geostratigraphy at the site. In many cases, the features grouped within a phase had similar but not identical stratigraphic unit assignments, but all phases followed the basic rule that constituent features could not be from temporally separated stratigraphic units. For instance, a feature that was coeval with the deposition of Unit IIA could be grouped with a similarly aged feature located in the unconformity between Units I and III, but it could not be grouped with a similarly aged feature that was identified as originating at the Unit IIA surface. The geostratigraphy was then used to structure the associated phases into a sequential

Table 9. Radiocarbon Dates from Features in Upper and Lower Divisions of Stratigraphic Units, Falcon Landing

Aeon No.	Feature No.	Feature Type	Stratigraphic Unit	Description	2σ Calibrated Range
1519	15096	nonthermal pit	IIs/sf surface	MSU 15070 (upper), pedestaled Unit IIs/sf upper	cal A.D. 980–1150
1520	15142	nonthermal pit	II surface	MSU 15070 (lower) Unit II surface	2880–2630 cal B.C.
1521	15191	nonthermal pit	IIs/sf surface	MSU 15068 (upper), pedestaled Unit IIs/sf surface	1270–1110 cal B.C.
1522	15197	thermal pit	IIs/sf	MSU 15068 (lower), Unit IIs/sf	1380–1130 cal B.C.
1523	18028	thermal pit	IIs/sf surface	MSU15355 (upper), pedestaled Unit IIs/sf surface	1050–920 cal B.C.
1524	15457	thermal pit	IIA	MSU 15355 (lower), Unit IIA	2900–2670 cal B.C.
1525	15317	thermal pit	I surface	MSU 15249 (lower), Unit I surface	3340–3030 cal B.C.
1526	15319	nonthermal pit	II	MSU 15249 (upper), Unit II	2870–2620 cal B.C.
1527	11130	nonthermal pit (bell-shaped)	IIA surface	MSU 11075 (upper), Unit IIA surface	790–550 cal B.C.
1532	11156	nonthermal pit	II surface	MSU 11075 (lower), Unit II surface	2930–2880 cal B.C.
1533	10925	nonthermal pit	IIA surface	above/top of Area A charcoal deposit (Feature 10951), Unit IIA surface	2860–2580 cal B.C.
1534	18439	thermal pit	IIA	below Area A charcoal deposit (Feature 10951), Unit IIA	2860–2580 cal B.C.

Table 10. Radiocarbon Dates from Selected Features based on Contents, Falcon Landing

Aeon No.	Feature No.	Subfeature No.	Feature Type	Stratigraphic Unit	Description	2σ Calibrated Range
1481	1523		thermal pit	I surface	pit with Chiricahua projectile point	2870–2630 cal B.C.
1487	13071	16970	house-in-pit	IIs/sf surface	maize pollen recovered from floor fill	970–830 cal B.C.
1489	14702		house-in-pit	III2cf	San Pedro projectile point on floor	cal A.D. 20–120
1490	14755		nonthermal pit	IIs/sf	pit with San Pedro projectile point	1260–1050 cal B.C.
1491	15173		nonthermal pit	IIs/sf	pit with San Pedro projectile point	1270–1050 cal B.C.
1492	17908	20285	house-in-pit	III2cf	San Pedro projectile point on floor	160 cal B.C.–cal A.D. 330
1496	4370		nonthermal pit	III1	pit with stone pipe	1380–1120 cal B.C.
1497	4626		thermal pit	IV	pit with indeterminate buff ware sherd	cal A.D. 980–1150
1498	10514		thermal pit	IV surface	pit with Gila Plain, Salt variety sherd	cal A.D. 1050–1220
1500	15482		thermal pit	IIs/sf surface	thermal pit with incipient plainware sherd	1200–1000 cal B.C.

framework, such that sets of clearly stratified phases, such as those associated with Stratigraphic Units IIA and IIs/sf, were ordered sequentially, while sets of phases associated with more-ambiguous units, such as the relationship between Units IIs/sf and III, were allowed to overlap. Furthermore, in the case of the phase associated with Unit IIA, there was sufficient temporal patterning between the features located in Area A and in Area B that the phase was modeled as two overlapping occupational episodes focused on the respective areas (i.e., Episode 2A in Area A and Episode 2B in Area B).

OxCal then used the constraints introduced by this structure to calculate the modeled posterior density estimate of each feature's calendar age and to assess the integrity of the overall model. In many cases, these constraints resulted in more-refined age estimates by requiring one set of features to be older (or younger) than another, thus truncating the probability distributions of the unmodeled calibrated radiocarbon dates. The program checks the validity of the posterior density estimates by comparing them to the unmodeled distributions and calculating the percent overlap, or agreement, between the two. A threshold value of 60 percent (analogous to the 0.05 significance level in a chi-square [χ^2] test) is used to determine whether the agreement between the unmodeled and posterior distributions is acceptable; values that fall below 60 percent indicate a problem with the radiocarbon result, the inferences used to place it within the model, or both. Perfect agreement between the unmodeled and posterior distributions will result in an agreement index of 100 percent; this indicates that the model enacted no change on the unmodeled probability distribution. Agreement indexes greater than 100 percent indicate that the posterior density estimate is fully encapsulated by the probability distribution, resulting in a more precise modeled date range (i.e., the unmodeled date has been truncated on both ends). Indexes less than 100 percent indicate that the posterior density estimate overlaps with a portion of the unmodeled probability distribution and extends beyond the limit of the unmodeled distribution. The age of each phase, or episode, identified in the model was defined by the oldest and youngest date of the posterior age estimates of the associated features.

Several sets of spatially and temporally clustered features were noted within the broader occupational episodes, and these were interpreted as representing discrete occupational events within the site history. In terms of real time, these may or may not represent sets of features that were used at the same time, but they were considered to be coeval within the resolution of the radiocarbon timescale. The statistical integrity of these groups was assessed in OxCal through a χ^2 test of the calibrated probability distributions (Ward and Wilson's Case 2, Ward and Wilson 1978), and a combined probability distribution was calculated for each group that passed the test by multiplying the constituent sample probability distributions together. This produced a combined calendar age for the associated event and the constituent features.

Results

This section presents the results of the georchaeological and chronological study of the Luke Solar project. Initially, each stratigraphic unit is presented beginning with the oldest and continuing in chronological order. The age, soil and lithological characteristics, depositional environment, and physical and chemical attributes of each unit are fully described. This is followed by examples of specific stratigraphic sections with a focus on feature-stratum relationships in the spatially and temporally clustered occupational episodes identified in OxCal. Finally, the results of the OxCal model are presented, starting with the modeled geochronology followed by the presentation of temporally clustered occupational episodes identified in the model. All radiocarbon dates presented in this chapter are uncalibrated unless otherwise indicated.

The application of large volumes of saline well water (presumably contaminated with salt from the Luke Salt Body) during dust-control operations has impacted soil pH and EC values. Fortunately, soil pH was also tested in the field using a portable test kit prior to the application of the highly alkaline well water. These values are presented along with the laboratory pH levels for some of the profiles. The EC values for Trench (TR) 9067 probably do not represent natural levels, because large volumes of dust-control water were applied to this area, so the results for TR 9067 have been discarded from the study.

Litchfield Ranch (LR) Formation

The LR Formation was a stratified sequence of late Pleistocene alluvial fan sediments capped with a moderately developed paleosol. The formation was typically encountered at depths exceeding 1 m below the modern surface. The basic soil-morphological properties of the paleosol included Stage II to II+ pedogenic carbonates (few to common soft masses or nodules); dark brown (7.5YR 3/4 moist) surface horizon to strong brown (7.5YR 4/6 moist) Bky or Btky horizons; few to common discontinuous clay films on ped surfaces and along pores; faint to distinct yellowish red (5YR 4/6–5/6 moist) Fe^{3+} concentrations; and in most instances, few fine to medium gypsum concentrations (Appendix 2.3). In the central and northern portions of the project area, these soil horizons were developed in normally graded (that is, fining upwards) medial to distal (middle fan to fan toe) alluvial-fan sediments characterized by broad shallow channels infilled with loamy sand to sandy loams. These coarser sediments graded up to silt loam or silty clay loam sheet-flood deposits. In the southern part of the project area, the normally graded sequence was interrupted by 10–15-cm-thick carbonate and/or dark silt loam lenses. In all locations, the broad shallow channels at the base of the LR Formation cut into a well-developed paleosol characterized by Stage III+ to IV pedogenic carbonates. This relict middle Pleistocene soil was much older than cultural deposits in the project area and was therefore not described in detail.

Particle-size analysis of the LR Formation indicated sand contents graded from 80 percent at the base to 27 percent at the surface in Trench 9066. However, in Trench 9067 sand content decreased with depth from 20 to 11 percent (Figures 14 and 15). Silt content decreased with depth in the formation from 71 percent near the surface to 11 percent at the base in Trench 9066. Although silt content increased with depth in Trench 9067 (see Figures 14 and 15), in most locations, the formation was normally graded based on field textures. Clay content was low throughout the formation (1.3–5.4 percent). The EC in TR 9066 ranged from less than 0.6 dS/m (deciSiemens per meter) at the base of the trench to a maximum of 6.8 dS/m in the calcium carbonate/gypsum lens from 160–170 cm below surface (cmbs). Soil pH ranged from 8.4 to 9.4 in TR 9066, 8.45 to 8.90 in TR 9067, and 8.6 to 8.8 in TR 4211 (see Figures 14 and 15). The maximum $CaCO_3$ content of the LR Formation varied from 7.5 percent in TR 9066 to 15.0 percent in TR 4211 (see Figure 14). Mehlich-3 extractable P was low in all analyzed samples (16–34 ppm) and SOM ranged from 0.3 to 3.6 percent.

Stable C analysis of SOM in the LR Formation produced values from -24.30‰ within the carbonate/gypsum lens in TR 9066 to -16.97‰ in TR 9067 (Figure 15; see Figure 14). The average of all LR Formation samples was -19.88‰, the most negative of all geologic units analyzed. The $\delta^{13}C$ values differed significantly between depositional settings, with channels having more-negative values compared to the sheet-flood fan deposits.

A single radiocarbon date from SOM in the LR Formation yielded an uncalibrated age of 15,150 ± 70 ^{14}C yr B.P. (16,680–16,080 cal B.C.) (see Table 8). This date was obtained from a dark-colored silt loam lens in TR 9066 (Figure 16). The silt lens was superimposed by a 10-cm-thick silt loam deposit moderately cemented with $CaCO_3$ and gypsum. The pH and $CaCO_3$ content suggest it was primarily cemented with gypsum. Soil development in the LR Formation was consistent with this radiocarbon date and with other soils that date to the late Pleistocene in the arid Southwest (Birkeland 1999; Gile et al. 1981; Machette 1985). Although numerous trenches exposed the LR Formation, no archaeological features or artifacts were identified in association with this deposit.

Unit I

Unit I was encountered below Units II, III1, III2, or IIs/sf in the central, southwest, south, and northeast portions of Falcon Landing (see Figure 16). Although the pedogenic features of Unit I varied depending on the age and thickness of the overlying strata, the morphology of Unit I Bk horizons was generally characterized by Stage I pedogenic carbonates (few to common filaments and threads), strong brown to brown (7.5YR 5/6–4/4 moist) soil colors, and moderate to strong subangular blocky structure. Where the unit was

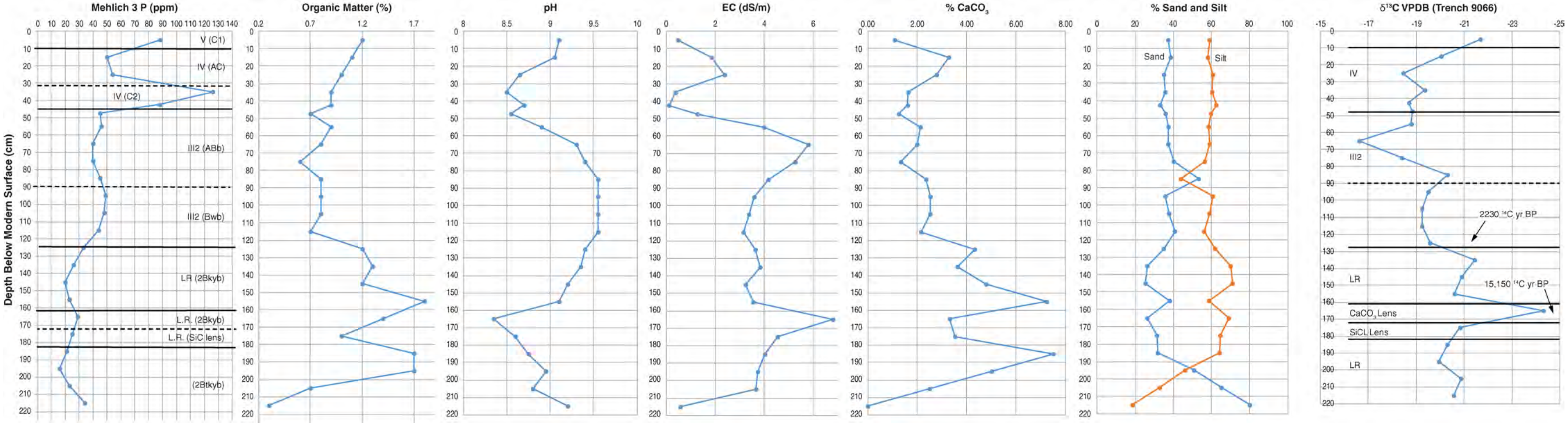


Figure 14. Particle size, organic carbon, calcium carbonate content, available P, pH, electrical conductivity and δ13C values of Trench 9066.

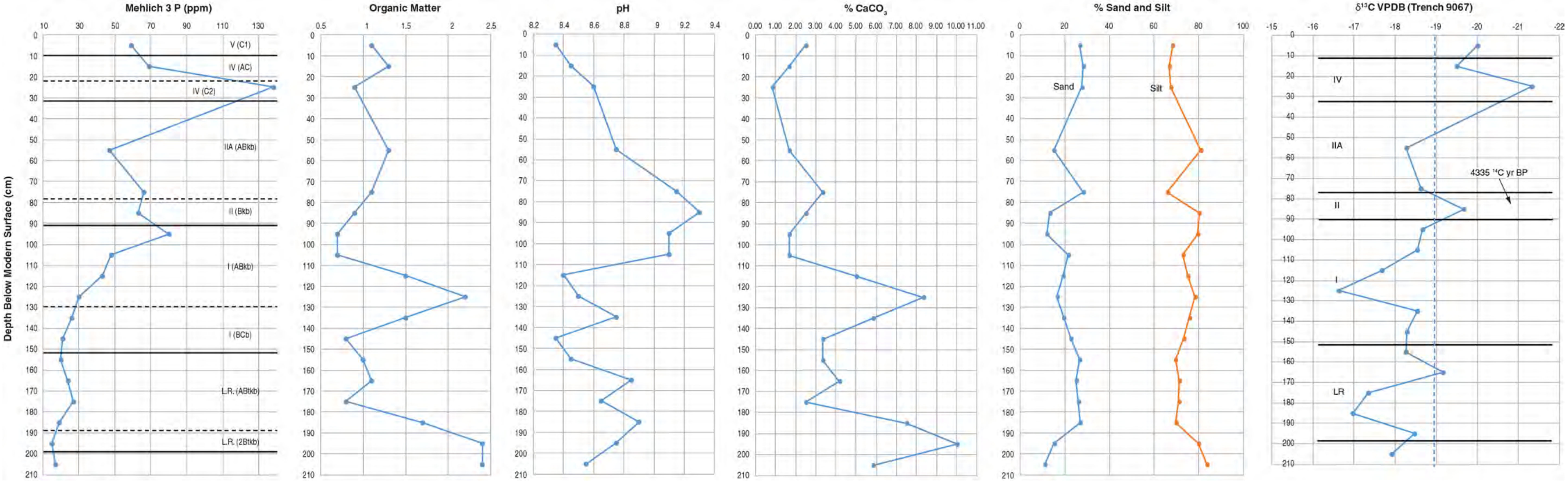


Figure 15. Particle size, organic carbon, calcium carbonate content, available P, pH, electrical conductivity and δ13C values of Trench 9067.

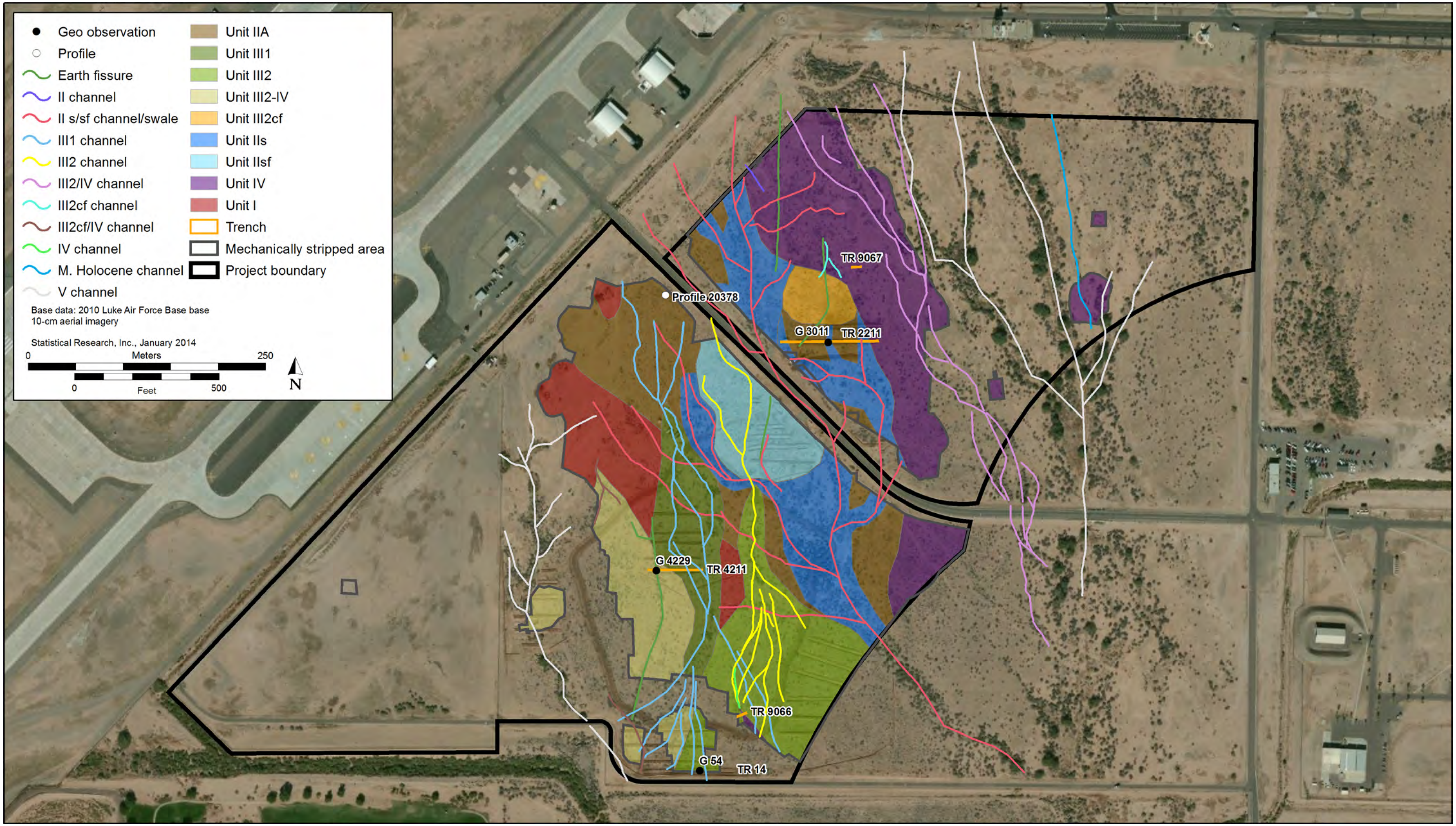


Figure 16. Geologic map of pre-stripped surface (minus Unit V) showing profile locations mentioned in text.

not deeply buried by younger deposits, an overlying ABk soil horizon with slightly darker soil colors was documented. The base of Unit I commonly contained higher-energy sandy loams with fine to medium subround and subangular gravels or in some instances a 10–15-cm-thick sand lens capping a thin gravel deposit. Silt loam sheet-flood deposits commonly formed the upper part of the unit. The base of Unit I in some areas formed a distinct erosional unconformity where shallow channels were cut into the LR Formation. Unit I primarily represents alluvial-fan deposition in a distributary flow setting.

Particle-size analysis of Unit I indicated silt was the dominant particle size in the middle to upper portions of the unit. In some instances, silt contents approached 80 percent (TR 9067). Sand, along with the fine to coarse gravel, increased near the base of the unit. Clay contents ranged from less than 2 percent in Profile 20378 to 8.6 percent in TR 9067. Soil pH varied from 8.4 to 9.1 and EC from 5.81 to 7.06 dS/m (Table 11). The maximum $CaCO_3$ content in Unit I Bk and ABkb horizons ranged from 2.1 to 8.3 percent. The highest SOM (2.2 percent) occurred in an ABkb horizon in TR 9067. SOM was low, less than 1.5 percent, for all other horizons. Mehlich-3 extractable P was generally low, although a moderate increase was detected near the surface of the ABkb horizon in TR 9067 (see Table 11). The $\delta^{13}C$ values of SOM in Unit I ranged from -15.60 in TR 4211 to -23.05 at the base of a Unit I channel in Profile 20378 (Figure 17). Similar to the LR Formation, $\delta^{13}C$ values were more-negative in channels compared to sheet-flood depositional settings. The average $\delta^{13}C$ value for all analyzed Unit I sediments was -18.85‰ (see Table 11).

Six radiocarbon dates from detrital charcoal provided depositional dates for Unit I. Four dates from near the base of the unit returned ages of 7950 ± 30, 7945 ± 30, 7740 ± 30, and 7695 ± 30 ^{14}C yr B.P. (see Table 8)

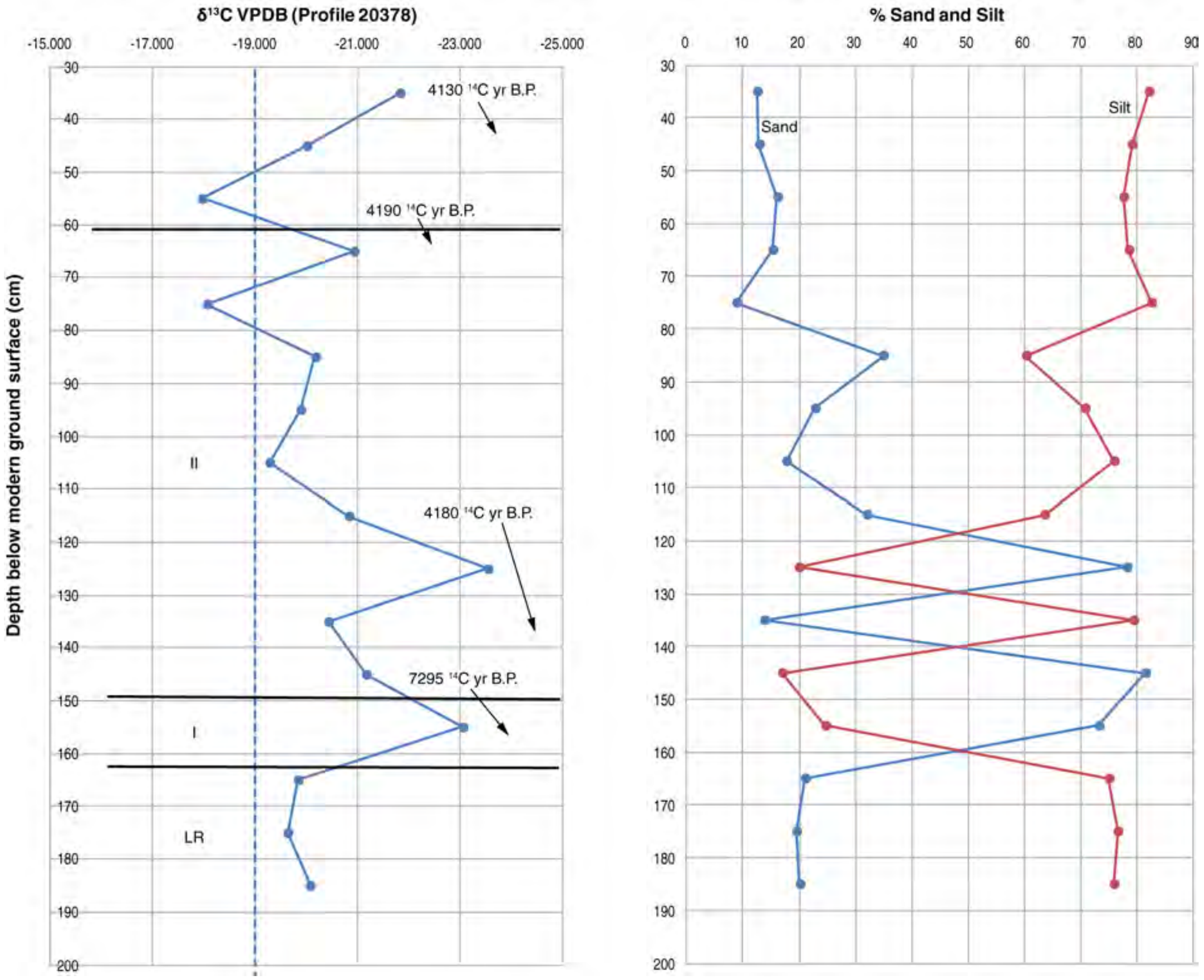


Figure 17. Particle size and δ13C values of soil organic matter from Profile 20378.

Table 11. Chemical and Physical Soil Data

Profile	Mid-Depth (cm)	Stratigraphic Unit	Horizon	P (ppm)	pH	% OM	EC (dS/m)	% $CaCO_3$	% Sand	% Silt	%Clay	δ^{13}C‰ SOM
TR 211 (0–10 cm)	5	IIs/sf	A	88	8.9	1.4	1.17	1.04	33.4	62.2	4.5	-18.60
TR 211 (10–30 cm)	20	IIs/sf	A	63	9.4	1.2	0.64	2.98	32.0	63.6	4.5	-17.77
TR 211 (30–50 cm)	40	IIs/sf	Bw1	57	9.5	1.4	3.16	4.59	32.0	64.3	3.7	-19.20
TR 211 (50–70 cm)	60	IIs/sf	Bw2	55	9.7	1	4.75	2.97	32.3	64.2	3.5	-20.91
TR 211 (70–115 cm)	92.5	IIA/II	AB b	57	9.05	1.4	9.8	0.00	8.5	84.4	7.1	-19.48
TR 211 (115–130 cm)	122.5	I	Bkb	41	9	0.8	5.81	2.05	34.6	59.5	5.8	-21.64
TR 9066 (0–10 cm)	5	V	C1	88	9.1	1.2	0.49	1.08	37.4	59.1	3.5	-21.68
TR 9066 (10–20 cm)	15	IV	AC	50	9.05	1.1	1.848	3.27	38.7	58.1	3.2	-20.05
TR 9066 (20–30 cm)	25	IV	AC	54	8.65	1	2.38	2.78	35.2	60.9	4.0	-18.46
TR 9066 (30–40 cm)	35	IV	C2	126	8.5	0.9	0.383	1.64	35.9	60.4	3.7	-19.36
TR 9066 (40–45 cm)	42.5	IV	C2	88	8.7	0.9	0.114	1.61	33.2	62.5	4.3	-18.70
TR 9066 (45–50 cm)	47.5	IV	C2	45	8.55	0.7	1.281	1.25	36.1	59.8	4.1	-18.84
TR 9066 (50–60 cm)	55	III2	2AB b	46	8.9	0.9	3.99	2.13	37.6	58.6	3.8	-18.80
TR 9066 (60–70 cm)	65	III2	2AB b	40	9.3	0.8	5.8	1.99	37.5	59.1	3.5	-16.63
TR 9066 (70–80 cm)	75	III2	2AB b	40	9.4	0.6	5.26	1.33	40.3	56.5	3.2	-18.40
TR 9066 (80–90 cm)	85	III2	2AB b	45	9.55	0.8	4.17	2.35	53.3	44.2	2.6	-20.31
TR 9066 (90–100 cm)	95	III2	2Bwb	49	9.55	0.8	3.59	2.52	35.9	60.7	3.3	-19.51
TR 9066 (100–110 cm)	105	III2	2Bwb	48	9.55	0.8	3.37	2.52	37.8	59.0	3.2	-19.24
TR 9066 (110–120 cm)	115	III2	2Bwb	44	9.55	0.7	3.15	2.15	40.9	56.2	2.8	-19.24
TR 9066 (120–130 cm)	125	LR	2Bkyb	33	9.4	1.2	3.64	4.32	35.0	61.9	3.0	-19.58
TR 9066 (130–140 cm)	135	LR	2Bkyb	26	9.35	1.3	3.83	3.62	26.5	70.1	3.4	-21.44
TR 9066 (140–150 cm)	145	LR	2Bkyb	20	9.2	1.2	3.24	4.78	25.6	71.0	3.4	-20.90
TR 9066 (150–160 cm)	155	LR	2Bkyb	23	9.1	1.8	3.55	7.23	38.2	58.8	3.0	-20.60
TR 9066 (160–170 cm)	165	LR $CaCO_3$ lens	3Bkb	29	8.35	1.4	6.8	3.31	26.5	69.1	4.4	-24.30
TR 9066 (170–180 cm)	175	LR SiCl lens	3Bkb	25	8.6	1	4.54	3.52	31.5	64.7	3.8	-20.83
TR 9066 (180–190 cm)	185	LR	4Bkyb	21	8.75	1.7	4.02	7.51	32.0	64.2	3.8	-20.30
TR 9066 (190–200 cm)	195	LR	4Bkyb	16	8.95	1.7	3.73	5.00	50.9	46.2	2.8	-19.95
TR 9066 (200–210 cm)	205	LR	4Bkyb	23	8.8	0.7	3.66	2.50	65.3	32.9	1.8	-20.87
TR 9066 (210–220 cm)	215	LR	4Bkyb	34	9.2	0.3	0.577	0.00	80.1	18.7	1.3	-20.57
TR 9067 (0–10 cm)	5	V	C1	59	8.35	1.1	N/A	2.50	26.7	68.3	5.1	-20.01

Profile	Mid-Depth (cm)	Stratigraphic Unit	Horizon	P (ppm)	pH	% OM	EC (dS/m)	% $CaCO_3$	% Sand	% Silt	%Clay	δ^{13}C‰ SOM
TR 9067 (10–20 cm)	15	IV	AC	69	8.45	1.3	N/A	1.67	28.3	66.8	4.9	-19.50
TR 9067 (20–30 cm)	25	IV	C2	138	8.6	0.9	N/A	0.83	27.6	67.4	4.9	-21.33
TR 9067 (50–60 cm)	55	IIA	AB k	47	8.75	1.3	N/A	1.67	15.0	80.9	4.1	-18.27
* no 30–40 or 40–50 cm sample												
TR 9067 (70–80 cm)	75	IIA	AB k	66	9.15	1.1	N/A	3.34	28.2	66.0	5.8	-18.62
* no 60–70 cm sample												
TR 9067 (80–90 cm)	85	II	Bk1	63	9.3	0.9	N/A	2.50	13.4	80.2	6.5	-19.66
TR 9067 (90–100 cm)	95	I	ABkb	80	9.1	0.7	N/A	1.67	11.9	79.5	8.6	-18.67
TR 9067 (100–110 cm)	105	I	ABkb	48	9.1	0.7	N/A	1.67	21.6	72.9	5.5	-18.54
TR 9067 (110–120 cm)	115	I	ABkb	43	8.4	1.5	N/A	5.00	19.2	75.1	5.7	-17.67
TR 9067 (120–130 cm)	125	I	ABkb	30	8.5	2.2	N/A	8.34	16.5	78.4	5.1	-16.62
TR 9067 (130–140 cm)	135	I	BCb	26	8.75	1.5	N/A	5.84	19.4	75.8	4.7	-18.54
TR 9067 (140–150 cm)	145	I	BCb	21	8.35	0.8	N/A	3.34	22.6	73.3	4.1	-18.29
TR 9067 (150–160 cm)	155	LR	AB tkb	20	8.45	1	N/A	3.34	26.6	69.5	3.9	-18.26
TR 9067 (160–170 cm)	165	LR	AB tkb	24	8.85	1.1	N/A	4.17	25.1	71.3	3.6	-19.16
TR 9067 (170–180 cm)	175	LR	AB tkb	27	8.65	0.8	N/A	2.50	26.0	71.1	2.9	-17.35
TR 9067 (180–190 cm)	185	LR	AB tkb	19	8.9	1.7	N/A	7.51	26.8	69.8	3.4	-16.97
TR 9067 (190–200 cm)	195	LR	2Btkb	15	8.75	2.4	N/A	10.01	15.2	79.8	5.0	-18.47
TR 9067 (200–210 cm)	205	LR	3Btkb	17	8.55	2.4	N/A	5.84	11.0	83.6	5.4	-17.91
TR 4211 A Horizon		III1	A	65	8.05	2.6	17.52	6.67	22.0	73.3	4.8	-20.73
TR 4211 Bk1 Horizon		I	Bk1	53	8.65	1.3	7.06	5.00	35.0	61.5	3.5	-20.37
TR 4211 2Bk1b Horizon		LR	2Bk1b	27	8.6	3.6	7.2	15.01	28.8	68.1	3.1	-15.60
TR 4211 2Bk2b Horizon		LR	2Bk2b	17	8.75	2.5	5.29	10.01	30.5	66.6	2.9	-19.49
TR 14 A Horizon (0–36 cm)	18	III1/III2	A	52	8.8	1.5	0.476	2.50	23.0	72.5	4.5	-21.31
TR 14 Bk1 Horizon (36–60 cm)	48	III1	Bk1	55	8.5	1.2	4.34	3.34	22.6	71.6	5.7	-17.55
TR 14 2Bk2 Horizon (60–105)	82.5	III1	2Bk2	32	8.3	0.6	7.36	1.67	51.9	45.2	2.9	-19.95
TR 14 3Bkb Horizon (105–130 cm)	117.5	III1	2Bk3	16	8.1	2.3	7.94	9.17	39.3	57.9	2.8	-21.24
Profile 20378 (40–50 cm)		IIA	AB k	N/A	N/A	N/A	N/A	N/A	12.5	82.0	5.5	-21.82
Profile 20378 (50–60 cm)		IIA	AB k	N/A	N/A	N/A	N/A	N/A	12.8	79.0	8.1	-20.01
Profile 20378 (60–70 cm)		II	Bk	N/A	N/A	N/A	N/A	N/A	16.1	77.5	6.4	-17.96

contnued on next page

Profile	Mid-Depth (cm)	Stratigraphic Unit	Horizon	P (ppm)	pH	% OM	EC (dS/m)	% $CaCO_3$	% Sand	% Silt	%Clay	$\delta^{13}C$‰ SOM
Profile 20378 (70–80 cm)		II	Bk	N/A	N/A	N/A	N/A	N/A	15.2	78.4	6.3	-20.93
Profile 20378 (80–90 cm)		II	Bk	N/A	N/A	N/A	N/A	N/A	8.8	82.5	8.7	-18.07
Profile 20378 (90–100 cm)		II	C1	N/A	N/A	N/A	N/A	N/A	34.8	60.2	4.9	-20.18
Profile 20378 (100–110 cm)		II	C1	N/A	N/A	N/A	N/A	N/A	22.8	70.7	6.6	-19.89
Profile 20378 (110–120 cm)		II	C1	N/A	N/A	N/A	N/A	N/A	17.7	75.8	6.5	-19.28
Profile 20378 (120–130 cm)		II	C1	N/A	N/A	N/A	N/A	N/A	32.0	63.5	4.5	-20.83
Profile 20378 (130–140 cm)		II	2C2	N/A	N/A	N/A	N/A	N/A	78.1	19.9	2.0	-23.54
Profile 20378 (140–150 cm)		II	3C3	N/A	N/A	N/A	N/A	N/A	13.8	79.3	6.9	-20.43
Profile 20378 (150–160 cm)		I	4C4	N/A	N/A	N/A	N/A	N/A	81.4	17.0	1.6	-21.17
Profile 20378 (160–170 cm)		I	4C5	N/A	N/A	N/A	N/A	N/A	73.2	24.6	2.3	-23.05
Profile 20378 (170–180 cm)		LR	Btkb	N/A	N/A	N/A	N/A	N/A	21.0	74.9	4.1	-19.84
Profile 20378 (180–190 cm)		LR	Btkb	N/A	N/A	N/A	N/A	N/A	19.4	76.5	4.1	-19.64
Profile 20378 (190–200 cm)		LR	Btkb	N/A	N/A	N/A	N/A	N/A	20.1	75.8	4.1	-20.07

Charcoal from the upper part of the unit returned uncalibrated ages of 7060 ± 20 and 7295 ± 25 ^{14}C yr B.P. A single cultural feature (Feature 10307) associated with a Unit I channel returned the uncalibrated age of 7950 ± 30 ^{14}C yr B.P. (see Table 8). The OxCal-modeled age range for Unit I is 7040–5320 cal B.C. Although a number of features intruded into the surface of Unit I, Feature 10307 was the only feature identified that was coeval with Unit I deposition.

Unit II

Similar to Unit I, Unit II represents alluvial-fan deposition in a distributary flow environment; however, Unit II deposits were more channelized, which suggests a more-proximal fan setting. The soil developed in Unit II was typically described as a Bk horizon with few Stage I pedogenic carbonates, dark yellowish brown (10YR 4/4 moist) soil colors, and moderate subangular blocky structure. In some instances, thick Unit II deposits were separated into an upper silt loam Bk horizon and a lower loam to sandy loam BCk or C soil horizon. Unit II was most extensively mapped in the central and northern portions of the project area (see Figure 16).

Particle-size analysis and texture (estimated by the ribbon method in the field) indicated that Unit II graded from a sandy loam with 70–80 percent sand at its base up to a silt loam with over 80 percent silt near the top of the unit. Clay content was below 10 percent throughout Unit II (see Table 11). Soil pH recorded colorimetrically in the field ranged from 8.2 to 9.0, but lab analysis indicated a pH of 9.3 in TR 9067 (see Table 11). SOM measured 0.9 percent. Mehlich-3 extractable P was 63 ppm and the $CaCO_3$ content was 2.5 percent.

Five radiocarbon dates from detrital charcoal confine the deposition of Unit II to a brief period between 4335 ± 20 and 4115 ± 15 ^{14}C yr B.P. The OxCal-modeled age range is 2970–2730 cal yr B.C. Several cultural features were identified at the boundary between Unit II and IIA, but very few were deeply buried in Unit II deposits (Figure 18).

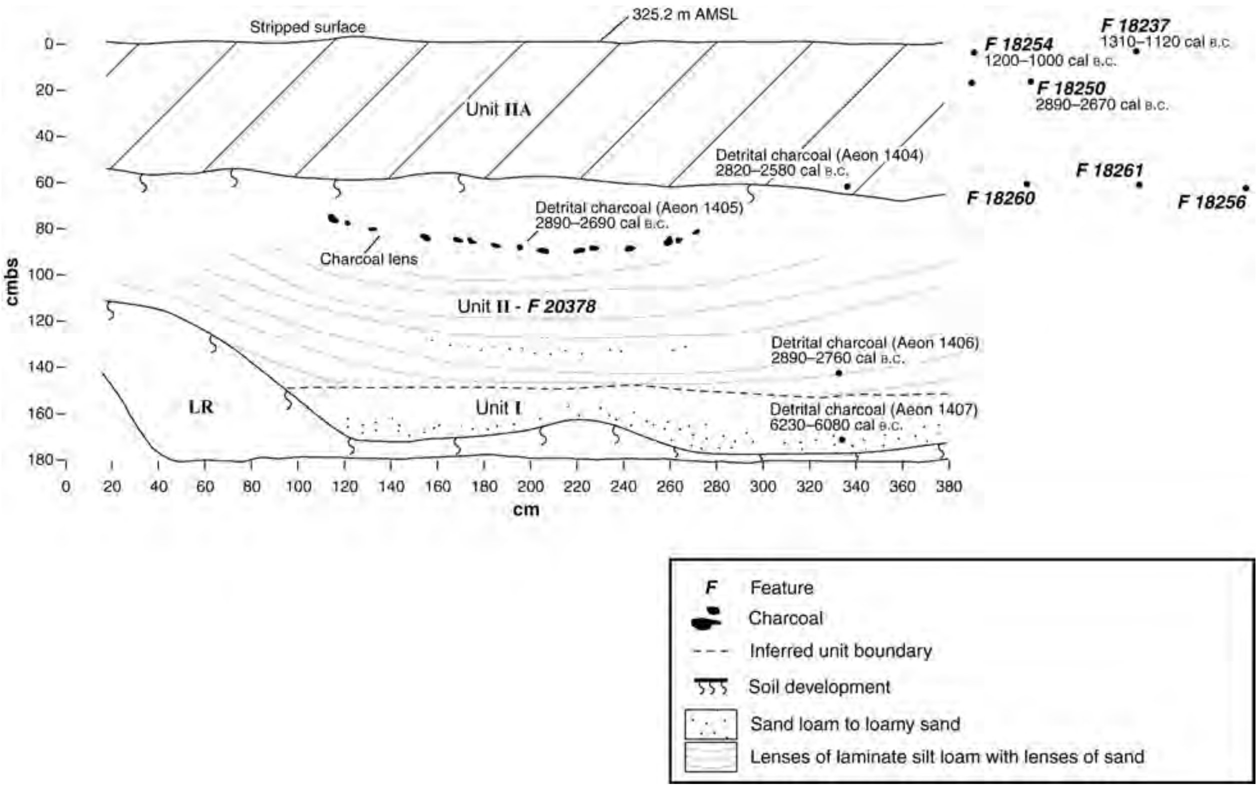


Figure 18. Profile 20378.

Unit IIA

Unit IIA was a darker-colored dark brown to dark yellowish brown (10YR 3/3–3/4 moist) silt loam sheet flood deposit up to 50 cm in total thickness. Soil development in the unit has resulted in the formation of an ABk horizon. Soil morphological characteristics included Stage I or Stage I- pedogenic carbonates, moderate to strong subangular blocky structure, and moderate levels (1–5 percent of total horizon) of bioturbation via insect burrowing (termites). Closely spaced particle-size analysis and the presence of cultural features at the contact between Units II and IIA indicated these were two distinct depositional units separated by a brief unconformity (see Figure 18). The length of time represented by the unconformity varied slightly between sampling locations.

Particle-size analysis revealed a slight increase in sand and a decrease in silt and clay at the base of Unit IIA. Conversely, the upper part of the unit displayed a slight increase in silt and a decrease in sand (see Figure 17; Table 11). Clay content ranged from 4.1 to 7.1 percent throughout the unit. Soil pH varied from 8.8 to 9.2. SOM content ranged from 1.1 to 1.4 percent, and the maximum $CaCO_3$ content was 3.3 percent. Mehlich-3 extractable P ranged from 47 to 66 ppm (see Table 11). Stable C analysis of SOM in Units II and IIA produced values that ranged from -17.96 to -23.54, both in Profile 20378 (see Figure 17). The average $\delta^{13}C$ value for all analyzed Unit II and IIA deposits was -19.84, an approximate 1‰ decrease from Unit I (see Figure 17; Table 11).

Although the exact age of Unit IIA varied slightly by location, eight radiocarbon dates from detrital charcoal and intrusive cultural features across Falcon Landing confine the deposition of Unit IIA between 4190 ± 20 and 3985 ± 20 ^{14}C yr B.P. (see Table 8). The OxCal-modeled age range for the unit is 2810–2420 cal yr B.C. The 80-year overlap that exists between upper II and lower IIA deposits is likely related to errors inherent to radiocarbon dating (e.g., old wood, postdepositional mixing, recycled charcoal, etc.) and the relatively brief period of time represented by the deposition of Units II and IIA (less than 350 years). The up-fan migration of the Unit IIA alluvial-fan reach might also account for some of the overlap as the down-fan Unit II surface was buried slightly before the up-fan Unit II deposits.

Unit IIs/sf

Unit IIs/sf represents alluvial-fan swale/channel(s) fills and sheet-flood deposits (sf). Unit IIs/sf deposits were the result of secondary fan processes that began immediately after the deposition of Units II and IIA. This included localized infilling of swales and deposition along an organized drainage network (see Figure 16). In the shallow swales that characterized the northern portion of Falcon Landing, the unit was commonly less than 50 cm thick. However, Unit IIs/sf deposits in deep swales and channels in the central and east-central portions of the site exceeded 1 m in thickness. Unit IIs/sf deposits included upper swale fills and prevalent sheet-flood deposits in the central portion of Falcon Landing where they mantled Unit II and IIA deposits. Upper and lower Unit IIs/sf deposits were combined because the unconformity separating them was difficult to identify and correlate across the site. Soil morphological characteristics included weakly developed dark yellowish brown (10YR 4/6 moist) Bw horizons with no visible carbonates and moderate subangular blocky structure. In some locations, Unit IIs/sf contained an over-thickened dark yellowish brown (10YR 3/4 moist) A horizon. The application of 1N HCl indicated the presence of finely disseminated carbonates in both the A and Bw horizons. Intact bedding features in the form of fine laminations were typically visible at the base of swales. When present, gravels were subrounded and less than 5 mm in diameter (fine gravels). Total gravel content throughout the unit was less than 1 percent by volume, but gravel content and size increased at the base of the Unit IIs/sf sheet-flood deposits.

Particle-size analysis of Unit IIs/sf indicated shallow swales were not graded and were infilled with silt loams (32–33 percent sand, 62–64 percent silt, and 4–5 percent clay) (see Table 11). Field textures indicated Unit IIs/sf sheet-flood and channel deposits were normally graded with sandy loams at the base grading up to silt loams. Soil pH varied from 8.9 to 9.7 and EC from 1.0 to 4.75 dS/m. Mehlich-3 extractable P was low in the Bw horizons (55–57 ppm) but increased moderately in the A horizons (63–88 ppm). SOM ranged from 1.0 to 1.4 in the Bw horizons and from 1.2 to 1.4 percent in the A horizons. $CaCO_3$ content varied from

1.0 to 4.6 percent (see Table 11). The $\delta^{13}C$ values of SOM from Unit IIs/sf deposits ranged from -17.12 to -20.91‰ with an average of -18.47‰ (see Table 11).

Four radiocarbon dates from detrital charcoal constrain the deposition of the lower Unit IIs/sf fills between 3940 ± 20 and 3670 ± 20 ^{14}C yr B.P. (see Table 8). Cultural features stratified in the upper part of the unit indicate the upper portion was deposited between 3005 ± 20 and 2805 ± 25 ^{14}C yr B.P. These dates suggest a hiatus from 3670 to 3010 ^{14}C yr B.P. The OxCal-modeled age range for Unit IIs/sf as a whole is 2570–790 cal B.C. Upper IIs/sf deposits were similar in age to Unit III1.

Unit III1

Unit III1 was deposited along a discontinuous ephemeral channel network that flowed south from the south-central portion of Falcon Landing into Site 68 (see Figure 16). Along the incised master channel, the unit was approximately 90–100 cm thick. Along the alluvial-fan reach at Site 68 the total thickness varied considerably in a bar-and-swale distributary flow setting. Soil morphological characteristics of Unit III1 deposits included few Stage I pedogenic carbonates (few fine filaments or threads along root channels), brown to strong brown (7.5YR 4/6–4/4 moist) soil colors, and moderately developed subangular blocky structure.

Particle-size analysis revealed a normally graded sequence of fine sandy loam at the base (52 percent sand, 45 percent silt) grading up to a silt loam (23 percent sand, 73 percent silt) in the middle and upper parts of the unit (see Table 11). Clay contents ranged from 2.9 percent at the base to 5.7 percent near the top of the unit. Soil pH ranged from 8.1 to 8.8 and EC from 0.5 to 17.5 dS/m. Mehlich-3 extractable P varied from 32 ppm in the sandy loam Bk horizons to 65 ppm in the A horizons. SOM followed a similar trend with a low of 0.6 percent in the Bk horizons and a high of 1.5 percent in the A horizons. $CaCO_3$ content ranged from 1.7 to 3.3 percent. The $\delta^{13}C$ values of SOM from the Unit III1 alluvial-fan reach ranged from -17.55 to -20.73‰ with an average of -19.30‰ (see Table 11). A single sample from upper Unit III1 deposits along the master channel reach yielded a value of -21.31‰.

Six radiocarbon dates, two from detrital charcoal and four from stratified features, bracket Unit III1 deposition between 3005 ± 25 and 2835 ± 15 ^{14}C yr B.P. (see Table 8). The first depositional date comes from the incised channel network in the south-central portion of Falcon Landing. Here, detrital charcoal from upper channel fills dated to 2985 ± 20 ^{14}C yr B.P. Charcoal recovered from the lower Unit III1 deposits in the alluvial-fan reach yielded an uncalibrated age of 2950 ± 20 ^{14}C yr B.P. A date from a cultural feature (Feature 4370) near the base of Unit III1 at Falcon Landing returned a radiocarbon age 3005 ± 25 ^{14}C yr B.P. (see Table 8) indicating deposition of the unit by this time. Two cultural features near the top of the unit yielded uncalibrated ages of 2835 ± 15 ^{14}C yr B.P. (Features 4343 and 4287). The OxCal-modeled age range for Unit III1 is 1380–920 cal yr B.C.; Unit III1 was coeval with the upper Unit IIs/sf fills in the central and northern portions of Falcon Landing.

Units III2 and III2cf

Unit III2 was a widespread master channel–alluvial-fan deposit in the southeastern portion of Falcon Landing (see Figure 16). Unit III2cf represented smaller alluvial-fan reaches in the north-central and southwestern portions of Falcon Landing. Unit III2cf master channel and headcut tributary reaches could not be traced in trenches and were not visible in aerial imagery. Typically, Unit III2 alluvial-fan-reach deposits were less than 50 cm thick. The unit attained a maximum thickness of 75 cm in a distributary flow channel near the fan head in TR 9066 (see Figure 16). Unit III2cf alluvial-fan-reach deposits ranged in total thickness from 20 to 80 cm. Soil formation in both units was restricted to weakly developed Bw horizons with no visible pedogenic carbonates and weak to moderate subangular blocky structure.

Particle-size analysis indicated most of the Unit III2 deposits were silt loams; however, sand content was generally higher throughout the unit compared to Unit III1 with the exception of a III1 channel deposit in TR 14. (see Table 11). In TR 9066, the maximum sand content was 53.3 percent (80–90 cmbs) and the maximum silt content was 60.7 percent (90–100 cmbs). Clay content ranged from 2.6 to 3.8 percent. Soil pH varied from 8.9 to 9.6 and EC from 3.15 to 5.80 dS/m (see Table 11). SOM content remained below 1.0 percent with a range of 0.6–0.9 percent. The maximum $CaCO_3$ content was 2.5 percent in the upper Bw horizon in TR 9066 (see Figure 14). Chemical and physical soil data were not obtained from Unit III2cf; however, particle size determined in the field was very similar to Unit III2. The $\delta^{13}C$ values for Unit III2 from near the fan head in TR 9066 averaged -18.96‰ with a range of -16.63 to -19.58‰ (see Table 11).

Three Unit III2 detrital charcoal samples yielded uncalibrated ages of 2230 ± 20, 2410 ± 20, and 2380 ± 25 ^{14}C yr B.P. (see Table 8).The OxCal-modeled age range for Unit III2 deposition is 720–200 cal B.C. Detrital charcoal from the Unit III2cf alluvial-fan reach in the north-central part of Falcon Landing dated to 1915 ± 35 to 1840 ± 40 ^{14}C yr B.P. (see Table 9). In the southwestern portion of Falcon Landing, Unit III2cf was constrained to less than 1930 ± 25 ^{14}C yr B.P. The OxCal-modeled age for Unit III2cf is 160 cal B.C.–cal A.D. 340.

Unit IV

Unit IV was a thin sheet-flood deposit (typically less than 40 cm thick) located primarily along the eastern quarter of the project area (see Figure 16). Soil morphology of this unit was characterized by a dark yellowish brown (10YR 3/4 moist) AC soil horizon with incipient soil structure over a massive dark yellowish brown (10YR 4/4 moist) C horizon. Both the AC and C horizons retained some original bedding features. The application of 1N HCl indicated the presence of finely disseminated carbonates.

Particle-size analysis indicated Unit IV was a silt loam with 33–39 percent sand, 58–67 percent silt, and 3.2–4.9 percent clay (see Table 11). Soil pH ranged from 8.45 to 9.05 and EC from 0.11 to 2.4 dS/m. SOM varied from 1.3 percent in the AC horizons to 0.7 percent in the underlying C horizons. The $CaCO_3$ content was highest in the upper AC horizons where it ranged from 1.7 to 3.3 percent. Mehlich-3 extractable P was low in the AC horizons (50–69 ppm), but elevated levels were detected in the C horizons (126–138 ppm). The $\delta^{13}C$ values of SOM in Unit IV ranged from -18.46 to -21.33‰, with an average of -19.46‰ (see Table 11).

Four radiocarbon dates constrain the age of Unit IV deposition. A cultural feature (Feature 19067) very near the base of Unit IV returned an uncalibrated age of 1400 ± 20 ^{14}C yr B.P. (see Table 8). A single detrital charcoal date from the middle of the unit yielded an age of 1300 ± 20 ^{14}C yr B.P. The earliest cultural features intruding into the surface of the unit dated to 975 ± 25 and 970 ± 25 ^{14}C yr B.P. (Features 11072 and 14655, respectively). These dates bracket the timing of deposition between 1400 ± 20 and 1000 ± 20 ^{14}C yr B.P. The OxCal-modeled age range for Unit IV is cal A.D. 610–1220.

Unit V

Unit V was a ubiquitous silt loam sheet-flood deposit directly below the modern ground surface across most of the project area. Soil formation in the unit was nonexistent. The unit was typically composed of a single dark yellowish brown (10YR 4/4 moist) massive silt loam C horizon. Intact bedding features in the form of laminations were a common attribute. In most locations, Unit V was less than 10 cm thick. Low Unit V coppice dunes below the sparse vegetation across the project area indicated some reworking by wind.

Particle-size analysis revealed Unit V was a silt loam with 27–37 percent sand, 59–68 percent silt, and 3.5–5.1 percent clay. Soil pH ranged from 8.35 to 9.10 and a single EC measurement yielded 0.49 dS/m (see Table 11). SOM content varied from 1.1 to 1.2 percent and $CaCO_3$ from 1.1 to 2.5 percent. Mehlich-3 extractable P ranged from 59 to 88 ppm. Two Unit V samples yielded $\delta^{13}C$ values of -21.01 and -21.68‰.

A single radiocarbon date from a cultural feature capped by Unit V provided a maximum age for the unit. This feature (Feature 2630) returned an uncalibrated age of 270 ± 20 ^{14}C yr B.P. (cal A.D. 1520–1800) (see Table 8). Because only one radiocarbon date constrains the age of Unit V, it was not included in the OxCal model.

Falcon Landing Grid H5, Geologic Cross Section 1

In the north-central portion of Falcon Landing, a small isolated channel fan contained stratified Red Mountain phase components in Unit III2cf and San Pedro phase occupations on the buried surface of Unit IIs/sf (Figures 19 and 20). The drainage feeding the Unit III2cf fan was obscured by younger deposits in aerial imagery, but it could be traced a short distance to the north on the mechanically stripped surface. The stratigraphy of this area was complex because it contained Unit II and IIA fan-toe deposits, Unit IIs/sf swale fills, and a Unit III2cf alluvial fan. A swale centered on the eastern end of TR 2213 (Geo 2593) preserved a well-stratified sequence of these deposits (see Figure 19).

Located on the buried Unit IIs/sf surface, a subfeature of Feature 18887 (structure) yielded an age of 1120–1000 cal B.C. placing it in the San Pedro phase (see Figure 19, TR 2213; Table 8). Below Unit IIs/sf, detrital charcoal from Unit IIA dated to 2840–2490 cal B.C. These dates confined Unit IIs/sf between 2840–2490 cal B.C and 1120–1000 cal B.C. at this location. San Pedro phase occupation on the Unit IIs/sf surface took place during the hiatus between Unit IIs/sf and III2cf deposition or approximately 1000–160 cal B.C.

The Red Mountain phase occupations were associated with a Unit III2cf mid-fan to fan-toe environment dominated by low-energy sheet-flood deposits. Detrital charcoal recovered from a 1-by-1-m test pit excavated into this unit yielded a basal age of cal A.D. 1–210 and an upper date of cal A.D. 70–250 (see Figure 19; Table 8). Three features preserved in the Unit III2cf deposit dated to 160 cal B.C.–cal A.D. 330 (Subfeature 20285), cal A.D. 20–120 (Feature 14702), and 20 cal B.C.–cal A.D. 120 (Feature 2529) (see Figure 19; Table 8). This indicated most of Unit III2cf was deposited over a brief period of time in the Early Ceramic period.

Falcon Landing Grids B4–5, Geologic Cross Section 2

In the southeast section of Falcon Landing, Unit III2 deposits blanketed the eroded surface of Unit I (see Figure 16). Occupations on the Unit I surface primarily dated to the early Chiricahua and Cienega phases, and those within and on the surface of Unit III2 dated to the Hohokam pre-Classic period. Unit III2 in this area was deposited along the fan toe of a north-south-trending Unit III1 and III2 drainage network (see Figure 16). These drainages formed a broad alluvial-fan reach in the south and southeast and an incised channel network in the central part of Falcon Landing. The drainages likely extended to the north, but twentieth-century landscape disturbance has masked their presence outside of the project boundaries (see Figure 16).

Unit III2 deposits were marked by a lack of pedogenic carbonates and a weakly to moderately developed Bw soil horizon. These horizons stand in marked contrast to the Unit I Bk horizons characterized by Stage I secondary carbonates and a moderate level of rubification (that is, reddening of the soil profile caused by oxidation of iron). The stratigraphic boundary between Units I and III2 was both wavy and abrupt, which indicates the surface of Unit I was eroded prior to burial. Several shallow rills and gullies were documented on the Unit I surface in the southeastern portion of Falcon Landing, which is not surprising given that the Unit I surface was exposed for nearly 5,000 years (a Unit I/III2 hiatus) at the surface.

A radiocarbon date obtained from detrital charcoal near the base of Unit III2 returned a calibrated age of 390–200 cal B.C. (see Table 8). This corresponds with buried Cienega phase features that dated to 770–540 cal B.C. on the Unit I surface. An upper depositional age for Unit III2 was not obtained in the area, but the oldest dated features intruding into the surface of Unit III2 date to the pre-Classic (Feature 1290) (Figure 21). This confines the age of Unit III2 in this area between approximately 390–200 cal B.C. and cal A.D. 640–670. Soil development, however, indicates that Unit III2 deposition ended a significant time prior to this.

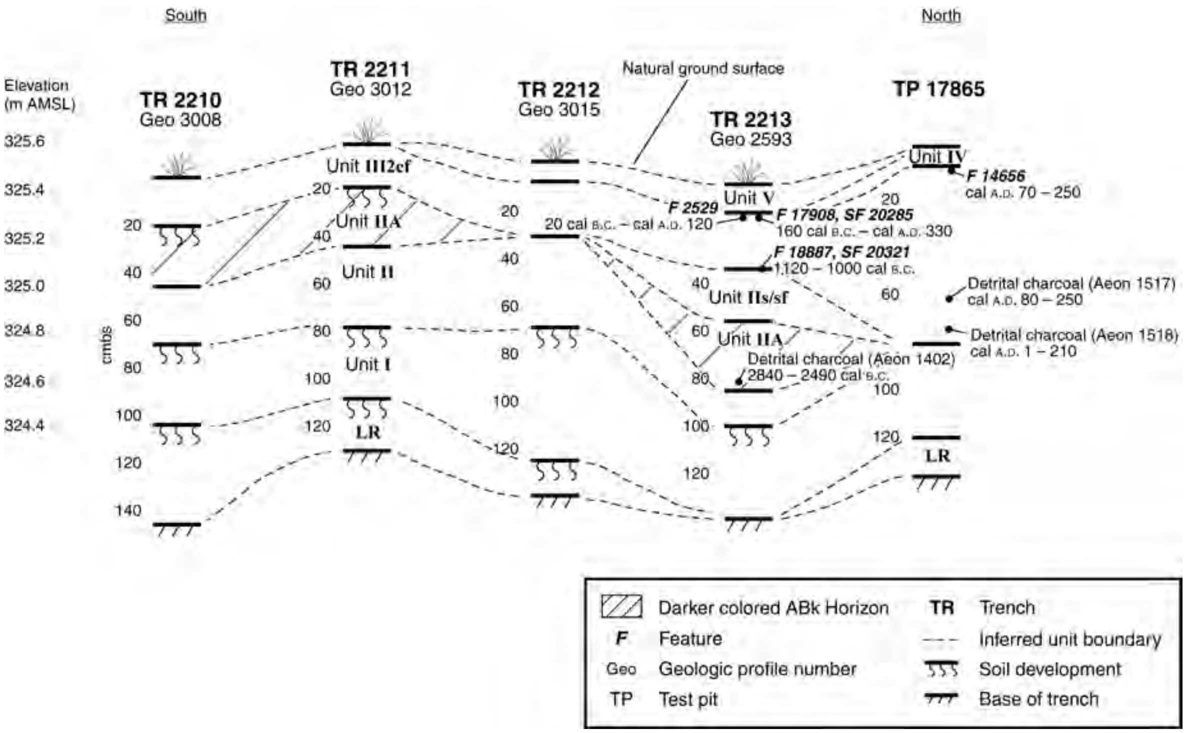


Figure 19. Geologic Cross Section 1, San Pedro and Red Mountain phase occupations, Falcon Landing (Grid H5).

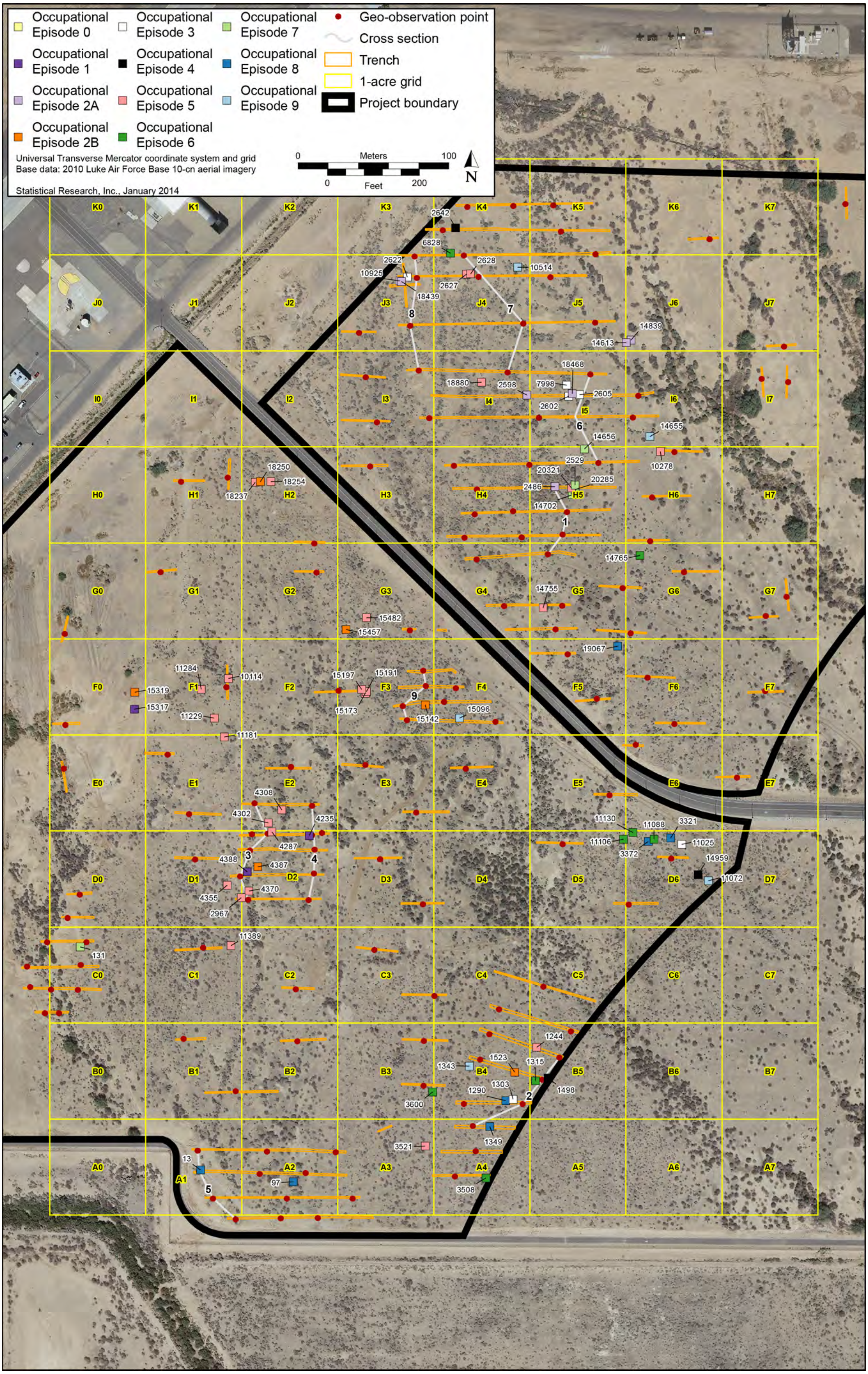


Figure 20. Map showing location of geologic cross sections, trenches, profiles, and occupational episodes.

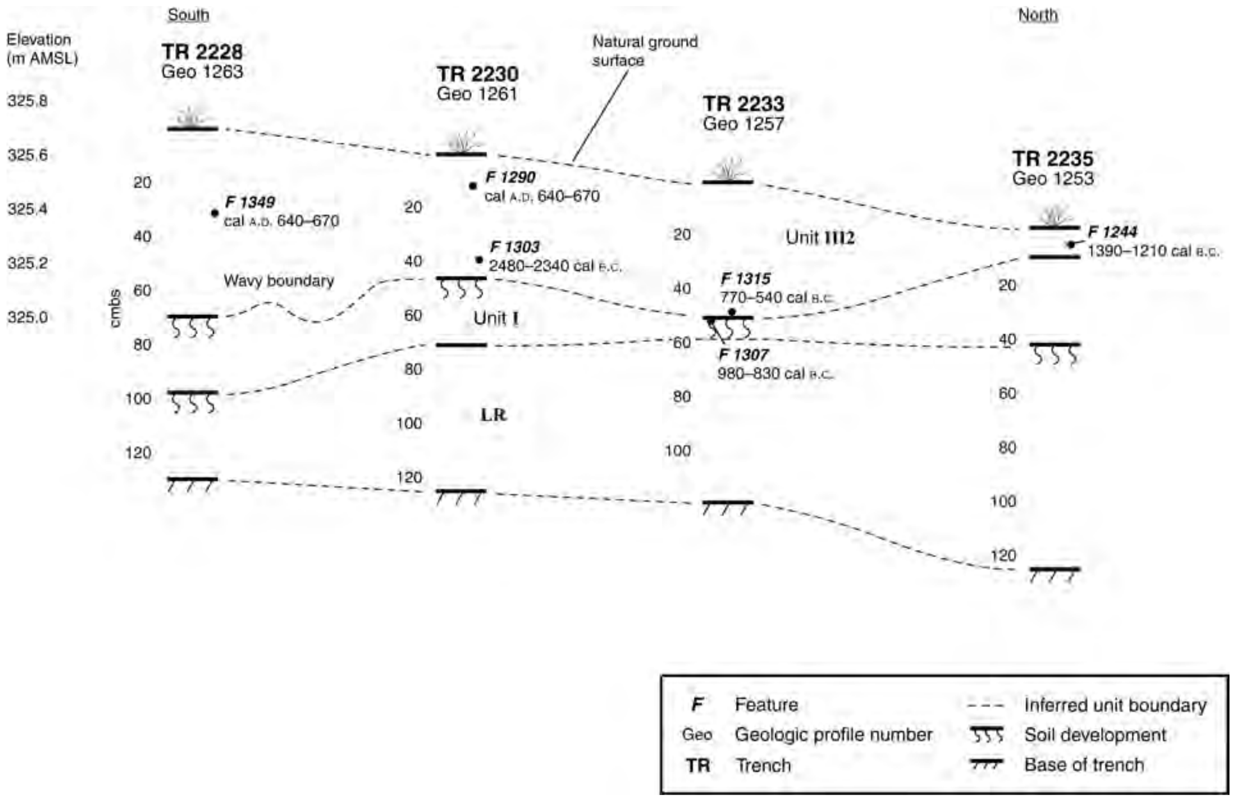


Figure 21. Geologic Cross Section 2, early Chiricahua and Cienega phase, and Hohokam pre-Classic period occupations in the southern portion of Falcon landing (Grid B4–B5).

Falcon Landing and Site 68 Grids D2–E2–C2, Geologic Cross Sections 3 and 4

In south-central Falcon Landing, early Chiricahua and San Pedro phase occupations were associated with the surface of Unit I and interstratified within the master channel reach of Unit III1, respectively (see Figures 16 and 20). The master channel flowed to the south until reaching an intersection point in the southern project area (Site 68) where it began to spread out laterally to form a small alluvial fan. Along the master channel reach, the Unit III1 channels were incised into a Unit I surface containing a number of early Chiricahua phase features. Some Middle Archaic (and possibly Early Archaic) features were probably truncated or completely removed during the formation of these channels.

Detrital charcoal from mid to upper Unit III1 deposits along the incised-channel reach yielded a calibrated age of 1310–1120 cal B.C., and several San Pedro phase features interstratified in Unit III1 master channel deposits dated between 1130–1000 and 1010–920 cal B.C. (Figure 22; see Table 8). These dates indicate incision of the Unit III1 channel likely occurred around or just prior to 1200–1100 cal B.C. Age-depth relationships of San Pedro phase features in the Unit III1 channel fills further suggest that channels were largely filled in with alluvium by 920 cal B.C. early Chiricahua phase features intruding into the surface of Unit I and buried by Unit III1 dated to 3340–3090, 3020–2890, and 2890–2690 cal B.C. (see Figure 22). Most of the features were shallowly buried by Unit III1 near-channel (overbank) alluvium. Very few Middle Archaic features were identified below Unit III1 channels (see Figure 22).

To the south in the alluvial-fan reach (Site 68), charcoal recovered from near the base of a Unit III1 fan head–mid-fan channel dated to 1270–1050 cal B.C. The base of this channel was moderately cemented by groundwater carbonates. All of the dated features intruding into the surface of Unit III1 in the alluvial-fan reach (Site 68) dated to the pre-Classic period (Figure 23). Dates from the alluvial-fan and master channel reach of Unit III1 indicate this ephemeral fan drainage was active for less than 450 years during the San Pedro phase.

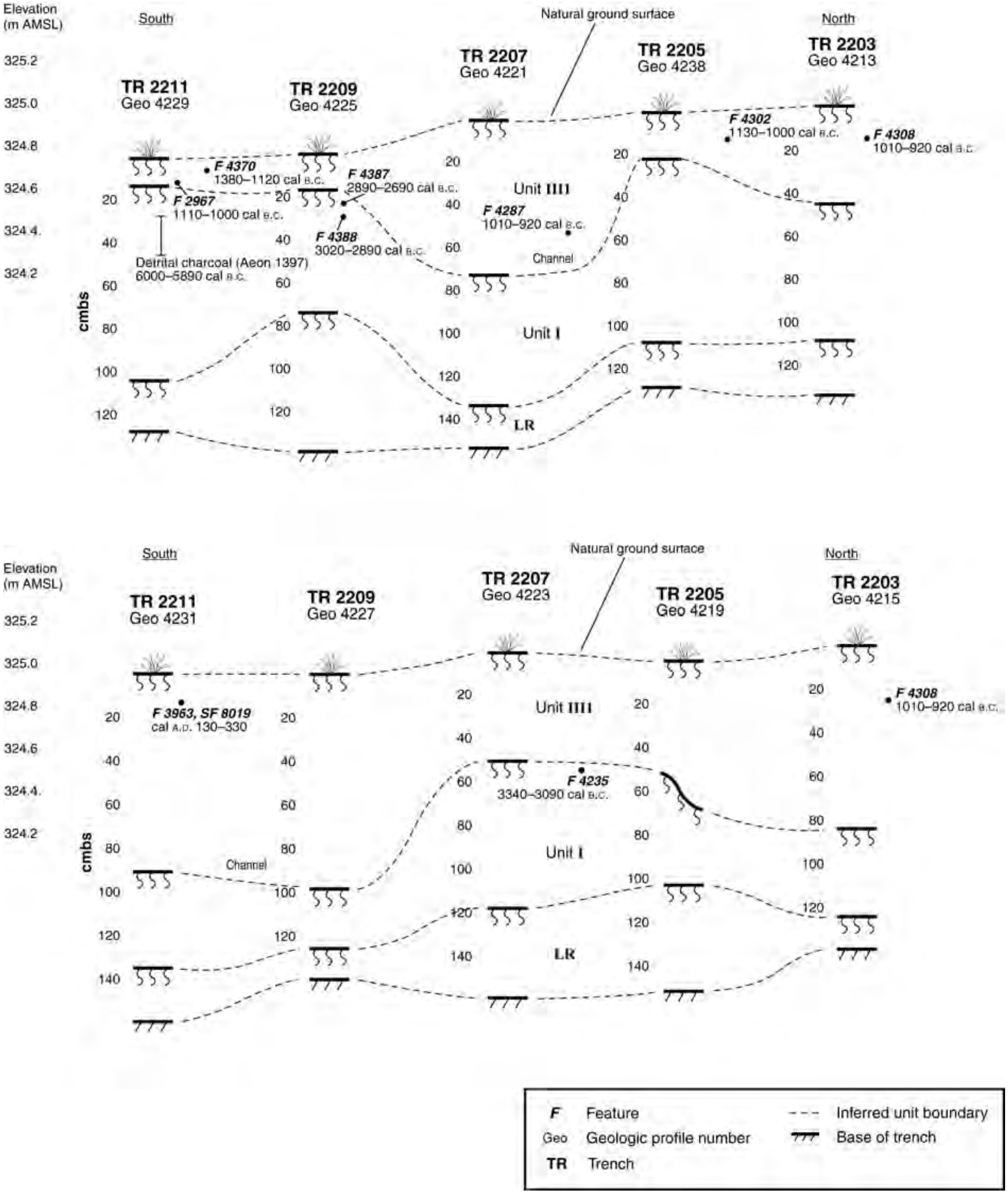


Figure 22. Geologic Cross Sections 3 and 4, early Chiricahua and San Pedro phase occupations in south-central Falcon Landing (Grids D2–E2–C2).

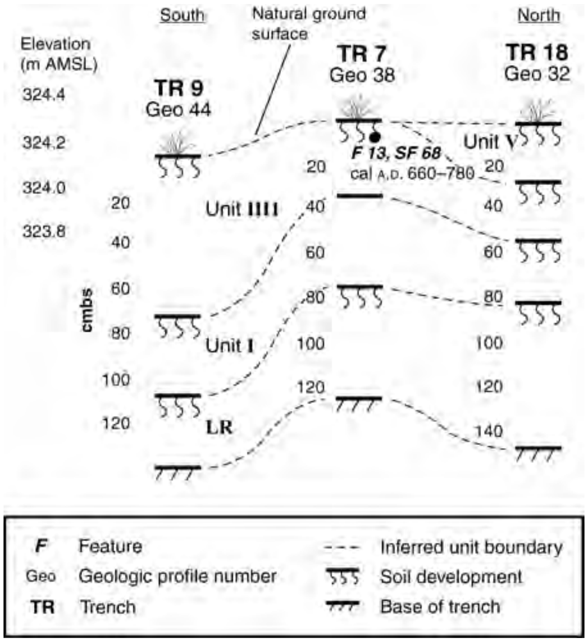


Figure 23. Geologic Cross Section 5, Unit III1 alluvial-fan reach, Site 68 (Grid A1).

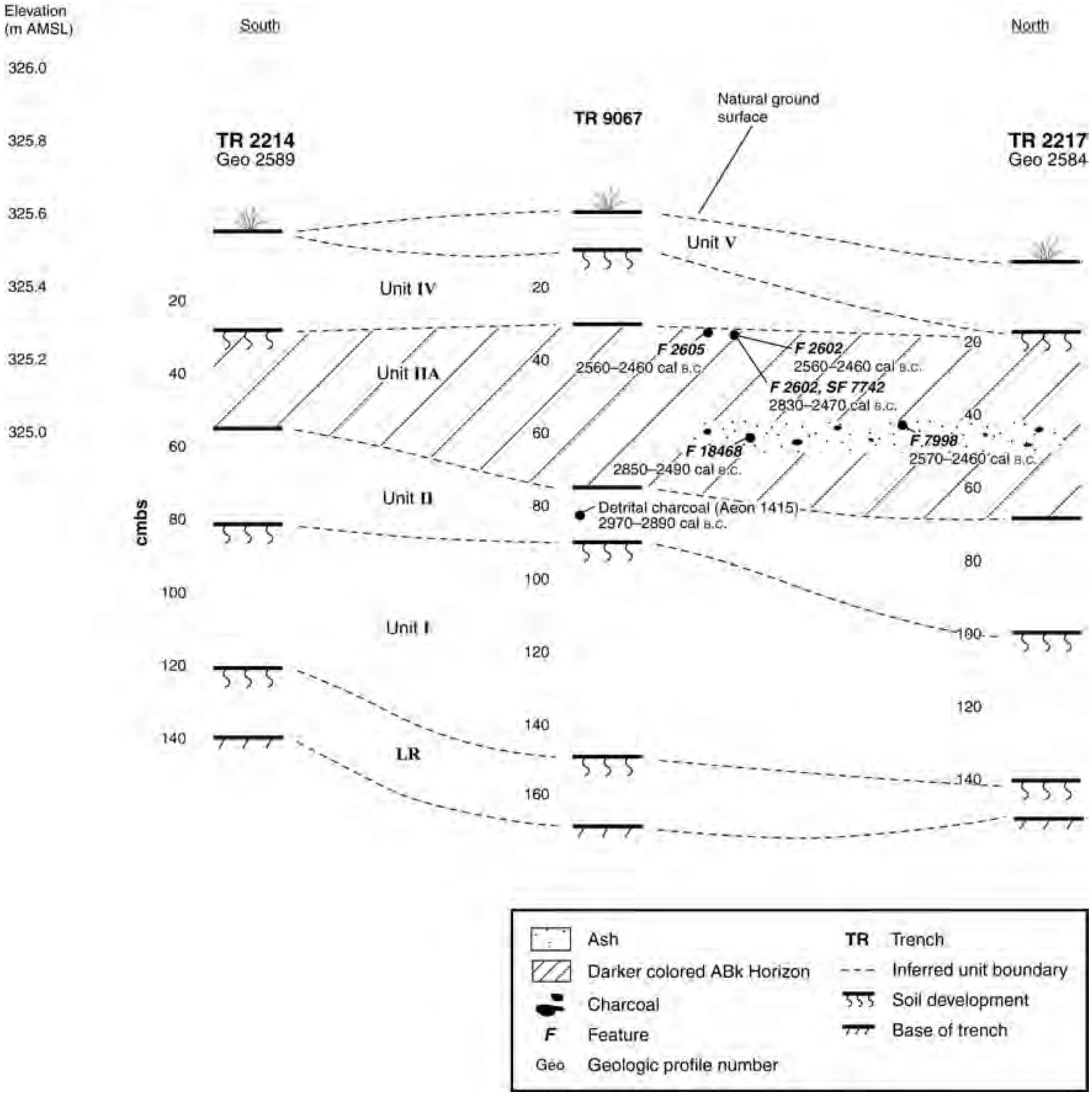


Figure 24. Geologic Cross Section 6, early Chiricahua phase occupation in north-central Falcon Landing (Grid I5).

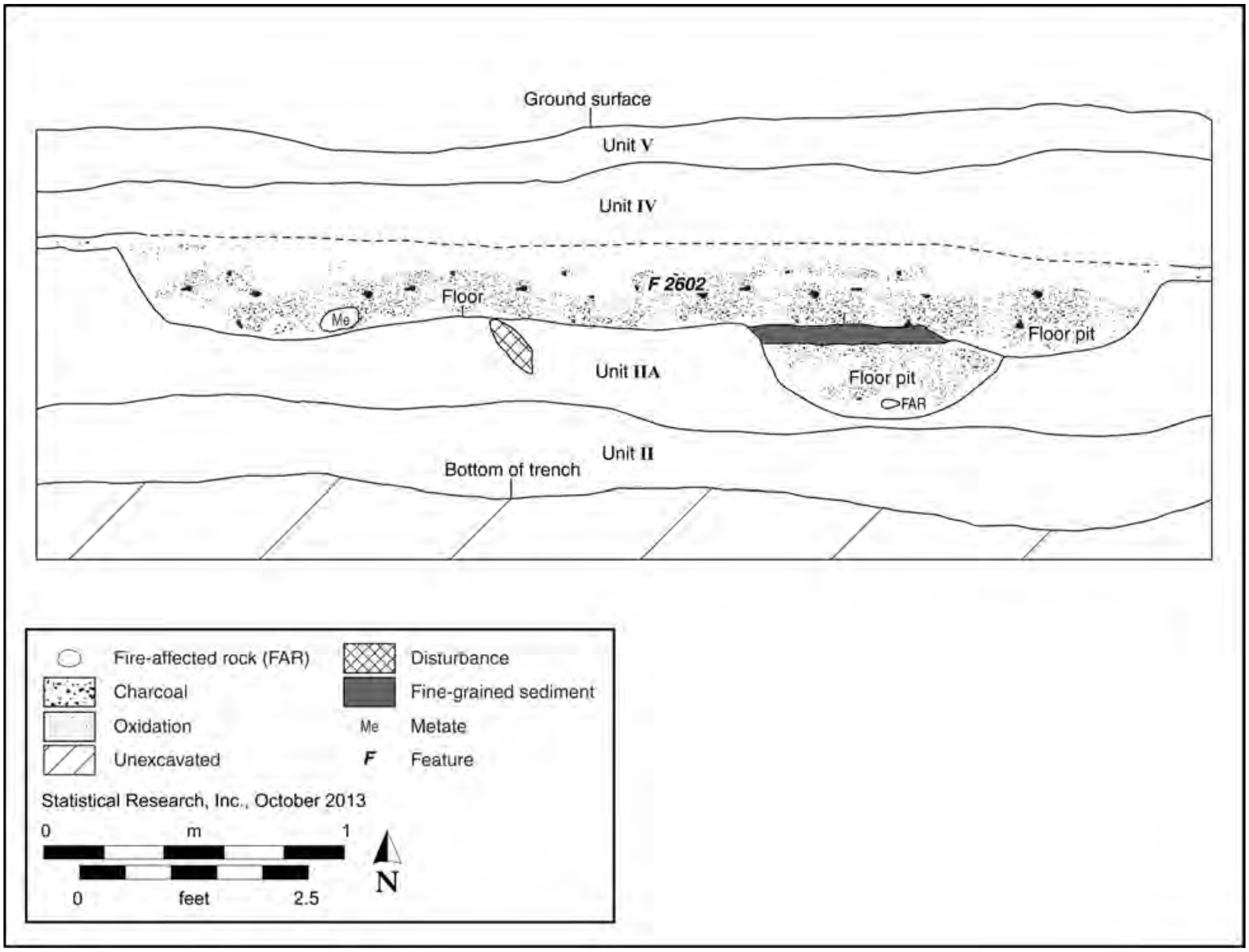


Figure 25. Profile drawing of Trench 2216.

Falcon Landing Grid I5, Geologic Cross Section 6

In the north-central portion of Falcon Landing, early Chiricahua phase occupations occurred in tandem with Unit IIA mid-fan to fan-toe sheet-flood deposition (see Figures 16 and 20). The Middle Archaic features were associated with either a fluvially reworked charcoal/ash lens or the surface of Unit IIA (Figures 24 and 25). Those features on the surface of Unit IIA were shallowly buried (25–30 cm) by Unit IV and V deposits.

Initial occupation during the early Chiricahua phase began around 2850–2490 cal B.C. (Feature 18468) in tandem with Unit IIA deposition (see Figure 24; Table 8). Many of the early Chiricahua features in this area originated within a conspicuous fluvially reworked charcoal/ash lens that could be traced across the north-central portion of Falcon Landing. Charcoal recovered from the Unit IIA lens yielded a calibrated age of 2840–2490 cal B.C., and several features originating within the lens dated to 2850–2490 and 2570–2460 cal B.C. (see Figures 24 and 25; Table 8). Finally, two features originating at the surface of IIA yielded the same calibrated age of 2560–2460 cal B.C. (Features 2602 and 2605), thus providing a minimum age for the unit (see Figure 24). Unit II and IIA deposition was not channelized and appears to represent unconfined overland flow (sheetflooding) at the lower mid-fan or fan toe.

Units IV and V were not directly dated at this location, but the degree of soil formation coupled with their stratigraphic position provided a way to correlate them with dated deposits nearby. The hiatus between the deposition of Units IIA and IV at this location represents a period of approximately 3,000 years. Conversely, Unit IIA fan deposition took place over a brief period between 2970–2890 and 2560–2460 cal B.C. (approximately 400 years) at this location (see Figure 24). Those features coeval with Unit IIA deposition were buried very quickly while those on the surface were exposed to more-intense bioturbation processes acting over millennia. Additionally, based on relative dating, any features intruding into the surface of Unit IIA at the Unit IIA/IV hiatus could date anytime between 2420 cal B.C. to cal A.D. 610 (Middle Archaic to Pioneer).

Falcon Landing Grids J3–J4, Geologic Cross Sections 7 and 8

The early Chiricahua phase occupations in the northwestern part of Falcon Landing were stratigraphically similar to those in Grid I5 (see Figures 20 and 24). Detrital charcoal recovered from Unit II dated to 2900–2760 cal B.C. and stratified cultural features in Unit IIA returned calibrated ages similar to those from Grid I5 (2860–2580 cal B.C.) (Figure 26; see Table 8). Feature 2622, which originated at the surface of Unit IIA, returned a calibrated age of 2560–2460 cal B.C. (Figure 27; see Table 8). Also, similar to Grid I5, some of the Unit IIA (early Chiricahua phase) occupations had been fluvially reworked forming multiple thin discontinuous charcoal lenses.

During Unit II and IIA deposition at this location, flow was more channelized, which indicates a mid-fan to upper-fan depositional environment. The fan head was probably situated a short distance to the west-northwest, somewhere in the vicinity of the modern flight line of the runway. A shallow Unit II channel incised into Unit I had a northwest-southeast trend with flow to the southeast. The Unit IIA deposits were thinly laminated silts and very fine sands, which indicates that during the early Chiricahua phase occupation this area was a shallow swale that conveyed lower-energy flow to the southeast. Most of the Middle Archaic period features were interstratified within these laminated deposits.

East of Feature 10951, the San Pedro phase occupation on the Unit IIs/sf surface was subsequently buried by Unit IV (Figure 28). Detrital charcoal from Unit IIs/sf returned a calibrated age of 2140–1970 cal B.C., and two San Pedro phase structures intruding into the surface of Unit IIs/sf yielded ages of 1030–890 and 840–800 cal B.C. (Features 2629 and 2627, respectively) (see Figure 28). To the southwest near the eastern end of TR 2218, Unit IIs/sf deposits were constrained between 2900–2760 and 970–830 cal B.C. These dates confine the filling of swales on the Unit II and/or IIA surface at this location between 2900–2760 and

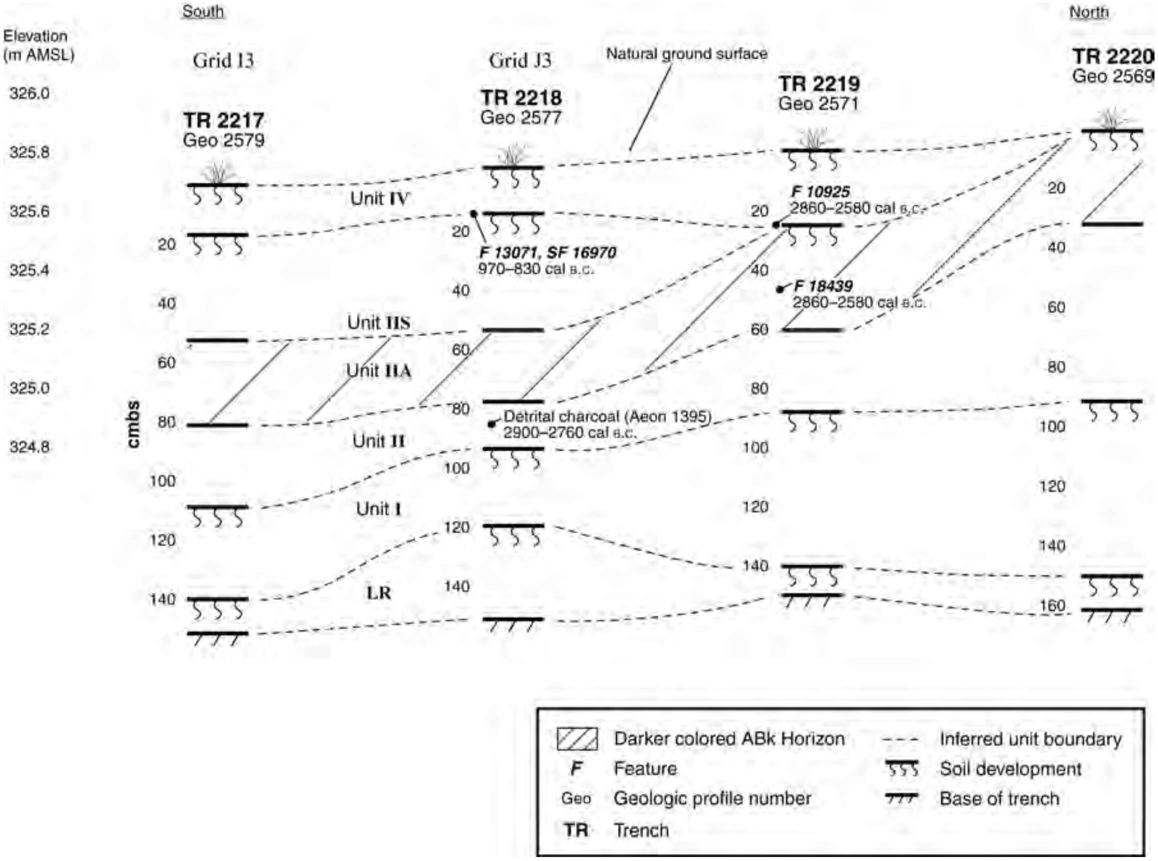


Figure 26. Geologic Cross Section 7, early Chiricahua phase occupation in northeastern Falcon Landing (Grid J3).

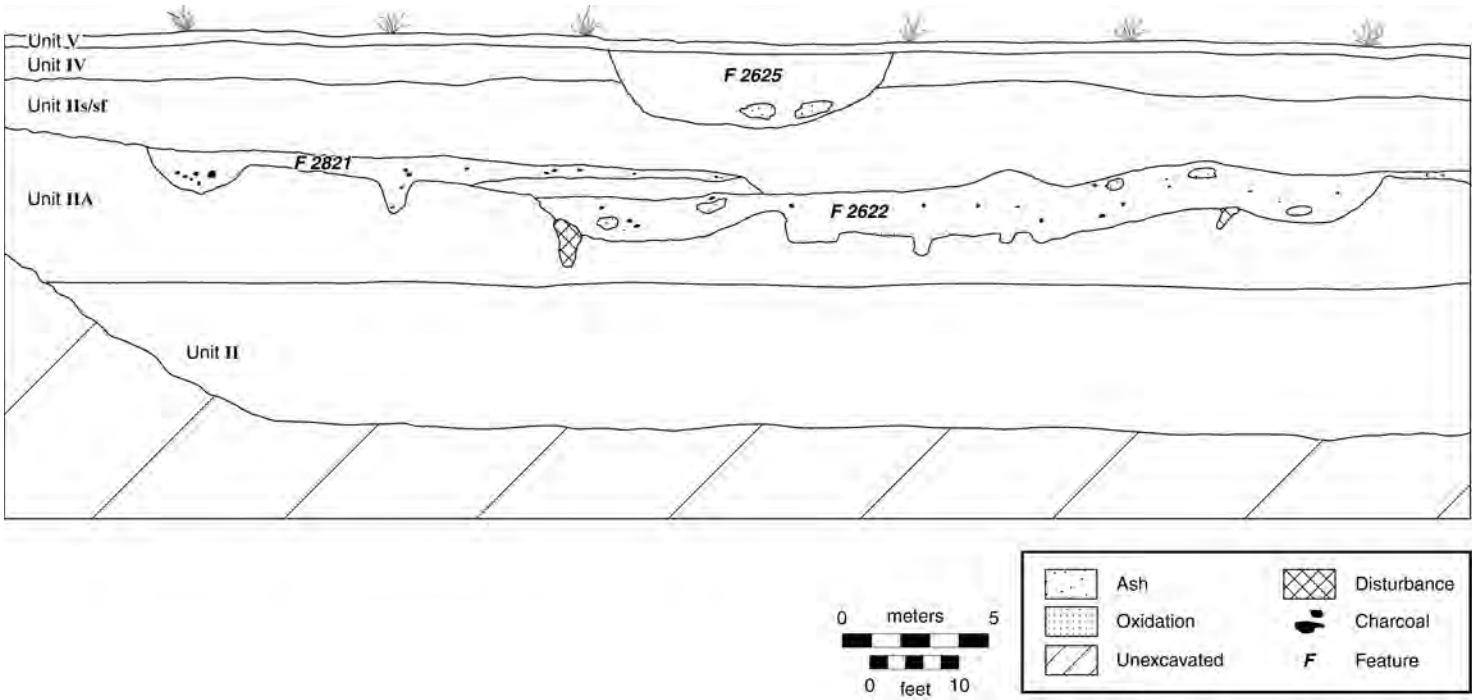


Figure 27. Profile drawing of Trench 2219.

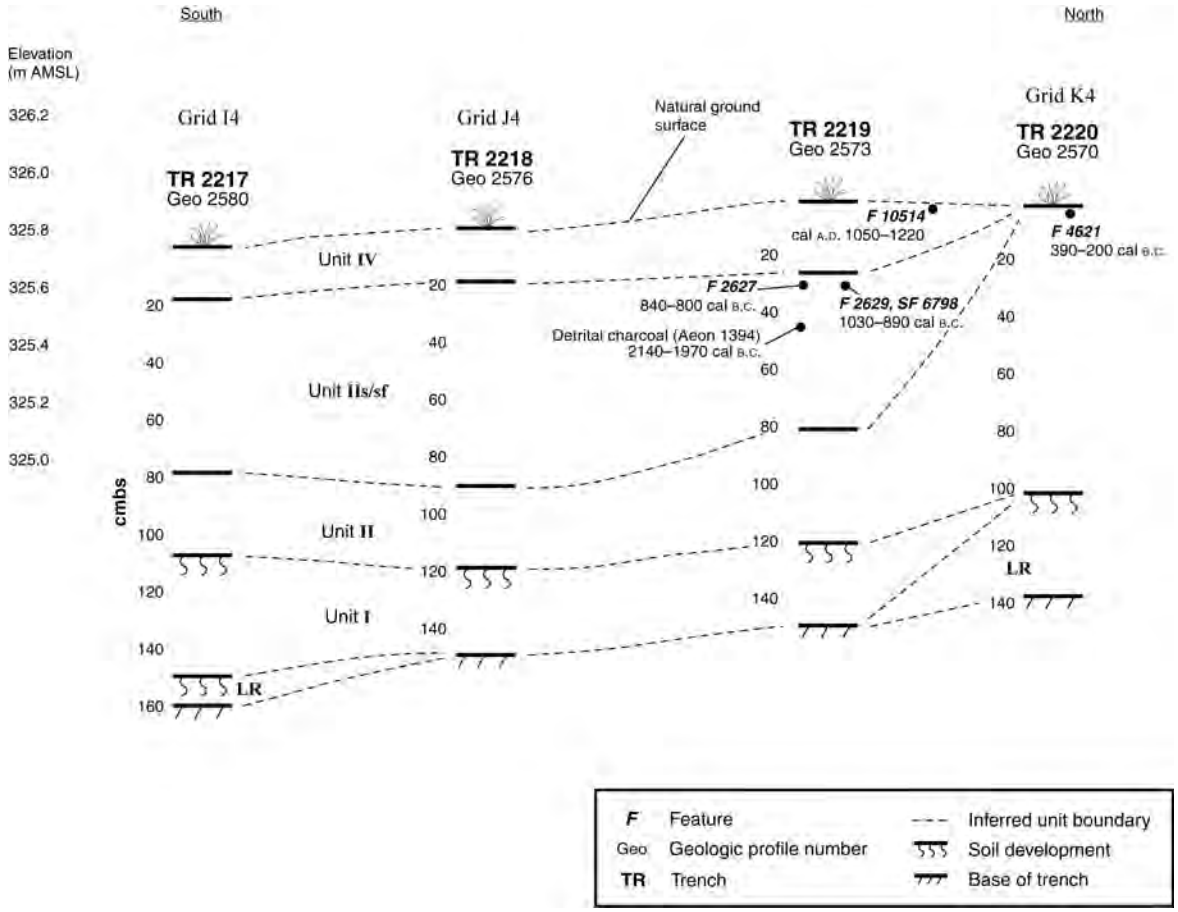


Figure 28. Geologic Cross Section 8, San Pedro occupations in north-central Falcon Landing (Grid J4).

1010–920 cal B.C. Unit IV was not directly dated here, but Feature 10514 intruded into the surface of Unit IV and returned a calibrated age of cal A.D. 1050–1220 (see Table 8). This date provided a minimum age for the end of Unit IV deposition at this location.

Falcon Landing Grid F3, Geologic Cross Section 9

In the central part of Falcon Landing, early Chiricahua and San Pedro phase occupations were documented on the buried surface of Unit II, coeval with Unit IIs/sf, and on the surface of Unit IIs/sf deposits (see Figure 16). The early Chiricahua phase features were associated with the surface of Unit II, which was buried anywhere from 50–80 cm by Unit IIs/sf sheet-flood deposits (see Figure 28). San Pedro phase features were interstratified in the Unit IIs/sf deposits that covered much of this area, with most originating in the upper 20 cm of the unit (Figure 29, see Figure 16). The Unit IIs/sf surface was either exposed on the modern surface or capped by a thin Unit V sheet-flood deposit.

Early Chiricahua phase features originating at the boundary of Units II and IIs/sf were dated to 2880–2630 (Feature 15142) and 2900–2670 cal B.C. (Feature 15457, not shown in cross section) (see Figure 29; Table 8). These dates provide a minimum age for Unit II and a maximum age for Unit IIs/sf at this location. Dates obtained from lower Unit IIs/sf deposits to the east, however, dated to 2470–2290 cal B.C. (Aeon Sample No. 1401, see Table 8). The surface of Unit II appears to have been minimally eroded during the initial Unit IIs/sf sheetflooding.

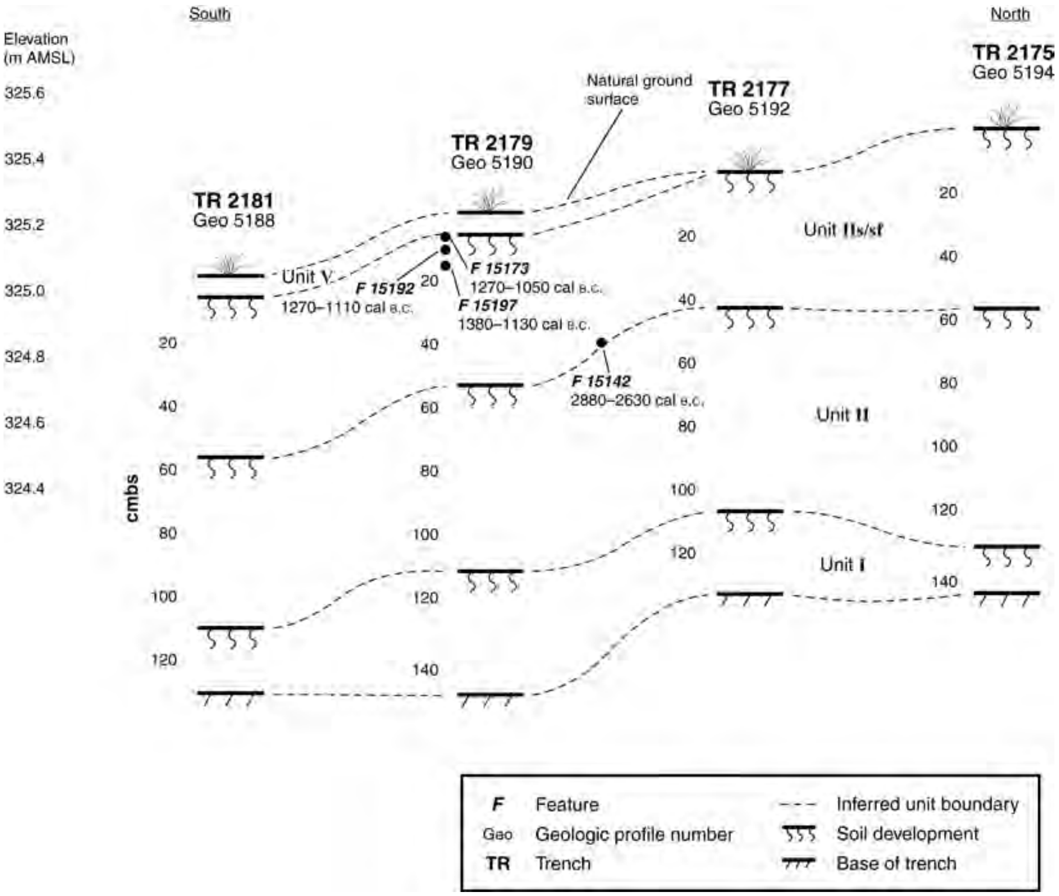


Figure 29. Geologic Cross Section 9, early Chiricahua and San Pedro occupations in central Falcon Landing (Grid F3).

San Pedro phase occupations at this location were dated between 1380–1130 and 1270–1050 cal B.C. (see Figure 29; Table 8). Immediately to the northwest of this cross section, San Pedro features originating at the surface of Unit IIs/sf yielded calibrated ages of 1050–920 cal B.C. (Feature 18028) and 1200–1000 cal B.C. (Feature 15482) (see Table 8).

OxCal Modeling Results

A project-wide OxCal model was constructed using the geochronology and stratigraphic assignments of the dated features to order the radiocarbon dates into depositional units. The OxCal-modeling software used this structure to constrain the calibrated ages calculated for the radiocarbon dates by minimizing the temporal overlap between stratified dates (a sequence of dates separated by minimal radiocarbon years). Agreement indexes (equivalent to χ^2 values) were then calculated for the overall model structure as well as individual dates and components of the model (Appendix 2.4). The model structure was fairly straightforward for Units I and IIA, but the lack of stratigraphic sequencing between Unit IIs/sf and Unit III (namely, the similarity in the dates between Unit IIs/sf and Unit III1) made it necessary to treat these two units as separate and potentially coeval, or at least overlapping, sequences. Thus, the dates from Unit III did not provide an end date for Unit IIs/sf deposition. Rather, Unit IV provided the end date for both of these units.

The OxCal model generally supported the geochronology model. Unit I deposition occurred between 7040 and 5320 cal B.C., at a 95 percent confidence level. Unit II began accumulating by 2970 cal B.C., following a 2,350-year depositional hiatus. It is important to note that this date is related to the beginning of

Table 12. OxCal-Modeled Geochronology Results

Stratigraphic Unit	OxCal-Modeled Age Range
I	7040–5320 cal B.C.
II	2970–2730 cal B.C.
IIA	2810–2420 cal B.C.
IIs/sf	2570–790 cal B.C.
III1	1380–920 cal B.C.
III2	720–200 cal B.C.
III2cf	160 cal B.C.–cal A.D. 340
IV	cal A.D. 610–1220

Unit II deposition, not to cultural activity at the site. There are a few slightly earlier radiocarbon dates that document human activity at the site in the 3300–3000 cal B.C. range, but these dates are related to features that intruded below the surface of Unit I in an area that was not overlain by Unit II and may be related to a period of surface stability prior to the start of Unit II deposition. The Unit IIA dates provide upper constraints on the age of Unit II, and the model calculated that the transition from Unit II to IIA occurred between 2850 and 2730 cal B.C. This give a maximum age range for Unit II of 2970–2730 cal B.C. (Table 12).

The upper age for Unit IIA is constrained by the overlying dates of Unit IIs/sf and Unit III. The transition from Unit IIA deposition to the Unit IIs/sf and/or Unit III depositional episodes occurred between 2540 and 2400 cal B.C. This gives a maximum age range for Unit IIA of 2810–2420 cal B.C. and for Units II and IIA of 2970–2420 cal B.C. The timing of Unit IIs/sf deposition was slightly more difficult to identify. The lower part of this unit appears to have been deposited between 2470 and 1940 cal B.C., and it included one feature, Feature 14959 (2130–1940 cal B.C.). The bulk of the dates obtained for this unit came from coeval features that dated between 1380 and 910 cal B.C. A series of features identified as originating at the surface of the unit provides a minimum age date for the unit; these features date between 1200 and 790 cal B.C. The significant overlap in date ranges obtained for the upper part of the unit and the surface of the unit suggests that portions of the site stabilized earlier than others during this depositional period.

Unit III1 and III2 dates were more difficult to determine because depositional dates were not obtained from areas where these two units were stratified at a single location. However, Unit III1 appears to have formed between 1380 and 920 cal B.C., and Unit III2 appears to have formed between 720 and 200 cal B.C. Finally, Unit III2cf represents an even later period of deposition during the Unit III time period. This unit was dated by two depositional dates and four coeval features, for a date range of 160 cal B.C.–cal A.D. 340. Over all, Unit III deposits date between 1380 cal B.C. and cal A.D. 340.

Finally, the dates obtained for Unit IV indicate that it was formed between cal A.D. 610 and 1220. Only one of the dates related to this unit was derived from detrital charcoal, with the rest obtained from features coeval with unit deposition or intrusive to the unit surface.

Occupational Episodes

The geochronology framework developed above was used to structure and order the features into potentially coeval groups (Table 13; see Figure 20). Group membership was based in part on the rule that features belonging to temporally separated stratigraphic units could not belong to the same occupational episode, despite statistical similarity in radiocarbon age. Thus, occupational episodes identified at the site greatly mirror the geochronology in that episodes tend to break by stratigraphic unit. Features from stratigraphic unconformities were placed within episodes and aligned with the geochronology framework by their radiocarbon date, which again ensured that their stratigraphic location did not violate the overall framework (e.g., a feature from a Unit I/III1 unconformity could not be placed in an episode aligned with Unit III2 or later). In addition

Table 13. Occupational Episodes and Radiocarbon Dates Used for the Oxcal Model

Occupational Episode	Aeon Lab No.	Feature No.	Range
0	1548	10307	7040–6690 cal B.C.
1	1525	15317	3340–3030 cal B.C.
1	676	4235	3340–3090 cal B.C.
1	747	4388	3020–2890 cal B.C.
2B	1524	15457	2900–2670 cal B.C.
2B	1443	4387	2890–2690 cal B.C.
2B	1506	18250	2890–2670 cal B.C.
2B	1520	15142	2880–2630 cal B.C.
2B	1481	1523	2870–2630 cal B.C.
2B	1526	15319	2870–2620 cal B.C.
2A.1	1533	10925	2860–2580 cal B.C.
2A.1	1534	18439	2860–2580 cal B.C.
2A	1535	18468	2850–2490 cal B.C.
2A	1402	2598	2840–2490 cal B.C.
2A.2	1488	14613	2840–2500 cal B.C.
2A.2	1508	14839	2840–2500 cal B.C.
2A	736	2486	2840–2490 cal B.C.
2A	1442	7998	2570–2460 cal B.C.
3	1514	11025	2570–2340 cal B.C.
3.1	737	2602	2560–2460 cal B.C.
3.1	738	2605	2560–2460 cal B.C.
3.1	741	2622	2560–2460 cal B.C.
3	680	1303	2480–2340 cal B.C.
4	1445	2642	2200–2030 cal B.C.
4	1499	14959	2130–1940 cal B.C.
4	1444	1498	1880–1690 cal B.C.
4	1438	1438	1440–1310 cal B.C.
5	681	1244	1390–1210 cal B.C.
5.1	1440	11229	1380–1210 cal B.C.
5.1	1441	10114	1380–1210 cal B.C.
5	1496	4370	1380–1120 cal B.C.
5	1522	15197	1380–1130 cal B.C.
5	1437	3521	1310–1120 cal B.C.
5	1507	18237	1310–1120 cal B.C.
5	1503	11284	1300–1120 cal B.C.
5	1491	15173	1270–1050 cal B.C.
5	1510	11389	1270–1110 cal B.C.
5	1521	15191	1270–1110 cal B.C.
5	1490	14755	1260–1050 cal B.C.
5	1502	18880	1260–1040 cal B.C.
5	1483	3256	1200–930 cal B.C.
5	1500	15482	1200–1000 cal B.C.
5	1505	18254	1200–1000 cal B.C.

continued on next page

Occupational Episode	Aeon Lab No.	Feature No.	Range
5.3	1494	20321	1120–1000 cal B.C.
5.2	1439	11181	1110–1000 cal B.C.
5.3	1485	10278	1120–1000 cal B.C.
5.2	1408	2967	1110–1000 cal B.C.
5.2	678	4302	1110–1000 cal B.C.
5.2	750	4355	1110–1000 cal B.C.
5	1523	18028	1050–920 cal B.C.
5	749	4343	1050–920 cal B.C.
5	1446	2629	1030–890 cal B.C.
5.4	677	4287	1010–920 cal B.C.
5.4	748	4308	1010–920 cal B.C.
5	745	1307	980–830 cal B.C.
5	1487	16970	970–830 cal B.C.
5	1493	18192	910–810 cal B.C.
5	1538	15256	900–800 cal B.C.
5.5	740	2627	840–800 cal B.C.
5.5	742	2628	840–800 cal B.C.
6.1	1504	11106	790–550 cal B.C.
6.1	1527	11130	790–550 cal B.C.
6.2	1515	3508	770–540 cal B.C.
6.2	744	1315	770–540 cal B.C.
6	1512	11088	750–400 cal B.C.
6	1509	3600	720–400 cal B.C.
6	1484	6828	390–200 cal B.C.
6	1511	14765	370–160 cal B.C.
7	1492	20285	160 cal B.C.–cal A.D. 330
7.1	1482	2529	cal A.D. 20–120
7.1	1489	14702	cal A.D. 20–120
7	1547	131	cal A.D. 10–130
7	1516	14656	cal A.D. 70–250
8	1501	19067	cal A.D. 610–670
8.1	674	1349	cal A.D. 640–670
8.1	679	1290	cal A.D. 640–670
8.2	1495	3321	cal A.D. 650–770
8.2	1513	3372	cal A.D. 650–770
8.3	1543	97	cal A.D. 660–780
8.3	1546	13	cal A.D. 660–780
9	1519	15096	cal A.D. 980–1150
9	1536	14655	cal A.D. 1010–1160
9	1537	11072	cal A.D. 1010–1160
9	1498	10514	cal A.D. 1050–1220
9	743	1343	cal A.D. 1180–1270

to stratigraphic placement, the spatial distribution of similarly aged features across the site was also taken into account. In the case of Occupational Episode 2, spatial and temporal patterning between the northern and southern areas of Falcon Landing was detected. Therefore, these features were divided into Episodes 2A and 2B, which should be treated as spatially separated but potentially overlapping or coeval occupations at the site. Finally, it was noted that there were several cases of spatially clustered features with statistically indistinguishable radiocarbon dates. We interpreted these to represent discrete occupational events within the broader occupational episode. In terms of real time, these may or may not represent sets of features that were used at the same time, but they are considered to be coeval within the resolution of the radiocarbon timescale. For these sets of features, the combined age was calculated in OxCal and the combined radiocarbon age and χ^2 statistics are provided for the event.

Episode 0 (7040–6690 cal B.C.)

This episode occurred during the formation of Unit I and is represented by a single date from a thermal pit (Feature 10307) located in the extreme eastern part of the site (see Figure 20; Table 13). This feature intruded into Unit I alluvium along a middle Holocene channel in the northeastern part of the project area.

Episode 1 (3340–2890 cal B.C.)

Episode I occurred prior to the formation of Unit II and is represented by three features, including a structure (Feature 4388) located in the western part of the site (see Figure 20; Table 13). All three features originated at the surface of Unit I and were bound by noncontiguous strata. Given the complexity of the site stratigraphy and the potential age range of the stable Unit I surface in areas of stratigraphic unconformity, we hesitated to extend this episode to undated features.

Episode 2 (2890–2490 cal B.C.)

This episode took place during the deposition of Unit IIA across the northern and central part of Falcon Landing (see Figure 20). The features dating to this episode were clustered in several areas in the northern and southern part of the site. Episode 2A (2860–2490 cal B.C.) is represented by eight features in two clusters (see Table 13). The first cluster, Event 2A.1, consists of two extramural pits (Features 10925 and 18439) located in the far northern part of the site. A combined radiocarbon age of 2860–2580 cal B.C. was calculated for the event (χ^2: $df = 1$, $T = 0.380$, $T_{0.05} = 3.841$), where T presents knowledge about the age before radiocarbon dating, or probability a priori (see Michczyński and Pazdur 2003:41). Event 2A.2, the second cluster, consists of a structure (Feature 14613) and nearby pit (Feature 14839) located in the northeastern part of Falcon Landing; a combined age of 2840–2500 cal B.C. was calculated for this group (χ^2: $df = 1$, $T = 1.068$, $T_{0.05} = 3.841$).

Episode 3 (2570–2340 cal B.C.)

Episode 3 is represented by five features located at the surface of Unit IIA and is coeval with the end of Unit IIA deposition prior to the start of swale infilling (Unit IIs/sf). Three of the features, all structures, were located in the northern part of Area A. Two of these structures (Features 2602 and 2605) appear to reflect an occupational event (see Figure 20; Table 13). The third structure (Feature 2622) was located north of this cluster but has been included because of its general proximity and the similarity of its date. A combined age of 2560–2460 cal B.C. was calculated for this group (χ^2: $df = 3$, $T = 1.244$, $T_{0.05} = 7.815$). The two other features dated to this episode (Features 11025 and 1303) were located in the far southern part of Falcon Landing.

Episode 4 (2200–1310 cal B.C.)

Episode 4 occurred during the initial period of swale infilling (Unit IIs/sf) and is represented by a structure (Feature 2642) in the northern part of Falcon Landing and one pit (Feature 14959) in the southern part of the site. This episode was defined by the geochronology model, with little else to link the features.

Episode 5 (1390–800 cal B.C.)

This episode encompasses the broad range of time marked by the formation of Unit IIs/sf and Unit III1. This episode is represented by 33 features from across the project area, including five different events that are almost all temporally distinct within the episode (see Figure 20). Event 5.1 consists of two structures (Features 10114 and 11229) in proximity to one another along the eastern part of Falcon Landing. A combined age of 1380–1210 cal B.C. was calculated for this pair of structure (χ^2: *df* = 1, T = 0.014, $T_{0.05}$ = 3.841) (see Table 13). Event 5.2 consists of three structures (Features 2967, 4302, and 11181) and an extramural pit (Feature 4355) located along the eastern edge of Falcon Landing but south of Event 5.1. A combined age of 1110–1000 cal B.C. was calculated for this group (χ^2: *df* = 3, T = 0.749, $T_{0.05}$ = 7.815). Event 5.3 was also identified in the eastern portion of Falcon Landing and consists of a structure (Feature 18887/Subfeature 20321) and a possible reservoir (Feature 10278). A combined age of 1120–1000 cal B.C. was calculated for this pair of features (χ^2: *df* = 1, T = 0.517, $T_{0.05}$ = 3.841), which is coeval with Event 5.2. Event 5.4 consists of a structure (Feature 4308) and an extramural pit (Feature 4287) located near Event 5.2. A combined age of 1010–920 cal B.C. was calculated for this group (χ^2: *df* = 1, T = 0.932, $T_{0.05}$ = 3.841). Finally, Event 5.5 consists of two adjacent structures (Features 2627 and 2628) located along the northern edge of Falcon Landing. A combined age of 840–800 cal B.C. was calculated for this pair of structures (χ^2: *df* = 1, T = 1.162, $T_{0.05}$ = 3.841). Of the 33 features mapped to the Episode 5 occupation, roughly half were located along the eastern part of the site, including three of the five events, suggesting that this part of the site was heavily used during this period.

Episode 6 (790–160 cal B.C.)

Episode 6 occurred during the formation of Unit III2 and is represented by eight features that included two events. Six of the features, including both events (Event 6.1 and Event 6.2), were located along the southeastern edge of Falcon Landing (see Figure 20). One of the events, Event 6.1, consists of two adjacent extramural pits (Features 11106 and 11130) located along the southeastern edge of the site. A combined age of 790–550 cal B.C. was calculated for this group (χ^2: *df* = 1, T = 0.965, $T_{0.05}$ = 3.841) (see Table 13). The other event, Event 6.2, consists of two extramural pits (Features 1315 and 3508) located near the southern tip of Falcon Landing with a combined age of 770–540 cal B.C. (χ^2: *df* = 1, T = 0.053, $T_{0.05}$ = 3.841). These two pairs of features were located in the same general part of the site and so it is possible that they are related. Two additional extramural pits (Features 3600 and 11088) from this general area were mapped to the Episode 6 occupation, but their respective radiocarbon dates were statistically different from those of the two pairs of features. The last two features from this episode were located in the east-central part of Falcon Landing and included a structure (Feature 4621/Subfeature 6828) and an extramural pit (Feature 14765).

Episode 7 (cal A.D. 10–250)

This episode occurred during the channel-fan deposition of Unit III2cf in the north-central part of Falcon Landing and Site 423. Four of the five features in this episode were located here, including two adjacent structures (Features 2529 and 14702) that form Event 7.1. A combined age of cal A.D. 20–120 was calculated for this pair of structures (χ^2: *df* = 1, T = 1.322, $T_{0.05}$ = 3.841). It is likely that an intramural pit (Feature 20285) located in this cluster belongs to this event, but because of the very large radiocarbon error for the associated sample, this feature was excluded from the combined age calculation. The remaining features in this episode include a charcoal lens (Feature 14656) located near Event 7.1, and a fire-affected rock (FAR) concentration (Feature 131) located at Site 423.

Episode 8 (cal A.D. 610–780)

Episode 8 occurred during the formation of Unit IV and consists of seven features representing three events. Six of the seven features, and all three events, were located along the central and east-central part of Falcon Landing and Site 68 (see Figure 18). The seventh feature, an extramural pit (Feature 19067), was located near the southern tip of the site. Event 8.1 consists of a structure (Feature 1290) and an extramural pit (Feature 1349) located near the southern tip of Falcon Landing. A combined age of cal A.D. 640–670 was calculated for this pair of features (χ^2: *df* = 1, T = 0.533, $T_{0.05}$ = 3.841) (see Table 13). Event 8.2 consists of a structure (Feature 3321) and a ground stone cache (Feature 3372), located northeast of Event 8.1. A combined age of cal A.D. 650–770 was calculated for this pair of features (χ^2: *df* = 1, T = 1.197, $T_{0.05}$ = 3.841). Event 8.3 consists of a structure (Feature 13) and an extramural pit (Feature 97) located on Site 68. A combined age of cal A.D. 660–780 was calculated for this pair of features (χ^2: *df* = 1, T = 0.577, $T_{0.05}$ = 3.841).

Episode 9 (cal A.D. 980–1270)

Episode 9 is represented by five extramural pits (Features 1343, 10514, 11072, 14655, and 15096) that intruded into the surface of Unit IV, and it is coeval with the end of deposition and the beginning of stabilization of that unit's surface. The pits were scattered across the site and appear to reflect the period of general site use.

The stratigraphic control provided by the geochronological model allowed many of the undated features to be placed in time. In total, 1,603 features were coeval with deposition of the stratigraphic units and 1,334 were situated at the depositional hiatus (unconformity) between units. Many of the coeval features have improved age control compared to features located at major unconformities because most of the deposits in the Luke Solar project area represent a relatively brief period of geologic time. This suggested that major deposition was the product of distinct pulses of flooding rather than small annual or seasonal floods acting over millennia. The age assignment of features located at unconformities was particularly problematic where the early and late-middle Holocene units (Units I and II) were shallowly buried by latest Holocene deposits (Units IV and V). In these areas, the Unit I and II surfaces were available for cultural use from 3,000 (Unit IIA/IV unconformity) to over 6,800 years (Unit I/V unconformity). The features associated with these long depositional hiatuses could not be assigned a meaningful age based simply on the site stratigraphy. Additionally, because of the large size of the project area and the limited number of radiocarbon dates, it was not possible to obtain adequate age control in some areas of the site. Although soil morphology, stratigraphic position, and a few isolated radiocarbon dates allowed us to narrow down the age of the deposit, there was not enough temporal information to assign some deposits to a specific allomember. This was a distinct problem for Unit IIs/sf and Unit III deposits because they had similar soil morphological characteristics. In these instances, the stratum in question was assigned to multiple units, i.e., Unit III1/III2 or IIs/sf /III1, which resulted in a broader potential age estimate.

The following section presents the feature-stratum assignments for the Luke Solar project. This includes a breakdown of coeval and surface-dated features along with a complete breakdown of features assigned to specific unconformities. Coeval features represent prehistoric occupations in tandem with alluvial deposition. These features were situated between the upper and lower unconformities of the stratigraphic units correlated across the project area (see Figure 12). As noted previously, 1,603 features were assigned coeval dates based on their stratigraphic positions (Figure 30). Of these, 82 percent dated to the Archaic period with Units IIA and IIs/sf containing the most features. Features coeval with Units II and IIA are well constrained between 2970 and 2570 cal B.C. (early Chiricahua phase) and represent a major period of Middle

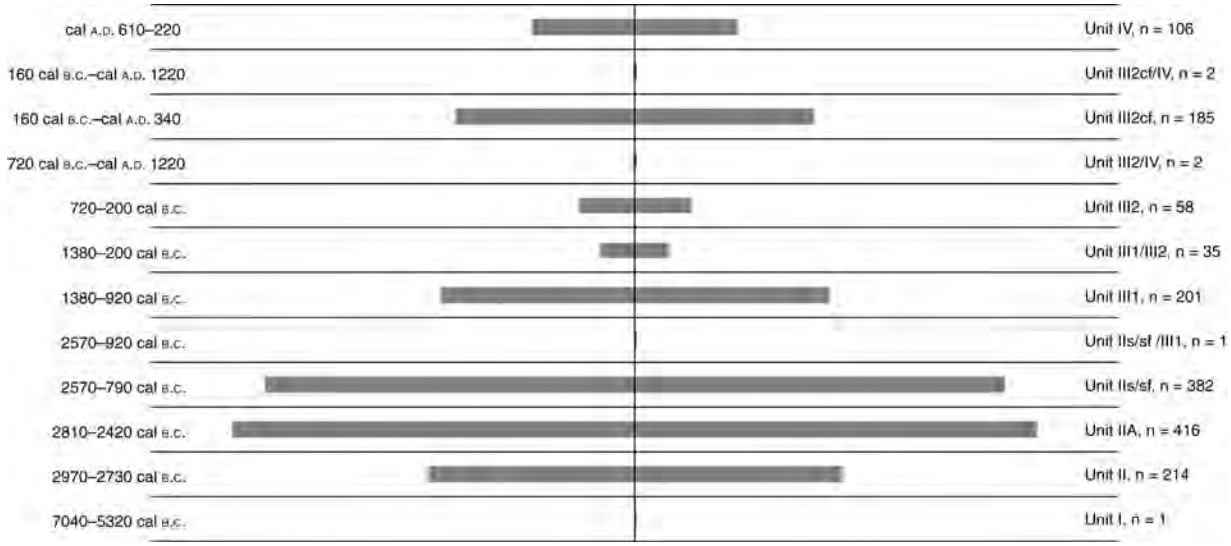


Figure 30. Features per stratigraphic unit (coeval).

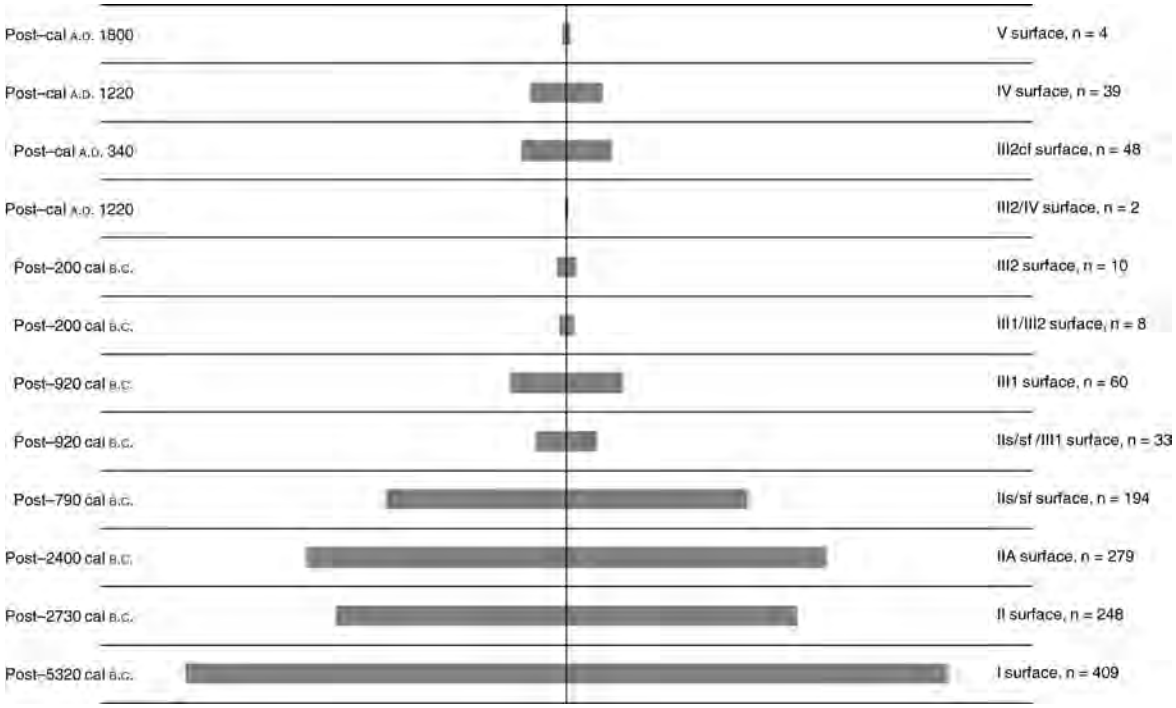


Figure 31. Features per unconformity (surface).

Archaic occupation. Significant numbers of features were also associated with Unit III1 (1380–920 cal B.C.), which places them in the San Pedro phase. About 18 percent of the coeval features date to the Cienega–Red Mountain phases, and these were primarily associated with Unit III2cf (160 cal B.C.–cal A.D. 340) or Unit IV (cal A.D. 610–1220) alluvial-fan-reach deposits (see Figure 30).

Features documented at the major unconformities between depositional units represent occupation on stable alluvial-fan surfaces. In total, 1,334 features were associated with the surface (upper unconformity) of the stratigraphic units (Figure 31). Because the oldest surfaces were available for cultural use for a longer span of time, they had the greatest number of features. The surfaces of Units I and II (II, IIA, and IIs/sf) were the most intensively occupied, accounting for 85 percent of all surface features. Of the latest Holocene units, the surfaces of Unit III2cf (available after cal A.D. 340) and IV (available after cal A.D. 1220) appear to have been more extensively used by pre-Classic and Classic period groups (see Figure 31).

Although the time of deposition for each stratigraphic unit was fairly well constrained across the project area, the length of time a specific surface was available for use varied considerably by location. This was a direct product of the lateral stratigraphic complexity associated with alluvial-fan environments. For example, the geochronology indicates that the surface of Unit I was primarily available for cultural use by 5320 cal B.C.; however, it was subsequently buried by Units II, IIA, IIs/sf, III1, III2, III2cf, IV, or V at different localities. There was not a single location in the project area where all units appeared in a stratified sequence. Instead, along the western side of Falcon Landing, Unit I was buried by Units III, IV, and/or V, whereas in the central area of the site it was buried by Unit II (see Figure 16). When the temporal-spatial variability associated with these surfaces is considered, the feature-stratum associations become much more complex (Figure 32). As with Figure 31, the number of features associated with each surface was largely influenced by the length of time represented by the unconformity and, to some extent, the total area of the surface covered by the overlying stratum (see Figure 32). The older strata have also been subjected to longer periods of erosion and thus have suffered more deleterious effects. Unit I in particular has been incised by Unit II, III, and IV fan drainages in some areas of the site. The decreases in features associated with some of the Units I/II, I/III, and I/IV unconformities are likely related more to erosion than lack of use by prehistoric groups.

Discussion

The following text focuses on the geomorphic history and prehistoric landscape context of the Luke Solar project area. This discussion begins with an environmental reconstruction of the area that incorporates the geomorphic history, paleoenvironmental context, and the OxCal-modeled archaeological chronology. To the degree possible, this landscape reconstruction is placed within a regional framework by correlation with other paleoenvironmental proxies.

Geomorphic History and Prehistoric Landscape Context

The oldest deposit identified in the project area has a buried soil that was completely cemented by secondary $CaCO_3$. Soils with similar Stage IV carbonates (caliche) have been dated to the middle Pleistocene (greater than 120 ka) in other areas of the Southwest (Birkeland 1999; Machette 1985). The upper contact of this soil with the lower LR Formation represents a hiatus that likely spanned 100,000 years or more. During this time, soil formation in an arid environment similar to the modern climate created the petrocalcic horizon. This was followed by a period of erosion during which the overlying surface horizons were removed in most areas, exposing the $CaCO_3$-cemented horizon at the surface. It is not known if other late Pleistocene deposits predating the LR Formation accumulated on the surface of this relict soil. If these once existed, they too would have been stripped by erosion. It is important to note that age control for the pre-Holocene deposits is

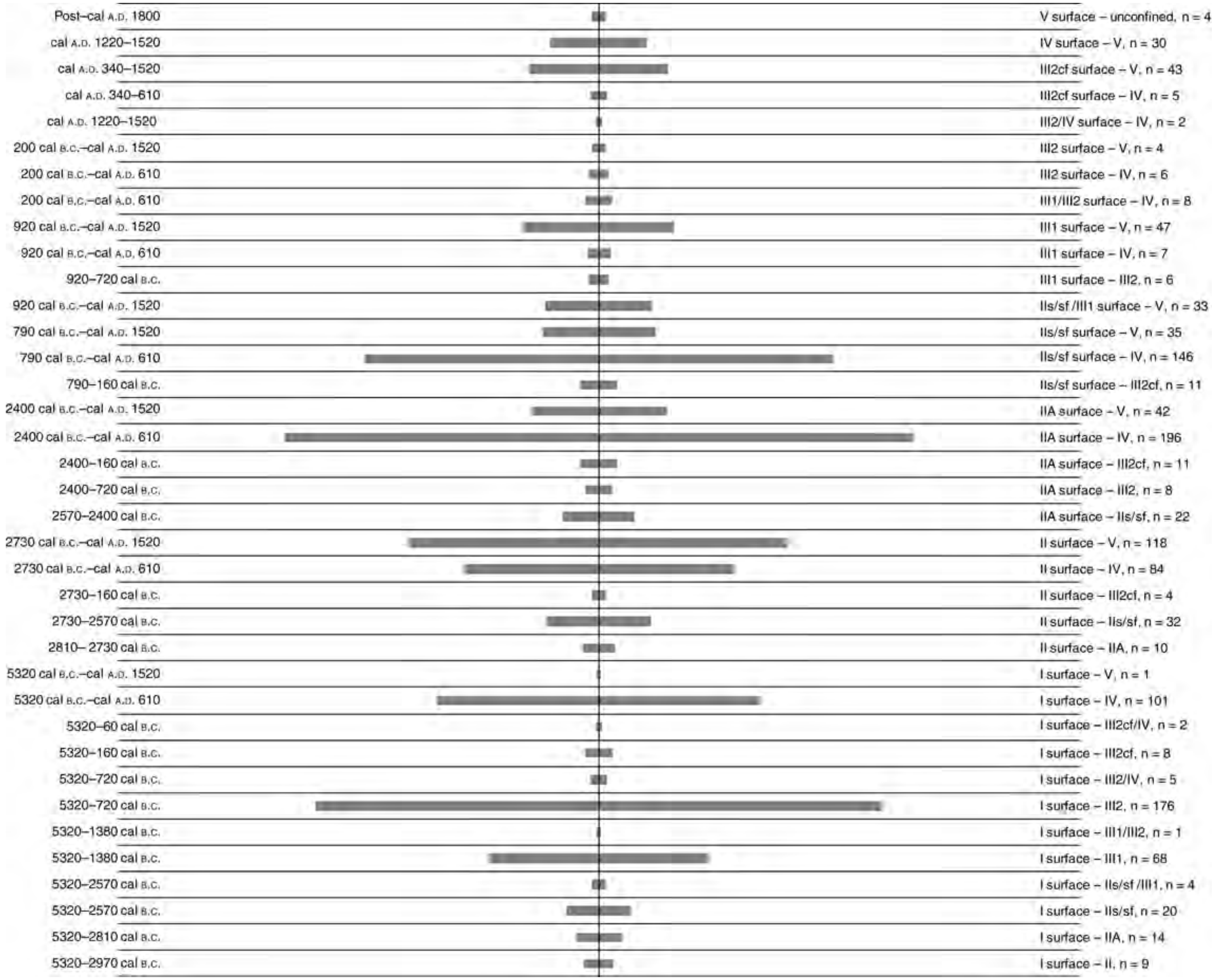


Figure 32. Feature per unconformity by overlying stratum.

limited because radiocarbon dating focused on archaeological deposits. The late Pleistocene reconstruction is incomplete and is largely dependent on relative dating and correlation with regional geomorphic studies.

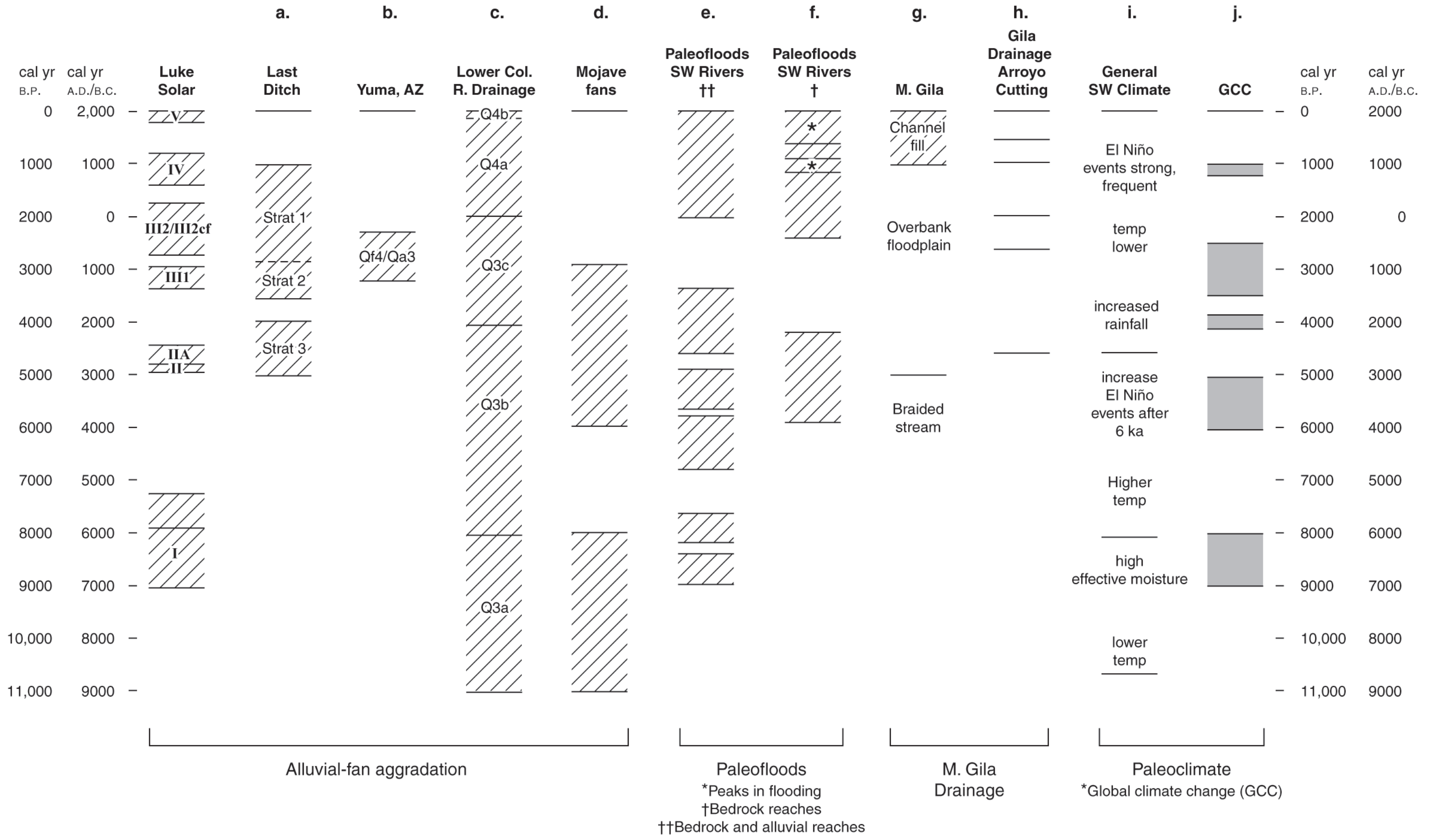
Following the middle-late Pleistocene hiatus, the late Pleistocene LR Formation deposits began to accumulate. Deposition of the LR Formation marks a net change in the landscape from erosion and removal of sediment to one dominated by aggradation. A date from organic matter in a dark-colored silt loam lens in the formation yielded a calibrated age of 16,680–16,080 cal B.C. (TR 9066, see Figure 16; Table 8), indicating this change took place around the last glacial maximum. The presence of a dark-colored silt loam to silty clay loam lens, higher levels of organic matter throughout the formation, groundwater carbonate lenses, and generally more-negative SOM $\delta^{13}C$ values all suggest a more mesic environment than present conditions, with more abundant C3 vegetation. Although fossil pollen was not preserved in the LR Formation, the late Wisconsin component of Sonoran Desert pack-rat middens indicates a predominance of xeric juniper woodland dominated by California juniper (*Juniperus californica*), live oak (*Quercus* spp.), Joshua tree (*Yucca* spp.), Whipple yucca (*Hesperoyucca whipplei*), and Bigelow beargrass (*Nolina bigelovii*) at elevations between 300 and 600 m (Van Devender 1990; Van Devender et al. 1991). The elevation of the Luke Solar project area (320 m AMSL) places it in this late Wisconsin ecological zone.

Following deposition of the LR Formation, another period of nondeposition and soil formation ensued. During this time, soil horizons were developed in the LR Formation alluvium, and deposition in the project area was highly localized. Because radiocarbon dates were not obtained from the upper part of the LR Formation, it is not known when aggradation ceased in the late Pleistocene. However, the single radiocarbon date, coupled with the more-advanced stages of pedogenesis, suggests deposition ended before the first human occupation of North America. If there had been a Paleoindian occupation, it would have been present on the surface of the LR Formation and buried by the early Holocene Unit I. No cultural resources, however, were identified in association with the surface of the LR Formation in the project area.

The Holocene stratigraphic record at Luke Solar began with the deposition of Unit I around 7040 cal B.C. (Figure 33). This date corresponds with the complete transition from late Wisconsin xeric woodlands to more-modern Sonoran Desert plant communities, and a shift from winter-dominated to summer monsoon–dominated precipitation patterns across southern Arizona (Van Devender 1990). The fossil record from pack-rat middens suggests early Holocene precipitation was greater than today, with rainfall occurring primarily in the summer months (Van Devender 1990). This period also correlates with an episode of significant and rapid global climate change dated in numerous paleoclimatic records between 9000 and 8000 cal yr B.P. (approximately 7000–6000 cal B.C.) (Mayewski et al. 2004). At lower latitudes, this global event was characterized by a period of increased aridity in a generally wet, early Holocene and a shift in precipitation regimes (deMenocal et al. 2000). At Montezuma Well in central Arizona, lower lake levels were marked by a transition from lake muds to peat around 8000 yr B.P. (approximately 7000 cal B.C.) and a pronounced increase in charcoal at 7300 yr B.P. (approximately 6000 cal B.C.), suggesting burning of the marsh surrounding the lake (Davis and Shafer 1992).

At Luke Solar, the beginning of Unit I deposition was characterized by the filling of broad shallow channels with dark silty clay loams and sandy loam alluvium containing thin lenses of $CaCO_3$. The $CaCO_3$ lenses were subsequently capped with a sand lens containing more abundant pieces of charcoal. The carbonate lenses and dark fine-grained channel fills were confined to the southern part of the project area, and the Unit I channels to the north were primarily infilled with sandy loams. Dates from the charcoal dispersed in the sand lens in the southern project area yielded ages of 6600–6460 and 6650–6490 cal B.C., whereas in the central project area, Unit I sandy loam channel fills dated to 6230–6080 cal B.C. Unfortunately, pollen preservation was very poor in Unit I, but stable C analysis indicates $\delta^{13}C$ values for Unit I channel deposits were more negative (from -21.00 to -23.00), suggesting C3-dominated plant communities likely existed (see Figures 14 and 15; Table 11). Unit I sheet-flood deposits in the north-central portion of Falcon Landing were more positive, thus indicating a plant community with more C4 and/or CAM species, such as succulents, grasses, and weedy annuals (e.g., *Chenopodium*/*Amaranthus* [cheno-ams]).

Unit I was deposited initially along a series of broad shallow channels incised into the LR Formation. These distributary channels likely fed into an alluvial-fan-toe reach south and east of the project area. The presence of carbonate lenses and dark fine-textured deposits at the base of the channels in the southern portion



a. Phillips et al. 2001
b. Bacon et al. 2010
c. Bull 1991
d. Miller et al. 2010
e. Harden et al. 2010
f. Ely 1997
g. Waters 2008
h. Waters and Haynes 2001
i. Van Devender 1990
j. Majewski et al. 2004

▨ Episodes of global climate change

Figure 33. Comparison of Luke Solar chronology with regional paleoenvironmental proxies and alluvial records.

of Falcon Landing suggests low-energy deposition accompanied by a high water table. As the channels continued to infill with sediment, a shift in the Unit I drainage network from an incised channel reach to an alluvial-fan reach took place. A radiocarbon date from Unit I silt loam sheet-flood deposits near the south-central portion of Falcon Landing indicate deposition of the sheet-flood deposits ended around 6000–5890 cal B.C.

The oldest dated feature in the project area was associated with a Unit I wash that ran north to south along the eastern project area, very near the location of the modern wash. This feature was a small extramural pit dated to 7040–6690 cal B.C., and detrital charcoal from overlying channel deposits yielded a calibrated age of 5470–5320 cal B.C. The coarser-grained deposits of the feature indicate occupation on a mid-channel bar or similar near-channel environment. The overlying date also suggests this wash was still active after the primary deposition of Unit I ended around 6000 cal B.C. in other areas. Although the presence of an Early Archaic-period feature near the base of Unit I suggests an early presence at Luke Solar (Occupational Episode 0), no other cultural resources were documented in association with Unit I deposition.

After the deposition of Unit I, the middle Holocene at Luke Solar was marked by a period of relative quiescence. From 6000 to 3000 cal B.C., deposition was largely confined to a middle Holocene wash located east of Falcon Landing. Infilling of shallow swales and the development of a drainage network on the Unit I surface also occurred, but these deposits were not widespread. The regional middle Holocene fossil record from pack-rat middens indicate hot summers with summer rainfall greater than today (Van Devender 1990). Regional alluvial-fan records indicate a lack of fan aggradation between 6000 and 4000 cal B.C. in the eastern Mojave Desert and prior to 3000 cal B.C. on the McDowell Mountains piedmont in the Luke Basin during the middle Holocene (Miller et al. 2010; Phillips et al. 2009) (see Figure 33). Currently, there is no evidence for any significant landscape changes during the middle Holocene (between 5320 and 2970 cal B.C.) in the Luke Solar project area. Radiocarbon dates from features intruding into the Unit I surface suggest increased occupation of the project area did not take place until the Middle Archaic period (Occupational Episode 1).

The middle Holocene hiatus at Luke Solar ended around 3000 cal B.C. with a pulse of alluvial-fan aggradation coupled with increased Middle Archaic period (early Chiricahua phase) occupation. Beginning between 4900 and 4000 cal B.C., paleoclimate proxy records detect climatic anomalies associated with enhanced ENSO climatic patterns (Ely 1997; Miller et al. 2010; Wagner 2006; Waters and Haynes 2001). A high stand of Paleolake Cochise, the expansion of *cienegas* along a tributary of Whitewater Draw, and the expansion of grassland taxa at 5400 cal B.P. (approximately 3400 cal B.C.) at the San Bernardino *cienega* could mark an increase in winter precipitation at this time (Minckley et al. 2011; Waters 1989; Windingstad and Ballenger 2010). At the Cave of Bells in the Santa Rita Mountains, the Holocene speleothem record also suggests a period of stronger summer monsoons and increased summer temperatures between 6.9 and 3.5 ka (approximately 4900 to 1500 cal B.C.) (Wagner 2006). In the desert Southwest, widespread alluvial-fan aggradation dated between 4000 and 1000 cal B.C. correlates with the detected climatic anomalies (Bacon et al. 2010; Miller et al. 2010) (see Figure 33).

At Luke Solar, a pulse of alluvial-fan aggradation lasting from 2970 to 2420 cal B.C. (Units II and IIA) correlates with another local episode of fan aggradation at the Last Ditch site between 3000 and 2000 cal B.C. (Phillips et al. 2009). Initially, Unit II deposition occurred primarily along shallow channels incised into Unit I or the LR Formation along the west-central and northwestern portions of Falcon Landing. The Unit II deposits became less channelized to the east, indicating a shift from an incised channel reach to an alluvial-fan reach from west to east across the project area. Radiocarbon dates from the upper part of Unit II indicate deposition ceased around 2730 cal B.C. Early Chiricahua phase features were documented both on the surface and within Unit II deposits. Around 2810 to 2730 cal B.C., the up-fan migration of the alluvial fan toe resulted in the aggradation of Unit IIA sheet-flood deposits across the central project area. Detrital charcoal dates and dates from early Chiricahua phase pit features intruding into the surface of Unit IIA deposits indicate deposition of the unit occurred over a relatively brief period between 2810 and 2420 cal B.C.

The correlation of the deposition of Units II and IIA with radiocarbon-dated and stratigraphically dated features indicates a pronounced increase in cultural use during the early Chiricahua phase in tandem with alluvial-fan aggradation. The pooled probabilities of the ^{14}C data set are represented by the shaded density distribution in Figure 34 (left ordinate axis). Cumulative distribution plots (right ordinate axis) are overlaid, corresponding to the three principal means of establishing dates: ^{14}C, coeval (in tandem with deposition),

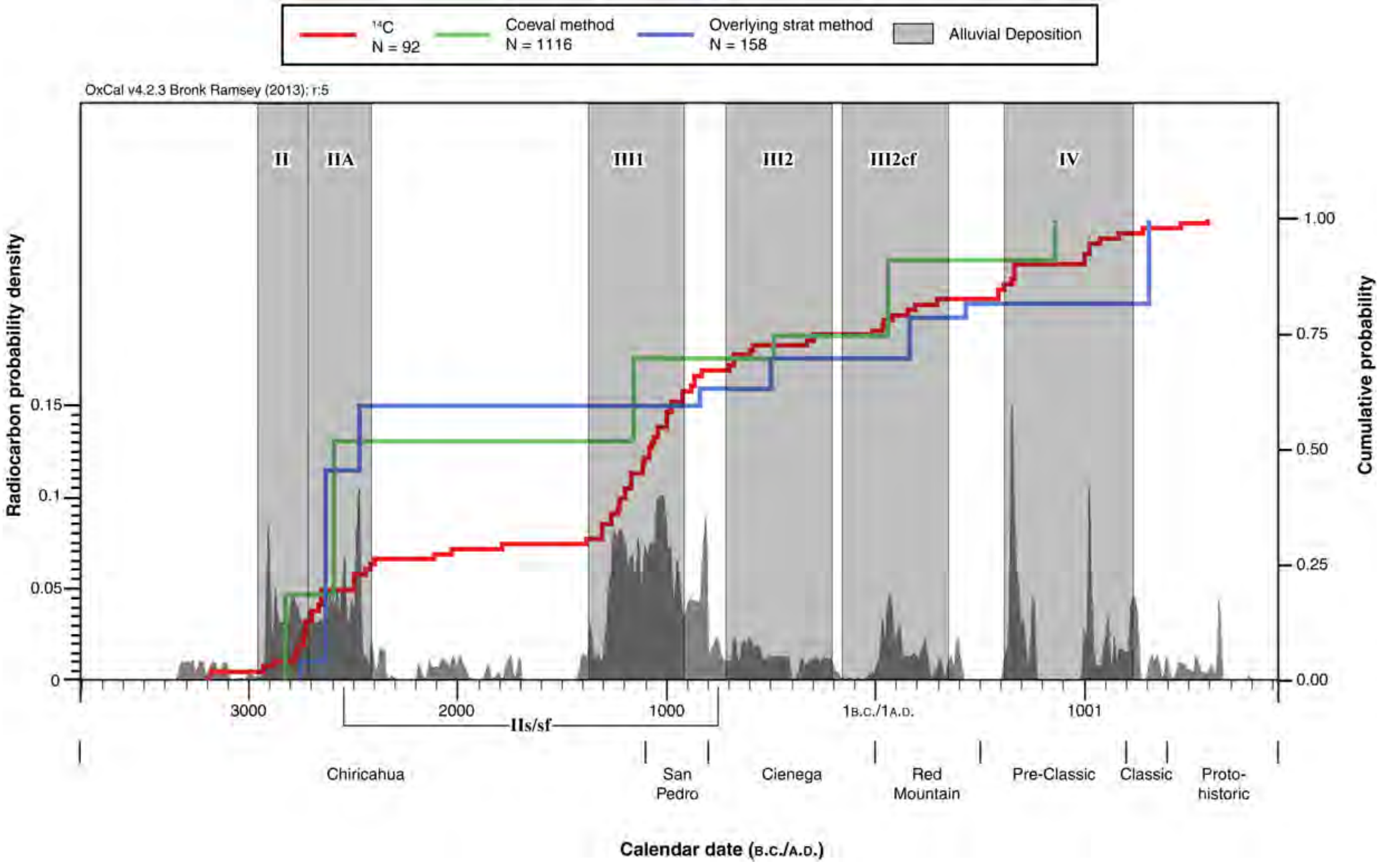


Figure 34. Geochronological model correlated to the pooled probabilities of the ^{14}C data set and cumulative probabilities of the stratigraphically dated features.

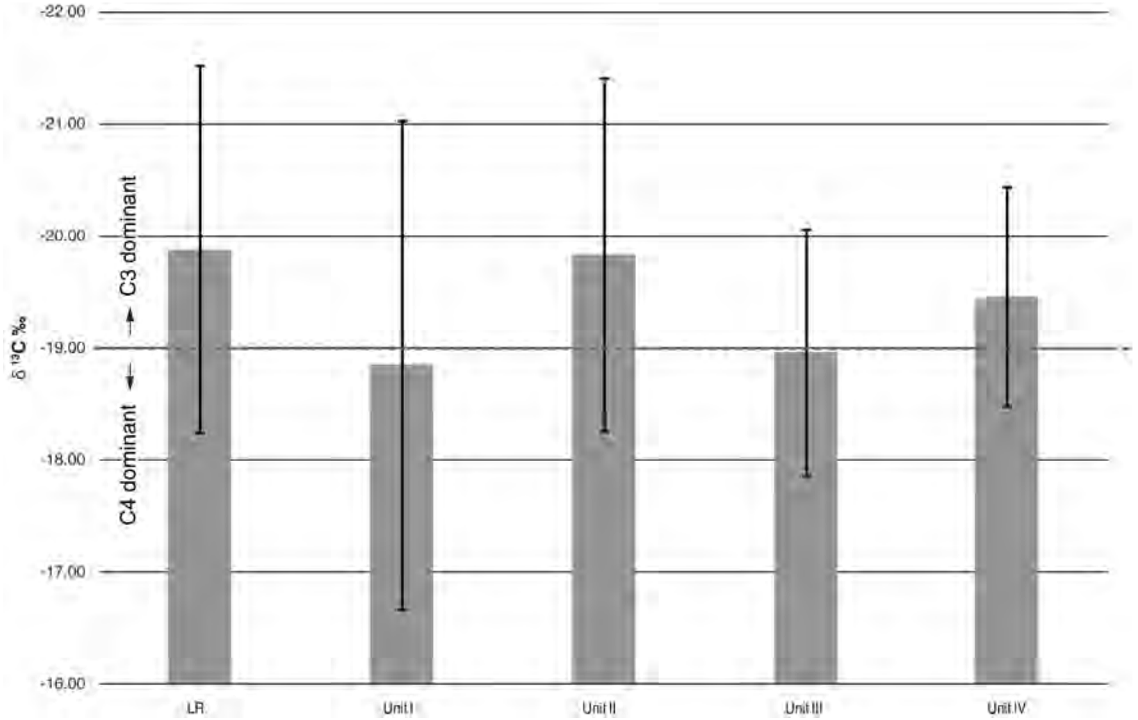


Figure 35. Average soil organic matter δ13C (VPDB) values of major stratigraphic units.

and overlying stratum (feature located at uncomformity). The steps in the cumulative distribution are based on median ages, which is an oversimplification of data points that are individually distributed non-normally. Nonetheless, at this scale of representation, this method depicts an accurate view of the relative frequency of dated features (only dates with ranges less than 1,000 years were used in this plot). Care must be taken when interpreting these data because cultural features were used to constrain the ages of some stratigraphic units. This is problematic because the feature dates could significantly postdate the end of deposition for the unit in question. Depositional dates from detrital charcoal or coeval features within the units suggest that this was not the case for most units because there was not a significant difference in age between the depositional and postdepositional (intrusive cultural feature) dates. However, the upper date for Unit III2 and the upper and lower dates for Unit IV are largely dependent on dates from cultural features. Assuming that the number of radiocarbon dates at least approximate the population of samples available for dating, the frequency of radiocarbon dates indicated by the dark shading at the bottom of Figure 34 provides an estimate of the intensity of human use of the project area over time, which is a proxy measure of temporal changes in occupational intensity.

Paleoenvironmental proxy data for Units II and IIA come from $\delta^{13}C$ values of SOM, fossil pollen, macrobotanical remains, and the stratigraphic record. The $\delta^{13}C$ values of SOM from Unit II and IIA deposits yielded values more negative than those obtained for Unit I, suggesting the increased contribution of C3 and/or CAM species to the SOM pool (Figure 35). Similar to Unit I channel deposits, Unit II channels had more-negative $\delta^{13}C$ values indicating the presence of woody C3 species (e.g., mesquite, palo verde, etc.). Macrobotanical remains recovered from the stratigraphic units were dominated by charred mesquite wood, which further suggests the presence of mesquite along shallow channels and swales and/or a nearby mesquite bosque (see Chapter 6, this volume). Fossil pollen from Unit IIA indicates the predominance of cheno-am and sunflower family (Asteraceae) species and lesser amounts of grass (see Chapter 7, this volume). The higher proportion of cheno-am and grass species correlates with the less-negative $\delta^{13}C$ values returned for the Unit IIA sheet-flood deposits. The abundance of disturbance taxa in both the pollen and macrobotanical record could be related to the enhanced alluvial aggradation that took place during the deposition of Units II and IIA. Pioneering vegetation such as cheno-am species (e.g., goosefoot and pigweed) commonly thrive in disturbed environments found in areas of active deposition and at archaeological sites. As fresh alluvium was seasonally deposited during winter and/or summer precipitation events, pioneer species such as cheno-ams likely moved in and quickly colonized the new fan deposits. An increase in sunflower family and grass pollen in early Chiricahua phase structures might also suggest an increase in winter/spring precipitation (see Chapter 7, this volume).

Following Unit IIA deposition, distinct pulses of fan aggradation were not recorded again in the project area until the onset of Unit III1 deposition at 1380 cal B.C. (see Figure 33). During this time, swales on the Unit IIA surface continued to accumulate sediment and a headcut tributary–master channel reach transmitted surface runoff to the east-southeast (see Figure 16). The alluvium associated with these swales and channel reaches was deposited between 2570 and 790 cal B.C. (Unit IIs/sf). The latter part of Unit IIs/sf deposition corresponds with Unit III1 in the south-central portion of the project area. Unfortunately, there was not a clear unconformity between the lower and upper Unit IIs/sf deposits, which makes correlation difficult. Although cultural features were associated with Unit IIs/sf, a distinct decrease in the number of radiocarbon-dated features was evident, particularly between 1700 and 1400 cal B.C. (see Figure 34). A couple of coeval features were identified in Unit IIs/sf deposits, however, indicating continued Middle to Late Archaic occupation (Occupational Episode 4) (see Figure 30).

In the northern half of Falcon Landing, lower Unit IIs/sf deposition was restricted mainly to secondary swale filling with limited or no channelized flow. An organized drainage appears to have developed on the surface of Unit IIA, with a master channel running northwest to southeast along what is now Strike Eagle Road (see Figure 16). The $\delta^{13}C$ values from Unit IIs/sf swale fills were similar to those from Unit IIA sheet-flood deposits (see Table 11). Regional paleoclimatic proxies and alluvial-fan records also indicate continued ENSO climatic patterns and fan aggradation until at least 700 cal B.C. (Bacon et al. 2010; Miller et al. 2010; Mitchell et al. 2003; Wagner 2006). If there was not a significant change in climate patterns, as these paleoclimate proxies suggest, the shift in the local depositional setting from an alluvial-fan to a headcut–master channel reach was more likely related to internal adjustments in the drainage network such as reach migration.

The start of Unit III deposition around 1400 cal B.C. marked the beginning of nearly continuous alluvial-fan deposition somewhere in the project area. "On-site" fan drainages remained active until just after cal A.D. 300, with pulses of deposition at 1380–920 cal B.C., 720–200 cal B.C. and 160 cal B.C.–cal A.D. 340 (Units III1, III2, and III2cf) (see Figures 33 and 34). A pronounced increase in radiocarbon-dated and stratigraphically dated features corresponds with Unit III1, and to a lesser extent, Unit III2cf deposition, thus indicating more-intensive cultural use of the project area at these times (Occupational Episodes 5, 6, and 7) (see Figure 32). Unit III1 and III2 headcut and master channel reaches run north–south across the south-central portion of Falcon Landing (see Figure 16). The alluvial-fan reaches were primarily centered in the far southern and the southeastern corner of the project area. Unit III2cf (channel fan) represents smaller alluvial-fan reaches in the north-central and southwestern part of Falcon Landing. Although the Unit III1 fan system appears to have been active for a limited time during the San Pedro phase, Unit III2 (III2 and III2cf combined) fans remained active until cal A.D. 340 (Cienega and Red Mountain phases).

The construction of a possible reservoir (Feature 10278) during the Late Archaic (around 1120–1000 cal B.C.) in the northeastern portion of Falcon Landing (see Chapter 4, Volume 1) corresponds with Unit III1 deposition in other areas of the site. Walk-in wells of similar age (ca. 1000 cal B.C.) have been identified along McClellan Wash on the Gila River Indian Community (Wright et al. 2013). The construction of these wells was interpreted to be a response to drought and lowered water tables during a period of enhanced ENSO climatic patterns.

Overall, Unit III deposition in the Luke Solar project area corresponds with fan aggradation in other parts of the Sonoran Desert dated between 1200 and 300 cal B.C. (Bacon et al. 2010; Lui, Phillips, Pohl, and Campbell 1996; Phillips et al. 2009). This event may have been triggered by a strengthened NAM identified in several paleoclimatic proxies between 1500 and 500 cal B.C. (Asmerom et al. 2007; Mayewski et al. 2004; Pérez-Cruz 2006; Sandweiss et al. 2001) (see Figure 33). Compared to Units II and IIA, $\delta^{13}C$ values of SOM in Unit III deposits were more positive, which suggests increased C4 and/or CAM plant species such as cheno-ams and succulents (in all likelihood, the former). Fossil pollen from late Chiricahua and Red Mountain house floors also indicate an increase in cheno-am species compared to the earlier Chiricahua and

Cienega phases. Because cheno-ams flower during the summer, this likely reflects an increase in summer monsoons during the late Chiricahua and Red Mountain phases (see Chapter 7, this volume).

Following a 300–350-year hiatus after the deposition of Unit III2cf, shallow channel and sheet-flood alluvium (Unit IV) began to accumulate in the eastern part of Falcon Landing around cal A.D. 610 (see Figures 33 and 34). This new pulse of aggradation corresponds with an increase in radiocarbon-dated and stratigraphically dated pre-Classic features (Occupational Episodes 8 and 9) (see Figure 34). Although the upper and lower age of Unit IV is poorly constrained by feature dates, this period corresponds with widespread arroyo formation and flooding in many regional alluvial records (Ely 1997; Huckleberry et al. 2013; Waters 2008; Waters and Haynes 2001) (see Figure 33). Initial Unit IV deposition occurred along shallowly incised channels near the eastern edge and the far southeastern corner of Falcon Landing (see Figure 16). Upstream migration of the alluvial-fan reach then deposited a thin sheet-flood deposit. Pre-Classic period occupations were stratified in the alluvial-fan reach, particularly in the far east-central portion of Falcon Landing. One of the more interesting aspects of Unit IV is that it had some of the highest levels of available P in the project area (see Table 11). This probably signals cultural inputs of P and therefore more-intensive use of the area during the pre-Classic period.

The δ^{13}C values from Unit IV reveal more-negative values compared to Unit III, suggesting an increase in C3 and/or CAM species. Fossil pollen recovered from Unit IV generally indicates the continued dominance of cheno-am species; however, sunflower family pollen (C3 plants such as brittlebush [*Encelia* spp.] and desert broom [*Baccharis sarothroides*]) also became more abundant in pre-Classic-period house floors (see Chapter 7, this volume).

After cal A.D. 1220, deposition on the site appears to have been minimal until the deposition of Unit V. Unit V was deposited along incised channels east of Falcon Landing and the western edge of Site 423 and formed a thin mantle of silt loam sheet-flood deposits across much of the project area (see Figure 16). Age control for the unit is poor and is based on a date obtained from a feature buried by Unit V sheet-flood deposits. This date constrained the age of Unit V to less than cal A.D. 1520–1800 (270 ± 20 ^{14}C yr B.P.) (see Table 8). Fossil pollen from Unit V indicated the continued presence of cheno-am and sunflower family species along with a few succulents (see Chapter 7, this volume). Two Unit V samples returned δ^{13}C values of -21.68 and -20.01 (see Table 11). Several Protohistoric period features were documented on the Unit V surface.

Salt Domes and Local Hydrology

Existing soil, geologic, and hydrologic data collected for the immediate area indicate low groundwater transmissivity (i.e., the rate at which groundwater flows horizontally in an aquifer) and slow permeability of water in areas adjacent to the salt domes (Eaton et al. 1972; Soil Survey Staff 2013). Aerial photographs taken in August of 1956 (monsoon season) show a pronounced increase in vegetation where multiple channels converge on a topographic low adjacent to the southern dome (Figure 36). On soil survey maps this area is mapped as the Glenbar clay loam, with the La Palma and Pinal soil series located immediately to the east (see Figure 7). The La Palma and Pinal series represent relict soils containing indurated horizons within the upper 100 cm, and the Glenbar series is a young soil composed of stratified clay loams and silty clay loams (Soil Survey Staff 2013). Well-developed soils with indurated horizons are not typical of surfaces on distal piedmonts because they are usually deeply buried by younger alluvium. Their presence east of LAFB is likely related to the uplift of relict alluvium above the Luke Salt Body during the formation of the salt domes (Eaton et al. 1972). The most significant impact of these horizons is that they are generally impermeable or very slowly permeable, which creates a strong potential for perched water tables. The official soil series description for the La Palma series, in fact, describes the presence of a perched relict water table (Soil Survey Staff 2013). The fine-textured deposits of the Glenbar series indicate very low-energy deposition in slow-moving and/or ponded water. The presence of increased vegetation in association with the above soil series suggests that low-energy surface runoff was collected and retained for some time in this area.

Evidence for elevated and/or perched water tables (i.e., episaturation) also comes from several carbonate/gypsum lenses identified in the southern portion of Falcon Landing and across Site 68. The lenses were

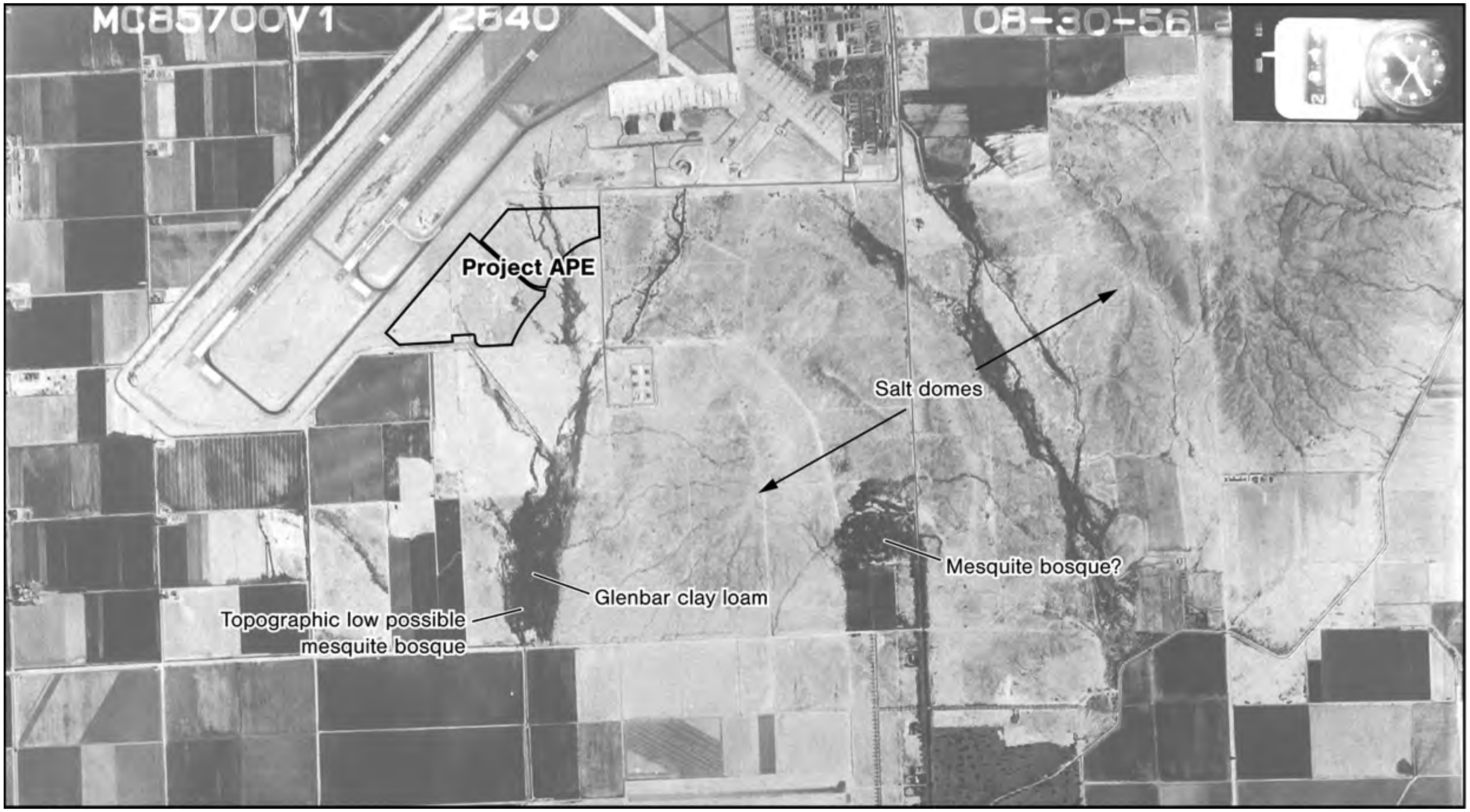


Figure 36. 1956 aerial photograph of LAFB and the surrounding area.

documented in the LR Formation, at the base of Unit I, and within some of the Unit III alluvial-fan deposits. Unfortunately, capillary fringe lenses are difficult to date stratigraphically because they can be significantly younger than the sedimentary deposit with which they are associated. Their presence, however, strongly indicates that water tables were close to the surface at least periodically during the Holocene.

The combined evidence indicates that local geologic conditions supported a seasonal perched and/or elevated water table and that surface runoff was at least temporarily retained in a topographic low adjacent to the southern salt dome. The presence of relict indurated soil horizons within 100 cm of the modern surface further resulted in low permeability of infiltrating soil water and possibly created a seasonal source of surface water for prehistoric groups, particularly during periods of enhanced NAM or winter/spring precipitation. The potential for this area to have supported a mesquite bosque is high and is reinforced by the ubiquitous presence of mesquite wood during all time periods in the macrobotanical record (see Chapter 6, this volume). The predominance of cheno-ams in the pollen record, along with elevated natural soil-salinity levels in the area, also supports the idea that saltbush was the prevailing local cheno-am species (see Chapter 7, this volume). As seasonally high or perched water tables dropped, salts were naturally concentrated over time. Mesquite, particularly screwbean mesquite (*P. pubescens*), and *Atriplex* spp. are both salt-tolerant and may have outcompeted less-tolerant species in the area (Felker et al. 1981; Miyamoto 2008). The EC of soils in the project area was generally less than 8 dS/m and probably would not have been a limiting factor for either velvet mesquite (*P. velutina*), which is less tolerant, or screwbean mesquite. Salinity levels were probably greater where water accumulated near the southern salt dome and may have been a limiting factor for nontolerant species.

Summary and Conclusions

Construction of a geochronological model at Luke Solar provided a temporal context for most of the undated cultural features. Although not deeply stratified, the ephemeral fan drainages feeding into the project area created a laterally complex stratigraphic sequence with spatially and temporally separated depositional units. Careful correlation of the units across space via radiocarbon dating, soil-stratigraphic relationships, and surface mapping served as the basis for identifying distinct pulses of alluvial-fan aggradation between 7040 and 5320 cal B.C. (Unit I), 2970 and 2420 cal B.C. (Units II and IIA), 1380 cal B.C. and cal A.D. 340 (Units III1, III2, and III2cf), and between cal A.D. 610 and 1220 (Unit IV). This stratigraphic sequence provided the framework for the OxCal model that identified nine distinct occupational episodes. Episodes of occupation corresponded very closely with the timing of fan aggradation, particularly between 2970 and 2420 cal B.C. (Units II and IIA, early Chiricahua phase), 1380 and 920 cal B.C. (Unit III1, late Chiricahua and San Pedro phases), and between 160 cal B.C. and cal A.D. 340 (Unit III2cf, Cienega and Red Mountain phases), thus indicating more-intensive use when deposition was active. Although deposition in the project area was, at times, controlled by factors other than climate, aggradation on the fan in the Luke Solar project area corresponds with widespread climatically induced fan activity after 4000 cal B.C. in the eastern Mojave Desert and 3000 cal B.C. in the Sonoran Desert. Correlation with regional alluvial-fan records indicate Units II and IIA were deposited at the same time as the Middle Archaic-period fan at the Last Ditch site, and Units III1 and III2 correspond very closely with late Holocene fans dated near Yuma and Ajo, Arizona. This suggests that many desert piedmonts in southern Arizona were actively aggrading during the Middle to Late Archaic periods. Consequently, these settings have a high potential for containing buried Archaic occupations. This is particularly true on distal *bajadas* where younger Holocene fan deposits bury older landforms.

Prehistoric groups were likely drawn to the Luke Solar project area for a number of reasons. Episodes of widespread late Holocene (after 4000 cal B.C.) fan activity in the desert Southwest appear to have been a result of increased precipitation during enhanced ENSO climatic patterns. Although both increased winter/spring and NAM precipitation have been correlated with ENSO patterns, the dominance of cheno-am species (summer flowering) in the archaeological and paleoenvironmental pollen records suggests deposition primarily during summer monsoons. Periods of enhanced winter/spring precipitation, as evidenced by an increase in sunflower family species at the expense of cheno-ams, might also have occurred during the late Chiricahua (Unit IIs/sf) and Cienega (Unit III2) phases. Increased surface runoff entering the Luke Solar project area during periods of active fan aggradation ultimately reached the salt domes east of Falcon Landing, where it was likely retained for short periods of time. Indurated relict soil horizons in this area impeded infiltrating soil water and maintained a perched water table close to the surface, which supported a niche community of mesquite (probably a mesquite bosque) and other plant species of economic importance to humans in prehistory. Actively aggrading fan surfaces also appear to have favored the expansion of disturbance taxa, especially cheno-am species, in the area. The presence of salts more soluble than $CaCO_3$ in local soils probably favored salt-tolerant species such as *Atriplex* spp. and screwbean mesquite in some areas. As a modern analogue, channels and swales on active piedmont surfaces are commonly marked by an increase in mesquite, ironwood, and palo verde, while active fan lobes seasonally support weedy annuals. The paleoenvironmental reconstruction for the Luke Solar project indicates a similar environment existed, although enhanced to some degree by local hydrogeologic conditions.

CHAPTER 3

Stone Artifacts

Jesse A. M. Ballenger, Matthew C. Pailes, John D. Hall,
Robert M. Wegener, Janet L. Griffitts, and Amelia M. Natoli

This chapter describes and interprets the stone artifacts recovered during the Luke Solar project, which involved two phases of extensive data recovery between November 2010 and April 2013 (see Volume 1). In particular, the unprecedented mechanical stripping of 46 acres uncovered an extensive array of prehistoric features and artifacts at one principal site (Falcon Landing), along with the substantially smaller Sites 68, 423, and 437, and isolated surface artifacts collected from the modern surfaces of nonsite areas. At Falcon Landing alone, almost 44 contiguous acres were mechanically stripped to an average depth of 40 cmbs, and 3,006 buried features were identified, of which 1,638 (55 percent) underwent controlled sampling. Included among those features were 48 structures, 2,738 extramural-pit features, 14 activity areas, and 2 middens, as well as many hundreds of complete ground stone artifacts encountered and collected from buried nonfeature contexts (see Chapter 3, Volume 1).

Of particular importance is the fact that the bulk of these features and artifacts accumulated in the project area sometime after approximately 5300 B.C., and most features dated after 3300 B.C. (see Chapter 2). In total, 20,588 stone artifacts—348 flaked stone tools, 7,715 pieces of flaked stone debitage, 2,319 ground/battered stone artifacts and preforms, and 10,206 fragments of FAR—were included in the project collection. Ninety-eight percent of those artifacts were collected from Falcon Landing. The Falcon Landing collection represents a monumental effort to locate and recover a highly dispersed and uniquely preserved "landscape" of tools, and it is the focus of this chapter.

The chapter is organized into three primary sections: a restatement of the research design and the research questions asked of the stone artifacts in Chapter 2, Volume 1, of this series; a review of important Middle Archaic period lithic collections and a summary of Middle Archaic period lithic technology; and a descriptive analysis of the Luke Solar project lithic collection and a discussion of the results as they relate to the activities, social organization, land use, and cultural associations of the groups who created the archaeological record at Falcon Landing and the smaller adjacent sites.

Research Design

The Archaic period of the U.S. Southwest represents nearly 9,000 years of environmental and cultural change between late Pleistocene extinctions and the widespread appearance of ceramic tools and sedentary agricultural villages (Irwin-Williams 1979; Jennings 1957; Willey and Phillips 1958). Huckell (1995) recognized that a foraging economy at the end of the Archaic period, in the Late Archaic/Early Agricultural period, sustained people before and after the appearance of maize agriculture and drew attention to the idea that riverine farming included significant social and technological changes. Although the technological requirements of foraging and farming were different, the lithic technologies of Middle Archaic period foragers and Early Agricultural period farmers remained remarkably stable (Haury 1950; Huckell 1996; Sliva 2005). Archaeological evidence that hunter-gatherer subsistence technologies changed little over a period of 5,000 years that witnessed the introduction of maize and the development of sedentary floodplain farming is at odds with the evolutionary and practical expectations of technological change. Isolating the technological strategies that were favored by increased sedentism requires a better understanding of pre-agricultural technologies. The character of the Luke Solar project collection is of special interest because it is a nonmaize technology, and as such, it uniquely spotlights *forager behaviors* in the cultural and technological evolution of Ceramic period societies in the Sonoran Desert. It is also an index collection for the lower piedmonts of the Southern Basin and Range, a vast environment that has been mostly dismissed in models of regional hunter-gatherer land use. This section outlines the theoretical context for the interpretation of the Luke Solar project flaked stone and ground stone collections and summarizes the historical context of Archaic period typologies and analyses.

Theoretical Orientation

The research design relied on stone tools to trace the cultural traditions present at the site, as well as interaction and mobility, subsistence, site function, and technological change (see Chapter 2, Volume 1). The archaeological correlates used to measure these affinities and behaviors surveyed an immense body of literature that incorporates the ethnographic record; artifact form, function, and style; typology; evolutionary expectations; actualistic experiments; provenance studies; sampling; chronology; and behavioral considerations about the formation of archaeological sites. This analysis is built around the study of technological organization that incorporated behavioral ecology, ethnographic analogy, actualistic research, and archaeological theory to address many of the key questions posed in the research design.

The technological organization of foragers was intimately connected to food choices, movement, environmental constraints, and social customs. Stone tools often provide the only means for reconstructing the behaviors of highly mobile foragers who left little else behind (Bamforth 1991; Binford 1991; Kelly 1988; M. Nelson 1991). The concept of technological organization asserts that the ways in which tools were made, used, transported, and discarded by foragers are key to deciphering adaptive strategies (M. Nelson 1991). Predictions about technological strategies are typically based on energy, time, risk, and reproduction. The most profound constraints on technology included mobility (Binford 1977; Kuhn 1995), raw-material availability (Andrefsky 1994; Bamforth 1986), and the structure of food and prey (Bleed 1986; Kelly and Todd 1988; Torrence 1983). Because mobility and provisioning strategies varied according to age, sex, and status (Bliege-Bird 1999; Kelly 1995), the tools of men and women were not alike and responded differently to change.

Curated and expedient tools represent two ends of a spectrum of choices about how tools were acquired and treated (Shott 1996). Curated tools that were transported away from their sites of use and maintained to maximize their utility before eventually being lost or discarded. These technologies are conventionally associated with the logistical task of acquiring food or materials elsewhere and returning with them. Expedient tools were manufactured, used, and discarded at the sites of use—a strategy Binford (1977) associated with residential mobility, or the movement of people to resources. A major obstacle in using the concepts of curated and expedient tools to interpret hunter-gatherer settlement patterns is the fact that raw-material scarcity or abundance affected collectors and foragers alike. Increased curation is to be expected in areas devoid of suitable rocks, and in those cases, residentially mobile foragers also "curated" their tools (Bamforth 1986).

The technological organization of hunter-gatherers has also been described in terms of provisioning strategies. Kuhn (1995) distinguished two solutions used by people to predict the locations of tools and resources: the provisioning of individuals and the provisioning of places. Highly mobile foraging required constant planning and readiness to capture, gather, and process future resources, especially the knowledge, raw materials, and tools required to do so. Ideally, a forager's tools should have done a lot of work for the energy invested in making and carrying them. The provisioning of people was necessary in order to immediately and efficiently harvest the resources encountered while moving, and it is associated with formal tools made from high-quality raw materials. Formal tools required more manufacture than expedient tools and produced diagnostic tailings, often biface-thinning flakes and vesicular-basalt flakes, in the cases of flaked stone and ground stone tools, respectively.

The preparation required by high mobility is contrasted to the nonpreparation afforded by sedentism or habitual site reuse, which allowed foragers to gradually provision places with the raw materials needed to collect resources there or elsewhere. The cost of provisioning individual foragers was mitigated by increasing the utility of a transported tool kit relative to its weight. Kuhn (1994) reasoned that mobile tool kits should be composed of tools or tool blanks rather than cores, because they possess more edge per volume and because cores contain excess baggage. The provisioning of places is linked to logistically organized settlement systems and is expected to favor expedient tools (Kuhn 1995). Informal, large cores; the accumulation of local raw materials; and the disposal of tools before they broke or wore out are some of the things expected at places provisioned by logistically organized hunter-gatherers. The provisioning of both individuals and places is predicted to have occurred within long-distance logistical land-use systems. The fact that foragers "geared up" and collectors sometimes used expedient tools is key to understanding technological systems that have been blurred by the archaeological record.

Evolutionary models of ground stone tools have focused on the efficiency of processing plant foods, especially as measured by grinding-surface area (Hard et al. 1996; Mauldin 1993) and design investment (Adams 2002). One analytical obstacle affecting predictive models in regard to ground stone tools and forager mobility relates to the fact that ground stone tools do not obey the same rules as flaked stone tools. Unlike the typical biface or core, ground stone tools were highly durable and may have been useful for years; so, their potential utility could have greatly exceeded their cost. Formal modifications and improvements to "site furniture," such as usable metates, should have been favored in situations in which the time spent making a better tool reduced the time it took to grind the same quantity of seeds with an unimproved tool. Buonasera (2012) pointed out that this condition would always have favored the manufacture of formal ground stone tools if modification increased their efficiency.

Falcon Landing offers a unique opportunity to examine hunter-gatherer energy investments in individual- and site-provisioning strategies, because all of the stone tools at the site were transported there. Using that as a starting point, the male- and female-oriented stone tools at Falcon Landing were evaluated as a technology under high selective pressure. Describing how the tools were chosen, transported, manufactured, used, and discarded provides information about site-provisioning strategies that related to human subsistence, land-use patterns, and the sexual division of labor before and after the introduction of maize farming to the U.S. Southwest.

Middle Archaic Period Collections and Analysis

The lithic technologies of regional Middle Archaic period groups have been described within a cultural-historical framework that is pervasive in discussions of spatial and temporal variability. In southeastern Arizona and west-central New Mexico, Archaic period tools have conventionally been described within the typological context of the Cochise culture (Irwin-Williams 1979; Sayles and Antevs 1941), namely the Chiricahua phase. In western Arizona and the lower Colorado River region, Middle Archaic period sites are typically described as part of the Amargosan culture sequence (Rogers 1939), specifically the Amargosa II phase. Much of the Sonoran Desert is between these culture areas, and deciphering whether Middle Archaic period artifacts are Cochise or Amargosan was a major theme of the excavations at Ventana Cave, where the co-occurrence of Cochise- and Amargosan-tradition projectile points was represented by the Chiricahua–Amargosa II component (Haury 1950). Since that time, McGuire (1982:178) has explained some of the adaptive and technological differences between the Amargosan and Cochise cultures in terms of environmental gradients, arguing that the Chihuahuan Desert grasslands of southeastern Arizona accommodated a greater reliance on grasses and agave, whereas the hyper-arid Papaguería provided succulents and especially mesquite. Following Huckell (1995), this chapter distinguishes the San Pedro and Cienega phases of the Late Archaic/Early Agricultural period from the preceding Chiricahua phase of the Cochise cultural sequence.

A variable assortment of hafted bifaces, including Gypsum, Elko, Pinto/San Jose, and Cortaro projectile point types, is a hallmark of Middle Archaic period sites (Huckell 1996; Sayles 1983), but the namesake form is a side-notched point recognized as the Chiricahua type (Dick 1965:30; Sayles 1983:75). The geographic distribution of unequivocal Chiricahua-type projectile points is unclear because of morphological ambiguities with adjacent styles, but McGuire (1982:177) observed them in collections from the lower Colorado River region (Rogers 1939:Plate 16). Late Archaic period occupations can be signaled by the widespread appearance of large corner-notched points that define the San Pedro phase of the Cochise culture. Cienega-type projectile points mark the diminution of corner-notched points, the appearance of ceramic containers, increased sedentism, economic intensification, agrarian population increases, and increased social complexity during the Early Agricultural period (Huckell 1996; Kohler et al. 2008; Mabry 2008).

Knowledge about Middle Archaic period technologies in the Sonoran Desert is based on a short list of projects that have resulted in significant collections, generally at sites that indicated multiple occupations by geographically disparate groups. Large, single-component Chiricahua phase lithic assemblages are not known, but important Middle Archaic period collections containing Chiricahua phase projectile points have been described from Cave Creek and Whitewater Draw (Sayles 1983; Sayles and Antevs 1941), Ventana Cave (Haury 1950), the Picacho Dune Field (Bayham et al. 1986; Shackley 1986), the Harquahala Valley (Bostwick 1988), the middle San Pedro and middle Santa Cruz River valleys (Gregory, ed. 1999; Whalen 1971), the Mogollon Mountains (Dick 1965), and a limited number of surface sites on the upper piedmonts of the Santa Rita (Huckell 1984a) and Santa Catalina (Agenbroad 1970) Mountains (Figure 37). Late Archaic period collections from several sites in the middle Santa Cruz and upper San Pedro River basins have been described and synthesized (Huckell 1988; Sliva 2005). This section provides a concise summary of important Chiricahua phase collections in relation to widespread impressions about lithic technological organization and change during the transition to sedentary village life.

Cave Creek Midden and Whitewater Draw

The Chiricahua phase type site, Cave Creek Midden (G. P. Chiricahua 3:16), is located in the Chihuahuan Desert grasslands, on the eastern flank of the Chiricahua Mountains (see Figure 37). The site was excavated by the Gila Pueblo Archaeological Foundation as part of a project initiated in 1935 to investigate the association of ground stone tools with late Pleistocene faunal remains, as witnessed by Byron Cummings at the Double Adobe site (Thompson 1983:1). The project incorporated aerial reconnaissance and pedestrian surveys to locate 70 Archaic period sites in Cochise County, Arizona, and another 30 sites in the surrounding area. Originally reported by Sayles and Antevs (1941), Cave Creek Midden was one of four phases ultimately recognized during what is now generally regarded as the Middle Archaic period (Huckell 1996). The lithic technology of the Cochise culture is based on roughly 4,000 tools from principally four type sites. Sayles (1983) described 40 artifact types identified in the analysis, 5 related to plant processing, and 3 related to hunting. The Cave Creek Midden collection highlighted by Sayles (1983) was somewhat of an abstraction of the major themes for the Chiricahua phase documented there but also at several other Archaic period sites exposed along Whitewater Draw.

In the Cochise cultural chronology, the Chiricahua phase is distinguished by the appearance of more formalized and abundant ground stone, including the mortar and pestle; basin metates, rather than the previous slab variety; shaped manos; more-diverse flaked stone; and the appearance of side-notched projectile points between about 3,500 and 8,000 years ago (Sayles 1983:153). It is now apparent, however, that the beginning of the Chiricahua phase may have been closer to 3500 B.C. (Waters 1986; Whalen 1971). From Cave Creek and Whitewater Draw, Sayles (1983:114–124) described slab and basin metates, shaped manos, mortars, pestles, and hammerstones, as well as choppers, planes, high-domed scrapers, end and side scrapers, bifaces, and projectile points and rare gravers, perforators, and drills, accompanied by a core-flake-reduction technology. Unique among the tools was the “proto-pestle,” described as a shaped handstone characterized by one convex end and one flat end that were polished from use (Sayles 1983:Figure 6.20). These traits were subsequently identified at several sites concentrated between the upper Gila River and Ventana Cave, as described below.

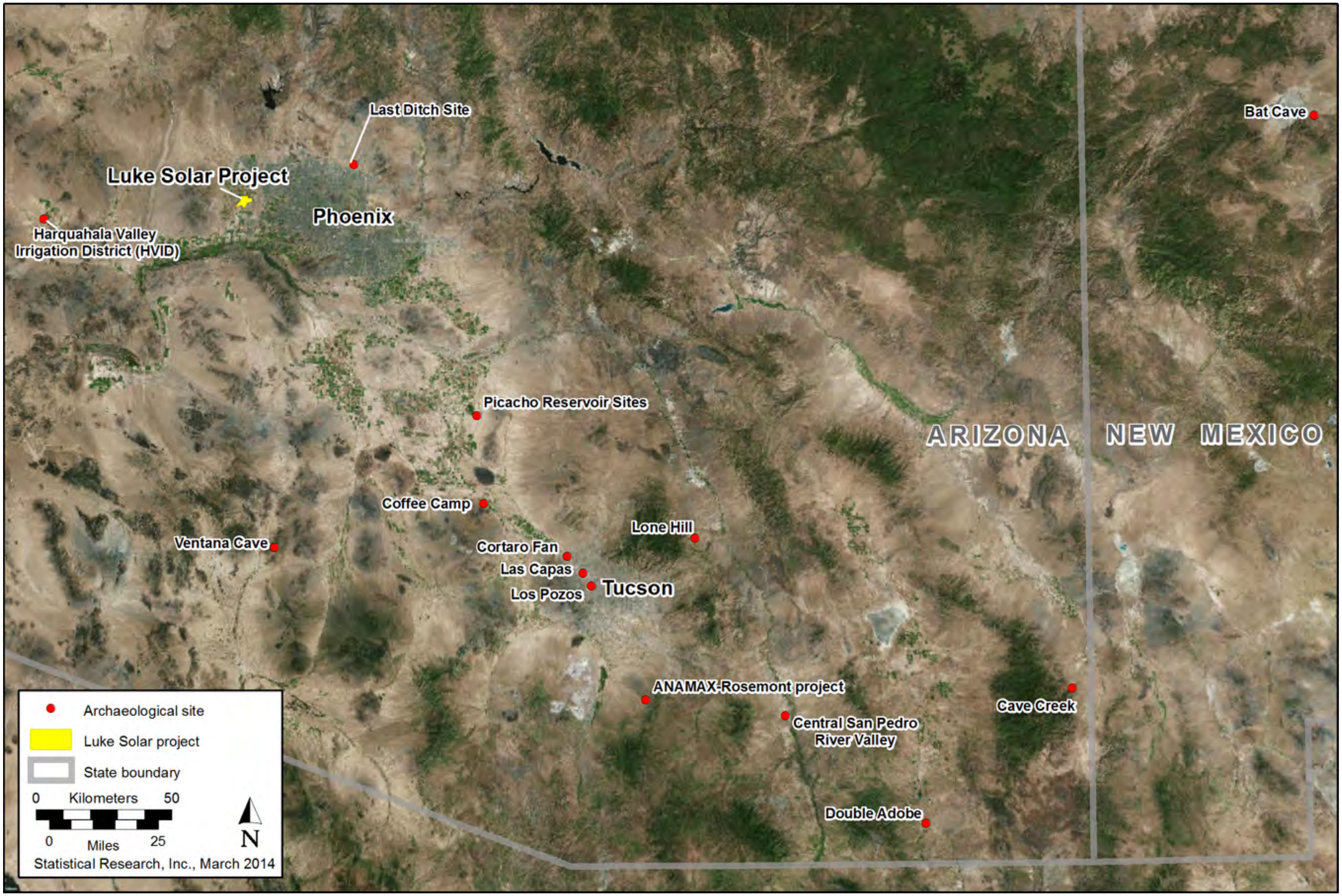


Figure 37. Map showing the locations of significant Middle Archaic period sites and projects in the southern Southwest.

Bat Cave

Located on the Plains of San Augustin, 10 miles southeast of the small town of Horse Springs, Catron County, New Mexico (see Figure 37), and overlooking pluvial Lake San Augustin at an elevation of 6,906 feet AMSL, the Bat Cave excavations were undertaken between 1947 and 1950 (Dick 1965). The primary purpose of the archaeological research was the examination of the Archaic period origins of the Mogollon culture (Haury 1936) and the validity of the Wet Leggett complex of the Cochise culture in the Pine Lawn Valley as a local expression of the Cochise culture (Martin et al. 1949). Haury and Sayles (1947) also used the presence of San Pedro points during the Hilltop and Cottonwood phases of the Mogollon culture to argue for a direct relationship between the San Pedro phase of the Cochise culture and the Mogollon culture. Dick (1965:1) ultimately concluded that the Bat Cave excavations substantiated the assertions of Martin and Haury in regard to a Cochise origin for the Mogollon culture.

In addition to that, and based on Ernst Antevs's (1948) interpretation of the stratigraphic records at both Bat and Ventana Caves and their paleoenvironmental implications, a very close correspondence between the stratigraphic records and their climatic implications in terms of the then-newly proposed Neothermal ages was drawn (Antevs 1948). The closeness of the correspondence between the two cave records was described as follows: "Geologically the deposits at Bat Cave are duplicated in Ventana Cave in south central Arizona. The dates assigned to the Ventana deposits by Bryan agree to within a 500-year latitude" (Haury 1950:119–126).

Also of importance was the examination of projectile-point-production age ranges based on the stratigraphic occurrence of projectile points throughout the Bat Cave deposits. Particularly important were the recognition and also the duplication of the general sequence of Chiricahua-style points predating San Pedro–style dart points, as documented previously at Cave Creek Midden and Whitewater Draw (Sayles and Antevs 1941) and then at Ventana Cave (Haury 1950; Huckell and Haynes 2003). Co-occurring with the Chiricahua-style dart point at Bat Cave were Types 5 and 9 (Dick 1965:Figure 24). Type 5 is a triangular, corner-notched dart point with a straight base that matches the Elko Corner-notched type in form and age as originally defined for the Great Basin by Heizer and Baumhoff (1961:128; see also Holmer 1986). Type 9 exhibits a generalized triangular blade form and a shallow, concave base very similar in form and age to the Cortaro dart-point form of southern Arizona (Roth and Huckell 1992). The Cortaro point is of particular interest because of its repeated association with maize remains radiocarbon dated to ca. 2100 B.C. from the Santa Cruz River in Tucson (Gregory, ed. 1999; Mabry 2008).

Bat Cave figures prominently in the history of research concerning early maize in the New World. Maize remains were abundant in the cave deposits and included 766 shelled cobs, 125 loose kernels, 8 husk fragments, 10 leaf sheaths, and 5 tassels or tassel fragments distributed through Cave Levels VI–I and representing a distinct evolutionary sequence (Mangelsdorf and Smith 1949:243–244). Using conventional radiocarbon dating, Dick (1965:93–95) argued that the maize was available to the occupants of Bat Cave no later than 3049 B.C. That date, however, was not a direct date on the maize remains themselves; rather, it was obtained from other charred plant material from the oldest layer containing maize remains. Later, direct dating of the maize indicated that maize was first available to the site occupants as early as 1523–1132 cal. B.C., at the 95 percent confidence interval (Wills 1988:Table 18). Regardless of the precise timing, the association at Bat Cave of early maize with what are now known to be clear Middle Archaic period point types, such as Chiricahua and arguably Cortaro, is certain. Although the Middle Archaic period age of the Bat Cave maize has been refined, the role that Bat Cave played in the thinking of mid-twentieth-century archaeologists of the U.S. Southwest cannot be understated. In particular, of all the site excavations in the lower U.S. Southwest, Bat Cave contributed perhaps most significantly to our discipline's earliest thinking about the origins of agriculture and the articulation of the Chiricahua phase of the Cochise culture with the transmission of maize into the U.S. Southwest.

Lone Hill

The Lone Hill site (AZ BB:10:17 [ASM]) is a surface site at the base of Lone Hill, a prominent landform along the eastern *bajada* of the Santa Catalina Mountains (see Figure 37). Lone Hill would have functioned as an excellent vantage point for Archaic period groups in the region and is about 8 km (5 miles) west of the San Pedro River. The Lone Hill site was systematically investigated by Agenbroad (1970) through placement of an approximately 650-by-400-foot grid over the surface expression of the site. The grid was subdivided into 10-by-10-foot study units, and a random sample of 135 squares was surface collected. Artifacts recovered from the grid squares included 68 manos, 35 metates, 165 projectile points, 52 scrapers, 28 unifaces, 24 bifaces, 14 cores, 2 drills, a hammerstone, a stone disk, and over 13,000 pieces of debitage (Agenbroad 1970:15–68). Nearly 30 hearths or rock concentrations were also identified by Agenbroad (1970:14), many of which were test-excavated for datable material.

Directly dating the site proved difficult. Charcoal recovered from a single hearth was radiocarbon dated and demonstrated use of the site during the Protohistoric period (ca. A.D. 1650). A thermoluminescence date was obtained from another hearth and provided a date of ca. 5700 B.P. (Agenbroad 1970:70), corresponding to the Early Archaic period. Using projectile points as an indirect-dating method, Agenbroad assigned the Lone Hill site to the Chiricahua phase of the Cochise culture based on the similarity of materials to those reported by Sayles and Antevs (1941). Of the 96 projectile points classified by type at the Lone Hill site, over 60 percent corresponded to Middle Archaic period styles, such as Pinto/San Jose, Chiricahua, and Gypsum.

An overwhelming majority of tertiary or bifacial-reduction debris was present, indicating that the occupants of the Lone Hill site likely reduced cores off-site and transported bifaces or bifacial cores to the site. All the manos recovered were the one-handed variety, and almost all the metates were basin shaped. The abundance of biface debris and the relatively high numbers of flaked stone and ground stone tools led Agenbroad (1970:72–73) to argue that the Lone Hill site was either an extended occupation or a seasonal camp occupied repeatedly for the purposes of obtaining and processing animal and plant resources; he interpreted the number of inverted metates as an indication of anticipated return. The Lone Hill site is an example of a similar circumstance recognized by Whalen (1971) along the San Pedro River in which Middle Archaic period groups moved between the *bajada* and riparian areas on a seasonal basis. For example, the Lone Hill site is approximately 4 km (2.5 miles) east of Mesquite Flat Spring, a well-known spring that is still active today. Middle Archaic period groups were undoubtedly tethered to such springs and utilized other upper-*bajada* resources in the Santa Catalina Mountains, such as piñon nuts and artiodactyls (deer), in the fall and winter months, exploiting riparian resources along the San Pedro River during warmer months.

San Pedro Valley

In the San Pedro Valley, Whalen (1971) recorded 90 sites in a 100-square-mile survey area between the Whetstone Mountains and the San Pedro River (see Figure 37). Eighty-two of the sites were considered Archaic period, or "non-ceramic" (Whalen 1971:104). Whalen selected 12 of the Archaic period sites for study, and those sites underwent surface collection and detailed analysis. Whalen (1971:106) selected 6 sites located on the upper *bajada* of the Whetstone Mountains (i.e., *bajada* sites), and the other 6 sites were located on the terrace above the San Pedro River (i.e., riverine sites). Over 47,000 lithic artifacts were collected from the 12 sites, including over 900 bifaces, blades, choppers, drills, knives, projectile points, scrapers, and used flakes. Fewer than 60 ground stone items were collected and represented both mano and metate fragments. Whalen (1971:199) categorized the sites into Chiricahua phase (n = 6), San Pedro phase (n = 3), and unknown (n = 3) based on the presence of diagnostic Chiricahua and San Pedro projectile points. No other projectile point types were identified. Whalen also identified hearths at several of the sites, but none was systematically excavated.

Using data from the 12 sites, Whalen (1971, 1975) was able to distinguish interesting patterns, particularly in regard to settlement, technology, and site function. Whalen (1971:199–200) divided the 12 sites into two functional categories: work camps and base camps. Following Binford and Binford (1966), base camps were considered more-permanent locations dedicated to food preparation and tool manufacture, and work camps were considered more temporary resource-extraction locations used for hunting or plant-food procurement or as stone-quarrying locales. Overall, 4 Chiricahua phase sites were located on the upper *bajada*, with 2 in riverine settings. The Chiricahua phase sites were also evenly distributed by site type: the 4 *bajada* sites were 2 base camps and 2 work camps. The Chiricahua phase sites along the river were 1 base camp and 1 work camp. Two of the San Pedro phase sites were located on the *bajada*: 1 base camp and 1 work camp. One San Pedro phase base camp was located in a riverine setting. All 3 sites of indeterminate age were located along the river, and they were identified as 2 work camps and 1 base camp (Whalen 1971:199–200). A 6–10-km-wide strip of middle *bajada* landform was "practically devoid of sites" (Whalen 1975:205).

Whalen (1971:204) argued that the presence of large and small sites in two distinct environmental zones indicated that Archaic period groups utilized a wide range of biotic resources on a seasonal basis. Whalen also recognized that sites situated on the *bajada* were more numerous and represented much-more-intensive occupation. The primary reason for the disparity between settlement locations was believed to have been associated with the potential resources available in the two locations, as well as the activities associated with utilizing those resources. The seasonal availability of piñon nuts and artiodactyls (deer) in the upland zones would have been attractive to Archaic period groups. As a result, sites located in upper-*bajada* settings represent a greater diversity of activities and more-intensive occupations associated with gathering piñon nuts and hunting deer. They may also represent successive occupations, perhaps locations where different family groups converged to participate in social interactions beyond the normal familial group (Whalen 1971:205–208).

The *bajada*-riverine dichotomy first recognized by Whalen (1971, 1975) along the San Pedro River was an important aspect of Archaic period settlement and land use. Whalen's analysis of Cochise sites set the stage for future analyses by researchers who have studied the Middle and Late Archaic/Early Agricultural period in southern Arizona (see Diehl, ed. 2005; Huckell 1995; Premo and Mabry 2003; Roth 1989, 1996; Roth and Freeman 2008). The dual upland-lowland settlement pattern and economic variability have also been recognized in other areas (see Matson 1991; Wills 1988) and stand as a persistent model of Middle and Late Archaic period land use in the U.S. Southwest.

In 1992, SWCA conducted subsequent survey and testing of multiple sites grouped together as AZ EE:3:28+ (ASM) on the upper *bajada* in the vicinity of Kartchner Caverns State Park (Phillips et al. 1993). Using backhoe trenches, test units, and surface surveys, SWCA identified four prehistoric surface features described as roasting pits or hearths. Test pit excavations did not identify subsurface features, but a small amount of flaked stone debris was encountered in shallow sediments resting on rock or an argillic horizon. Surface collections resulted in the "mass analysis" of 34,305 pieces of debitage, and formal analysis of 581 flaked stone tools. Ceramic artifacts numbered 192 sherds, mostly plain wares. Ground stone artifacts were rare, consisting of only 27 manos or metate fragments, and faunal specimens consisted of 54 fragmentary and burned bones, mostly of artiodactyls. The dominant activity at the site was flaked stone tool refurbishment, quarrying, and biface production using locally available cherts. Numerous styles of Archaic projectile points were identified at the site, especially Pinto (n = 12) and tapering stemmed (n = 7), with only rare examples of Chiricahua (n = 1), San Pedro (n = 2), Cortaro (n = 1), and Elko (n = 1) points.

Ventana Cave

One of the best records of Archaic period occupation in the U.S. Southwest came from the stratigraphy of Ventana Cave (Haury 1950). Located almost due south of LAFB, at a distance of about 130 km (80 miles) (see Figure 37), Ventana Cave had a sequence of occupation from the late Paleoindian period through the Historical period Tohono O'odham. Over 11,000 stone artifacts were recovered form Ventana Cave, including an impressive number of stone tools and projectile points. The stratigraphy of Ventana Cave was divided into three main culture-bearing layers: the Volcanic Debris, the Red Sand layer, and the Midden (Haury 1950:Figure 8). Materials from the lowest layer in the cave, the Volcanic Debris, were designated by Haury (1950:176–199) as the Ventana complex and contained 2 projectile points (1 quartz leaf-shaped point and 1 basalt concave-base point identified as Folsom), 11 knives, 63 scrapers, 3 gravers, 3 choppers, 6 planes, 1 hammerstone, and 1 mano. The age of the Volcanic Debris has since been reevaluated to coincide with the late Paleoindian or Early Archaic period (ca. 10,500–8800 B.C.), and the possible Folsom point has been reinterpreted as a late Paleoindian Plains or Great Basin nonfluted, lanceolate form (Huckell and Haynes 2003). Overlying the Volcanic Debris is the Red Sand layer, which contained 7 knives, 22 scrapers, 4 planes, and 21 leaf-shaped and stemmed projectile points. Haury (1950:294) attributed this layer to the Ventana–Amargosa I complex, based on the projectile points and their similarity to Rogers's (1939) finds in the Mojave Desert. The points were later interpreted as possible Great Basin Stemmed or Jay points (Freeman 1999). Above the Red Sand layer was a large, massive midden deposit that was divided into a lower "moist" midden and an upper "dry" midden.

The Midden layer contributed about 99 percent of the stone artifacts collected from Ventana Cave, including over 3,000 unifaces (planes, scrapers, gravers, and flake knives) and over 4,000 bifaces (including over 2,000 projectile points and knives). The high numbers and proportions of scrapers and planes led Haury (1950:207–212) to postulate a heavy use of woodworking and animal-hide processing during the Archaic period. These tools were predominantly manufactured from volcanic cobbles and exhibited significant edge modification. Ground stone items included over 1,000 manos and 2,000 metates (particularly basin metates) as well as several miscellaneous ground stone items, such as pipes, axes, pendants balls, beads, and rings. Interestingly, 114 pestles were recovered from the Midden, but only 2 stone mortars were found. The cave contained a small concentration of bedrock mortars. The pestles included cylindrical, conical, well-shaped, and unshaped varieties.

Despite significant mixing of the upper midden deposits, Haury (1950:338–341, Plate 22) arranged the diagnostic projectile points into temporal categories based on the different levels excavated through the Midden. The base of the Midden (Levels 5–8) contained Middle Archaic period projectile points, including San Jose/Pinto, Chiricahua, Gypsum, and possibly Cortaro points. Haury attributed those points to the Chiricahua–Amargosa II (Pinto) complex associated with sites investigated in the western deserts (Campbell and Campbell 1935; Harrington 1933). The upper portion of the "moist" midden (Levels 3–5) was considered by Haury to represent the San Pedro complex defined by Sayles and Antevs (1941) and contained numerous San Pedro and Cienega points. Haury (1950:294–296) observed that the stratigraphic ordering of projectile points throughout Ventana Cave correlated well to the projectile point forms established by earlier archaeological investigations in the Great Basin, the Mojave Desert, and southeastern Arizona (Campbell and Campbell 1935; Harrington 1933; Sayles and Antevs 1941). Haury (1950:296–297) also pointed out that San Pedro points were found immediately below the ceramic horizon, at the boundary between the moist and dry portions of the midden. At that subtle stratigraphic break, Haury recognized, the San Pedro points marked a sharp contrast to the preceding Amargosa II point forms, and the use of San Pedro points likely persisted into the early Christian era, with agriculture likely beginning around the same time. Finally, the dry, upper midden deposit (Levels 1 and 2) as well as the surface of Ventana Cave contained Hohokam, Protohistoric period, and Historical period Tohono O'odham remains.

Haury (1950:544) formed the impression that plant gathering and processing exceeded hunting in importance during the Chiricahua–Amargosa II phase, but a reexamination of the fauna by Bayham (1982) showed a linear increase in the proportion of artiodactyls in the site fauna. The gradual selection of large game is interpreted to reflect the transition from residential mobility during the Middle Archaic period to increasingly logistical mobility strategies thereafter as sedentary village life developed in the floodplains. The shift toward larger game was accompanied by an increase in projectile points, bifaces, and flake knives, and manos and metates became proportionally fewer. Ventana Cave may have been a base camp during the Middle Archaic period, but by Hohokam times, it was a logistical hunting/foraging camp (Szuter and Bayham 1989).

Rosemont Sites

Between 1975 and 1982, the ASM conducted the archaeological mitigation for the proposed ANAMAX-Rosemont mine, including an approximately 26-square-mile land exchange in the northern Santa Rita Mountains (Huckell 1984a) (see Figure 37). Numerous sites were identified in the Rosemont area that were

Archaic period in age or had Archaic period components. Of those, 10 Archaic period sites were thoroughly investigated by Huckell (1984a) in the Rosemont area, including the Wasp Canyon site (AZ EE:2:62 [ASM]), the South Canyon site (AZ EE:2:82 [ASM]), the McCleary Canyon site (AZ EE:2:102 [ASM]), and the Split Ridge site (AZ EE:2:103 [ASM]), among others. Two other Archaic period sites were excavated in the Sycamore Canyon area (AZ EE:2:100 [ASM] and AZ EE:2:101 [ASM]) by Tagg et al. (1984), and that study also included the investigation of 7 lithic-quarry sites.

Just under 8,000 flaked stone and ground stone artifacts were recovered from the 10 Archaic period sites in the Rosemont area, including debitage, scrapers, cores, unifaces, bifaces, perforators, cobble tools, and projectile points as well as manos, basin and slab metates, and small mortars. Features attributed to the Archaic period occupations included ephemeral structures, rock clusters, pits, hearths (rock-filled pits), and artifact concentrations. The Archaic period sites investigated in the Rosemont area included Early, Middle, and Late Archaic period remains, based on the analysis of the diagnostic projectile points. Diagnostic point types included several tapering-stemmed points indicative of Early Archaic period forms, including Great Basin Stemmed points described by Layton (1979), a possible Silver Lake point similar to that described by Amsden (1937), and a few possible Jay points as originally described by Irwin-Williams (1973). Middle Archaic period occupations were defined by the presence of Pinto/San Jose, Gypsum, and Chiricahua projectile points. Finally, the presence of San Pedro and Elko projectile points demonstrated several Late Archaic period occupations, as well. At the Split Ridge site, in particular, several untyped Late Archaic period projectile points were later designated as Cienega points by Huckell (1995:52), and others were later interpreted as Empire points by Sliva (2005:95).

At the two Sycamore Canyon sites, Tagg and Huckell (1984a) excavated several large rock concentrations and roasting pits, including a possible rock-lined structure. Approximately 3,000 flaked stone and ground stone artifacts were recovered from the two Sycamore Canyon sites, including debitage, cores, scrapers, unifaces, bifaces, and perforators as well as manos, metate fragments, and pitted stones. Excavations also recovered several Early, Middle, and Late Archaic period projectile points, including numerous triangular concave-base points that Roth and Huckell (1992) later defined as Cortaro points. Other points included possible Pinto and possible Great Basin Stemmed points as well as Chiricahua and Cienega points (Tagg and Huckell 1984a:Figure 2.20). Lithic-quarry sites investigated by Ervin and Tagg (1984) demonstrated that the prehistoric inhabitants of the northern Santa Rita Mountains practiced opportunistic lithic procurement of bedrock and in secondary-cobble quarries. For example, silicified limestone was heavily exploited from a select few bedrock exposures, and a more casual exploitation of abundant secondary quartzite and metasediment alluvial cobbles was identified throughout the natural ridge surfaces in the Rosemont area (Ervin and Tagg 1984:57–59).

Overall, the Archaic period sites in the northern Santa Rita Mountains produced some of the first evidence of Archaic period occupations in montane settings. Of particular importance was the identification of several possible Early Archaic period occupations containing tapering-stemmed projectile points (Huckell 1984a:257). The northern Santa Rita Mountains are rich in economic resources. The Rosemont sites were in proximity to dependable sources of water, diverse plant communities, populations of large- and small-game animals, and ample raw lithic materials (Huckell 1984a:238–248). Using the diversity of tools per site, Huckell (1984a:235–236) was able to assign functions to different sites. For example, the Wasp Canyon and McCleary Canyon sites contained abundant bifaces, scrapers, and projectile points, indicating that hunting and hide processing were important activities. Conversely, the South Canyon site had a nearly even distribution of tool types, indicating a more generalized mixture of activities such as hunting, plant-food processing, and tool manufacture. Thus, Huckell was able to demonstrate the presence of specialized multiple-activity sites, unspecialized multiple-activity sites, and limited-activity sites. Huckell (1984a:253–255) also identified trends in settlement location. Early and Middle Archaic period sites tended to be located in the upper elevations, and Late Archaic period sites tended to be situated in lower elevations on the *bajada*.

Picacho Reservoir

Along the lower *bajada* of the Picacho Mountains (see Figure 37) are several sites with Middle Archaic period components that were excavated for the Tucson Aqueduct Project in the 1980s (Bayham et al. 1986). Data from the Picacho Reservoir Archaic Project became the first solid archaeological evidence of Middle Archaic period occupation in the immediate vicinity of the Phoenix Basin. Three distinct Middle Archaic period occupations were apparent at Picacho Reservoir, including the Buried Dune sites (AZ AA:3:15 [ASU] and AZ AA:3:16 [ASU]), the Arroyo site (AZ AA:3:28 [ASU]), and the Gate sites (AZ AA:3:8 [ASU] and AZ AA:3:9 [ASU]). The Buried Dune sites were situated in a lower-*bajada* environment that was covered by aeolian sand forming a small dune field. Radiocarbon dates for the Buried Dune sites clustered around 4300 B.P. (ca. 3480–2420 cal. B.C.) (Bayham et al. 1986:Appendix A). The Buried Dune sites had a relatively low diversity of lithic tools as well as a preponderance of nonlocal material types. Palynological data suggested that the Dune sites were occupied during winter or early spring and that the Buried Dune sites represent an ephemeral, single-component, short-term field camp that was likely occupied during the winter months (Bayham and Morris 1986:369). The Arroyo site, on the other hand, is located along the banks of an arroyo to the south of the Buried Dune sites. Radiocarbon dates for the Arroyo site were derived from a substantial midden and fell between 4950 and 3650 B.P. (ca. 3875–1730 cal. B.C.) (Bayham et al. 1986:Appendix A). Lithic-raw-material selection at the Arroyo site indicated the use of a local felsite quarry and represented a more generalized assemblage of tools and debitage. These data suggest that the Arroyo site represents a more intensive long-term base camp that was occupied during the summer and fall (Bayham and Morris 1986:369). The Gate sites were located farther to the east, in an alluvial plain south of Brady Wash. The modern vegetation at the Gate sites consisted of predominantly saltbush and wolfberry, similar to the vegetation at LAFB. Radiocarbon dates from the Gate sites ranged between 4900 and 4100 B.P. (ca. 3895–2415 cal. B.C.) (Bayham et al. 1986:Appendix A). The Middle Archaic period components of the Gate sites were interpreted as a hunting and gathering base camp.

Ground stone artifacts recovered from Picacho Reservoir were predominantly one-handed manos and slab metates. Much of the ground stone had also been burned, indicating reuse of exhausted or broken ground stone items as thermal mass. Interestingly, three ground stone items from the Gate sites were categorized by Morris (1986:261) as “mullers,” and the descriptions of these artifacts were strikingly similar to those of the Lukeoliths identified in the Luke Solar project area. The mullers were extensively shaped; had broad, rounded ends; and were worked, both bifacially and on the ends. Morris interpreted the mullers as implements used to crush materials in a circular motion, rather than through the pounding action of a pestle or the grinding motion of a mano.

Chiricahua projectile points constituted the most numerous type at Picacho Reservoir, and similar to those in the Luke Solar project collection, exhibited a significant amount of resharpening. Importantly, the buried archaeological contexts at the Buried Dune sites were associated with primarily Pinto/San Jose–style projectile points, whereas the Gate sites and the midden at the Arroyo site contained primarily Chiricahua-style projectile points (Bayham 1986a:225–238). The distinctive projectile point styles recovered from the discrete site locations were crucial observations. The mutually exclusive projectile point styles suggest disparate subsistence and mobility strategies as well as possibly discrete socioeconomic groups (Bayham and Morris 1986:371–372). The Arroyo and Gate sites are considered to have been intensive or repeated occupations by Chiricahua-point-using groups. The Buried Dune site is considered to have been a short-term field camp associated with Pinto/San Jose points.

Northern Tucson Basin

The Tucson Basin Survey was performed to address the topic of Late Archaic settlement and subsistence patterns between the Picacho, Tortolita, and Tucson mountains. Combining previous investigations and new surveys and excavations, Roth (1989) documented the distribution of Middle to Late Archaic sites across various environmental zones, including floodplain, terraces, and the lower and upper *bajada*. Late Archaic sites were defined based on the presence of Cortaro, San Pedro, and Cienega type projectile points, with the largest sites also containing ceramic components. Using site size, artifact density, and artifact diversity indices, Roth (1989:138) defined large and small multiple activity sites, limited activity sites, and lithic procurement sites. Catchment analysis was used to demonstrate that Late Archaic sites along the Santa Cruz River and in the Tortolita Mountains provided easy access to multiple ecological zones.

A total of 34 Late Archaic sites bearing diagnostic projectile points were located during the project, with sites occurring either in the Santa Cruz River floodplain and on its terraces and along its tributaries or on the upper *bajada* of the Tucson Mountains and, especially, the Tortolita Mountains. Roth (1989:157) attributes the high density of sites on the upper *bajada* to good site visibility and the presence of springs and upland riparian habitats. With the exception of a Late Archaic feature at the Dairy site, Archaic evidence on the lower *bajada* was limited to isolated finds.

Excavations were performed at two sites. Located in the vicinity of a spring on the upper *bajada* of the Tortolita Mountains, site AA:12:84 (ASM) contained 68 stone tools on its surface, including 2 Pinto, 3 San Pedro, and 3 Cienega projectile points, as well as 3 manos and 2 slab metates. Ten 2-by-2-m excavation units yielded two possible Late Archaic features that contained, collectively, one unidentified mammal bone fragment and palo verde, mesquite, cholla, and saguaro charcoal, as well as hedgehog cactus seeds. Deer, rabbit, canid, and desert tortoise bones were identified in nonfeature excavations. Excavated flaked stone tools included three additional Cienega points and one San Pedro point, as well as bifaces, scrapers, retouched flakes, cores, and a chopper. Two manos, two polishing stones, and two slab metates were included in the excavated ground stone collection. Based on data from this and other nearby sites, Roth (1989:183) inferred that most Late Archaic sites on the upper *bajada* were used as seasonal, short-term camps.

Excavations were also performed at the Cortaro Fan site (AZ AA:12:486 [ASM]), the Cortaro projectile-point-type site (Roth and Huckell 1992) and the largest Archaic site in the study area. Thirty-two surface features were recorded, consisting of fire-affected rock (FAR) features, ground stone clusters, and activity areas containing a mixture of flaked stone, fire-affected ground stone fragments, and occasional faunal bone fragments. One midden contained ashy deposits as deep as 1.5 m below the surface. A total of 265 stone tools were collected from the surface. A total of 49 test units, most measuring 2 by 2 m, were excavated to recover an additional 124 stone tools. Survey, 20 backhoe trenches, and hand excavations revealed 14 surface features and 18 subsurface features, mostly hearths and roasting pits, although three poorly preserved post holes were documented. Two San Pedro phase hearths yielded maize, but a wide variety of wild plants, including mesquite, cheno-ams, dropseed, and chia were utilized at the site. Rabbits, deer, rodents, and birds dominated the faunal collection. In contrast to upper *bajada* sites, the Cortaro Fan site indicates intensive use of floodplain settings during the Late Archaic (Roth 1989:201).

Four Middle Archaic sites were recorded as part of the Tucson Basin Survey, as indicated by the presence of Elko, Pelona, Pinto, and stemmed projectile points. An additional Middle Archaic site containing three Chiricahua points was recorded by Hewitt and Stephen (1981). All of the Middle Archaic sites were located in the Tortolita Mountains; evidence of Middle Archaic occupation in the Tucson Mountains and the Santa Cruz River floodplain was limited to isolated projectile points.

Harquahala Valley

Surface collection and excavation of eight sites as part of the Harquahala Valley Irrigation Project (HVIP), located approximately 65 km west/northwest of the Luke Solar project area (see Figure 37), documented the seasonal exploitation of local lower Sonoran Desert–subdivision resources through much of the Archaic period (Bostwick 1988). Somewhat in response to a need identified by Huckell (1979:133), primary HVIP research objectives were the systematic collection and detailed analysis of the total range of artifact types present, with the goal of contributing to a database of well-defined, diagnostic Archaic period artifacts. Data recovery consisted of the complete collection of all surface artifacts at each site; the excavation of 22 backhoe trenches, which indicated that the sites were almost entirely surficial; the excavation of randomly placed 2-by-2-m excavation units; and the identification and sampling of a total of 18 shallowly buried features distributed across the eight HVIP sites (Bostwick 1988:39). Very much like at Falcon Landing, the buried features primarily consisted of FAR clusters and also included a roasting pit, a hearth, a bone cluster, and a grinding station. The total HVIP artifact collection consisted of 6,256 flaked stone artifacts, 1,449 ground stone artifacts, 61 hammerstones, and 42 ceramic sherds. Most of those artifacts were recovered from the surfaces of the Lookout (AZ S:7:30 [ASM]) and Apothecary (AZ S:7:36 [ASM]) sites.

Recovered Middle and Late Archaic period dart points were dominated by Chiricahua (n = 5) and, especially, San Pedro (n = 11) styles (Bostwick 1988:Table 7.6). A sixth Chiricahua point was also identifiable in the report by Bostwick (1988:Figure 7.12). Other point forms not attributed to type by Bostwick included what can be interpreted as 3 parallel-stemmed points that could be classified as Datil points (Bostwick 1988:Figures 7.10, 7.13, and 7.15). An Elko Corner-notched point (Bostwick 1988:Figure 7.13) and a Cienega point (Bostwick 1988:Figure 7.15) were also identifiable. Examination of the recovered cores and debitage indicated that initial core reduction was not conducted at the project sites and that middle to late bifacial reduction and biface refurbishing were primary site activities. Geochemical sourcing of 41 of 44 collected obsidian artifacts revealed that the nearby Vulture source, located 32 km from the HVIP sites, was most often used, but a wide-ranging obsidian-procurement sphere may have been in operation at certain times, as evidenced by the presence of obsidian from seven additional sources, ranging from the Sauceda Mountains, to the south, to Tank Mountain, to the west; Partridge Creek, to the north; R S Hill, to the northeast; and Burro and Mule Creeks, to the east.

One-handed manos and slab metates composed nearly 67 percent of the extensive HVIP ground stone collection. No trough metates were recovered. Interestingly, 38 percent of the metates exhibited evidence of manufacturing via flaking. Thirteen pestles were recovered, primarily from the Apothecary site, from which 7 of the 9 recovered specimens were complete. The rest of the ground stone collection consisted of abraders, lapstones, spheroids, a stone ball, and indeterminate metate fragments (Bostwick 1988:Table 137). Pollen and macrobotanical analyses focused on select excavated features, but neither analysis provided conclusive results concerning specific taxa used aboriginally at the sites. Overall similarities between the HVIP ground stone collection and the collections from Ventana and Bat Caves and from the Cochise-culture type sites were readily apparent, however (Bostwick 1988:165).

Los Pozos

The Los Pozos site, located in the floodplain of the middle Santa Cruz River (see Figure 37), is generally not included in discussions of significant Chiricahua phase collections, because the Middle Archaic period occupation there was assigned to an "unnamed interval" between 1200 B.C. and perhaps 2100 B.C. (Mabry 2005a:51), and no Chiricahua-type points have been reported there. The Los Pozos site is located in the Holocene floodplain and was investigated using 55 m^2 of excavation across a deeply buried occupation. The occupation was characterized by lenses of ashy debris and five cooking features that contained lagomorph and artiodactyl bones, FAR, one core, and nine flakes, as well as one oxidized, shallow depression (Gregory, ed. 1999; Sliva 1999). The features indicated occupations between 2700 and 1900 B.C. (Gregory and Baar 1999:28).

Sliva (1999) described 2,875 flaked stone artifacts from the Archaic period component, 95 percent of which were flakes. The flaked stone debris was characterized by mostly fine-grained local volcanic materials, although several varieties of chert were represented amid the debitage. More than half the debitage was probably biface-thinning debris. The tools included small ("exhausted") multidirectional and unidirectional bifaces, biface flakes, and rare biface cores (Sliva 1999:35–41). Only 6 flakes showed evidence of having been utilized, and retouched unifaces, including scrapers, were also scarce. The biface collection included mostly broken pieces made from local materials. The prevalent tool at the site was the projectile point, represented by 4 untyped side-notched points, 14 Cortaro points, and 2 distal fragments. The Cortaro points were so poorly executed that Sliva interpreted them to be a form of expedient knife/projectile point. One of the untyped side-notched projectile points (Sliva 1999:Figure 3.4d) appeared to be a Chiricahua point.

The site was interpreted to be a "gearing-up" site that was used by logistically organized hunting parties during the Middle Archaic period.

Middle Archaic Period Land Use and Technological Organization

Based on the sites and projects discussed above and many smaller sites and projects, a general model of Archaic period land use has emerged that sets the Middle Archaic period at the forager end of a long pause between the introduction of maize and the appearance of sedentary agricultural villages. The settlement patterns modeled for Middle Archaic period groups in the basin-and-range landscape of the U.S. Southwest have focused on two environments: the basins and the ranges. A dual-zone pattern of seasonal transhumance has predicted the movement of highly mobile forager groups between summer-fall residential sites and winter-spring hunting camps (Huckell 1996; Whalen 1971; Wills 1988). For the Tucson Basin, Roth and Freeman (2008) proposed a schedule involving the seasonal movement of Middle Archaic period foragers between floodplains and upper-piedmont/montane sites. In that construct, floodplain base camps witnessed late-spring occupations devoted to harvesting spring plants and mesquite, and by summer, Middle Archaic period groups moved onto piedmont slopes to collect saguaros at small sites, returning to the floodplains in late summer to exploit weedy annuals, grasses, and mesquite, until winter, when they moved into montane environments to collect nut masts and to hunt. The lower *bajadas* separating riverine and montane/upper-*bajada* environments do not rank as important human habitats or resources in these models.

The scale of Middle Archaic period mobility is imagined to have been large, based on obsidian-provenance studies and ethnographic analogies (Roth 2000; Shackley 1986; Vierra 1994). The introduction of maize farming is expected to have decreased residential movements and favored the use of logistical task groups—a change in strategy that Mabry (2005b:12) argued was complete by the San Pedro phase in the Tucson Basin. Premo and Mabry (2003) used GIS data from more than 60 sites in the Tucson Basin to evaluate Late Archaic/Early Agricultural period settlement patterns, concluding that a model including "farmer-collectors" who occupied large villages in the floodplains and used logistical forays to exploit patchy, seasonal resources at higher elevations best matched the bimodal distribution of sites.

The technological consequences of a drastic reduction in residential mobility during the Middle Archaic period are not evident in the stone tools. Middle and Late Archaic period lithic technologies have indicated strong continuity and have been characterized as indistinguishable, except for changes in projectile points (Dick 1965; Haury 1950; Huckell 1996; Sayles 1983; Sliva 2005). Shackley (1990:77) also noted that the diversity of informal flaked stone tools described in Middle Archaic period collections contrasts with the limited number of formal tool types, with the primary exception of projectile points. Sliva (2005:86–92) applied a forager-collector model to a substantial body of published data, exploring the frequency of bifaces and unifaces between the inferred site types, and concluded that a complementary tool set was used by Archaic period foragers and later agriculturalists alike during their seasonal rounds or task-oriented forays. Perhaps the only distinction between Middle and Late Archaic period flaked stone tools is the more frequent use of high-quality raw materials during the Middle Archaic period (Huckell 1996:355; Sliva 2001:103–104). These findings reinforce arguments that the incorporation of maize was a "non-event" in the lives of pre-ceramic foragers (Haury 1950; Martin et al. 1952; Minnis 1985).

The archaeology of the Middle Archaic period in the U.S. Southwest clearly articulates with widespread environmental, social, and technological changes that mark a wholesale increase in the abundance and intensive processing of available plant foods relative to the early archaic. This is important, because among nearly all contemporary hunter-gatherers, women gathered and processed plants, and men hunted animals, especially large animals. Plant gathering was local, low risk, and sustainable; in behavioral ecology, it is regarded as a risk-aversion strategy that underwrote the risky, high-payoff hunting behaviors of men (Bliege-Bird 1999). The technological organization of Middle Archaic period populations in coastal California was examined by Buonasera (2012) within a context of population expansions, increased sedentism, territorial circumscription, and the intensified processing of lower-ranked foods (acorns) (McGuire and Hildebrandt 1994). The widespread proliferation of the mortar and pestle in coastal California is argued to mark a significant increase in the sexual division of labor around 3500 B.C. (Jones 1996).

Nowhere in the U.S. Southwest does the Middle Archaic period archaeological record indicate the level of social complexity that was occurring at some locations in coastal California, but it does show the appearance of diverse plant-food-processing technologies in an economy characterized by logistical hunting strategies and increased plant processing—a system that would have demanded significant labor investments by women. The sexual division of labor practiced by Middle Archaic period foraging societies in the U.S. Southwest is unknown, however, and archaeological sites have been characterized by a mixture of subsistence pursuits and, usually, utilitarian artifacts. The lack of change observed in the lithic technologies of Middle Archaic period to Cienega phase foraging populations may indicate that the sexual division of labor that typified complex coastal societies did not go hand-in-hand with increased plant processing. In terms of mobility, an unchanging lithic technology suggests that people either maintained high residential mobility until the latter part of the Cienega period or practiced frequent, long-range logistical mobility earlier than has been thought (Diehl and Waters 2006; Roth 1995). Mabry (2005a:61) pointed out that both the Cave Creek Midden site and the Arroyo site were associated with occupational middens, and Fish et al. (1992) argued that resource abundance and diversity in riverine settings and elevated basins would have necessitated only biseasonal movements during the Late Archaic period.

Setting

The Luke Solar project collection comes from the rockless lower distal piedmont between the White Tank Mountains and the Agua Fria River, on the western edge of the Phoenix Basin. In the context of stone industries, the most profound aspect of the project setting is the absence of rocks. The availability and quality of raw materials played important roles in how people managed expendable resources such as stone tools and whether their assemblages appear to have been "curated" or "expedient" (Bamforth 1986). Another important aspect of the project setting is its low biodiversity. Situated at an elevation of approximately 350 m AMSL, LAFB is located in the Lower Colorado Subdivision of the Sonoran Desert, where late Holocene climax community vegetation was dominated by saltbush, grasses, and mesquite (see Chapter 2, Volume 1). A complete review of the project setting has been provided in Chapter 2, Volume 1. Here, we review the lithic landscape around LAFB and call out its archaeological significance.

The nearby Agua Fria River runs north–south for approximately 145 km and has headwaters around Prescott, Arizona. The modern bedload and terrace gravels of the Agua Fria River originate from high-energy floods draining roughly 3,700 km^2 of mountains before entering the Phoenix Basin about 30 km north of LAFB. Bedload materials are highly rounded, and a study of modern gravel operations in the Agua Fria River indicated that most clasts have been transported farther than 40 km (Langer et al. 2010). The Agua Fria River channel is now confined 7 km east of the Luke Solar project area, across a broad fan with a slope of less than 0.5 percent. The Agua Fria River channel would have provided an abundant and economical source of pebble- to boulder-sized rocks for flaked- and ground-stone-tool needs.

Quantitative estimates of the amounts of chert, vesicular basalt, and other important lithic types in the Agua Fria River are not available, but the relative abundances of the most common rock types were provided by Langer et al. (2010). Basalt constituted a small percentage of lithic clasts, at 2 percent; meta-rhyolites, 9 percent; and combined tertiary felsic-volcanic/sedimentary rocks, 31 percent (see Chapter 2, Volume 1). Various other coarse-grained metamorphic and plutonic rocks made up the remainder of the sample. The Agua Fria River offers an ample supply of rocks suitable for the production of both flaked stone and ground stone tools in the Luke Solar project collection. Cherts and other cryptocrystalline materials were not reported in commercial gravel studies (Langer et al. 2010), but a brief, informal survey of the local Agua Fria River gravels by SRI successfully located a modest supply of fine-grained rhyolite, basalt, and chert nodules.

Other potential sources of rock are ancient gravel units exposed in the vicinity of the salt domes immediately south of the project area. According to Cooley (Eaton et al. 1972:2), those deposits consist of rounded to subrounded pebbles as well as a few rounded cobbles and small boulders as much as 40 cm in length composed of volcanic, granite-gneiss, and other silicic rocks similar to those transported by the Agua Fria River (see Chapter 2). However, the location of those gravel-bearing exposures is unknown and therefore assumed to be of limited size and accessibility. The White Tank Mountains, located approximately 13 km to the west-northwest, could have served as a source of tabular ground stone materials. Those mountains are predominantly plutonic, mostly granitic, but also include a variety of more mafic compositions (Reynolds et al. 2002). Some amount of metamorphic material, especially gneiss, is also available. To the north, the Hieroglyphic Mountains provide a greater diversity of lithic types. Low- to medium-grade metamorphic materials predominate in surface exposures, but a variety of felsic and mafic volcanic units are also present (Burr 1992). To the northeast, the Hedgepeth Hills would provide an ample supply of basaltic cobbles. These landforms are drained by the Agua Fria River and its tributaries, however; so, their rocks are available in the local gravels. The only common prehistoric material lacking in the Agua Fria River basin is obsidian, and the nearest outcrop is the Vulture source, approximately 45 km west of LAFB (Shackley 2005).

As described in the previous section, well-documented Middle Archaic period collections are generally from rocky settings near channels, on the upper piedmont, or inside caves. Lower piedmonts generally lack the diversity of stone resources required by hunter-gatherers. The wide disparity between food resources and technological resources makes these locations ideal for examining forager solutions under high selective pressure.

Methods

The Luke Solar project lithic analysis was conducted in the SRI laboratory in Tucson, Arizona, between April and July 2013. A representative sample of stone artifacts constituting less than 5 percent of the total sample was assessed by the lead author to guide the analysis, and a protocol was provided by Brad Vierra. The flaked stone analysis was performed by Matt Pailes, Karry Blake, and Jesse Ballenger. Matt Pailes and Jesse Ballenger described the complete ground stone items. Matt Pailes provided photomicrographs and observations. Nick Hlatky and Cannon Daughtrey assisted with the FAR analysis. John Hall and Amelia Natoli examined the co-occurrence of complete artifacts (caches). John Hall and Robert Wegener summarized previous Middle Archaic period projects and collections. Janet Griffitts graciously described the stone pipe and beads. All observations were entered into SRID 2, a proprietary inter-relational database.

The chronology of the Luke Solar project sites played a paramount role in how the analysis was conducted and how the results are organized. The lithic analysis was prioritized based on the project radiocarbon-sampling process, which prioritized contents from thermal features. Burning, in general, guided the selection of which features were sampled in the mechanically stripped areas (see Chapter 3, Volume 1). The contents of structures and projectile-point-bearing pits received priority over a list of recovery contexts with diminishing potential for chronological control. Consequently, the analysis began with a look at the projectile points and the burned, broken ground stone from thermal features and concluded with the complete, extramural ground stone. Because so many complete ground stone items were not associated with thermal features, a minority of them were precisely dated. Chronological control for the Luke Solar project collection was provided by radiocarbon dating and geologic correlation; 16 percent of the artifacts in the collection were from radiocarbon-dated features, and the remaining artifacts were dated based on their stratigraphic positions (see Chapter 2). The analytical groups used to organize the lithic artifacts included the Sulphur Spring (9500–3500 B.C.), early Chiricahua (3500–2100 B.C.), late Chiricahua (2100–1200 B.C.), San Pedro (1200–800 B.C.), Cienega (800 B.C.–A.D. 50), and Red Mountain (A.D. 50–400) phases and the pre-Classic (A.D. 400–1150), Classic (A.D. 1150–1450), Protohistoric (1450–1800), and Historical (post-1800) periods. Many stratigraphically dated artifacts were included in the Cochise group (pre-800 B.C.) or the Cochise to Historical period group (pre- and post-800 B.C.) or were not dated.

During the course of the analysis and data entry, raw-material and morphological type specimens were set aside in a reference collection. This collection permitted constant visual checks by the analysts and numbered several-hundred items. In this regard, the Luke Solar project analysis was thorough and consistent. Analysis of the Luke Solar project collection included the morphometric and technological descriptions of each artifact, following conventional methods and landmarks (Adams 2002; Andrefsky 2005; Cotterell and Kamminga 1987; Odell 2004); macroscopic and low-power microscopic use-wear analysis on select tool classes; raw-material analysis, including geochemical sourcing; and consultation with Native American elders. Several artifact photographs are included to show the range of variability in the collection, and wear patterns on select types were digitized. This section reviews the methodological protocols and decisions that guided the analysis.

Definitions and Analysis

Typological classification is the cornerstone of artifact analysis, but it can also be the most subjective component of analysis, and it masks variation. Certain ground stone tools belong to what Adams (2002) characterizes as "fuzzy sets" that do not conform to ideal typologies. The Luke Solar project collection, for example, illustrates how alluvial cobbles test the tenuous connection between form and function. The function of an implement more easily lends itself to nominal categorizations, as opposed to the continuous variation present in form. This is especially pronounced in the case of alluvial-cobble-based assemblages in which different functional types lie along what is truly an unbroken gradient toward a common form. This is most pronounced in regard to a unique class of implements formally referred to as "Lukeoliths." These tools lie on the continuum that spans metates and pestles (Figure 38). At each of the two ends of the spectrum, form correlates to an obvious functional role, and the schema is coherent. As one approaches the center of the continuum, the relationship between form and function becomes ambiguous. In such cases, we relied on wear patterns to determine the primary function of an implement and recorded additional wear as secondary. Projectile point classification also requires decisions about what are often poorly made, worn-out, and broken tools. We illustrate nearly all of the "typed" projectile points in the collection. The artifact classes used to organize the lithic collection included flaked stone, ground and battered stone, and expedient stone, as defined in the following sections.

Raw Materials

The earliest typological decisions made during the analysis concerned raw-material types. Representative rock types were selected from the flaked stone and ground stone collections and used as references throughout the analysis. Raw-material identification was based on macroscopic and, when necessary, microscopic inspections using an Olympus SZX12 with a magnification range of 7×–90×. Lithic classifications that grade into one another based on chemical composition (e.g., rhyolite, dacite, andesite, and basalt) were determined solely according to macroscopic qualities of visible mineral grains and texture. All stone materials were assigned to one of 53 generic rock types. Flaked stone subtypes were created based on a project-specific reference collection that included 12 rhyolites, 9 cherts, 4 basalts, 3 quartzites, and 1 example each of chalcedony and siltstone. The flaked stone subtypes described in the analysis are defined in Table 14.

Obsidian artifacts were identified during the inventory and analysis process and sent to Dr. Steven Shackley for provenance analysis via Energy Dispersive X-ray Fluorescence (EDXRF), including several minute obsidian flakes identified in flotation samples. With the exception of a broken projectile point associated with a cremation burial at Site 68, all of the obsidian included in the Luke Solar project collection was submitted for EDXRF analysis. Shackley has provided the methods and protocols of the obsidian-provenance analysis (see Appendix 3.1).

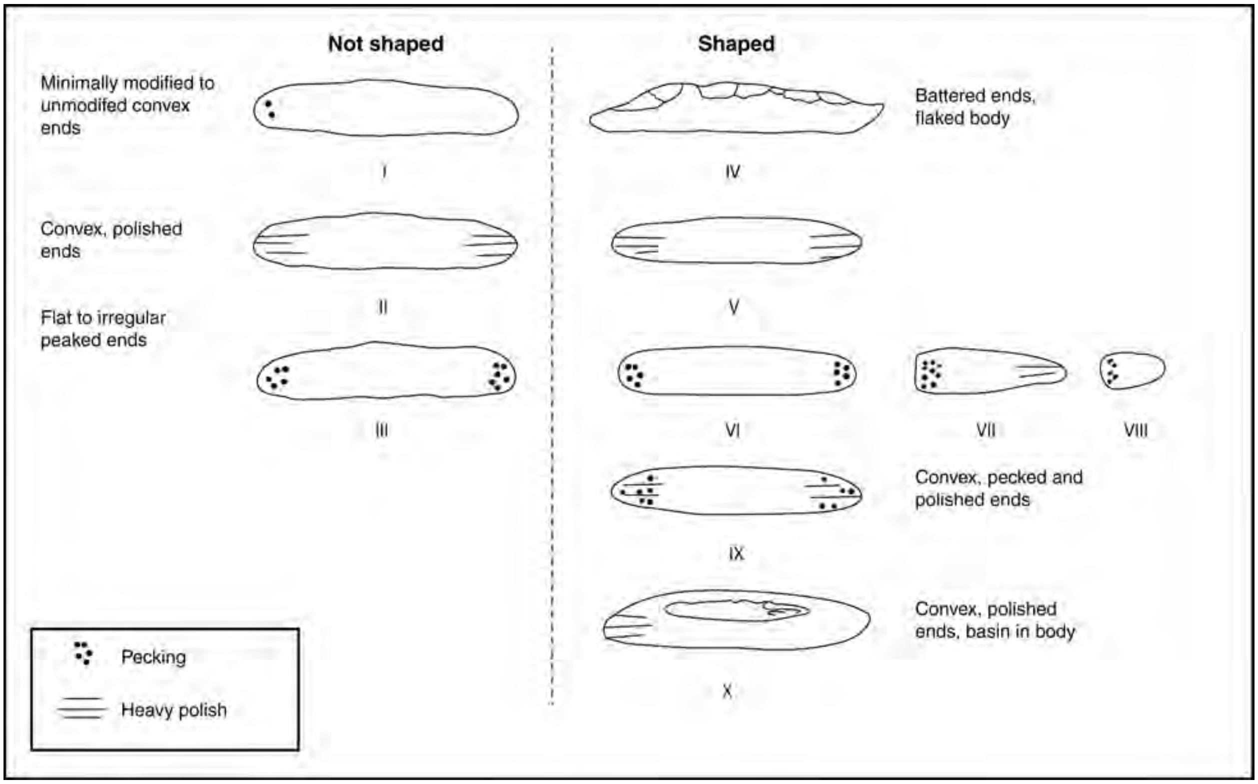


Figure 38. Schematic representation of pestle subtypes recognized in the Luke Solar project analysis.

Table 14. Raw-Material Subtypes Identified in Falcon Landing Flaked Stone Collection

Subtype Name	Description
Chert 1	This material is mottled with a base color near 10YR 7/2. Accessory colors include speckles and streaks of red and blotches of light to dark gray. The material is most often translucent but varies to opaque. Internal flaws are rare but larger grains of silica were observed.
Chert 2	This material is a generally homogenous but slightly variable with a glossy luster and color near 10YR 7/3. Its cortex is a light brown, 7.5YR 6/4. The material is generally translucent with occasional zones that are more white or orange in color.
Chert 3	This material is an opaque glossy, deep red color closest to 7.5R 3/4. It is most often speckled with areas of translucent white to gray that appear dark due to the opaqueness of the surrounding red material. SRI collected a small nodule of chert resembling this material from the local gravels of the Agua Fria River.
Chert 4	This material is quite similar to Chert 3 with a glossy luster and color range centered around 7.5R 3/6. It is typically speckled with very small black, opaque spots.
Chert 5	This material is also an opaque, glossy red with a base color closest to 7.5R 3/3. It contains many small speckles and veins of translucent to opaque white.
Chert 6	This material is an opaque, glossy, banded gray with a base color near 2.5YR 6/1. It has numerous inclusions of friable silica, which likely formed in very small vesicles.
Chert 7	This material is an opaque, glossy, mottled purple-gray and white with an amalgamated color closest to 5YR 5/1. The mottling is fine enough that the color appears homogenous unless inspected closely.
Chert 8	This material is a matte tan, 7.5YR 6/2. It contains numerous very small speckles that are black in color.
Chert 9	This material is a predominantly yellow-brown opaque matte color closest to 7.5YR 4/6. It is mottled by streaks of translucent material that appear gray and speckles of opaque white.
Siltstone 1	This material includes a range of matte colors from 5YR 4/2 to 2.5YR 6/2. It is often banded with darker streaks. The texture is quite fine, but is clearly more coarse than cryptocrystalline material.
Metaquartzite 1	This material ranges in color from 10YR 7/4 to 7.5YR 5/6. The color variation will often be present on a single flake. The material is highly metamorphosed, creating a glossy, sugary appearance common to quartzites.

Subtype Name	**Description**
Metaquartzite 2	This is a matte gray-brown closest to 10YR 5/2. The material is very homogenous and very fine grained and easily mistaken for a volcanic rhyolite.
Metaquartzite 3	This material is most similar to 7.5YR 4/1. The material has streaks of lighter-colored material and is very glossy with a sugary texture.
Metaquartzite 4	This material is gray-green to red in color. The cortex has rectangular (cell-like) structures, with interior laminate structures causing microscopic steps on the breaking surface
Basalt 1	This is an extremely fine-grained almost glossy material with no visible grain boundaries and fracture properties very similar to cryptocrystalline material. It is usually a homogenous black color, but occasionally contains bands of slightly greener and coarser material.
Basalt 2	This is also an essentially homogenous black material. It is a coarser material than Basalt 1with correspondingly cruder fracture properties.
Basalt 3	This material is a homogenous reddish black with color close to 10R 2.5/1. The cortex is a more clearly red color near 10R 4/2. The material is extremely fine grained and smooth. Basalt 3 is the only possible nonlocal variety of basalt in the reference collection.
Basalt 4	This material is most similar to 5Y 3/1. It is streaked with nonparallel bands of a slightly green lighter color. It is very fine grained but more coarse than Basalt 1 or Basalt 3. Basalt 4 is common in the flaked stone collection.
Rhyolite 1	This material is highly variable and may represent several different source materials. It ranges in matte colors from 7.5R 5/2 to 7.5YR 6/1. All varieties are mottled with various streaks and bands of reddish and grayish material. Small phenocrysts of quartz and feldspars—most likely plagioclase—are occasionally present.
Rhyolite 2	This material's base color is closest to a matte 10YR 6/3, but large splotchy areas of a pinkish to reddish hue are also present. Very small phenocrysts of quartz are present. The texture is slightly glassy.
Rhyolite 3	This material is fairly homogenous within individual specimens but ranges from 10R 4/2 to 5R 4/1. Small speckles and streaks of slightly different colors are occasionally present. The range of base colors may indicate this material actually comes from multiple sources. The texture is glassy, with rare and very small phenocrysts of quartz.
Rhyolite 4	This material is highly mottled and speckled. Its base color is bimodal around 7.5R 3/4 and 2.5YR 4/1. Most varieties contain small black speckles produced by very small imperfections and vesicles. Mottling tends to mix the two predominant colors with some small gradient between the two. The material is glassy.
Rhyolite 5	This material is quite similar to Rhyolite 1 with a matte color near 7.5YR 5/1. Unlike Rhyolite 1, it lacks streaks, but is very similar in texture. Very small phenocrysts are present.
Rhyolite 6	This material is nearly black with some varieties grading into a very dark gray. The material is glassy and of high quality but contains many distinctly green, translucent phenocrysts up to 4 mm in diameter.
Rhyolite 7	This material is a matte reddish brown, 2.5YR 5/3. It appears superficially similar to Siltstone 1, but it is finer grained and often contains bands and streaks of darker, more reddish material.
Rhyolite 8	This material is near black, 5YR 2.5/1, but slightly translucent at the thinned edges with a reddish hue. It is glassy with no visible phenocrysts.
Rhyolite 9	This material is a weak red to pink, most often near 10R 5/3, but frequently grading into lighter colors. It is often banded with lighter shades of pink, but it is most easily identified by the presence of quartz phenocrysts, some as large as 2 mm.
Rhyolite 10	This material is a heavily banded weak red, 7.5R 4/3. Most of the bands are darker in color ranging towards a deep purple. Phenocrysts are common with sizes up to 2 mm. The material is coarser than many varieties, but is still glassy.
Rhyolite 11	This material most closely resembles 2.5YR 4/1. It is generally homogenous but a few dark speckles can be present as well as very small phenocrysts of quartz. The material is glassy.
Rhyolite 12	This material is most similar to 10Y 6/1. It is mottled with splotches of a deeper green color. The material is glassy.
Chalcedony 1	This material is mottled with a yellowish brown 10YR 5/6 as the dominant color. The mottling material is a translucent white. The material is glossy and of high quality.

Flaked Stone Artifact Classes

As an analytical unit, flaked stone artifacts are defined by their method of manufacture—that is, the percussion and pressure reduction of isotropic materials to achieve a desired form or to create a separate flake. Eight classes of flaked stone tools were used to describe the Luke Solar project collection, as discussed below.

Cores

Cores are the nuclei of flaked stone technologies, the parent rocks from which pieces were detached to create multiple tools and, in many circumstances, to reduce the core into a single tool. Core technologies vary across time and space in response to initial conditions (Andrefsky 1994), the purpose and design specifications of the desired flake (Cotterell and Kamminga 1987), and human settlement and mobility patterns (Parry and Kelly 1987). Formal cores with significant investment in shape are generally made lenticular (biface cores) or conical (blade cores), reduction strategies that Andrefsky (2005:137) distinguished as multidirectional or unidirectional, respectively. Informal cores that lack investment in shape can range from tabular to blocky, depending on nodule morphology and reduction intensity. Minimally flaked nodules that lack evidence of use were described as *tested cobbles*.

The Luke Solar project collection included two dominant core categories: *blocky cores* and *cobble-uniface cores*. Blocky cores include unidirectional and multidirectional cores that show opportunistic flake removals and less concern for core shape, whereas cobble unifaces show the systematic unifacial reduction of cobbles as generally having progressed from one polar end to the other. Both categories of cores are executed on alluvial cobbles. The utility of blocky cores and cobble unifaces is partly a function of volume. Blocky cores were measured on three conventional axes, whereas cobble-uniface measurements specified the longest flake scar (length), the width of the cobble (width), and the length of the cobble (thickness).

Less common core types include *biface/disk cores, flake cores,* and *blade cores*. Biface/disk cores are defined as large, thick, ovate bifaces with multiple large, controlled flake removals. Flake cores are large flakes, usually decortication flakes, that show the subsequent removal of large flakes. Blade cores are characterized by carefully prepared platforms and often unidirectional and parallel flake scars that are longer than they are wide. *Core tools* are typically cores with edge modification indicative of scraping or battering.

Debitage

The debitage analysis began by selecting the largest and richest collections available and sorting them into nodule-scale raw-material categories (Larson and Kornfeld 1997). Common, distinctive, and exceptionally high-quality varieties of raw materials were set aside as part of the reference collection. Debitage samples were analyzed as batches based on their proveniences and ranged from a single flake to several-hundred flakes; however, most batches contained fewer than five flakes each. The debitage analysis entailed sorting individual batches according to raw-material type, portion, technological type, size, platform type, platform preparation, cortex type and location, and thermal alteration.

Flake portion was recorded as *complete, proximal, distal, lateral,* or *indeterminate*. Technological type refers to the reduction strategy that produced the flake and included *core flakes, biface-thinning flakes, blades, bipolar flakes, microdebitage,* and *indeterminate/shatter*. Core flakes were distinguished by wide platforms that were plain or dihedral, platform angles greater than 75°, cortical surfaces, dorsal flake-scar orientation, thickness, and bulb morphology. Core-trimming flakes should be expected with the production of controlled flakes, but they vary with core technology and are difficult to isolate in archaeological assemblages. Biface-thinning flakes were recognized by multifaceted platforms, a ventral lip, acute platform angles, noncortical surfaces, dorsal flake-scar orientation, thinness and curvature, and bulb morphology. A bipolar flake created using a hammer-and-anvil technique may have compression rings and crushing on both polar ends, or bipolar flakes may be splinters and angular debris. All complete flakes were measured and placed in ordinal 10-mm size categories based on the length of each flake perpendicular to the platform. Microdebitage was defined as complete flakes measuring less than 10 mm each in length. Minute but incomplete pressure flakes were also classified as microdebitage.

Platform type was recorded as absent, crushed, cortical, single faceted, multifaceted, or dihedral, and platform preparation was determined based on evidence of edge grinding. Cortex was recorded as present or absent, and cortex type was described as primary, waterworn, or indeterminate. Cortex location was attributed to dorsal surfaces and platforms. Thermal discoloration, crazing, and pot lids were noted, when present.

Edge-Modified Flakes (EMFs)

EMFs are flakes that exhibit modification along one or more edges, independent of what agency created the modification. Sharp edges can be modified by wind and water, trampling, or transport. Some forms of platform preparation can also mimic retouch. EMFs are distinguished from scrapers and knives by their informal design, to include retouch that modified an edge without significantly reshaping the flake. Many EMFs probably functioned as expedient scrapers and knives. Modification created by edge retouch is easily detected, but use modification is difficult to detect, especially on coarse-grained raw materials. Each piece of debitage in the Luke Solar project collection was individually handled and inspected for retouch and macroscopic use modification. Retouched edges were described and measured in terms of number, length, and angle.

Scrapers

Scrapers are formal retouched pieces, most often flakes, that exhibit abrupt, unifacial, noninvasive retouch. Hafted and unhafted scrapers are distinguished by their morphologies and locations of retouch/use. Hafted scrapers functioned on one axis and are typically recognized as *end scrapers*, whereas unhafted scrapers could function on more than one axis and are generally described as *side scrapers* or ovoid scrapers. *End/side scrapers* show end and side retouch, although lateral flaking may be related to shaping rather than use. *Scrapers/planes* are high-domed scraper-like implements with planar bottoms that exhibit polished flake scars (arrises) and rounded/crushed edges from use as planes. Inverted, they can resemble unidirectional cores with prepared platforms, which they also may have been. The scrapers in the Luke Solar project collection were classified according to type, and their retouched edges were described and measured in the same manner as those of EMFs.

Knives

Flaked stone knives can range from unmodified flakes to blades and formal bifaces and have cutting edges that range from straight to serrated and retouch that is unifacial or bifacial. Despite their simple design requirements and universal use, “knife” is a poorly described artifact type in the U.S. Southwest. This category was used conservatively during the Luke Solar project analysis to describe a single unique retouched tool.

Drills

Awls and punches made from flaked stone are conventionally described as drills, but they obviously lack the characteristic drill threads. Drills were typically made from flakes by shaping one portion of a flake into a long, narrow projection with a diamond cross section and some form of tip, so that the finished tool was key shaped. Projectile points were occasionally reworked into drill-shaped implements.

Bifaces

Bifaces are flaked stone tools that have been deliberately worked on both sides. The reduction of large bifaces is sometimes expressed as a series of arbitrary stages defined by the dimensions and edge angles of a piece (Callahan 1979), but the model is less useful for describing small bifaces made on thin flakes. Biface-reduction trajectories generally resulted in one of four kinds of bifaces in the archaeological record: cores, knives, projectile point preforms, and projectile points. The items described as bifaces in the Luke Solar project collection were those deemed not to have functioned as cores, knives, or projectile points; many of them were in the size range of projectile points but lacked the symmetry and craftsmanship generally invested in finished projectile points. Many of the artifacts in the “biface” category appeared to be broken and discarded projectile point preforms. The biface sample was described in terms of five major attributes and variables: completeness, size, edge angle, breakage, and raw-material type.

Projectile Points

Projectile points are generally bifaces that possess haft and tip components for use as dart tips and arrowheads and are generally symmetrical in form. The projectile points were organized into a typological framework and documented in terms of their metric attributes, completeness, piercing potential, edge morphology, retouch, breakage type, and raw-material type.

The assumption behind measuring piercing potential is that it conveys information about the tool's function or intended function. Projectile points correlate to hunting in most interpretive constructs, but the archaeological and ethnographic records indicate that they also functioned as knives, awls, burins, and scrapers, among other things. The Luke Solar project collection included complete points that were extremely sharp and others that had dull, rounded tips. Sharpness is a component of any discussion about penetration (Knecht 1997; Waguespack et al. 2009), but projectile point sharpness is an unconventional measure. We measured piercing potential somewhat informally by the presence or absence of a sharp distal tip. Sharp tips are sharp to the touch and potentially capable of piercing the skin with moderate pressure against the anterior side of the index finger, whereas nonpiercing tips can be pressed firmly against the skin without risking a puncture. Edge morphology focused on the presence or absence of retouch, serrations, and beveling.

Accurate quantitative measures of biface retouch are usually beyond the reach of lithic analysts, but it is possible to infer whether or not a tool is still useful. Bifaces used as projectile points generally became shorter with breakage and tip refurbishment (Ahler and Geib 2000), whereas "projectile points" used also as knives became narrower and shorter with blade refurbishment (Shott and Ballenger 2007). For the Luke Solar project collection, retouch was recorded as present or absent and bifacial or unifacial. The presence of impact fractures was noted among the incomplete and retouched points. Finally, raw-material type was determined using the reference collection and was accompanied by an inspection for evidence of heat treatment or damage.

The Archaic period projectile point typology of the U.S. Southwest is famously ambiguous and convoluted, especially for the Middle Archaic period (Bayham 1986a; Huckell 1984a). The earliest post-Clovis projectile point collections of significant diversity and size are associated with the Chiricahua phase (Sayles 1983) and the Chiricahua–Amargosa II component at Ventana Cave (Haury 1950). A number of discrete types are now recognized in those and other collections (e.g., Loendorf and Rice 2004), but their age and significance, in terms of the human paleoecology of the U.S. Southwest and cultural affiliations, are still poorly understood. Each type has its own vagaries, as described below.

Contracting Stem

Several terms and formal type names have been used to describe dart points or knives characterized by a long, contracting stem but otherwise exhibiting a broad range of technological and stylistic variation. The most widely established type names include Lake Mohave and Silver Lake, which are characteristic of the Western Stemmed complex (Willig and Aikens 1988) and have occurred from California, across the Great Basin, to the lower Colorado River basin (Amsden 1937; Brott 1966; Rogers 1939; Warren 1967). Stemmed points from the northern U.S. Southwest are typically described as Jay-type points (Irwin-Williams 1973). Western Stemmed points at Paisley Caves, Oregon, dated to as early as 11,000–11,200 B.C. (Jenkins et al. 2012); Jay-type points have been dated to between about 5900 and 7000 B.C. (Irwin-Williams 1973; Wiens 1994) and possibly continued to be in use as late as 2500 B.C. (Vierra 2009). The Red Sand layer at Ventana Cave indicated that those forms were present in the U.S. Southwest after about 7700 B.C. (Huckell 1996).

Middle to Late Archaic period forms with contracting stems include the distinctive Gypsum Cave type (Harrington 1933) and generic forms sometimes described as "leaf shaped" (Bayham 1986a). Sayles (1983:76) described the latter from both San Pedro and Chiricahua phase components but attributed them to projectile point preforms. Haury (1950:266) compared the "leaf-shaped" bifaces from Ventana Cave to small knives reported in San Dieguito II collections (Rogers 1939:34).

Pinto/San Jose

Pinto/San Jose points are two separate projectile point types that represent historically entangled but clearly distinguishable tools at both ends of the typological spectrum (Justice 2002:142; Mabry 1998a:68). Pinto-type points symbolize Early Archaic period populations best known from the Mojave Desert and the Great Basin (Campbell and Campbell 1935; Harrington 1933; Rogers 1939), and San Jose points were widespread throughout the U.S. Southwest between about 4000 and 2200 B.C. (Bryan and Toulouse 1943; Irwin-Williams 1973). One problem is the enormous range of the typological spectrum. Warren (1980:73) described the Pinto typology as "schizoid," and Huckell (1996:340) described the San Jose type as a "catch-all" category. However, Pinto-type points with bifurcated bases have occurred across the U.S. Southwest, especially on the Colorado Plateau (Formby and Frey 1986), where they dated to between 7000 and 6000 B.C. (Bodily 2009; Janetski et al. 2012). Haury (1950:203) made comparisons between the stemmed points in the Red Sand layer at Ventana Cave and Pinto points, noting that the single difference was the lack of basal notching on the former. Pinto points continue into the overlying stratum, but comparisons with San Jose points are complicated, because the typological scheme employed by Haury (1950:Figures 50 and 51) did not distinguish basal notching from basal concavity. Bayham (1986a:Figure 10.4) introduced the "Pinto/San Jose" construct to describe the Picacho Reservoir Archaic Project collection that included as many as five Pinto points, one exhibiting a deep basal notch. Bayham (1986a:224) explicitly stated that most of the examples from that project collection more closely compared to the San Jose type.

First defined by Bryan and Toulouse (1943) in the vicinity of Grants, New Mexico, San Jose points are distinguished by relatively long stems that have incurvate edges and concave bases that are equal in width to their necks. Some have sharp basal corners, and others have small, rounded ears; serration is common (Sliva 2009). San Jose points extend from the Colorado and Coconino Plateaus of northern Arizona south to northern Sonora and Chihuahua, Mexico, and to the east as far as the Estancia Basin.

Chiricahua

The Chiricahua projectile point type was originally recognized as being intrusive into Chiricahua phase deposits at Cave Creek Midden (Sayles and Antevs 1941). It has also been described as an Amargosan technology, based on excavations at Ventana Cave (Haury 1950:299). The type was previously considered an unnamed and uncommon style diagnostic to the Middle or Late Archaic period (Huckell 1984a:196). Shackley (1990:67) pointed out that the Chiricahua projectile point type, itself, had yet to be precisely defined nearly 50 years after Sayles and Antevs (1941) described the Cochise cultural sequence. Some researchers still consider it a poor temporal marker (Wills 1988). Chiricahua points are typically described as short, side-notched, concave-based projectile points with excurvate blades that generally lack serrations but are often reworked (Bayham et al. 1986:429; Dick 1965:30; Lorentzen 1998:146; Sayles 1983:75). The type is difficult to distinguish from Middle Archaic San Rafael Side-notched points (Holmer 1986; Justice 2002:154). The size range of Chiricahua points has been poorly documented, because archaeological examples were frequently retouched and often completely exhausted. Lorentzen (1998:146) observed that Chiricahua points include both percussion- and pressure-flaked varieties, the latter on thin flakes. The distribution of these points is generally limited to the U.S. Southwest, with rare finds in Sonora, Mexico (Sanchez-Morales 2012), and the Coconino Plateau (Lyndon 2005:71).

Chiricahua points have been radiocarbon dated at a limited number of sites. Bayham (1986a:222) reviewed two dates reported by Sayles (1983:50) from the G. P. Sonora site (AZ FF:10:4 [ASM]) that ranged between 4400 and 1900 B.C. At the Buried Dune site, Bayham (1986a:226) recovered one Chiricahua point bracketed between 3500 and 2900 B.C., based on two AMS radiocarbon dates. A second Chiricahua point from the Buried Dune site was recovered from a midden associated with a single conventional radiocarbon age of between 3300 and 1700 B.C. Huckell (1996:337–338) provided a review of radiocarbon dates that placed Chiricahua points between approximately 3500 and 2400 B.C. Justice (2002:166) renamed the type Ventana Side-notched and assigned an age range of 3500–1800 B.C.

Cortaro

The Cortaro projectile point type was originally defined by Roth and Huckell (1992), based on excavations at the Cortaro Fan site (Roth 1989). Diagnostic traits include a triangular to lanceolate outline with a basal concavity that ranges from a deep indentation to nearly straight. Cortaro points are generally described as being thick, around 6–7 mm, and were made from percussion-flaked bifaces that were sometimes finished with fine pressure flaking. Broken and reworked blades are common, but they uniformly lack serration. Basal edges were not ground. Quality craftsmanship is rare compared to other Middle Archaic period projectile point types (Roth and Huckell 1992:357), so much so that Sliva (1999:41) questioned what functional niche the tool filled, suggesting that it could have been an expedient solution to knife or projectile point needs. The geographic distribution of Cortaro points appears to be limited to the U.S. Southwest.

The chronological range of Cortaro points was provided by Sliva (2009), based in large part on the Los Pozos site, where they appeared sometime between 3500 and 2100 B.C. The technology may have persisted into the Late Cienega phase, between 400 B.C. and A.D. 50. At Las Capas, SWCA Environmental Consultants (SWCA) determined that Cortaro points were the only points found in the Stratum 6B Middle Preceramic period deposits and were associated with early maize (ca. 1940–2200 B.C.). Empire and San Pedro points were recovered from the overlying Stratum 6A Late Preceramic period deposits. Cortaro-maize associations have also been documented at the Clearwater site (Diehl 1997).

San Pedro

The most common and widespread dart point from Late Archaic period sites is the San Pedro type as first described by Sayles (1983) and others. These include side- and corner-notched points that possess straight to convex bases, although concave bases are occasionally included in type descriptions (Roth and Huckell 1992:363). The morphology of San Pedro points overlaps with that of Elko Corner-notched points common to the Great Basin, but Shackley (1996) distinguished the San Pedro and Elko types based on neck width, shoulder width, thickness, and notch location. In his construct, Elko points are thinner, possess shoulders measuring greater than 25 mm, and have wider necks. Sliva (2009) described San Pedro notches as "half-heart-shaped to C-shaped" and noted that side notches, when present, are located on the lower (proximal) region of the biface. Expanding stems characterize both side- and corner-notched varieties. San Pedro blades are generally triangular and rarely serrated. Projectile points were manufactured from ovate, percussion-flaked bifaces and were finished using pressure flaking. Retouch is common and sometimes has obliterated the shoulder (Justice 2002:195). The age of San Pedro points defines the beginning of the San Pedro phase, around 1200 B.C. The type endured throughout the Cienega phase and did not disappear from the archaeological record until sometime during the Agua Caliente phase, between A.D. 50 and 500 (B. Huckell 1998).

Datil

Datil-type projectile points are distinguished by generally parallel-sided stems, straight to slightly convex bases, and often serrated blades that are frequently retouched, as originally described by Dick (1965) at Bat Cave, New Mexico. The distribution of Datil points covers much of the U.S. Southwest, and Justice (2002:174) assigned them an age range of 1600 B.C.–A.D. 300. The type collection was recovered from a context bearing early maize, but Wills (1988) estimated that Datil points at Bat Cave only dated to between about 900 and 200 B.C. In southeastern Arizona, Datil points have been compared to a similar stemmed variety of projectile point type that Stevens and Sliva (2002) termed Empire points and SWCA dated to between approximately 1600 and 1000 B.C. at Las Capas (Whittlesey et al. 2010:86). Empire points are most often associated with early San Pedro phase occupations (Stevens and Sliva 2002).

Elko Corner-Notched

Elko series projectile points include an array of subtypes, but they are generally broad and have deep corner notches, expanding stems, and concave bases (Heizer and Baumhoff 1961; Thomas 1981). The literature on Elko tools in the U.S. Southwest is limited, but Shackley (1996) provided a quantitative summary of a small collection of Elko-like points from the Harquahala Valley in western Arizona, and Stevens and Sliva (2002) provided a brief literature review and distinguished the type from Empire points common to southeastern Arizona. Lorentzen (1998:148) mapped their distribution throughout western Arizona and up the Gila River and its major tributaries. Estimates of the temporal range of Elko points in the U.S. Southwest are speculative, but it may have extended from 3500 B.C. to A.D. 700, based on one indirect radiocarbon date from the Split Ridge site and their association with well-dated types; however, they are generally attributed to the Late Archaic period (Huckell 1984a; Mabry and Stevens 2000; Stevens and Sliva 2002).

Colonial Stemmed

Sliva (1997:52) described the Colonial Stemmed projectile point type as possessing a triangular blade, a contracting stem, and lateral shoulders or oblique tangs, and she dated the type to between A.D. 750 and 950. Sayles (1965:109) first recognized the points as a highly specialized form at Snaketown and described the edges as finely serrated, sometimes deeply so, forming a saw-like edge.

Indeterminate

Projectile points that were too incomplete to type or did not fit comfortably into extant typological categories were described as indeterminate. None of the complete indeterminate points in the Luke Solar project collection exhibited good craftsmanship, which generally explains their aberrant form.

Ground/Battered Stone Artifact Classes

Ground/battered stone artifacts include objects that have been shaped by pecking and grinding to create a specific form of grinding stone or that achieved their form during use as grinding stones. This category also included battered stone objects that were generally not shaped but exhibited damage created by their use, such as hammerstones.

Hammerstones

Hammerstones were identified by evidence of battering, usually along the convex edges of river cobbles and occasionally on wider surfaces. Hammerstones were classified into two groups: those that served only as hammerstones and those that also functioned as cores. The latter category was composed of implements that first functioned as cores before being devoted to use as hammerstones. Aside from typological classification, the hammerstone analysis included length, width, and thickness measurements; raw-material identification; and the detection of thermal alteration. Hammerstones, not distinguished from pecking stones here, were necessary components in the manufacture of both flaked stone and ground stone tools.

Metates

Metates were classified as *basin metates, flat/concave metates,* or *grinding slabs*. For fragmented pieces, the categories of *indeterminate* and *indeterminate-basin metate* were also utilized. Basin metates possess concave wear surfaces that are oval to circular. Criteria were established to further divide basin metates following Adams (2002:100), defining *three-quarter-basin metates* as open on one end and *open-basin metates* as open on both ends. Basin metates of which the complete circumferences were approximately the same height relative to the nadir depths were categorized as *closed-basin metates*. Adams (2002:103) defined *flat/concave* metates as those that did not have preformed basins prior to use but also noted that subsequent use may have obliterated evidence of the distinction. The analysis of the Luke Solar project materials designated metates as *flat/concave* if it was apparent that the original working surfaces were initially planar. The type *grinding slab* was used to denote basin-shaped metates that were executed on naturally tabular stones. These forms often maintained relatively large unworked surface areas around the ground surfaces. Most often, these metates were minimally modified from their natural forms. Complex metate designs include *trough metates* and other highly shaped forms that generally required significant flaking to achieve their shape.

In addition to the type of metate, analysts recorded a number of categorical and ratio-scale variables for metates and other formal ground stone tools. The length, width, and thickness of each implement were recorded, as were the length, width, and depth of its worked surface. Categorical variables included material type, completeness, shaping method, manufacturing investment, cross-section shape, surface texture, and thermal alteration. Shaping methods were recorded as flaking, pecking, and grinding. Manufacturing investment was measured by the extent of shaping on the stone. Implements with pecking confined to their edges were classified as having had low investment, and implements with shaping that extended onto one or more faces were classified as having had high investment. It should be pointed out that manufacturing investment is not easily distinguished from tool maintenance, and this is true of all ground stone tools. Our definition of "high" manufacturing investment was relative to the Luke Solar project collection. Ground stone implements "shaped" from natural cobbles obviously did not require the same level of investment as metates shaped from blocky pieces of vesicular basalt.

Manos

Manos were divided into the subtypes *loaf mano, flat mano, cobble mano,* and *indeterminate*. Because the Luke Solar project collection is an alluvial-cobble-based technology, manos subtyped as loaf or flat may indicate increased use and attrition rather than functional diversity, but the classifications partly reflect the form of the metate on which a mano was executed. The attributes recorded included material type, completeness, shaping method, manufacturing investment, cross section, texture, direction of stroke, and thermal alteration. Ratio-scale measurements included the length, width, and thickness of each implement and the length and width of its worked surface(s). In regard to both the working surface(s) and the overall mano shape, length axis was designated as the long axis of a stone, perpendicular to the direction of use in a standard back-and-forth motion. The width was designated as perpendicular to the length and parallel to the direction of use.

Mortars

Stone mortars were the bottom components of a pounding technology and are characterized by deep, cylinder- to cone-shaped basins. Mortars were subclassified into the types *boulder, cobble,* and *shaped*. The standard set of variables was recorded, including material type, completeness, shaping method, manufacturing investment, cross-section shape, texture, and thermal alteration. Measurements included length, width, thickness, and basin depth.

Pestles

Pestles include a range of elongate forms that functioned as the top components of a pounding and crushing technology, as evidenced by design or use modification on one or both ends of a pestle. Haury (1950:321–324) distinguished four varieties of pestles from Ventana Cave: flat-ended, rounded-ended, shaped, and not shaped.

Attributes recorded for pestles included material type, completeness, shaping method, manufacturing investment, thermal alteration, worked-surface cross-section shape, worked-surface texture, and location of working. Implement length, width, and thickness were recorded for all complete specimens. The recordation of worked-surface metrics varied depending on type. When a worked surface occurred on a convex end, its height, or the distance it spanned from the end of the implement up the shaft, was recorded. For implements with flat-surfaced ends, length and width were recorded, and if use wear wrapped around and up the shaft of the implement, then a height was recorded. To achieve consistency, the implement end with the most acute profile was designated as proximal, and the opposite end, as distal. The Luke Solar project pestles were organized into several subtypes based on end morphology, manufacturing investment, size, and secondary use(s) (see Figure 38), as defined below.

Type I: This pestle subtype is completely unshaped and has been minimally affected by use. Use wear consists of small areas of light polish or pitting. Some pestles were identified as Type I based on contextual relationships with paired mortars.

Type II: This pestle subtype is characterized by unshaped forms that exhibit highly polished ends.

Type III: This pestle subtype is unshaped and has flat to irregular ends that have been pecked but not polished.

Type IV: This pestle subtype is characterized by coarse shaping (flaking) and convex to irregular ends that have been battered.

Type V: This pestle subtype is defined by fine shaping (pecking) and convex, highly polished ends. Heavily utilized examples exhibit beveled ends.

Type VI: This pestle subtype includes implements with fine shaping (pecking) and convex to irregular ends that have been battered or repecked.

Type VII: This subtype is a uniquely cone-shaped pestle that has one end with a flat surface that has been pecked; the other end (proximal) is acute and sometimes polished. The remainder of the implement has usually been finely shaped (pecked).

Type VIII: This pestle subtype includes barrel-shaped and short, squat cobbles with variable amounts of fine shaping (pecking). Ends have been flattened and pecked.

Type IX: This pestle subtype is characterized by fine shaping (pecking) and a combination of battered and polished ends.

Type X: This subtype includes uniquely large forms that have been modified into narrow basin metates.

Lukeoliths

The Luke Solar project ground stone collection included a unique category of implements that have been previously undocumented or underdocumented in the archaeological record of the U.S. Southwest. The typological efficacy of these tools was first recognized in the laboratory, where Aerostar Environmental Services, Inc., laboratory technicians isolated them and affectionately named them “clown shoes”—items that were too large to be manos but were not like metates. The items were also referred to as “millingstones” in some contexts of the analysis, because there was no type name for them in the database.

A brief literature search was performed to identify similar tools from regional Archaic or Ceramic period sites. One archaeological example associated with Middle to Late Archaic period occupations at the Fairchild site was depicted and described as a “rounded” pestle, a polished form attributed to wooden pestles (Windmiller 1973). From the Picacho Dune Field, Morris (1986:261) reported three shaped artifacts with broad, rounded ends that he compared to “unbattered” pestles. Sayles (1983:71) briefly described Chiricahua phase “proto-pestles” as shaped or unshaped handstones that each exhibited one pointed or beveled end that was polished, suggesting use as digging tools. Aside from these vague references, no mention was found of large, flat, pestle-like implements.

A representative sample of the items classified as Lukeoliths was displayed at the 2013 Pecos Conference in Flagstaff, Arizona, where a large knowledge base of regional archaeologists was on hand, and conference participants were allowed to handle and comment on the implements’ presumed functions. A few respondents thought they resembled two-handed manos at first glance, and others remarked that they were some form of multipurpose tool and not a distinctive type.

SRI also solicited the opinions of curators and collection managers at the ASM and the Maxwell Museum of Anthropology, SRI colleagues in California and New Mexico, Sonoran archaeologists affiliated with the National Autonomous University of Mexico, and archaeologists familiar with ground stone technologies in Australia, India, and Africa, none of whom were familiar with analogous ground stone objects. The ethnohistory of traditional technologies has been poorly documented. In 2013, several representatives of The Four Southern Tribes of Arizona were able to view and comment on the items. As discussed by Vanderpot in Chapter 9, traditional cultures developed complex perishable and nonperishable technologies that included special tools associated with intensive desert-plant-food processing—tools that have disappeared from the material record over a period of several centuries.

Objects that met the criteria for inclusion in the “Lukeolith” category were characterized by margins that had been variably pecked and ground to achieve an almond to subrectangular outline and distinctively polished or pecked ends. Several generalized patterns of use wear became apparent throughout the analysis. The most intuitively interpretable pattern was use of the large, oval face as a grinding surface. More commonly, specimens evidenced use wear on the ends. The area of use wear was often irregular in shape, extending some distance up the planar face of the implement and often farther up one or both edge margins. Often, the area of use had been visibly polished. On several implements, pecking was concentrated on one end or both ends of each and continued for a variable distance along the lengthwise axis. Three categories describe the type and location of pecking and polish (Figure 39):

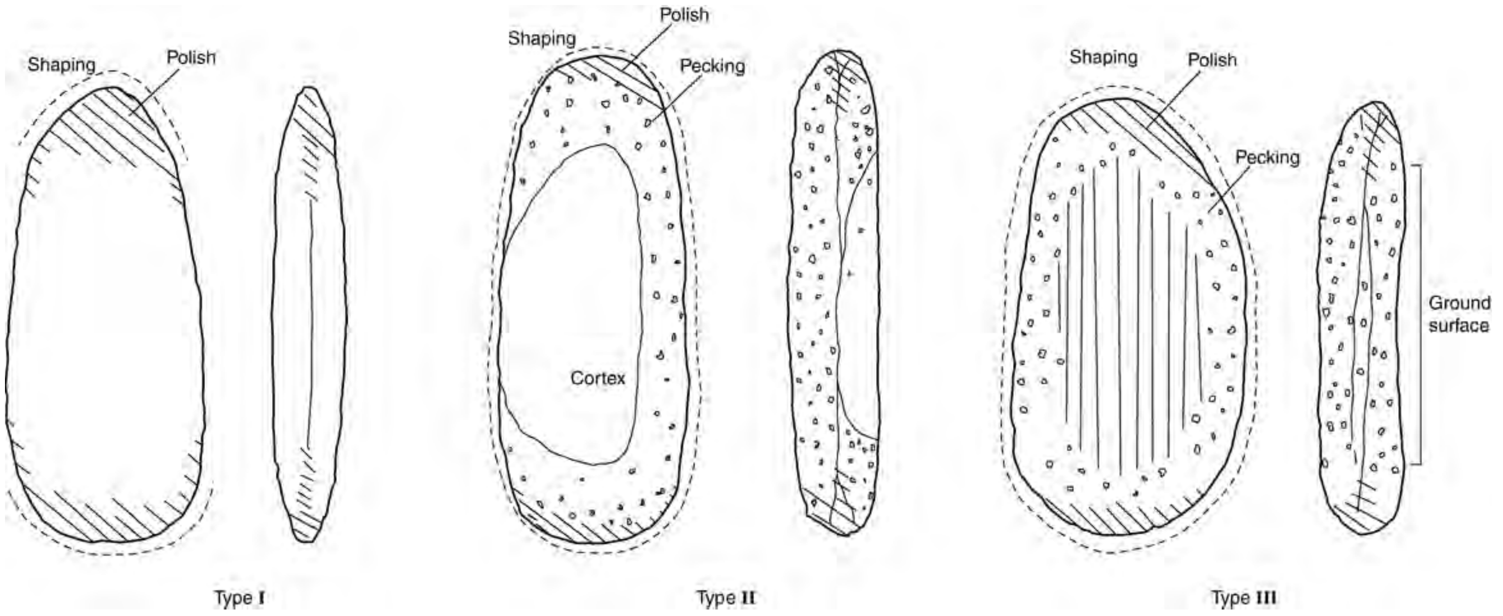


Figure 39. Schematic representation of Lukeolith types recognized in the Luke Solar project analysis.

Type 1: Minimal margin pecking; visible use modification on one or both ends (proximal and/or distal) characterized by a luster that wraps around the edges and intrudes a short distance onto the convex tool surfaces; no evidence of pecking or grinding on planar surfaces.

Type 2: Pecked ends and pecked planar surfaces; pecked ends have usually been subsequently polished to some extent by use.

Type 3: Pecking and/or polish on one or both ends, as well as use modification (grinding) on one or both convex to slightly concave planar surfaces.

The attributes recorded for Lukeoliths included material type, completeness, shaping method, manufacturing investment, thermal alteration, implement lateral-cross-section shape, implement longitudinal-cross-section shape, worked-surface texture, and worked-surface plan shape, when applicable. The location of modification was recorded as *entire, face, distal,* or *proximal*. "Proximal" was defined as the narrower or more acute end, and distal, as the broader or more obtuse end. Measurements were taken of implement length, width, and thickness. For implements with primarily planar-face modification, length and width measurements were taken at the location of maximum wear. For implements with end wear, one measurement was taken on each utilized end, to record the maximum distance that the wear extended down the length axis.

Netherstones

The tools in this category are difficult to describe, because the definition of a netherstone is a ground stone tool that does not fit into a conventional ground-stone-tool category. Generally, the term describes large, bottom-stone implements (or work surfaces) that do not have basins but are not flat metates. Some of the netherstones in the Luke Solar project collection had convex work surfaces. They were considered of expedient design by Adams (2002:143). Because netherstones constitute, by definition, an amorphous class of objects, no attempt was made to further subdivide them. The recorded variables included material type, completeness, shaping method, manufacturing investment, thermal alteration, worked-surface cross-section shape, worked-surface texture, and worked-surface plan shape. Measurements included the length, width, and thickness of each implement and the length, width, and depth of its worked surface. Many netherstones could be interpreted to be early-stage metates. The "netherstone" category was used conservatively, but several implements defied classification otherwise.

Indeterminate Ground Stone

Fragmented pieces of ground stone were classified as indeterminate if they were too small or amorphous to classify as formal tool types. Indeterminate fragments were inspected and described in terms of raw-material type, shaping method, manufacturing investment, and thermal alteration. For worked surfaces, profile shape, surface-plan shape, and surface texture were recorded. Weight was the only measurement commonly recorded on indeterminate specimens.

Manuports

Manuports are rocks that people have transported to the Luke Solar project area, but they were not visibly modified. At the Luke Solar project sites, all rocks were manuports. Manuports were possible blanks for the production of flaked stone and ground stone tools, depending on material type, or they were rejects.

FAR

FAR was defined as rock that exhibited evidence of thermal alternation, typically marked by fragmentation, discoloration, and soot from use as thermal mass. FAR is typically recovered from roasting pits and hearths and as secondary refuse. Nearly half of the FAR sample collected from Falcon Landing was inspected for raw-material type and recognizable pieces of ground stone tools.

Rare Items

A short list of rare, formal artifact types was included in the Luke Solar project collection, including the types *pipe*, *donut stone*, *tray*, *polisher*, and *stone beads* (Adams 2002). Conical pipes, sometimes referred to as "cloud blowers," were often made from vesicular basalt and have only rarely been recovered from Hohokam habitation sites. More often, they are recovered from Basketmaker period sites in the Four Corner's region and from Late Archaic period sites in southern and central Arizona. Perforated stone disks (donut stones) are common items at Hohokam and Early Agricultural period sites, but their function is subject to speculation. Polishers are smooth-textured pebble implements that were possibly used to polish pottery, stone, or plaster but are recognized by their own sheen. The term "tray" was used to describe a small, thin, relatively delicate, basin-shaped tool or container. Stone beads make up one of several types of personal ornaments that are common in southern Arizona, including pendants, nose plugs, figurines, and other objects of personal ornamentation.

Description of the Stone Artifact Collection

The following section describes the lithic collections from Falcon Landing as well as Sites 423, 437, and 68 and a small number of isolated artifact occurrences. Artifact descriptions are summarized and discussed at the level of objects and types.

Falcon Landing

The Falcon Landing collection does not seem large relative to the scale of the Luke Solar project, but it represents a substantial Archaic to Ceramic period collection. This section describes 148 flaked stone tools—including 54 complete and fragmented projectile points—183 cores, and 7,425 pieces of debitage. The ground stone collection totaled 2,283 broken and complete metates and various other tools, including 760 manos. SRI also collected 10,192 pieces of FAR, 1,866 of which were from dated features, and a small number of unique personal items (Table 15). For comparison, the Luke Solar project mano collection comprised approximately half the number of manos reported from Ventana Cave (Haury 1950:308) but nearly twice the number of manos summarized by Adams (2005) from Late Archaic/Early Agricultural period sites in the middle Santa Cruz River valley. This section describes the stone artifacts from Falcon Landing, which accounted for more than 98 percent of the Luke Solar project lithic collection.

Flaked Stone Artifacts

This section describes the flaked stone artifacts in the Falcon Landing collection (n = 7,756), organized at the level of objects and types. Each subsection includes a brief narrative about the character of the sample and is accompanied by descriptive tables and figures that convey the metric attributes, provenience information, and physical characteristics of the artifacts. The flaked-stone-artifact sample was recovered following a methodological approach that focused on pit features as the primary analytical units (see Chapter 3, Volume 1), and it faithfully represents that sampling approach. Slightly less than 10 percent of the flaked stone sample was not dated, and many of the artifacts were not well dated. Ninety-six percent of the collection was flake debris, and most of the collection lacked the chronological resolution needed to detect differences between the Middle Archaic and pre-Classic periods. We explore these limitations in the descriptive analysis. The descriptions begin with cores and flakes, followed by the tools made from those cores and flakes. Information on the obsidian sample is provided as additional description at the end of the section.

Table 15. Summary of Stone Artifacts Collected from Falcon Landing

Stone-Tool Type	Number
Formal tools	
Projectile point	53
Biface	34
End scraper	3
Side scraper	2
End/side scraper	4
Scraper/plane	1
Edge-modified flake (EMF)	47
Flake knife	1
Drill	3
Subtotal	148
Cores	
Cobble uniface	60
Blocky core	96
Biface/disk core	16
Flake core	6
Blade core	2
Tested cobble	3
Subtotal	183
Debitage	7,425
Ground stone	
Hammerstones	58
Indeterminate ground stone	537
Manos	
Cobble mano	663
Flat mano	1
Indeterminate mano	94
Loaf mano	2
Subtotal	760
Metates	
Closed-basin metate	82
Flat/concave metate	93
Grinding slab	29
Indeterminate metate	276
Indeterminate basin metate	92
Open-basin metate	1
Three-quarter-basin metate	2
Subtotal	575
Mortars	7
Pestles	94
Other ground stone	
Lukeolith	68
Netherstone	43
Subtotal	111
Manuports	121
Rare items	
Disk bead	13
Donut stone	1
Conical pipe	1
Polisher	1
Tray	1
Minerals	3
Subtotal	20
Total	10,039

Cores

The core tools at Falcon Landing are an important part of the site's character. Cores were found often by themselves in nonthermal pits, thermal pits, and a small number of structures but were also cached as multiples (Table 16). Most of the cores lacked chronological information, and there are no convincing arguments to be made about technological change based on the limited number of well-dated specimens, which did not distinguish themselves in terms of raw material, size, or technology. The early Chiricahua phase component contained 13 cores that could have been lost amid the rest of the collection, but two formal reduction strategies were evident by the early Chiricahua phase. Volcanic materials overwhelmingly dominated the core sample, with a predominance of fine-grained basalt and a secondary selection of glassy rhyolites. Chert was relatively rare in the core collection. Five cores located on the surface outside the APE were documented in the field and not collected.

In total, 183 cores were collected from the site (see Table 16)—enough that it was possible to distinguish two "ideal types" in the collection (Figure 40). The most distinctive cores were cobble unifaces, which were often made from fine-grained basalt and showed large, well-controlled flake removals. Cobble unifaces also showed exaggerated platform preparation for the removal of wide, secondary flakes, sometimes resulting in

Table 16. Summary Information Recorded on Cores, by Temporal Component, Falcon Landing

Characteristics	Sulphur Spring	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Total
Core Type									
Cobble uniface	—	2	2	2	—	7	6	41	60
Blocky core	1	9	—	1	4	12	15	54	96
Biface/disk core	—	1	—	—	—	1	1	13	16
Flake core	—	—	—	—	—	—	—	6	6
Blade core	—	1	—	—	—	—	—	1	2
Tested cobble	—	—	—	—	—	1	—	2	3
Total number of specimens	1	13	2	3	4	21	22	117	183
Metrics (mean, SD)[b]									
Cobble uniface									
Maximum long axis (mm)	n/a	55 (9)	85 (9)	72 (18)	n/a	95 (14)	89 (13)	91 (25)	
Volume (× 1,000) (mm^3)	n/a	63.1 (32.4)	240.9 (31.3)	273.6 (214.4)	n/a	387.0 (214.8)	394.2 (216.7)	403.5 (299.1)	
Maximum flake scar length (mm)	n/a	46 (21)	43 (12)	60 (14)	n/a	60 (34)	60 (24)	63 (25)	
Blocky and disk core									
Maximum long axis (mm)	48	68 (14)	n/a	n/a	53 (13)	49 (11)	66 (32)	70 (22)	
Volume (× 1,000) (mm^3)	54	146.6 (105.7)	n/a	n/a	63.3 (21.3)	78.6 (46.8)	164.2 (277.2)	205.0 (198.0)	
Edge Battered									
Cobble uniface	—	1	—	1	—	—	2	10	14
Blocky core	—	2	—	—	—	2	2	10	16
Recovery Context									
Activity area	—	—	—	—	2	—	—	—	2
Cache	—	—	—	—	—	1	2	—	3
FAR concentration	—	—	—	—	—	1	3	—	4
House-in-pit	—	6	1	2	—	—	—	—	9
Noncultural	—	—	—	—	—	—	3	—	3
Nonthermal pit	—	4	1	—	1	10	9	—	25
Posthole	—	—	—	1	—	1	—	—	2
Surface structure	—	—	—	—	—	—	1	—	1
Thermal pit	—	3	—	—	—	6	3	—	12
Thermal pit (bell shaped)	—	—	—	—	—	—	1	—	1
CBS/mixed	1	—	—	—	1	2	—	86	90
Site surface	—	—	—	—	—	—	—	31	31
Total	1	13	2	3	4	21	22	117	183
Raw Material									
Basalt 1	—	3	—	—	—	7	4	25	39
Basalt 2	—	6	1	1	—	3	3	31	45
Basalt 3	—	—	—	—	—	—	—	1	1
Basalt 4	—	—	—	—	—	—	3	4	7
Other basalt	—	—	—	—	—	1	1	10	12
Subtotal basalt	—	9	1	1	—	11	11	71	104

Characteristics	Sulphur Spring	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Total
Chert 1	—	—	—	—	1	1	—	—	2
Chert 3	—	—	—	—	—	—	1	—	1
Other chert	—	—	—	—	—	2	—	4	6
Subtotal chert	—	—	—	—	1	3	1	4	9
Metaquartzite	—	—	—	—	—	3	2	10	15
Metaquartzite 4	—	—	—	—	—	—	—	1	1
Subtotal metaquartzite	—	—	—	—	—	3	2	11	16
Rhyolite 1	—	—	—	—	—	—	—	1	1
Rhyolite 3	—	—	—	—	—	—	—	1	1
Rhyolite 4	—	—	—	—	—	—	1	—	1
Rhyolite 6	1	3	1	1	2	1	5	9	23
Rhyolite 8	—	—	—	—	—	—	1	—	1
Rhyolite 9	—	—	—	—	—	—	1	—	1
Rhyolite 11	—	—	—	—	—	—	—	1	1
Rhyolite 12	—	—	—	—	—	—	—	1	1
Other rhyolite	—	1	—	1	1	2	—	13	18
Subtotal rhyolite	1	4	1	2	3	3	8	26	48
Andesite	—	—	—	—	—	—	—	1	1
Chalcedony	—	—	—	—	—	1	—	1	2
Quartz	—	—	—	—	—	—	—	1	1
Schist	—	—	—	—	—	—	—	1	1
Siltstone	—	—	—	—	—	—	—	1	1
Total	1	13	2	3	4	21	22	117	183

Key: CBS = culture-bearing sediment; n/a = not applicable; SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

[b] Complete specimens.

so-called "orange-peel" (Goodyear 1974) or "backed" flakes. Several cobble-uniface examples were found in an exhausted condition, but cobble unifaces were generally produced from a large, bulky technology, and their average maximum length at Falcon Landing was often more than 90 mm. There was no size distinction between basalt and rhyolite cores. Round cobbles showed evidence of having first been split using an anvil; those may explain the small cobble unifaces with quasi blade-like flake removals. The average maximum flake-scar length for cobble unifaces wahhs in excess of 40 mm. Oddly, flakes of that size appeared to be underrepresented in the collection. Most of the large flakes that did occur in the collection had been poorly executed and discarded. Only 23 percent of the cobble-uniface cores showed evidence of edge battering or abrasion from use as core tools, some of which may have been related to platform preparation. Three cobbles were classified as tested cobbles, as opposed to cobble unifaces. A tested cobble could be an early-stage cobble uniface, but 2 of the 3 tested cobbles from Falcon Landing had been thermally altered and apparently were not deemed suitable as cores.

The other notable core technology was the biface/disk core. The example in Figure 40a was not dated; it was possibly made from Kaibab chert derived from the southern Colorado Plateau area. Disk/biface cores were generally made from large flake blanks, resulting in plano-convex cross sections. Disk/biface cores were not numerous at the site, because they were designed for transport and intensive use, and they experienced less-frequent discard. The cobble uniface and the biface/disk core represent two fundamentally different formal core technologies at the site.

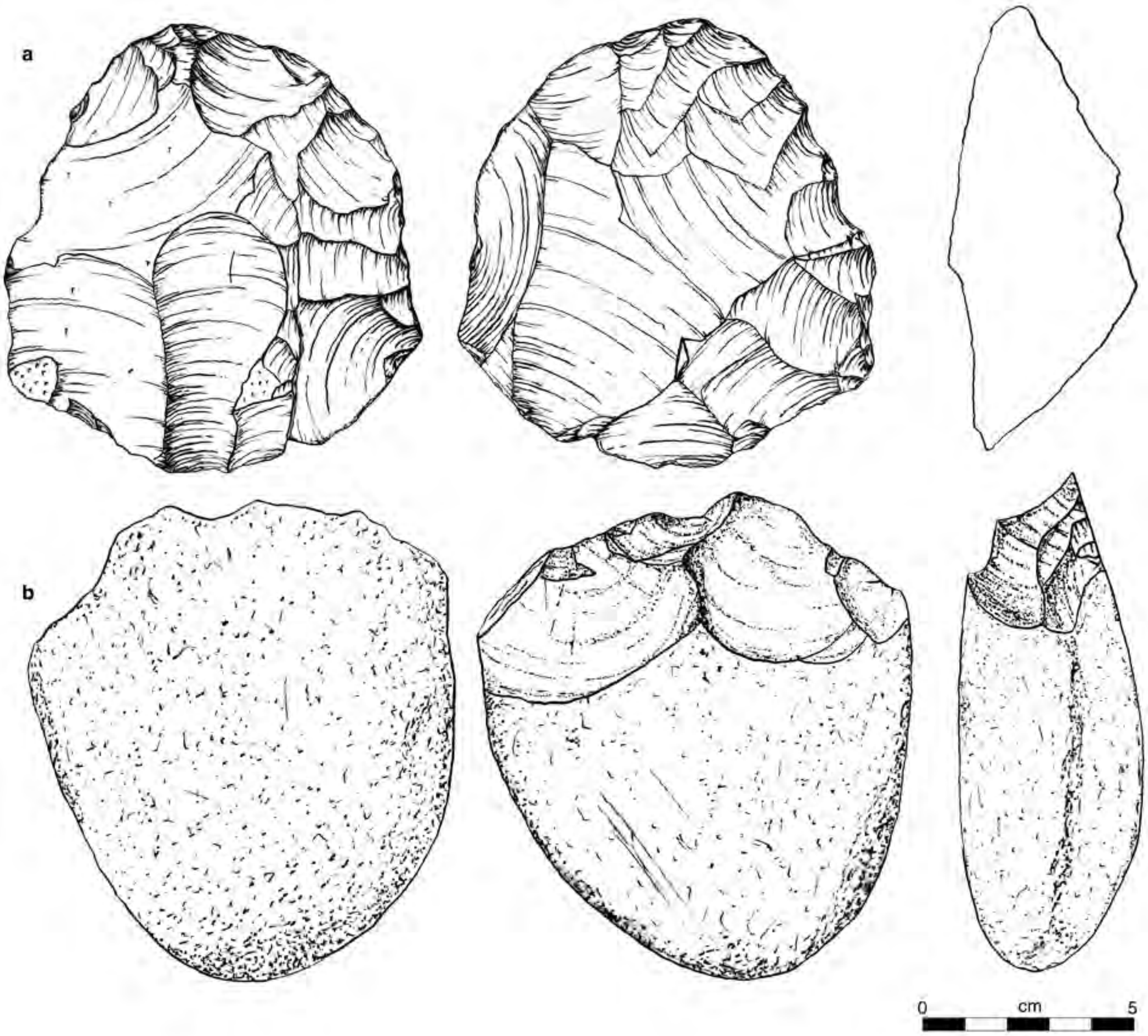


Figure 40. Cores from Falcon Landing (no temporal assignment available): (*a*) a chert biface/disk core from MSU 3671 (Inventory No. 04000C8FF) and (*b*) a basalt cobble uniface from MSU 1281 (Inventory No. 04000C033).

A large number of blocky cores were also described in the collection. These cobble-based cores showed more opportunistic flake removals, resulting in mostly bidirectional and multidirectional cores. Many of them may have begun much like a cobble uniface. Blocky cores at the site were also large, measuring 50–70 mm in maximum long axis, on average (see Table 16), and few were repurposed as core tools. The largest well-dated sample of cores included five multidirectional cores and an amorphous core associated with early Chiricahua phase thermal pits in Feature 2602 (see Chapter 4, Volume 1). Considering the differences in sample sizes, there was good concordance in the frequencies of raw-material varieties between the core collection and the debitage collection, confirming that basalt cobbles contributed somewhat proportionately to biface manufacture at the site, as did cherts and fine-grained rhyolites. This argument is further developed in the debitage analysis, below.

Debitage

The debitage collection from Falcon Landing consisted of 7,425 complete and incomplete flakes from a wide range of features and some nonfeature situations (Table 17). The sample contained 2,156 complete flakes and 1,170 proximal flake fragments as well as 4,099 other types of flake fragments. The complete and proximal fragments were the only specimens that we were confident represented 1 flake each, and we relied on that sample for many of our quantitative analyses. The complete flakes were generally small; about 91 percent of them measured less than 40 mm each in length. Twenty-two percent of the collection consisted of microdebitage measuring less than 10 mm in length, and the pieces were generally small, thin flakes that had been removed from bifaces. The most common flake types were biface-thinning flakes (53 percent), core-reduction flakes (18 percent), microdebitage (15 percent), and indeterminate flakes (14 percent) (these are percentages of the subsample of the flakes that could be identified by type). The debitage sample, albeit small, constituted the only artifact class that contained an appreciable sample of dated artifacts. The collection represented a small number of features that contained 100 flakes or more apiece and many more features that contained only 1 or 2 flakes apiece. From the outset, it was clear that the debitage sample was heavily weighted by a small number of features and discrete activities. Seventy pieces of debitage located outside the APE were documented in the field and not collected.

The early Chiricahua phase sample (n = 645) included the contents of 19 features with multiple flakes (n > 5) and other flakes from low-density features and nonfeature contexts, but nearly a third of the sample came from a shallowly buried early Chiricahua phase activity area (Feature 1303) that also included a few EMFs, a drill fragment, and a small number of manos associated with 4 nonthermal pits (see Chapter 4, Volume 1) (Figure 41). The late Chiricahua phase sample included 74 flakes recovered from a structure that also included faunal bone, manos, and a metate (Feature 1244). The largest collection of debitage included 626 flakes associated with Feature 4370, a late Chiricahua–early San Pedro phase (assigned to the Cochise group) nonthermal pit that contained 70 pieces of faunal bone, a stone pipe, and 3 projectile point distal tips. The feature was originally interpreted to be a structure. The debitage assemblage contained more than 20 unique varieties of basalt, rhyolite, quartzite, and cherts, mostly in the form of biface-thinning flakes and microdebitage, indicating that the debris represented the production of multiple bifaces.

The San Pedro phase sample was dominated by Feature 4302, a structure that contained an Elko Corner-notched projectile point fragment, and Feature 4355, a nonthermal pit that contained one San Pedro and one Datil projectile point. Seventy-five percent of the relatively large Cienega phase sample (n = 971) was from nonfeature and mixed contexts, but a smaller sample was from a Cienega phase activity area (Feature 1239) that contained a minor amount of faunal bone, two cores, a utilized flake, and a mano fragment. The Red Mountain phase sample came mostly from a structure that included a small number of plain ware sherds and broken mano and metate fragments (Feature 3963) and a deep charcoal/ash lens (Feature 14656). The small pre-Classic period sample represented the contents of a Snaketown phase structure (Feature 1290) that contained some faunal bone, two EMFs, and a small, unidentified mineral inclusion.

A single decortication flake of rhyolitic tuff was grab-sampled from the wall of TR 4211 and was associated with a radiocarbon date of 6000–5890 B.C. (Sulphur Spring phase), but it was from mixed deposits and does not warrant special description (see Table 17). The same level of attention was given to 1 flake assigned to the Protohistoric period and 3 flakes assigned to the Historical period. Table 17 shows that the other dated flake samples ranged from 103 (pre-Classic period) to 971 (Cienega phase) specimens and included a large amount of microdebitage. These numbers are extremely small for flaked stone analysis, because hundreds of small flakes can be created during the production of a single stone tool. Regardless, the variability observed in the debitage collection through time (between features) implies clear behavioral differences in raw-material use and the reduction/production stage of stone tools.

Raw materials in the Falcon Landing debitage sample showed the use of many different types of rock, but as a whole, the collection was dominated by fine-grained basalts and rhyolites and small contributions of chert, chalcedony, and quartzite (Figure 42; Table 18). Only 19 percent of the debitage sample was cortical (see Table 17), but 17 percent of it had alluvial-cobble cortex. The flaked-stone-raw-material reference collection included 52 specific and generic rock types that were used to measure the diversity of raw materials in the collection (see Table 14). The most diverse categories were rhyolites (12 varieties) and cherts

Table 17. Summary Information Recorded on Debitage, by Temporal Component, Falcon Landing

Characteristics	Sulphur Spring	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Red Mountain	Pre-Classic	Protohistoric	Historical	Cochise[a]	Cochise to Historical	Not Dated	Total
Portion													
Complete	1	207	40	101	215	73	47	—	1	740	389	342	2,156
Proximal	—	83	13	84	57	26	21	—	—	614	171	101	1,170
Distal	—	148	22	72	145	56	15	—	1	733	296	117	1,605
Midsection	—	50	9	53	55	19	10	—	1	453	127	44	821
Lateral	—	13	2	2	8	2	3	—	—	27	3	23	83
Indeterminate fragment	—	144	36	56	491	118	7	1	—	493	132	112	1,590
Number of specimens	1	645	122	368	971	294	103	1	3	3,060	1,118	739	7,425
Size Class (mm)[b]													
< 10	—	46	14	28	47	12	21	—	—	191	112	7	478
10–19	—	80	13	35	113	28	19	—	—	240	150	87	765
20–29	—	42	5	21	28	14	4	—	1	175	67	108	465
30–39	—	15	5	11	14	10	2	—	—	87	36	67	247
40–49	—	14	2	1	4	4	1	—	—	31	14	40	111
50–59	1	7	—	2	5	4	—	—	—	11	7	17	54
60–69	—	2	1	2	3	—	—	—	—	4	2	9	23
70–79	—	—	—	—	—	1	—	—	—	—	—	5	6
80–89	—	1	—	1	—	—	—	—	—	1	1	2	6
90–99	—	—	—	—	1	—	—	—	—	—	—	—	1
Subtotal	1	207	40	101	215	73	47	—	1	740	389	342	2,156
Cortex[b, c]													
Cortical	1	76	16	19	66	31	12	—	1	157	85	168	632
Noncortical	—	214	37	166	206	68	56	—	—	1,197	475	275	2,694
Noncortical/cortical ratio	—	2.8	2.3	8.7	3.1	2.2	4.7	—	—	7.6	5.6	1.6	4.3
Flake Type[b, c]													
Biface	—	125	16	105	109	39	20	—	1	878	281	192	1,766
Core	1	74	14	28	48	29	7	—	—	145	104	142	592
Blade	—	—	—	—	—	—	—	—	—	1	—	—	1
Bipolar	—	—	—	—	—	—	—	—	—	1	—	2	3
Microdebitage	—	47	14	31	46	13	22	—	—	203	113	7	496
Indeterminate	—	44	9	21	69	18	19	—	—	126	62	100	468

Characteristics	Sulphur Spring	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Red Mountain	Pre-Classic	Protohistoric	Historical	Cochise[a]	Cochise to Historical	Not Dated	Total
Platform Prepared[b, c]													
Biface flakes	—	54	11	45	76	26	6	—	—	450	128	97	893
Core flakes	—	7	2	3	2	9	1	—	—	25	10	10	69
Recovery Context													
Activity area	—	217	—	—	127	—	—	—	—	36	32	—	412
Burial	—	—	—	—	—	—	—	—	—	—	1	—	1
Cache	—	—	—	—	—	—	1	—	—	9	2	—	12
Charcoal/ash lens	—	2	—	—	1	92	—	—	—	44	3	—	142
FAR concentration	—	6	—	—	—	—	—	—	—	20	43	—	69
House-in-pit	—	33	100	184	30	193	94	—	—	227	234	—	1,095
Midden	—	78	—	18	—	—	—	—	—	—	—	—	96
Noncultural	—	6	—	—	—	—	—	1	—	—	39	—	46
Nonthermal pit	—	114	16	120	50	—	7	—	—	1,779	265	—	2,351
Nonthermal pit (bell shaped)	—	—	2	—	14	—	—	—	—	112	1	—	129
Posthole	—	—	4	9	—	1	—	—	—	—	2	—	16
Reservoir	—	—	—	6	—	—	—	—	—	—	—	—	6
Surface structure	—	—	—	—	2	—	—	—	—	5	—	—	7
Thermal pit	—	100	—	20	12	—	1	—	2	673	471	—	1,279
Thermal pit (bell shaped)	—	18	—	11	—	—	—	—	—	8	15	—	52
CBS/mixed	1	68	—	—	734	—	—	—	1	144	10	32	990
Site surface	—	—	—	—	—	—	—	—	—	1	—	707	708
Natural stratum	—	3	—	—	1	8	—	—	—	2	—	—	14
Total	1	645	122	368	971	294	103	1	3	3,060	1,118	739	7,425

Key: CBS = culture-bearing sediment.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

[b] Complete flakes.

[c] Proximal fragments.

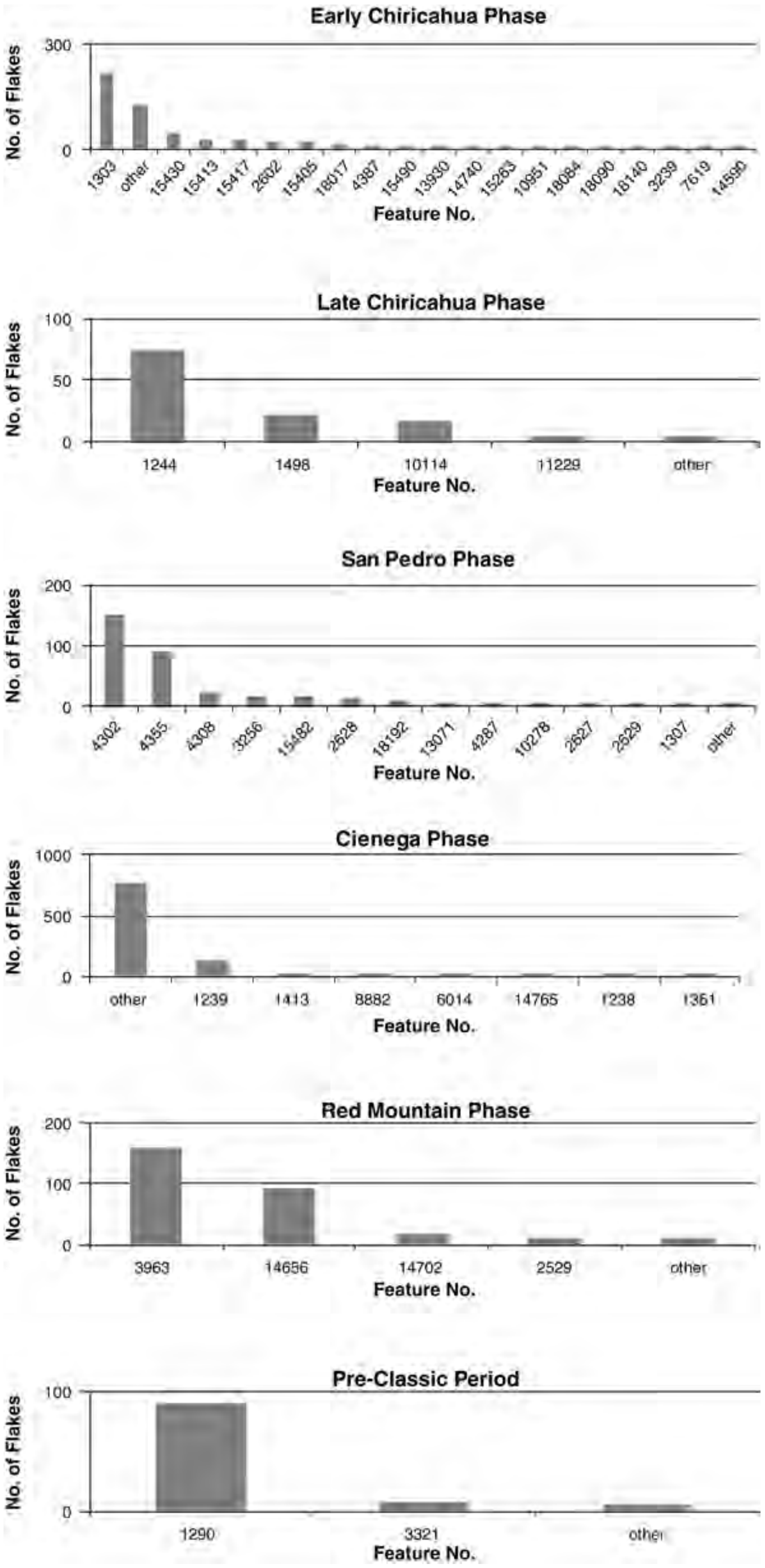


Figure 41. Recovery contexts (feature numbers) and sizes of the largest dated debitage samples at Falcon Landing.

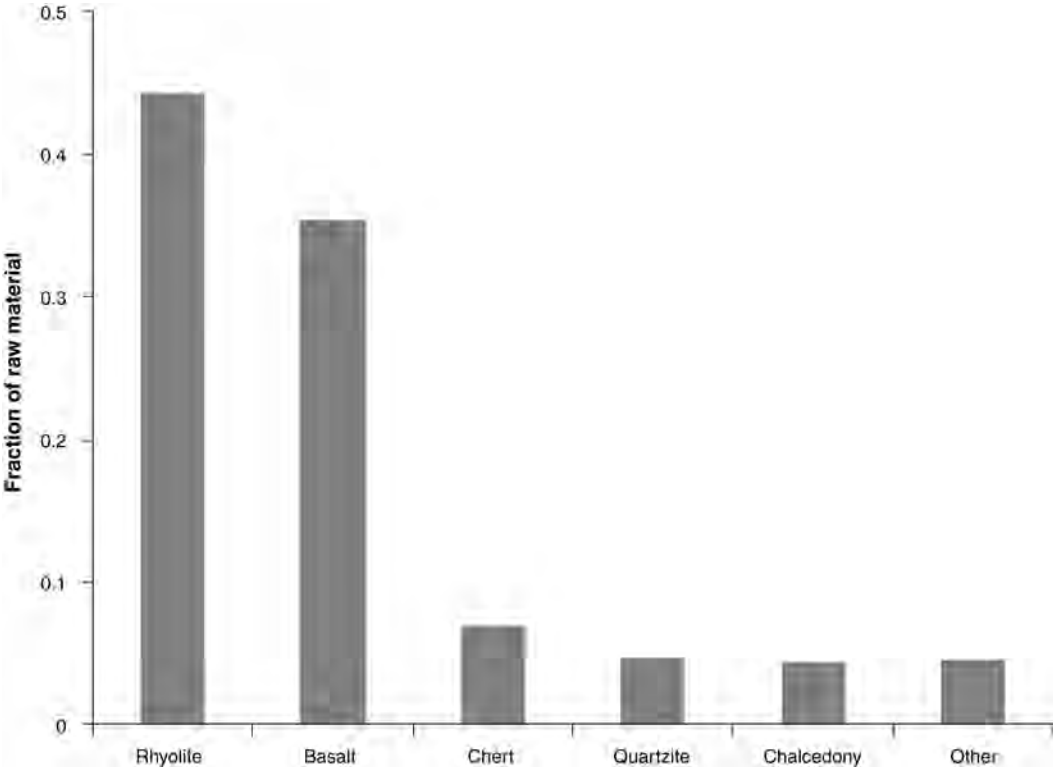


Figure 42. Proportions of the most-common raw materials in the debitage samples from Falcon Landing.

Table 18. Raw-Material Distribution among Flaked Stone Debitage, by Temporal Component, Falcon Landing

Material Type	Sulphur Spring	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Red Mountain	Pre-Classic	Protohistoric	Historical	Cochise[a]	Cochise to Historical	Not Dated	Total
Basalt 1	—	116	15	84	67	13	17	—	1	445	145	103	1,006
Basalt 2	—	79	24	37	72	46	7	—	—	364	91	83	803
Basalt 3	—	9	1	6	1	1	—	—	—	17	15	12	62
Basalt 4	—	9	4	9	9	1	5	—	—	27	7	5	76
Vesicular basalt	—	1	—	—	—	1	—	—	—	2	1	—	5
Other basalt	—	50	6	10	225	59	3	—	—	176	60	75	664
Subtotal basalt	—	264	50	146	374	121	32	—	1	1,031	319	278	2,616
Chert 1	—	8	—	1	7	1	4	—	—	27	6	3	57
Chert 2	—	3	—	5	15	—	2	—	—	21	4	3	53
Chert 3	—	1	—	1	2	—	4	—	—	3	1	—	12
Chert 4	—	—	—	—	3	—	1	—	—	3	2	1	10
Chert 5	—	—	—	—	2	—	1	—	—	4	1	—	8
Chert 6	—	—	—	2	1	1	1	—	—	6	—	—	11
Chert 7	—	9	1	2	2	—	—	—	—	8	—	—	22
Chert 8	—	1	—	—	9	—	—	—	—	4	—	1	15
Chert 9	—	—	—	—	1	—	—	—	—	2	7	—	10
Other chert	—	42	2	10	126	4	5	—	—	69	26	24	308
Subtotal chert	—	64	3	21	168	6	18	—	—	147	47	32	506
Metaquartzite 1	—	1	—	1	1	—	—	—	—	4	—	—	7
Metaquartzite 2	—	1	3	2	1	—	1	—	—	29	6	—	43
Metaquartzite 3	—	6	2	1	4	6	1	—	—	20	24	7	71
Metaquartzite 4	—	—	1	—	—	—	—	—	—	12	5	2	20
Other metaquartzite	—	10	2	7	6	3	1	—	1	97	25	46	198
Orthoquartzite	—	—	—	—	—	—	—	—	—	2	1	—	3
Subtotal metaquartzite	—	18	8	11	12	9	3	—	1	164	61	55	342
Rhyolite 1	—	29	20	47	28	38	6	1	—	329	205	44	747
Rhyolite 2	—	—	—	1	—	—	—	—	—	3	1	—	5
Rhyolite 3	—	11	2	6	6	1	1	—	—	105	60	15	207
Rhyolite 4	—	12	3	26	5	2	1	—	—	150	46	10	255
Rhyolite 5	—	1	—	—	1	1	—	—	1	5	—	1	10
Rhyolite 6	—	77	12	33	70	41	21	—	—	326	87	80	747

Material Type	Sulphur Spring	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Red Mountain	Pre-Classic	Protohistoric	Historical	Cochise[a]	Cochise to Historical	Not Dated	Total
Rhyolite 7	—	9	—	1	1	—	2	—	—	12	3	—	28
Rhyolite 8	—	3	—	2	1	2	—	—	—	16	10	11	45
Rhyolite 9	—	5	1	3	5	1	—	—	—	10	7	2	34
Rhyolite 10	—	—	—	1	—	1	—	—	—	16	1	—	19
Rhyolite 11	—	3	1	20	—	2	1	—	—	41	52	4	124
Rhyolite 12	—	—	2	1	—	—	—	—	—	6	—	4	13
Other rhyolite	—	80	5	27	101	58	3	—	—	469	145	150	1,038
Subtotal rhyolite	—	230	46	168	218	147	35	1	1	1,488	617	321	3,272
Andesite	—	—	—	—	2	—	—	—	—	1	1	5	9
Argillite	—	—	—	—	—	—	—	—	—	—	—	2	2
Caliche	—	—	—	—	2	—	—	—	—	—	—	—	2
Chalcedony	—	51	5	6	143	6	9	—	—	96	10	31	357
Breccia	—	—	—	—	—	—	—	—	—	1	—	—	1
Dacite	—	1	—	—	—	—	—	—	—	2	1	—	4
Granite	—	1	—	—	—	—	2	—	—	5	10	—	18
Metasediment	—	5	—	1	—	—	—	—	—	10	1	—	17
Limestone	—	—	—	—	2	—	—	—	—	2	1	1	6
Obsidian	—	2	—	—	27	—	—	—	—	5	1	—	35
Petrified wood	—	—	—	—	—	—	—	—	—	1	—	—	1
Phyllite	—	1	—	—	—	—	—	—	—	—	—	—	1
Quartz	—	8	8	11	19	4	4	—	—	26	10	12	102
Shale	—	—	—	—	—	1	—	—	—	—	—	—	1
Schist	—	—	—	—	—	—	—	—	—	—	1	—	1
Siltstone	—	—	2	3	4	—	—	—	—	36	35	2	82
Tuff	1	—	—	—	—	—	—	—	—	11	1	—	12
Indeterminate	—	—	—	1	—	—	—	—	—	34	2	—	37
Total	1	645	122	368	971	294	103	1	3	3,060	1,118	739	7,425

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

(9 varieties). The great diversity of the chert sample suggests that many of the chert artifacts were not derived from the Agua Fria River gravels, but those gravels have not been systematically surveyed for knappable cherts. A wide variety of rhyolites can be expected from the Agua Fria River gravels. The obsidian at Falcon Landing came from the southern Colorado Plateau and the Sonoran Desert and is analyzed and discussed in more detail at the end of this section. Important differences in raw-material use were evident between reduction methods, as described below.

The technological character of the dated sample is conveyed in a series of graphs in Figure 43. In most instances, the ratio of cortical to noncortical flakes was a reliable proxy for gauging reduction stages, from initial core reduction to transported core reduction and tool manufacture. The cobble-uniface cores at Falcon Landing partly spoiled that construct, however, because they were designed to produce cortical ("orange-peel") flakes throughout their use lives. With that caveat in mind, the San Pedro phase sample was isolated for having both the highest percentage of noncortical flakes and the highest proportion of biface-thinning flakes (see Figure 43a and b). The other dated samples had approximately equal proportions of biface-thinning flakes. The pre-Classic period sample had a disproportionate amount of noncortical microdebitage and, consequently, fewer biface or core-reduction flakes than the other samples. The core-reduction flakes left at Falcon Landing (see Figure 43c) were not necessarily expedient flake tools; most of them were too small to have been effectively used for that; however, many of them may have been core-trimming flakes produced in the process of creating large flakes for biface production. The microdebitage factored heavily into the analysis, as demonstrated in the pre-Classic period sample (see Figure 43d). All of the samples showed a combination of core, biface-thinning, and microdebitage flakes.

The three dominant materials at Falcon Landing (basalt, rhyolite, and chert) received differential treatment, repeating a predictable theme in the comparison of coarse-grained and fine-grained raw materials. As shown in Figure 44, basalt experienced slightly more core reduction, whereas rhyolite and cherts experienced significantly more biface reduction. Core reduction accounts for approximately 16 percent of all basalt debitage, whereas biface reduction accounts for 27 percent of the sample. At the other end of the spectrum, core reduction is responsible for 10 percent of all chert debitage, but 47 percent of the chert sample was produced by biface reduction. This pattern certainly reflects the "ready-made" condition of transported chert cores that did not require the decortication and shaping that local basalt and rhyolite cobbles did. It does not explain why rhyolite and basalt cobbles did not experience equal amounts of core reduction, but we attribute that to material quality rather than proximity.

Flake-to-core ratios can also inform on reduction intensity, the duration of site occupations, and tool transport (Parry and Kelly 1987). Among basalt, rhyolite, quartzite, and chert, the most intensively reduced material was rhyolite, with 67 core-reduction flakes per core. Chert also witnessed intensive reduction (56 flakes per core). Basalt and quartzite had much lower flake-to-core ratios (approximately 24 flakes per core each), although that does not mean that they were reduced with equal intensity. Quartzite was not a popular material for biface manufacture at the site, and its reduction intensity was low; basalt was intensively reduced, but not in relation to the number of cobble unifaces at the site.

All of the rocks at Falcon Landing were curated to a greater or lesser extent, and core flakes at Falcon Landing did not necessarily reflect prolonged habitation and the need for expedient flake tools. In fact, there was little evidence that expedient flake tools were in demand there, as discussed below. The interesting aspect of what is shown in Figure 44 is how much local material was invested in the production of bifaces. The treatments of rhyolites and cherts were nearly indistinguishable. This indicates that flaked stone reduction at Falcon Landing was highly focused on using local cobbles for the production of bifaces, but a number of nonlocal "mobile" cores obviously cycled through the site, as well. A look at raw-material use through time indicated that chert use was never high, but a minor increase occurred during the Cienega phase (Figure 45). The same graph shows the diversity of all raw-material varieties in each dated sample. Raw-material diversity was lowest for the Red Mountain phase and the pre-Classic period, but those samples sizes were very small. Basalt use was highly stable through time.

Early in the analysis, it was clear that flake artifacts at Falcon Landing did not represent the entire sequence of core reduction at the site. The collection had lots of big cores and lots of small biface-thinning flakes but very little between. As discussed previously, cobble unifaces and blocky cores were used to create

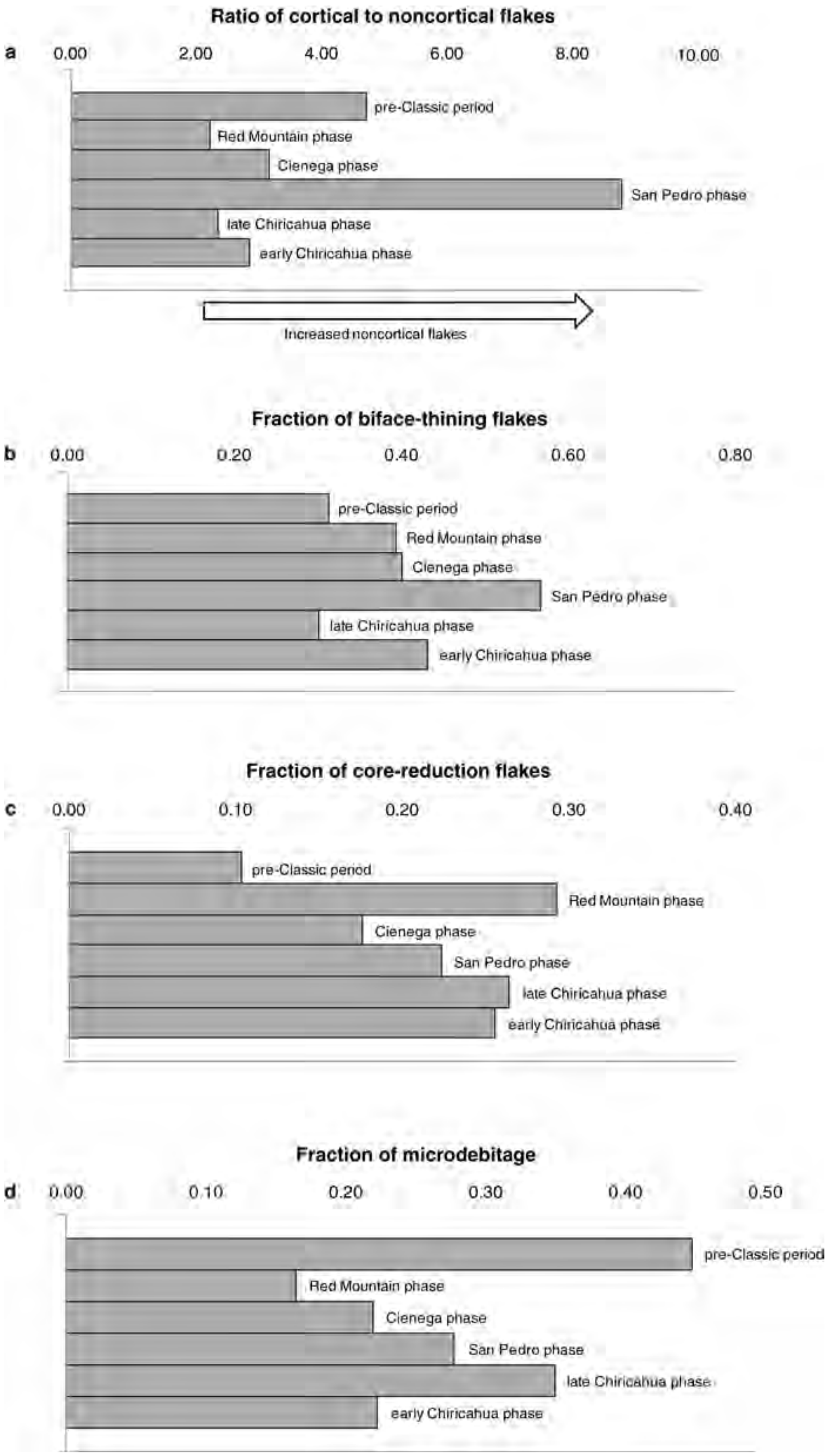


Figure 43. Technological summary of flaked stone debitage at Falcon Landing, including (*a*) the ratio of cortical to noncortical flakes, (*b*) the fraction of biface-thinning flakes, (*c*) the fraction of core-reduction flakes, and (*d*) the fraction of microdebitage.

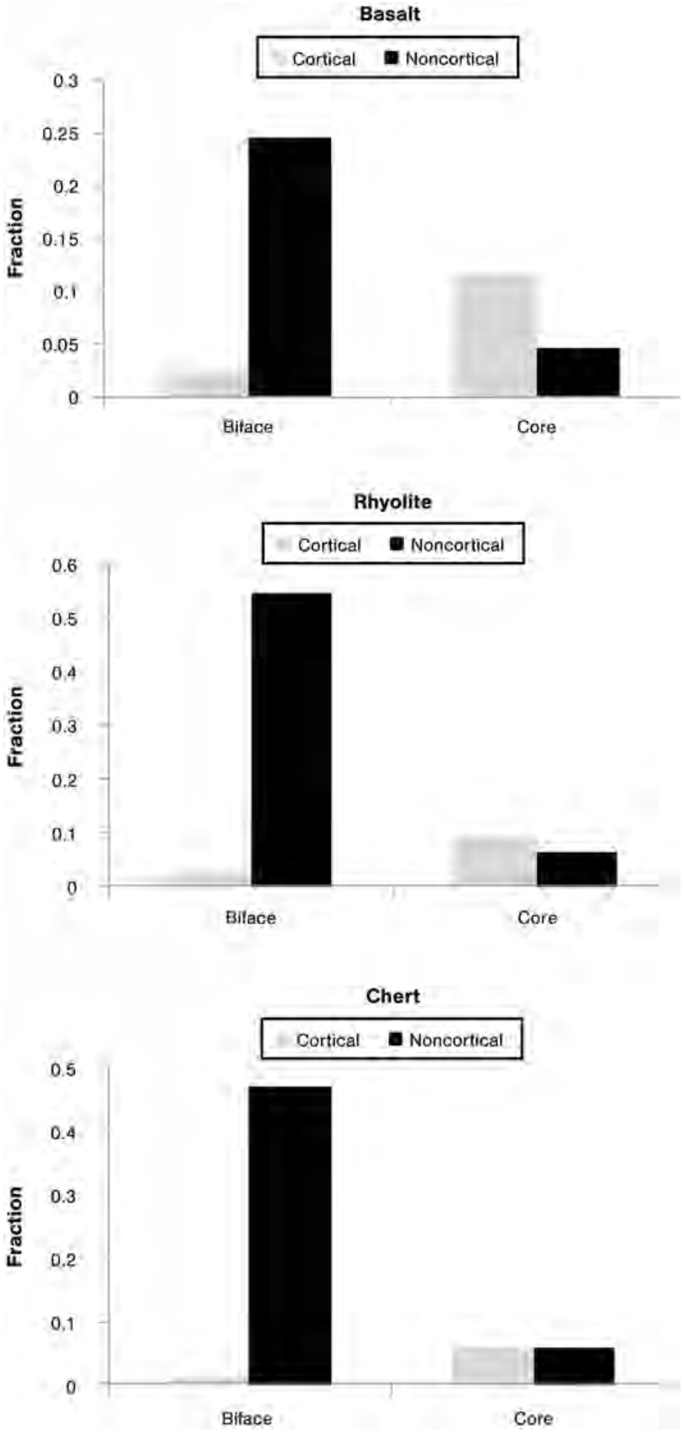


Figure 44. Distribution of cortical and noncortical biface-thinning flakes and core flakes at Falcon Landing made from basalt, rhyolite, and chert.

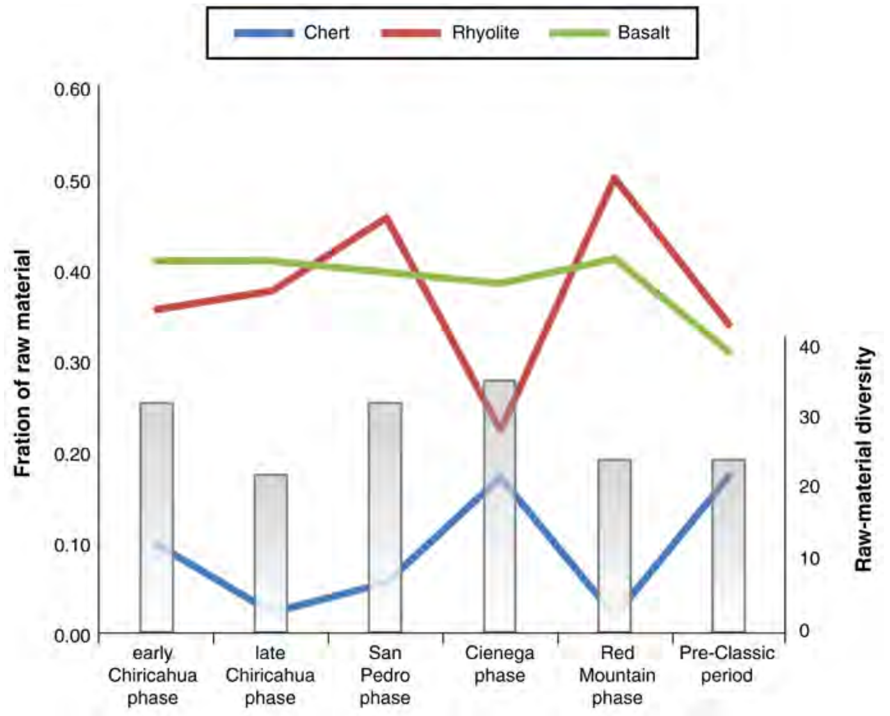


Figure 45. Proportions of all basalt, rhyolite, and chert artifacts and raw-material diversity at Falcon Landing.

flakes that ranged between about 40 and 60 mm (see Table 16), but less than 10 percent of the flakes in the sample measured greater than 40 mm. The cobble reduction performed at Falcon Landing should have resulted in more large flakes (Patterson 1990). Large flakes struck from cobble unifaces or blocky cores were either systematically reduced into bifaces or transported off-site, but they were not casually detached, used, and discarded.

Scrapers

The scraper collection amounted to only 10 artifacts, none of which was precisely dated (Table 19). The most remarkable aspect of the scraper collection was the paucity of scrapers at the site in comparison to other Archaic period assemblages. Of the 10 items classified as scrapers, only 3 were well-executed flakes with intensive retouch (e.g., Figure 46b and c). The rest were large and crude. They were distinguished from informal modified flakes by the length, location, and intensity of each retouched edge. One of the side scrapers was indirectly associated with a Sulphur Spring phase radiocarbon date, but it was not recovered from a feature. It was a large, broken flake of basalt with continuous retouch along one lateral edge. A single specimen was classified as a broken scraper/plane—a common form in other Middle Archaic period assemblages (Haury 1950:187; Sayles 1983:73) but one that was not heavily utilized at Falcon Landing. One peculiar edge-tool design was the use of a flat, cortical surface as the planar side of a scraper, creating a retouched-flake technology that was essentially upside-down, and this behavior was also seen in the modified-flake collection. The limited number of formal scrapers suggests that they did not fulfill a regular function at Falcon Landing.

EMFs

The character of the EMF collection, and the edge-tool industry in general, is disappointing compared to the character of other tools. Only 47 flakes showed some evidence of retouch. The EMFs can be separated into two modes: 38 small, broken flakes of fine-grained basalts, rhyolites, cherts, and a single obsidian piece that showed informal edge modification extending 1–3 mm along one edge and 9 large, mostly intact flakes of basalt that exhibited rounding, crushing, and/or crude retouch extending along the distal or lateral edges. Only 22 of the retouched implements were recovered from features (Table 20), including structures, nonthermal pits, and thermal pits, in nearly equal proportions, as well as activity areas, middens, and a FAR concentration.

Table 19. Summary Information Recorded on Scrapers, by Temporal Component, Falcon Landing

Characteristics	Sulphur Spring	Cochise[a]	Cochise to Historical	Not Dated	Total
			Type		
End scrapers	—	1	1	1	3
Side scrapers	1	—	1	—	2
End/side scrapers	—	2	1	1	4
Scraper/plane	—	—	—	1	1
No. complete	—	3	2	2	7
Total number of specimens	1	3	3	3	10
			Maximum Long Axis Range (mm)[b]		
		45–71	32–49	46–71	32–71
			Edge Morphology		
Straight	1	—	1	—	2
Concave	—	—	—	3	3
Convex	—	2	2	—	4
Irregular	—	1	—	—	1
Notched	—	—	—	—	—
Total	1	3	3	3	10
Edge angle (mean, SD)	70	73 (8)	65 (13)	68 (6)	n/a
			Recovery Context		
Noncultural	—	—	2	—	2
Nonthermal pit	—	1	1	—	2
Nonthermal pit (bell shaped)	—	1	—	—	1
Surface structure	—	1	—	—	1
CBS/mixed	1	—	—	2	3
Site surface	—	—	—	1	1
Total	1	3	3	3	10
			Raw Material		
Basalt 1	—	—	—	2	2
Basalt 2	1	1	—	—	2
Basalt 4	—	—	1	—	1
Chert 2	—	1	—	—	1
Other chert	—	—	1	—	1
Rhyolite 6	—	1	—	—	1
Chalcedony	—	—	1	—	1
Petrified wood	—	—	—	1	1
Total	1	3	3	3	10

Key: CBS = culture-bearing sediment; n/a = not applicable; SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

[b] Complete specimens.

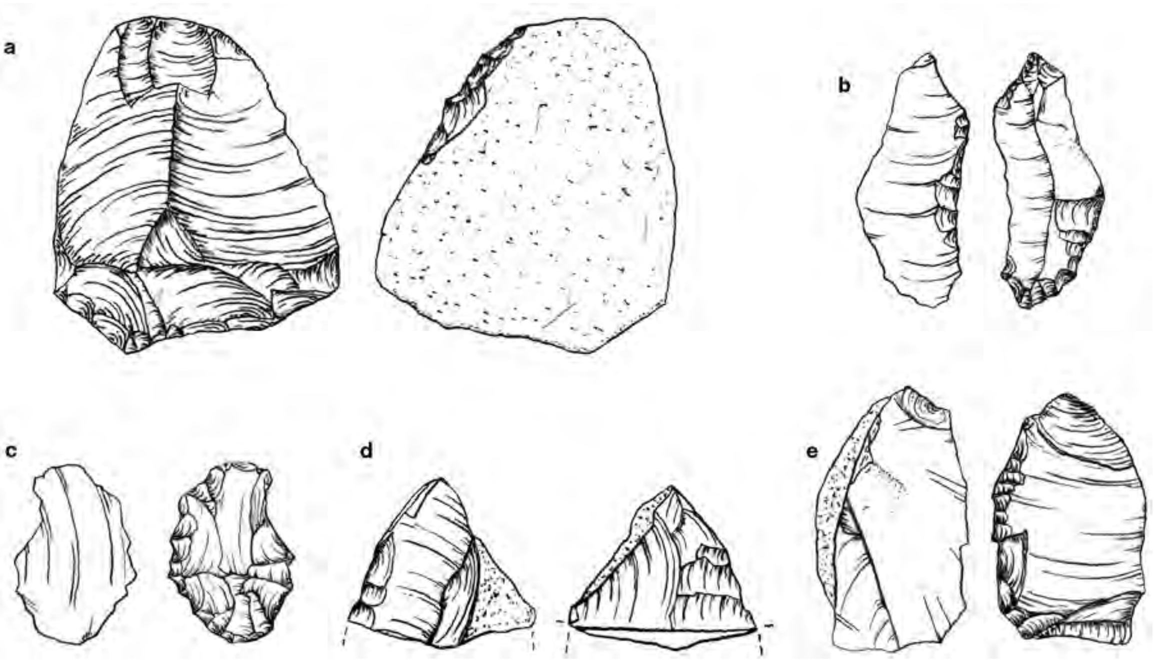


Figure 46. Scrapers and edge-modified flakes from Falcon Landing: (*a*) a basalt (Subtype 2) end scraper from Feature 8561, a surface structure (Inventory No. 04000CF9E, Cochise); (*b*) a chert end/side scraper from Feature 3551, a nonthermal pit (Inventory No. 040010FB9, Cochise); (*c*) a chalcedony end/side scraper from Feature 10118, a noncultural feature (Inventory No. 04000C49A, Cochise to Historical period); (*d*) a rhyolite (Subtype 8) edge-modified flake from Feature 1303, an activity area (Inventory No. 040010E8F, early Chiricahua phase); and (*e*) a chalcedony edge-modified flake from Feature 8156, a nonthermal pit (Inventory No. 0400111DC, Cochise). (*Note*: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

None of the artifacts was well executed or shaped. Two of the better-executed and more extensively modified examples are shown in Figure 46d and e.

The large EMFs can be compared to "ground-edged flakes" as described from Chiricahua phase components by Sayles (1983:Figure 6.12c), but they represented an insignificant portion of the Falcon Landing collection. The expedient use of large or small flakes as edge tools was not a common behavior at the site. One large, complete EMF made from basalt was collected from the wall of TR 10067, in a nonsite portion of the APE.

Knife

One relatively large obsidian-flake knife was recovered from Falcon Landing. The artifact is fully described in the section below that discusses the obsidian sample.

Drills

Three small drill fragments were included in the site collection, including a 13-by-10-by-5-mm basalt midsection from Feature 1303, an early Chiricahua phase structure. The item was weakly serrated and beveled, an attribute of projectile point blades that have been reduced to drill-like forms. Another 12-by-6-by-3-mm distal tip made from chalcedony with obvious use wear was found while evaluating a possible pit feature, but it was from a nonfeature context. The last drill was also made from chalcedony and was a 22-by-17-by-6-mm proximal fragment found in a nonfeature context during mechanical stripping in MSU 1281. Drills are not common in flaked stone assemblages, but their functions and distributions have not attracted careful

Table 20. Summary Information Recorded on Edge-Modified Flakes, by Temporal Component, Falcon Landing

Characteristics	Early Chiricahua	San Pedro	Cienega	Pre-Classic	Cochise[a]	Cochise to Historical	Not Dated	Total
				Portion				
Complete	3	—	1	—	7	3	18	32
Proximal	2	—	1	—	—	—	1	4
Distal	3	1	—	1	1	—	—	6
Midsection	—	—	1	—	1	—	1	3
Lateral	—	—	—	1	—	—	—	1
Indeterminate fragment	—	—	—	—	1	—	—	1
Total number of specimens	8	1	3	2	10	3	20	47
				Metrics (mm)				
Maximum long axis (mean, SD)	42 (24)	21	34 (5)	30 (13)	39 (20)	47 (31)	69 (29)	n/a
Edge angle (mean, SD)	52 (14)	80	40 (17)	73 (4)	49 (22)	47 (13)	58 (19)	n/a
				Recovery Context				
Activity area	3	—	1	—	—	—	—	4
FAR concentration	—	—	—	—	1	—	—	1
House-in-pit	2	—	—	2	—	1	—	5
Midden	2	—	—	—	—	—	—	2
Nonthermal pit	—	1	—	—	4	—	—	5
Thermal pit	—	—	—	—	3	2	—	5
CBS/mixed	1	—	2	—	2	—	13	18
Site surface	—	—	—	—	—	—	7	7
Total	8	1	3	2	10	3	20	47
				Raw Material				
Basalt 1	—	—	1	—	2	—	4	7
Basalt 2	2	—	—	—	—	—	5	7
Basalt 3	2	—	—	—	—	—	—	2
Basalt 4	—	—	—	—	—	—	1	1
Other basalt	—	—	—	—	—	—	1	1
Chert 1	—	—	—	—	—	—	1	1
Chert 2	—	1	—	—	—	—	—	1
Chert 9	—	—	—	—	1	—	—	1
Other chert	1	—	—	—	1	—	1	3
Metaquartzite 3	—	—	1	—	—	—	—	1
Other metaquartzite	—	—	—	—	—	—	1	1
Rhyolite 1	—	—	—	—	1	1	—	2
Rhyolite 6	1	—	—	—	—	—	3	4
Rhyolite 8	1	—	1	—	—	1	—	3
Rhyolite 11	—	—	—	—	—	—	1	1

Characteristics	Early Chiricahua	San Pedro	Cienega	Pre-Classic	Cochise[a]	Cochise to Historical	Not Dated	Total
Other rhyolite	—	—	—	—	1	—	2	3
Chalcedony	1	—	—	1	2	1	—	5
Obsidian	—	—	—	—	1	—	—	1
Siltstone	—	—	—	1	1	—	—	2
Total	8	1	3	2	10	3	20	47

Key: CBS = culture-bearing sediment; n/a = not applicable; SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

study. Haury (1950:301–303) documented 54 formal drills from Ventana Cave—nearly 1 percent of the flaked-stone-tool sample—and commented that they were rare at Snaketown and nonexistent at San Pedro phase sites in southeastern Arizona. The sample from Falcon Landing indicates infrequent drill-related tasks.

Bifaces

The biface collection from Falcon Landing consisted of 34 bifaces, 31 of which were broken. The sample included mostly poorly executed, small bifaces, but the larger pieces indicated the late-stage breakage of bifaces due to lateral bending breaks. A couple (n = 2) of the bifaces were well shaped and may represent the distal tips of completed San Pedro points (Figure 47b and c), but their pristine edges, form, and breakage demonstrated that they had not experienced use when they broke. Only 8 of the bifaces came from well-dated features or strata, including 2 bifaces from early Chiricahua phase nonthermal pits (Features 2465 and 14580). One of these (see Figure 47a) was a parallel-sided preform for what was probably intended to be a Chiricahua point, based on its age and comparison to the projectile point collection. Two well-made but minute biface fragments (1 by 1 cm) were manufactured from obsidian.

Feature 4302, a structure, contained 1 of the San Pedro phase bifaces, a thick piece of rhyolite associated with an Elko Corner-notched projectile point, and a small concentration of mostly basalt and rhyolite debitage. Feature 4308, another San Pedro house-in-pit, contained a rhyolite biface midsection amid fewer than 20 flakes of various materials (see Chapter 4, Volume 1). Discrete knapping stations or events were not identified during excavation or analysis. Even small debitage collections often contained multiple types and varieties of raw material. Four bifaces were found in Cienega phase deposits, but 2 of them were very small, lateral fragments from 2 separate obsidian bifaces (or points); 1 was excavated from a nonthermal pit (Feature 1469).

The interesting information provided by the bifaces is that the most-common raw materials were rhyolite, chert, and basalt (Table 21), which is disproportionate to the frequency of those materials in the debitage sample (see Table 17). Rhyolite and chert bifaces were clearly overrepresented, and basalt bifaces were underrepresented. Also, including the probable Chiricahua projectile point preform from Feature 14580, two general forms were found in the biface sample: a straight-based preform (see Figure 47a, d, and e) and a convex-based preform (see Figure 47f and h). The biface identified in Figure 47e was recovered from a thermal pit (Feature 3044) and appeared to have suffered a lateral break that had been carefully repaired using bifacial retouch.

Projectile Points

In total, 53 projectile points were recovered from Falcon Landing. Organized in terms of frequency, projectile point types recognized in the collection included Chiricahua (n = 9), San Pedro (n = 8), Cortaro (n = 4), Datil (n = 3), Elko Corner-notched (n = 1), generic contracting stem (n = 1), and Colonial Stemmed (n = 1) (Figures 48 and 49). The other 26 specimens were indeterminate dart points (n = 4) or dart-point fragments (n = 22) (Table 22). The most common recovery contexts for projectile points were pits, from which 16 projectile points were recovered. Other recovery contexts included structures (n = 6), a midden (n = 1),

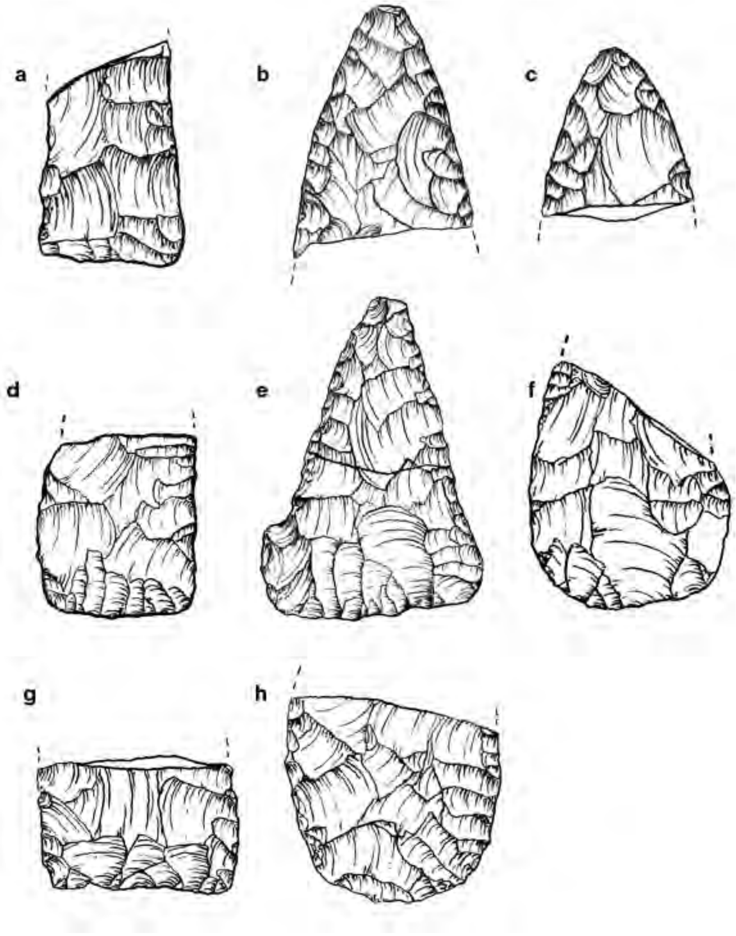


Figure 47. Bifaces from nonthermal-pit features (unless otherwise specified) at Falcon Landing: (*a*) rhyolite, from Feature 14580 (Inventory No. 04000F1F5, early Chiricahua phase); (*b*) basalt, from Feature 11390 (Inventory No. 04000E72C, poorly dated, Middle Archaic to Protohistoric period); (*c*) basalt, from Feature 4370 (Inventory No. 04000C2CF, Cochise); (*d*) rhyolite, from Feature 4370 (Inventory No. 040010FC0, Cochise); (*e*) chert, from thermal-pit Feature 3044 (Inventory No. 04000CF78, Cochise); (*f*) chert, from Feature 4370 (Inventory No. 04000C245, Cochise); (*g*) rhyolite, from a nonfeature context (Inventory No. 04000EF63, no temporal assignment available); and (*h*) rhyolite, from a nonfeature context (Inventory No. 04000EF4C, no temporal assignment available). (*Note*: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

Table 21. Summary Information Recorded on Bifaces, by Temporal Component, Falcon Landing

Characteristics	Early Chiricahua	San Pedro	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Total
				Portion			
Complete	—	—	—	2	—	—	2
Proximal	—	—	—	4	—	1	5
Distal	2	—	2	6	2	8	20
Midsection	—	1	—	—	—	1	2
Lateral	—	—	2	—	—	1	3
Indeterminate	—	1	—	1	—	—	2
Number of specimens	2	2	4	13	2	11	34
				Metrics[b]			
Width/thickness ratio (mean, SD)	2.91 (0.48)	2.94 (0.70)	2.11 (0.77)	2.99 (1.08)	2.97 (0.39)	3.25 (0.68)	n/a
				Recovery Context			
Activity area	—	—	—	1	—	—	1
House-in-pit	—	2	—	—	1	—	3
Nonthermal pit	2	—	1	8	—	—	11
Nonthermal pit (bell shaped)	—	—	—	1	—	—	1
Thermal pit	—	—	—	1	1	—	2
CBS/mixed	—	—	3	1	—	6	10
Natural stratum	—	—	—	1	—	—	1
Site surface	—	—	—	—	—	5	5
Total	2	2	4	13	2	11	34
				Raw Material			
Basalt 1	—	—	—	2	1	—	3
Basalt 2	—	—	—	3	—	—	3
Subtotal basalt	—	—	—	5	1	—	6
Chert 1	—	—	—	—	—	1	1
Chert 2	1	—	—	—	—	—	1
Other chert	—	—	1	2	—	1	4
Subtotal chert	1	—	1	2	—	2	6
Rhyolite 1	—	—	—	1	—	3	4
Rhyolite 3	—	—	1	—	1	—	2
Rhyolite 4	—	1	—	1	—	—	2
Rhyolite 6	1	—	—	2	—	2	5
Rhyolite 7	—	—	—	1	—	1	2
Rhyolite 8	—	1	—	—	—	—	1
Subtotal rhyolite	1	2	1	5	1	6	16
Chalcedony	—	—	—	—	—	3	3
Obsidian	—	—	2	—	—	—	2
Siltstone	—	—	—	1	—	—	1
Total	2	2	4	13	2	11	34

Key: CBS = culture-bearing sediment; n/a = not applicable; SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

[b] Lateral fragments excluded.

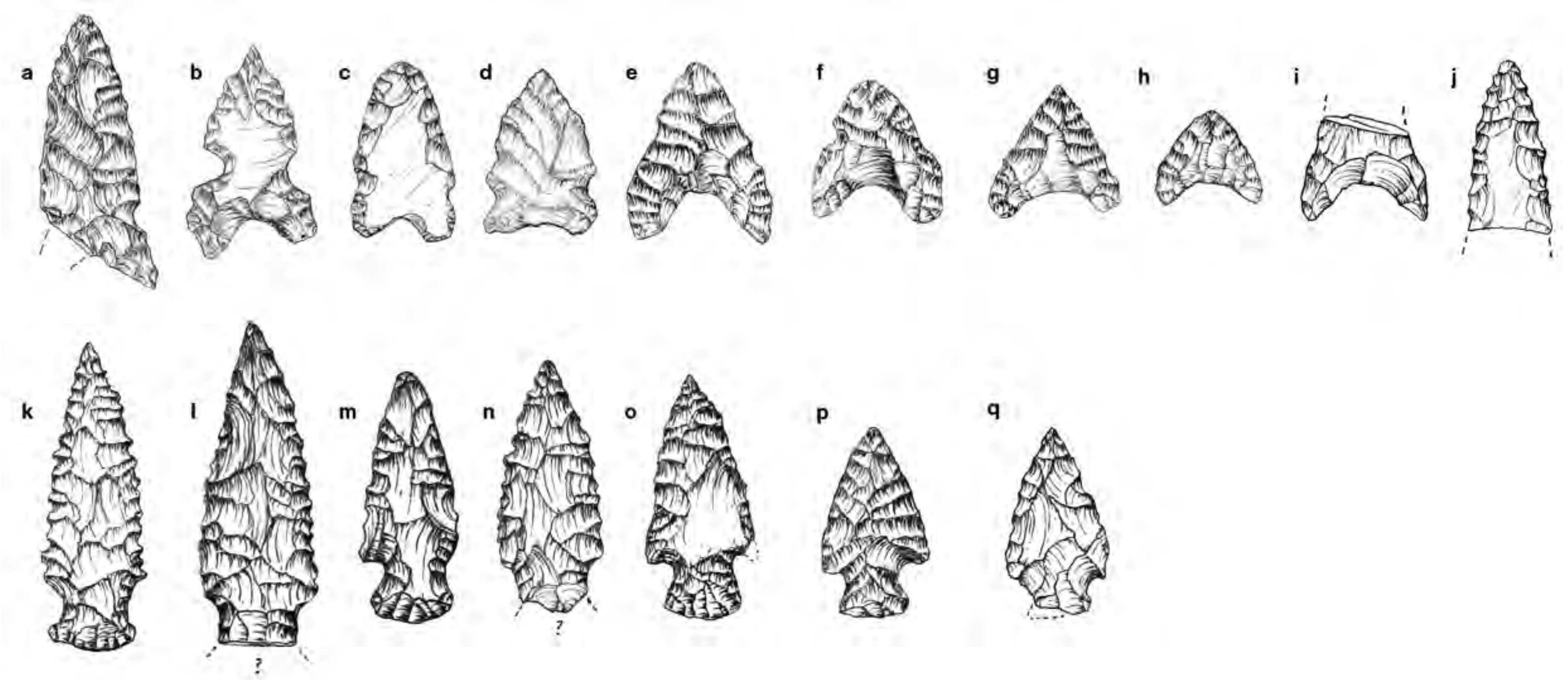


Figure 48. Chiricahua and San Pedro projectile points from Falcon Landing (from nonfeature contexts, unless otherwise specified). Chiricahua projectile points: (*a*) basalt, from Feature 1523, a thermal pit (Inventory No. 04000C5E2, early Chiricahua phase); (*b*) rhyolite (Inventory No. 04000C3F2, not dated); (*c*) basalt, from Feature 1535, a charcoal/ash lens (Inventory No. 04000C5EF, Cochise); (*d*) basalt (Inventory No. 04000C19D, not dated); (*e*) rhyolite (Inventory No. 04000E3E9, not dated); (*f*) basalt (Inventory No. 04000BF5F, not dated); (*g*) chalcedony (Inventory No. 04000C196, not dated); (*h*) chalcedony (Inventory No. 04000E3D5, not dated); (*i*) basalt, from Feature 1334, a nonthermal pit (Inventory No. 04000C646, late Chiricahua phase); and (*j*) rhyolite (probable Chiricahua), from Feature 4388, a house-in-pit (Inventory No. 04000C2C8, early Chiricahua phase). San Pedro projectile points: (*k*) rhyolite, from Feature 14755, a nonthermal pit (Inventory No. 04000FB97, Cochise); (*l*) rhyolite, from Feature 4355, a nonthermal pit (Inventory No. 04000C348, San Pedro phase); (*m*) basalt, from Feature 3256, a midden (Inventory No. 04000D226, San Pedro phase); (*n*) metaquartzite, from Feature 15173, a nonthermal pit (Inventory No. 04000F3A7, Cochise); (*o*) chert, from Feature 17908, a structure (Inventory No. 04000FB8A, Cochise); (*p*) rhyolite, from Feature 14702, a house-in-pit (Inventory No. 04000F5B9, Red Mountain phase); and (*q*) basalt (Inventory No. 04000C19A, not dated). (*Note*: “Cochise” indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

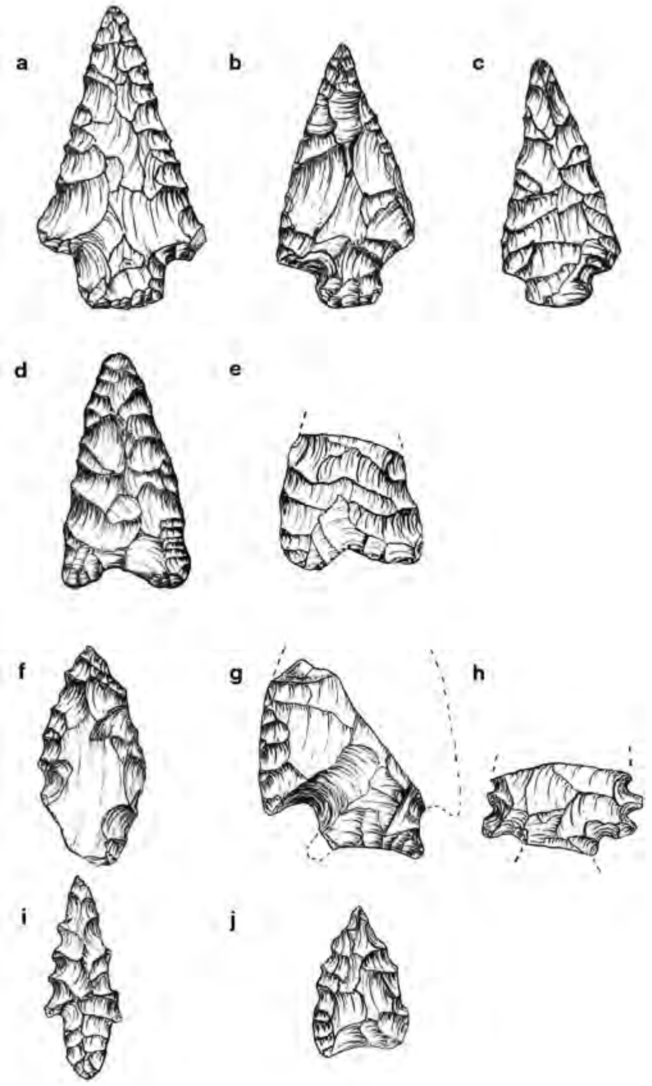


Figure 49. Additional projectile point types from Falcon Landing (from nonfeature contexts, unless otherwise specified). Datil projectile points: (*a*) basalt, from Feature 4355, a nonthermal pit (Inventory No. 04000C350, San Pedro phase); (*b*) chert (Inventory No. 04000F3A6, not dated); and (*c*) rhyolite, from Feature 18152, a nonthermal pit (Inventory No. 040010B88, early Chiricahua phase). Cortaro projectile points: (*d*) basalt, from Feature 1337, an activity area (Inventory No. 04000C8F7, Cochise), and (*e*) chalcedony, from Feature 1337, an activity area (Inventory No. 04000C8EC, Cochise). Other projectile point types: (*f*) basalt contracting stem (Inventory No. 040010798, not dated); (*g*) chert Elko Corner-notched, from Feature 4302, a house-in-pit (Inventory No. 04000C249, San Pedro phase); (*h*) basalt indeterminate (Inventory No. 04000BB78, not dated); (*i*) chalcedony Colonial Stemmed (Inventory No. 04000C9D6, not dated); and (*j*) basalt indeterminate, from Feature 10278, a possible reservoir (Inventory No. 04000FB91, San Pedro phase). (*Note*: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

Table 22. Attributes and Variables Recorded for Projectile Points, Falcon Landing

Catalog No.	Unit No.	Unit Type	Feature No.	Sub-feature	Feature Type	Type	Radiocarbon Age	Stratigraphic Age	Portion	Material Type	Material Subtype	Max. Length (mm)	Max. Width (mm)	Max. Thickness (mm)	Neck Width (mm)	Basal Width (mm)	Basal Concavity Depth (mm)	Piercing Tip	Serrations	Reworked	Beveling	Burned	Comments/Figure No
040010798	19174	point provenienced				contracting stem			complete	basalt		40	19	5.4				yes	yes	none	no	no	see Figure 3.13f
04000E3E9	11043	point provenienced				Chiricahua			complete	rhyolite		32	26	4.4	18.7	26	9	no	yes	blade	no	yes	heavily resharpened/see Figure 3.12e
04000BF5F	1301	point provenienced				Chiricahua			complete	basalt	basalt 2	26	23	4.7	14.4	23	6.3	no	no	blade	no	no	see Figure 3.12f
04000C3F2	3682	point provenienced				Chiricahua			complete	rhyolite	rhyolite 1	37	22	4.5	10.1	21	6	yes	yes	none	no	no	fashioned from thin flake/ see Figure 3.12b
04000C5E2	5532	section	1523		thermal pit	Chiricahua	2870–2630 B.C.		proximal, ear	basalt	basalt 2	50	22	5.3	14.8		5.2	yes	no	none	no	no	see Figure 3.12a
04000C646	5652	section	1334		nonthermal pit	Chiricahua	1440–1310 B.C.		proximal	basalt	basalt 2	20	23	4.2	17.1	23	6.3	indet.	indet.	indet.	no	no	see Figure 3.12i
04000C196	10111	point provenienced				Chiricahua			complete	chalcedony		23	24	4.6	18.5	24	4.1	yes	no	blade	no	no	heavily resharpened/see Figure 3.12g
04000E3D5	10501	point provenienced				Chiricahua			complete	chalcedony		16	19	4.3	13.7	19	3.4	no	no	blade	no	no	heavily resharpened/see Figure 3.12h
04000C5EF	5528	section	1535		charcoal/ash lens	Chiricahua		5320–720 B.C.	complete	basalt	basalt 2	32	18	3.7	15.5	18	4.3	no	no	none	no	no	fashioned from thin flake/ see Figure 3.12c
04000C19D	10200	point provenienced				Chiricahua			complete	basalt	basalt 2	30	21	4.2	16.5	21	1.9	yes	no	blade	no	no	see Figure 3.12d
04000FB8A	18697	section	17908	20285	house-in-pit	San Pedro	160 B.C.–A.D. 330		complete	chert		45	19	6.2	9.9	13.8		yes	no	blade	no	no	corner notched/see Figure 3.12o
04000FB97	18751	point provenienced	14755		nonthermal pit	San Pedro	1260–1050 B.C.		complete	rhyolite		55	19	5.7	11.4	15.7		yes	yes	none	no	no	side notched/see Figure 3.12k
04000F3A7	17386	point provenienced	15173		nonthermal pit	San Pedro	1270–1050 B.C.		distal, stem	metaquartzite	metaquartzite 3	45	19	5.3	12.7			yes	yes	none	no	no	side notched/see Figure 3.12n
04000F5B9	17622	section	14702		house-in-pit	San Pedro	A.D. 20–120		complete	rhyolite	rhyolite 1	34	20	6.3	9.1	12.7		yes	no	none	no	no	corner notched/see Figure 3.12p
04000C19A	10162	point provenienced				San Pedro			distal, stem	basalt	basalt 1	34	18	6.3	10.3			yes	no	blade	no	no	corner notched; proximal margin impact fractured/see Figure 3.12q
04000D226	8655	test pit	3256		midden	San Pedro	1200–930 B.C.		complete	basalt	basalt 2	46	18	7.8	11.2	16		no	yes	blade	no	no	corner notched; fragmented during excavation/see Figure 3.12m
04000D1E4	8230	test pit				indet.		720–200 B.C.	distal	rhyolite		21	18	4.4				no	no	indet.	no	no	
04000D21C	8230	test pit				San Pedro		720–200 B.C.	proximal	rhyolite		43	23	8.3	14.2	16.5		indet.	yes	none	no	no	side notched; probably broken during manufacture
04000C348	2898	test pit	4355		nonthermal pit	San Pedro	1110–1000 B.C.		distal, stem	rhyolite		59	21	7.9	13.5			yes	yes	blade	no	no	probably side notched; proximal margin missing/ see Figure 3.12l
04000C350	2898	test pit	4355		nonthermal pit	Datil	1110–1000 B.C.		complete	rhyolite	rhyolite 11	55	30	7.1	15	15.1		no	yes	blade	no	no	see Figure 3.13a
040010B88	18152	feature	18152		nonthermal pit	Datil		2810–2420 B.C.	complete	rhyolite	rhyolite 1	45	21	7	12.1	12.3		no	no	blade	no	no	see Figure 3.13c
04000F3A6	15374	point provenienced				Datil			complete	chert		48	25	8.5	11.2	11.6		yes	no	none	no	no	see Figure 3.13b
04000C8EC	6129	section	1337		activity area	Cortaro		5320–720 B.C.	proximal	chalcedony		25	25	4.7		25	3.8	indet.	indet.	indet.	no	no	see Figure 3.13e
04000C8F7	6212	point provenienced	1337		activity area	Cortaro		5320–720 B.C.	complete	basalt	basalt 1	42	23	5		23	3.1	no	no	blade	no	no	see Figure 3.13d
04000C19B	10163	point provenienced				Cortaro			proximal	basalt	basalt 2	27	25	8.8		25	3	indet.	indet.	blade	indet.	no	basal edge lightly ground
04000CF67	8133	section	1296		nonthermal pit	Cortaro		5320–720 B.C.	proximal	rhyolite	rhyolite 1	22	28	6.8			2.2	indet.	indet.	indet.	no	no	
04000C249	1569	test pit	4302		house-in-pit	Elko corner-notched	1130–1000 B.C.		proximal	chert		35	30	8.2	17.4			indet.	no	none	no	no	see Figure 3.13g
04000C9D6	6925	point provenienced				Colonial stemmed			complete	chalcedony		36	14	5.3		4.9		yes	yes	indet.	no	no	see Figure 3.13i

Catalog No.	Unit No.	Unit Type	Feature No.	Sub-feature	Feature Type	Type	Radiocarbon Age	Stratigraphic Age	Portion	Material Type	Material Subtype	Max. Length (mm)	Max. Width (mm)	Max. Thickness (mm)	Neck Width (mm)	Basal Width (mm)	Basal Concavity Depth (mm)	Piercing Tip	Serrations	Reworked	Beveling	Burned	Comments/Figure No
04000BD97	2045	point provenienced				indet.			complete	chalcedony		33	18	6.4	13.6	14		indet.	no	indet.	no	no	distal tip broken during excavation
04000BB78	2163	point provenienced				indet.			midsection	basalt	basalt 1	16	28	6.1				indet.	yes	indet.	no	no	possible San Jose/see Figure 3.13h
04000C23D	2875	test pit	4353		nonthermal pit	indet.		5320–1380 B.C.	distal	basalt	basalt 2	30	23	4.6				no	no	none	no	no	
04000C2C8	2892	test pit	4388		house-in-pit	indet.	3020–2890 B.C.		distal	rhyolite	rhyolite 6	32	15	3				yes	yes	none	no	no	probably Chiricahua/see Figure 3.12j
04000C0BA	4370	feature	4370		nonthermal pit	indet.	1380–1120 B.C.		distal	rhyolite	rhyolite 8	27	19	5.4				no	no	blade	no	no	
040010E83	2872	test pit	4370		nonthermal pit	indet.	1380–1120 B.C.		distal	basalt	basalt 1	20	14	6				indet.	no	indet.	indet.	no	possible impact fracture
04000C65F	3840	point provenienced				indet.			distal	rhyolite	rhyolite 1	37	23	6.5				yes	no	blade	no	no	
04000C231	4342	mechanical -stripping unit				indet.			midsection	basalt	basalt 1	29	25	5.1	13			indet.	no	none	no	no	blade edges dulled
04000C2C6	4518	section	4308	4515	thermal pit (bell shaped)	indet.	1010–920 B.C.		distal	basalt	basalt 1	21	20	4.1				indet.	no	none	no	no	modern break on tip
04000BF0E	5159	point provenienced				indet.			distal	rhyolite		42	17	6.8				no	no	indet.	yes	no	
04001104E	5641	section	1413		house-in-pit	indet.		720–200 B.C.	distal	basalt	basalt 2	19	16	4.4				indet.	no	none	indet.	no	impact fractured
04000C818	6086	section	1499		nonthermal pit	indet.		5320–720 B.C.	distal	chalcedony		8	13	3				no	indet.	none	indet.	no	
04000D69A	8874	test pit				indet.		720–200 B.C.	distal	rhyolite		32	17	6.6				no	no	blade	yes	no	
04000E3E8	10526	point provenienced	2009		FAR concentration	indet.		post-790 B.C.	distal	rhyolite		24	17	5.3				indet.	no	blade	no	no	possible impact fracture
04000E3D6	11026	point provenienced				indet.			complete	chalcedony		27	20	7.6	15.5	16.5		no	no	indet.	yes	no	
04000E3E7	11162	point provenienced				indet.			midsection	rhyolite	rhyolite 1	38	25	6.5				indet.	no	blade	yes	no	alternating, unifacial resharpening
040010B89	11295	feature	11295		nonthermal pit	indet.		2730 B.C.–A.D. 1520	distal	rhyolite	rhyolite 3	27	18	6.5				no	no	none	no	no	probably broken during manufacture
04000E72C	12562	section	11390		nonthermal pit	indet.		5320–160 B.C.	distal	basalt	basalt 1	45	32	7.8				no	no	none	no	no	ossible preform
040011DF8	13848	section	14740		thermal pit	indet.		2810–2420 B.C.	proximal	rhyolite	rhyolite 3	11	14	5.2				indet.	indet.	indet.	indet.	no	possible Datil point stem
04000FB91	14000	test pit	10278		reservoir	indet.	1120–1000 B.C.		complete	basalt	basalt 2	26	17	5	13.6	17	1	yes	no	indet.	no	no	see Figure 3.13j
04000ED06	14195	section	10615		house-in-pit	indet.		790 B.C.–A.D. 610	distal	rhyolite	rhyolite 3	42	24	8.7				no	yes	none	no	no	probably broken during manufacture
04001039D	18404	point provenienced				indet.			complete	basalt	basalt 2	26	16	5.3	13.4	11		no	no	indet.	no	no	
040010398	18405	point provenienced				indet.			distal	chalcedony		27	16	5.5				no	no	blade	no	no	broken on flaw during retouch
0400103A1	18415	point provenienced				indet.			distal	rhyolite	rhyolite 12	43	18	6.3				no	no	blade	yes	no	possible impact fracture
040010794	18483	point provenienced				indet.			distal	siltstone		29.2	14.7	6.1				no	yes	blade/base	no	no	impact fracture, heavily dulled blade edges

Key: indet. = indeterminate

a charcoal/ash lens (n = 1), a FAR concentration (n = 1), a reservoir (n = 1), and activity areas (n = 2). The remaining 25 projectile points were not associated with features. The projectile point sample is described according to type and then summarized as a collection, below.

Generic Contracting Stem

The single contracting-stem point collected from Falcon Landing was a complete biface characterized by nonpatterned percussion and minimal pressure flakes removed from the margins of a large basalt flake, creating a tapered stem and a serrated blade. Only one face of the tool had been completely flaked (see Figure 49f). Edge grinding was absent. The distal tip was extremely sharp, and the point did not appear to have been resharpened. It was not associated with a feature, and its age is uncertain.

Chiricahua

The Chiricahua projectile point sample from Falcon Landing included nine specimens that exhibited shallow to moderately deep side notches (see Figure 48a–i). The points were made from thin flakes with a mean maximum thickness of 4.4 mm. Only two of the intact points had discernibly serrated blades, and four had well-sharpened tips. Blade refurbishing was extensive on some specimens, and two points exhibited extensive retouch that extended below the side notches (see Figure 48g and h). Raw materials were basalt (n = 5), rhyolite (n = 2), and chalcedony (n = 2). Three of the points were collected from features, two of which were radiocarbon dated. A relatively large projectile point with a broken ear (see Figure 48a) was found in a thermal pit (Feature 1523), and a proximal basal fragment (see Figure 48i) was found in a nonthermal pit (Feature 1334). The dates for those features bracketed the type between 2870 and 1310 B.C. at Falcon Landing (see Table 22). The earliest dated projectile point fragment was a distal tip from structure Feature 4388, which was radiocarbon dated to between 3020 and 2890 B.C. The projectile point was manufactured on a thin flake and is probably a fragmented Chiricahua point, but its type attribution is not certain (see Figure 48j).

San Pedro and Cienega

The San Pedro type encompasses a wide range of variations on a common theme of large, notched projectile points, variations that may or may not have temporal, functional, or social significance. The San Pedro type has been applied to both corner and side-notched dart points with straight-to-convex bases (e.g., Justice 2002), confusing morphology with time and essentially defeating the purpose of artifact typology. The Luke Solar project collection included forms characterized by side and corner notches, blades that were often serrated, and convex bases. The geographical range of Late Archaic period corner- and side-notched points is vast, but some of the best-controlled samples in the U.S. Southwest have come from southeastern Arizona (Huckell 1995; Mabry 1998a; Sayles 1983; Stevens and Sliva 2002). Sliva (2005) summarized the Las Capas and Los Pozos collections from the middle Santa Cruz River valley, and San Pedro–type points from those sites were described as having straight or convex bases and, only rarely, serrated blades. The type examples shown by Sliva (2005:Figure 3.16) differed from those in the Luke Solar project collection in that they had remarkably straight bases and only subtle serrations.

The San Pedro projectile point sample from Falcon Landing was characterized by four side-notched and four corner-notched points manufactured from relatively thick flakes (see Figure 48k–q). The average thickness of the representative points was approximately 6.7 mm. Sharp, piercing tips (n = 6) and fine serrations (n = 5) were common. Four of the points appeared to have been resharpened before being lost or discarded, but extensively resharpened (exhausted) San Pedro points were absent. Breakage included three specimens with breaks along the basal margins and one specimen with a broken tip. All of the fractured pieces were suitable for refurbishment. Raw materials included rhyolite (n = 4), basalt (n = 2), metaquartzite (n = 1), and chert (n = 1).

Two of the points were relatively short, falling in the length range of Cienega points (Sliva 1999), but their neck widths (>9 mm) and thicknesses (>6 mm) were more robust than the typical Cienega point, and they are considered small San Pedro–style dart tips in this analysis. Bruce Huckell (personal communication, 2014) considers the points illustrated as Figures 48o and 48p to be Cienega-type points rather than San

Pedro. Those specimens are directly radiocarbon dated to the San Pedro–early Cienega phase transition (see Table 22), but our typological assignment is based on morphological characteristics rather than age.

The most common recovery context for the San Pedro collection was in nonthermal pits (n = 3 specimens). Two projectile points from Feature 4355, a San Pedro phase nonthermal pit, were described as different types. A large blade with an apparent neck portion had a flat base interpreted to be a snap and was included in the San Pedro–type category; the other projectile point was clearly stemmed by design and was included in the Datil-type category. Six of the San Pedro points were recovered from radiocarbon-dated features. The earliest age range was 1270–1050 B.C.; the latest age ranges were 160 B.C.–A.D. 330 and A.D. 20–120 (see Table 22), extending long after the end of the San Pedro phase as defined by Mabry (1995) but within the time interval that Sliva (2009) assigned to the occurrence of San Pedro points.

Cortaro

Four of the projectile points in the Falcon Landing sample were described as Cortaro. The Cortaro-point collection included a single complete specimen and three proximal fragments. Two of the points, including the complete example, were collected from an Archaic period activity area (Feature 1337). Those specimens each measured 5 mm or less in thickness and were atypically well made for the type (see Figure 49d and e). However, the remaining two specimens were typically thick and crude. Comparison to the Cortaro point collection analyzed by Roth and Huckell (1992) indicated that the Falcon Landing points could also be distinguished in terms of their maximum width and the increased depths of their basal concavities. Raw materials used to create the points included chalcedony (n = 1), basalt (n = 2), and rhyolite (n = 1) (see Table 22). No direct radiocarbon dates were available for the type.

Datil

The three stemmed points described as Datil-type projectile points were complete bifaces characterized by short stems, wide shoulders, and triangular blades (see Figure 49a–c). One of the points was recovered from Feature 4355, a San Pedro phase nonthermal pit (see Chapter 4, Volume 1), along with what was interpreted to be a broken side-notched (San Pedro) point (see Table 22). The co-occurrence of stemmed and San Pedro forms is common in Late Archaic period site collections. Another of the points (see Figure 49c) was indirectly dated to between 2810 and 2420 B.C., based on the stratigraphic position of a nonthermal pit (Feature 18152).

Elko Corner-Notched

A single distinctive Elko Corner-notched point was recovered from a structure containing a modest amount of flaked stone debris, a biface, a multidirectional core, a small amount of faunal bone, and an *Olivella*-shell bead. The projectile point was robust and well made and had been minimally retouched before experiencing a transverse fracture (see Figure 49g). The material was a distinctive variety of maroon chert, but the 154 pieces of flaked stone debitage recovered from the structure were dominated by basalt and rhyolite. The structure was associated with a radiocarbon date of 1130–1000 B.C.

Hohokam Colonial Stemmed

The single Ceramic period projectile point was a small, complete Colonial Stemmed–type point that was discovered on an unexcavated surface in the northern portion of Area A (see Figure 49i). The projectile point was made from chalcedony. A series of radiocarbon dates from Falcon Landing bracketed the Colonial period, but no Hohokam projectile points were found in a datable context.

Indeterminate

Four complete projectile points and 22 projectile point fragments were placed in the "indeterminate" category. The broken projectile points included 18 distal tips, 3 midsections, and only 1 proximal stem. One of the midsections exhibited pronounced serrations and may represent a San Jose–type projectile point, but that is speculative (see Figure 49h). Five distal tips were marked by impact fractures or possible impact fractures, but most breaks were lateral snaps. The complete examples were poorly made and amorphous, and the best-shaped point was a small, triangular point (see Figure 49j). The dominant raw materials included rhyolite (n = 12), basalt (n = 9), chalcedony (n = 4), and siltstone (n = 1). Recovery contexts varied, but 3 projectile point distal tips were collected from Feature 4370, a nonthermal pit, along with modest amounts of flaked stone debris and faunal bone and a conical pipe.

Projectile Point Summary

The projectile point collection from Falcon Landing contained an important display of utilitarian tools that had been lost, discarded, or abandoned at the site. The presence of Chiricahua, San Pedro, Datil, Cortaro, and Elko Corner-notched projectile points is of special interest, because Middle Archaic period sites are typically characterized by such diversity in projectile point types (Haury 1950; Sayles and Antevs 1941). The continuation of that pattern on the lower piedmont suggests that the co-occurrence of those types reflects not chance reoccupation of choice spots but adaptive continuity between the makers of successive point types, such as Chiricahua and San Pedro, or similar land-use and subsistence strategies between the makers of contemporaneous point types, such as San Pedro, Datil, and Elko Corner-notched. Falcon Landing is different from other Late Archaic/Early Agriculture period sites buried in central and southern Arizona (see Ballenger et al. 2011; Sliva 1999) because of the absence of Cienega-type points. In fact, with the exception of a single Colonial Stemmed point found on the surface, the lack of post–San Pedro phase projectile points (as well as ceramics) is striking in relation to the number of Cienega phase and later features excavated at the site (see Chapter 10). Possible explanations for this discrepancy are that Cienega and later groups did not use Falcon Landing as a springboard into upper *bajada* and montane hunting camps, or the participation of men at the site diminished significantly.

The contemporaneity of projectile point types was not testable at Falcon Landing, because few points were found in association with other points. A Datil point and a San Pedro point were described together from Feature 4355, a nonthermal pit, but the San Pedro-point candidate was broken and therefore lacked typological criteria. However, Falcon Landing did provide important new dates for Chiricahua-, San Pedro–, Datil-, and Elko-type points in the Sonoran Desert. The earliest age for Chiricahua points at the site (see Figure 48a) was no earlier than about 2870 B.C.—or 3020 B.C., if the broken specimen (see Figure 48j) was indeed a Chiricahua point. The latest Chiricahua point (see Figure 48i) was radiocarbon dated to no later than about 1310 B.C. Importantly, both of these directly dated points were good type specimens. The earliest San Pedro–type projectile points (see Figure 48k and n) were dated to no earlier than approximately 1270 B.C., and the most recent San Pedro point was dated to no later than about A.D. 330. Datil-type points were associated with a radiocarbon age of 1110–1000 B.C. (see Figure 49a) or were indirectly dated to between 2810 and 2420 B.C. (see Figure 49c). The Elko Corner-notched projectile point was late, dating to between 1110 and 1000 B.C. (see Figure 49g).

The raw materials in the projectile point sample were roughly predicted by the proportions of rhyolite, basalt, and chert in the debitage sample (see Figure 42). Rhyolite and basalt each accounted for nearly 40 percent of the projectile point sample, and 6 percent was made from chert. Breakage patterns in the projectile point collection included a small number of impact-fractured pieces, but lateral breaks were more common. Discarded projectile point bases, conventionally associated with post-hunt retooling opportunities (Towner and Warburton 1990), were limited in number, but distal tips were common. The only projectile point types that permitted generalization were the small Chiricahua and San Pedro samples, which were quite different. The complete Chiricahua points included a few specimens that had been carefully and extensively retouched (exhausted), and the San Pedro sample indicated little or no maintenance. The degree of resharpening executed on Chiricahua points was characteristic of the type (Justice 2002; Lorentzen 1998; Sliva 2009). The Falcon Landing Chiricahua and Cortaro points lacked the serration seen on some San Pedro points.

The Obsidian Sample

The basalt, rhyolite, chert, and other minor lithic resources transported to Falcon Landing are rea-sonably attributed to the nearby Agua Fria gravels, or unknown outcrops farther away. Obsidian is often the most popularly studied material in flaked stone collections because unlike most other raw materials in the Southwest, its geochemistry can provide high-resolution provenance information (Shackley 2005). For this reason, the obsidian sample collected during the Luke Solar project deserves special attention. This section concentrates on the obsidian artifacts included in the previous section. The entire obsidian collection included 39 obsidian artifacts from Falcon Landing, plus 1 side-notched San Pedro projectile point from a cremation burial at Site 68 that was not submitted for EDXRF analysis. The Falcon Landing collection included 2 small biface fragments, 1 large obsidian flake fashioned into a knife, a small EMF, and 35 pieces of debitage. The debitage was made up of 27 pieces of microdebitage and 8 small biface-thinning flakes.

Nine of the specimens were recovered from features (Table 23). The only piece of obsidian that was directly associated with a radiocarbon date was a fragment of microdebitage recovered from Feature 1303, a Middle Archaic activity area in Area B at Falcon Landing. Most of the other obsidian pieces from the site were found in nearby pit features and test pits. Based on the geochronological model applied to those units, the majority of the obsidian accumulated during the Cienega phase. Because it is doubtful that obsidian was only used in one small area of the site over the course of thousands of years, it is reasonable to assume that the obsidian concentration around Feature 1303 resulted from a single occupation, during either the Middle Archaic period or the Cienega phase.

Two bifaces were represented by small edge margins. One biface fragment made from Vulture obsidian was associated with Feature 1469, a pit that also contained one biface-thinning flake made from basalt. The craftsmanship and cross section of the fragment indicated that it may represent a broken projectile point or late-stage preform. The second small biface fragment was recovered from TP 8230 and was made from Government Mountain obsidian.

The largest piece of obsidian collected during the Luke Solar project was classified as a flaked stone knife (Figure 50). Discovered in TR 10041 in Area B and not associated with a feature, the item was made from a secondary decortication flake removed from a marekanite of Vulture obsidian. Based on the platform, force had been applied straight down and required some form of anvil. The lateral edges were serrated.

One small tool recovered from TP 8380 was classified as an EMF. Made from Vulture obsidian, the tool's modified edge measured less than 7 mm in length and was characterized by only marginal retouch or use modification.

Eight biface-thinning flakes were collected from Falcon Landing; four of them were associated with individual nonthermal features (Features 1240, 1365, and 20465) and a thermal feature (Feature 1481). Only two of the flakes were complete, and each of those was 13 mm or less in length. The biface-thinning flakes were made from Vulture (n = 3) and Government Mountain (n = 5) obsidian.

The majority of the obsidian artifacts collected during the Luke Solar project were classified as microdebitage (<10 mm in length), but most were only 4–6 mm in length. Of the 27 pieces of microdebitage collected from Falcon Landing, 11 were made from Government Mountain obsidian, 3 were made from Vulture obsidian, 1 was from an unknown source, and 1 was indeterminate. Eight pieces of microdebitage were too small for EDXRF analysis.

Ground Stone/Battered Stone Artifacts

This section describes the ground stone and battered stone artifacts in the Falcon Landing collection (n = 2,283), organized at the level of objects. The "working" ground and battered stone tools at the site were not contained in discernable pits, in most instances. Some chronological information was available from 1,223 ground/battered stone objects, but only 201 complete ground stone items were included in the early Chiricahua phase through pre-Classic period samples, and most of them were manos. Weight data were available from 1,934 complete and incomplete objects totaling more than 3,727 kg (8,217 pounds). The average complete metate weighed about 9 kg (20 pounds), and 1 of the boulder mortars transported to the site weighed 31 kg (68 pounds). Significantly more energy was dedicated to processing wild-plant resources than can be quantified using the lithic collection, because an indeterminate amount of FAR was described in the field.

Hammerstones

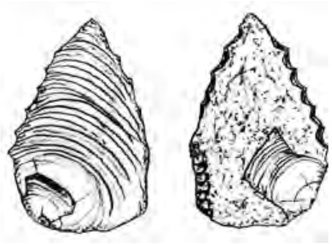
The hammerstones from Falcon Landing included 6 complete specimens that dated to the Chiricahua through Cienega phases and 52 others, mostly fragments, that dated to the Archaic period or later (Table 24).

Table 23. Attributes and Variables Recorded for Obsidian Artifacts, Falcon Landing

Catalog No.	Unit No.	Unit Type	Feature No.	Feature Type	Radiocarbon Age	Stratigraphic Age	Object	Type	Portion	Size Class (mm)	Maximum Length (mm)	Maximum Width (mm)	Maximum Thickness (mm)	Source	Number
04000C198	10041	trench				not dated	knife	flake knife	complete		24	39	5	Vulture	1
040011DCF	8230	test pit				Cienega	biface		lateral		15	6	5	Government Mountain	1
04000D1CA	8131	section	1469	nonthermal pit		Cienega	biface		lateral		11	9	4	Vulture	1
04000D237	8784	section	1481	thermal pit		Cochise	debitage	biface flake	proximal	10–19				Vulture	1
04000D202	8191	test pit	1240	nonthermal pit		Cochise	debitage	biface flake	distal	10–19				Vulture	1
0400120EE	8265	test pit				Cienega	debitage	biface flake	complete		13	9	1	Government Mountain	1
040010388	20465	feature	20465	nonthermal pit		early Chiricahua	debitage	biface flake	complete		11	17	3	Government Mountain	1
04000D823	8380	test pit				Cochise	edge-modified piece	core flake	complete		10	12	4	Vulture	1
04000C81E	6129	section	1337	activity area		Cochise	debitage	microdebitage	complete	<10				Vulture	1
04000CA17	6868	section	4625	FAR concentration		Cochise to Historical	debitage	microdebitage	distal	<10				indeterminate	1
04000FB30	18662	section	14684	nonthermal pit		Cochise	debitage	microdebitage	complete	<10				unknown	1
040010CF9	5424	hand-stripping unit	1303	activity area	2480–2340 B.C.	early Chiricahua	debitage	microdebitage	proximal	<10				too small	1
0400125D8	5592	section	1365	nonthermal pit		Cienega	debitage	biface flake	midsection	<10				Vulture	1
040011B98	8230	test pit				Cienega	debitage	microdebitage	proximal	<10				Government Mountain	1
040011B99	8265	test pit				Cienega	debitage	microdebitage	complete	<10				Government Mountain	1
040011B99	8265	test pit				Cienega	debitage	microdebitage	complete	<10				Vulture	1
040011B99	8265	test pit				Cienega	debitage	microdebitage	distal	<10				Government Mountain	2

Catalog No.	Unit No.	Unit Type	Feature No.	Feature Type	Radiocarbon Age	Stratigraphic Age	Object	Type	Portion	Size Class (mm)	Maximum Length (mm)	Maximum Width (mm)	Maximum Thickness (mm)	Source	Number
040011B99	8265	test pit				Cienega	debitage	microdebitage	indeterminate	<10				Government Mountain	1
040011B99	8265	test pit				Cienega	debitage	microdebitage	indeterminate	<10				too small	1
040011BC0	8949	test pit				Cienega	debitage	microdebitage	complete	<10				too small	2
040011BC9	8230	test pit				Cienega	debitage	microdebitage	complete	<10				Government Mountain	2
040011BEF	8380	test pit				Cienega	debitage	microdebitage	complete	<10				Government Mountain	1
040011BF0	8380	test pit				Cochise	debitage	biface flake	lateral	10–19				Government Mountain	1
040011CA7	8380	test pit				Cienega	debitage	microdebitage	complete	<10				Government Mountain	1
040011CA7	8380	test pit				Cienega	debitage	microdebitage	indeterminate	<10				too small	1
040011D08	8380	test pit				Cienega	debitage	microdebitage	complete	<10				Vulture	1
040011D08	8380	test pit				Cienega	debitage	microdebitage	indeterminate	<10				too small	1
040011D36	8949	test pit				Cienega	debitage	biface flake	proximal	10–19				Government Mountain	1
040011D4B	8282	test pit				Cienega	debitage	microdebitage	proximal	<10				Government Mountain	1
040011DC1	8382	test pit				Cienega	debitage	biface flake	midsection	<10				Government Mountain	1
040011DC1	8382	test pit				Cienega	debitage	microdebitage	complete	<10				too small	1
0400120ED	8265	test pit				Cienega	debitage	microdebitage	complete	<10				Government Mountain	1
0400120ED	8265	test pit				Cienega	debitage	microdebitage	complete	<10				too small	4
Total															39

Figure 50. Obsidian (Vulture) knife from a nonfeature context at Falcon Landing (Inventory No. 04000C198, no temporal assignment available).



Hammerstones were mostly found in thermal pits (24 percent), nonfeature contexts (26 percent), nonthermal pits (14 percent), and structures (14 percent). The collection was composed almost completely of oblong, nonfoliated metamorphic rocks and, more often, fine-grained, aphanitic volcanic materials. Basalt was by far the most prevalent material type. Hammerstones were probably utilized in two primary lithic-reduction activities. The hammerstones in the collection were utilized not only to reduce cores, such as cobble unifaces, but to modify (peck) most of the ground stone implements. The sizes of hammerstones left at the site varied, but the average maximum length was more than 8 cm (see Table 24). Because hammerstones are durable compared to cores, it is difficult to know how many of them to expect relative to flaked stone objects. The 6 complete hammerstones in the collection could have been used to create most or all the Falcon Landing core and flake collection, whereas Haury (1950:254) reported 885 hammerstones from Ventana Cave. The paucity of complete hammerstones relative to the numbers of cores and pecked ground stone at Falcon Landing suggests that hammerstones were not in high demand and were curated or selectively recycled as FAR. Cobble unifaces and other cores did not indicate frequent use as hammerstones. It is probable, given the emphasis placed on biface production at the site, that perishable, curated billets contributed most of the flaked stone debitage.

Metates

The metate collection from Falcon Landing included 575 artifacts, 145 (25 percent) of which were complete (Table 25). In total, 36 complete metates were recovered from features or deposits dated to the Chiricahua (n = 28) and Cienega (n = 8) phases; 53 were assigned to the Archaic period (Cochise group). The remaining metates were incomplete or essentially undated. None of the pit features at Falcon Landing contained more than 1 complete metate each. As described below, only one structure contained a complete metate. Complete metates were also recovered from thermal pits (n = 3) and nonthermal pits (n = 5). A small number of metates occurred as artifact concentrations or caches, as reviewed later in this section. Four of the examples of metate types in Figures 51–54 were from features. Feature 15317 contained a closed-basin metate (see Figure 51b) and is described in the Caches section of this chapter. A late Chiricahua phase structure contained a complete closed-basin metate (see Figure 51c) along with a small collection of flaked stone debris, animal bones, 2 complete manos, and 2 mano fragments (see Chapter 4, Volume 1).

Metates and metate fragments were ubiquitous in structures (n = 49), thermal pits (n = 143), nonthermal pits (n = 92), and FAR concentrations (n = 30), among other feature types (see Table 25). These were invariably small pieces incorporated into thermal features as mass. There were, in total, 430 incomplete metates in the site collection, and 347 (81 percent) of them showed evidence of thermal alteration. The densest concentrations of broken metates included 104 fragments from multiple pit features associated with Feature 2602, originally interpreted to be a large, deep house-in-pit structure. The next-largest concentration included 15 fragments associated with Feature 17253, a nonthermal pit.

The basin metates exhibited a wide range of forms (see Figures 51–54) constrained only by the limited functional requirements of providing a suitable working surface. A majority of metates reflected a manufacturing process that employed some combination of flaking, pecking, and/or grinding. Nearly 40 percent (n = 228) of the total sample showed extensive shaping; among complete specimens, approximately one-third of the metate sample exhibited shaping over more than half their exterior surfaces. Despite extensive surficial modification, no implements had been significantly reshaped from their natural river-cobble forms, and many complete implements had been shaped only on the worked surfaces and along the margins.

Table 24. Summary Information Recorded on Hammerstones, by Temporal Component, Falcon Landing

Characteristics	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Total
Portion								
Complete	3	—	2	1	8	2	15	31
Incomplete	8	1	2	—	6	7	3	27
Total number of specimens	11	1	4	1	14	9	18	58
Thermally Altered								
No	1	—	2	—	8	3	13	27
Yes	9	1	2	1	4	5	5	27
Not recorded	1	—	—	—	2	1	—	4
Metrics (mm)[b]								
Size range	68–91		85–145	65	65–115	56–133	57–112	56–145
Maximum length (mean, SD)	80 (9)		115 (30)		84 (18)	101 (32)	77 (16)	83 (24)
Recovery Context								
Cache	—	—	—	—	1	1	—	2
Charcoal/ash lens	—	—	—	—	2	—	—	2
FAR concentration	—	—	—	—	2	2	—	4
House-in-pit	2	—	4	—	—	2	—	8
Nonthermal pit	2	1	—	—	4	1	—	8
Thermal pit	7	—	—	—	4	3	—	14
CBS/mixed	—	—	—	1	1	—	13	15
Site surface	—	—	—	—	—	—	5	5
Total	11	1	4	1	14	9	18	58
Raw Material								
Andesite	—	—	—	—	1	1	1	3
Basalt	3	—	1	1	11	5	10	31
Vesicular basalt	1	—	—	—	—	—	—	1
Dacite	—	—	—	—	—	—	1	1
Rhyolite	6	1	1	—	2	3	4	17
Quartz	—	—	—	—	—	—	1	1
Quartzite	—	—	—	—	1	—	1	2
Indeterminate	—	—	2	—	—	—	—	2
Total	10	1	4	1	15	9	18	58

Key: CBS = culture-bearing sediment; SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

[b] Complete specimens.

Table 25. Summary Information Recorded on Metates, by Temporal Component, Falcon Landing

Characteristics	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Red Mountain	Cochise[a]	Cochise to Historical	Not Dated	Total
					Type				
Closed basin	11	1	—	4	—	29	21	16	82
Flat/concave basin	27	1	—	4	1	20	20	20	93
Grinding slab	1	—	—	1	—	6	10	11	29
Indeterminate basin	41	—	—	3	2	9	23	14	92
Indeterminate	113	1	4	4	5	60	49	40	276
Three-quarter basin	1	—	—	—	—	1	—	—	2
Open basin	—	—	—	—	—	—	—	1	1
Number of specimens	194	3	4	16	8	125	123	102	575
					Condition				
Complete	27	1	—	8	—	53	45	11	145
Fragment	167	2	4	8	8	72	78	91	430
					Material Texture				
Nonvesicular	149	3	4	14	7	105	106	84	472
Vesicular	45	—	—	2	1	20	17	18	103
					Thermally Altered				
No	40	1	1	10	—	55	52	69	228
Yes	154	2	3	6	8	70	71	33	347
					Residue				
No	192	3	4	16	8	121	122	101	567
Yes	2	—	—	—	—	4	1	1	8
					Manufacturing Investment				
High	85	3	2	2	5	50	41	40	228
Indeterminate	78	—	2	5	3	31	44	26	189
Low	31	—	—	9	—	44	38	36	158
					Surface Texture				
Coarse/resharpened	12	—	—	1	—	5	6	4	28
Indeterminate	12	—	1	1	1	10	5	10	40
Smooth	170	3	3	14	7	110	112	88	507
					Recovery Context				
Activity area	3	—	—	—	—	3	1	—	7
Cache	—	—	—	—	—	3	10	—	13
FAR concentration	6	—	—	—	—	7	17	—	30
House-in-pit	32	3	2	—	4	6	2	—	49
Noncultural	2	—	—	—	—	—	—	—	2
Nonthermal pit	8	—	2	2	4	41	35	—	92
Nonthermal pit (bell shaped)	4	—	—	—	—	2	—	—	6
Posthole	5	—	—	—	—	—	—	—	5
Thermal pit	106	—	—	2	—	13	22	—	143
CBS/mixed	28	—	—	12	—	49	36	88	213
Surface isolate	—	—	—	—	—	1	—	14	15
Total	194	3	4	16	8	125	123	102	575

Key: CBS = culture-bearing sediment.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

Figure 51. Closed-basin metates from early Chiricahua through Cienega phase contexts at Falcon Landing: (*a*) basalt (vesicular), from a nonfeature context (Inventory No. 004000F2B0, early Chiricahua phase); (*b*) basalt, from Feature 15317, a thermal pit (Inventory No. 04000F407, early Chiricahua phase); (*c*) basalt, from Feature 1244, a house-in-pit (Inventory No. 04000C4E4, late Chiricahua phase); and (*d*) basalt (vesicular), from a nonfeature context (Inventory No. 04000E73E, Cienega phase).

Figure 52. Closed-basin metates from Cochise to Historical period contexts at Falcon Landing: (*a*) schist, from a nonfeature context (Inventory No. 04000C8E4, Cochise); (*b*) andesite, from a nonfeature context (Inventory No. 04000F40B, Cochise); and (*c*) dacite (vesicular), from Feature 10622, a thermal pit (Inventory No. 040010795, Cochise to Historical period). (*Note*: “Cochise” indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

Figure 53. Basin metates from nonfeature contexts at Falcon Landing, both made of dacite: (*a*) Inventory No. 04000BFFE, Cienega phase, and (*b*) Inventory No. 04000F26F, Cochise to Historical period. (*Note*: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

Figure 54. Flat/concave metates from Falcon Landing: (*a*) dacite (vesicular), from Feature 15317, a thermal pit (Inventory No. 04000F629, early Chiricahua phase); (*b*) quartzite, from a nonfeature context (Inventory No. 04000CC3C, Cochise); and (*c*) basalt, from a nonfeature context (Inventory No. 04000C2F6, Cochise to Historical period). (*Note*: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

Both closed-basin- and flat-/concave-metate types evidenced sharp fall-offs above approximately 43 cm in length; average lengths were around 36 cm (Table 26). This size threshold probably correlated to the size and weight limits of rocks that could be effectively transported to the site. As previously mentioned, several of the implements were curiously thick and heavy, considering the infinite rock-size and -shape choices available in the Agua Fria River. The average closed-basin metate was roughly 11 cm thick, but some specimens ranged up to 20 cm in thickness. Some of the grinding slabs from Falcon Landing were less than 7 cm thick (Appendix 3.2). Thinness was not an important criterion for grinding tools, however, because grinding slabs accounted for only 5 percent of the metate sample.

Grinding slabs were almost completely executed on foliated metamorphic rocks, especially schist. Other metate forms were made using a variety of volcanic materials, principally rhyolite and basalt (Table 27). Only 5 percent of complete metates were made from quartzite. Most of the quartzite in the collection was on the lower end of the metamorphic range and remained somewhat friable. Vesicular basalt was common (16 percent of complete metates), especially among closed-basin metates. The completeness of the metates was difficult to evaluate, because they had been intensively recycled as FAR, and most fragments would have been indistinguishable as tools. The amount of FAR originating from metates was underestimated. Seventy-five percent of the sample was made up of incomplete metates. Of the fragmented pieces, 64 percent were

Table 26. Summary Metric Information Recorded on Closed-Basin and Flat/Concave Metates, by Temporal Component, Falcon Landing

Metrics	Closed-Basin Metates					Flat/Concave Metates				
	Early Chiricahua	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Early Chiricahua	Cienega	Cochise[a]	Cochise to Historical	Not Dated
Length (mm)										
Average	378.3	358.8	406	359.5	353.8	366.56	325	328.6	360.5	322.7
SD	85.6	16.5	66.2	61.8	64.8	62.28	88.9	48.6	59.1	49.4
n	9	4	29	21	8	16	3	18	16	9
Width (mm)										
Average	237.2	265	255.2	243.2	221.7	236.86	195	203.6	229.1	218.2
SD	33.18	65.6	38.7	48.8	28.1	57.64	21.8	44.3	42.8	39.4
n	9	4	29	21	12	16	3	18	17	11
Thickness (mm)										
Average	89.4	121.3	121.9	105.5	101.7	95	78.3	82.1	95.8	108.5
SD	17.03	67.3	41.7	35.2	32.6	32.09	12.6	22.4	26.7	40.5
n	9	4	29	21	12	16	3	18	17	13
Surface length (mm)										
Average	286.1	258.8	309.1	285	251.3	275	285	254.1	295.9	232.9
SD	70.25	54.8	64.2	68.6	52.2	68	92.6	65.8	53.2	40.8
n	9	4	28	21	8	16	3	17	16	12
Surface width (mm)										
Average	178.5	175	191.4	190.8	155.6	172.19	160	149.4	177.4	160.7
SD	28.67	58	44.4	44.4	47.9	49	15	43.7	36.8	31.2
n	10	4	28	21	13	16	3	17	16	14
Surface depth (mm)										
Average	24.7	30.5	33.6	29.5	25.5	6.4	3.3	4.5	4.4	5.9
SD	7.4	24.4	18.9	19.1	12.9	5.9	2.9	4.4	4.3	4
n	10	4	28	21	14	16	3	17	16	15

continued on next page

Metrics	Closed-Basin Metates					Flat/Concave Metates				
	Early Chiricahua	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Early Chiricahua	Cienega	Cochise[a]	Cochise to Historical	Not Dated
Utility[b]										
Average	0.71	0.71	0.71	0.7	0.73	0.93	0.95	0.95	0.95	0.94
SD	0.1	0.25	0.14	0.2	0.1	0.05	0.04	0.05	0.04	0.04
n	9	4	28	21	12	16	3	17	16	13
Weight (g)										
Average	16,200	14,316	14,559	10,880.4	8,115	10,581	3,590	8,074	11,039	9,900
SD	4,390	8,455	5,953	4,841	1,903	5,931	2,755	4,127	4,993	2,788
n	9	4	29	21	5	16	3	17	16	5

Key: SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

[b] Utility = (thickness-surface depth)/thickness.

Table 27. Raw-Material-Type Information Recorded on Metates, by Temporal Component, Falcon Landing

Material Type	Complete							Fragment									Total
	Early Chiricahua	Late Chiricahua	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Complete Total	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Red Mountain	Cochise[a]	Cochise to Historical	Not Dated	Fragment Total	
Andesite	1	—	2	2	7	1	13	1	—	—	—	—	1	1	2	5	18
Andesite (porphyritic)	2	—	—	2	4	2	10	6	—	—	—	—	—	2	3	11	21
Aplite	—	—	—	—	—	—	—	—	—	—	—	—	5	—	1	6	6
Basalt	4	1	1	5	4	1	16	45	2	4	1	4	17	25	27	125	141
Basalt (vesicular)	6	—	1	7	7	2	23	38	—	—	1	1	9	9	15	73	96
Dacite	2	—	1	7	3	2	15	2	—	—	1	—	6	2	6	17	32
Dacite (vesicular)	1	—	—	1	1	—	3	—	—	—	—	—	—	—	—	—	3
Diorite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	2
Gabbro	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	1
Gneiss	1	—	—	—	6	—	7	6	—	—	1	—	—	1	3	11	18
Granite	—	—	1	1	2	—	4	17	—	—	1	—	3	4	3	28	32
Granodiorite	—	—	—	—	—	—	—	1	—	—	—	—	—	1	1	3	3
Ignimbrite	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	1
Metamorphic (indeterminate)	—	—	—	—	—	—	—	—	—	—	—	—	2	3	—	5	5
Quartzite	2	—	1	3	1	1	8	4	—	—	—	—	6	—	1	11	19
Rhyolite	2	—	—	10	6	2	20	31	—	—	2	1	10	7	11	62	82
Rhyolite (porphyritic)	—	—	—	—	—	—	—	6	—	—	—	—	3	4	3	16	16
Rhyolite (vesicular)	—	—	—	1	—	—	1	—	—	—	—	—	2	—	1	3	4
Sandstone	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	1
Schist	6	—	1	13	4	—	24	4	—	—	1	2	8	17	12	44	68
Tuff	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	1
Tuff (rhyolitic)	—	—	—	—	—	—	—	3	—	—	—	—	—	2	—	5	5
Total	27	1	8	53	45	11	145	167	2	4	8	8	72	78	91	430	575

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

indeterminate in form, 25 percent were ascribable to basin metates of some form, and 11 percent were either flat/concave metates or grinding slabs. Basalt was disproportionally fragmented.

The metates recovered from Falcon Landing were dominated by basin and flat/concave forms. Both of these styles were used primarily for food processing. Flat/concave metates were only slightly smaller than closed-basin metates, and they had average surface areas[1] of 458 and 506 cm^2, respectively (see Appendix 3.2). Notably few of the metates from the Falcon Landing collection evidenced use wear that neared the point of tool exhaustion, but their surface textures were usually smooth from use (88 percent of sample). Freshly repecked surfaces were noted on a small number of implements. For closed-basin metates, the average remaining utility, a function of basin depth and tool thickness, was 0.72. Flat/concave metates had utility values greater than 0.90 (see Table 26). In the entire Falcon Landing collection, only 11 specimens had utility values of less than 50 percent of each rock's available thickness. There was no difference between the average utility values of metates recovered from early Chiricahua phase features and metates recovered from Cienega phase features or sediments (see Table 26).

Manos

In total, 760 manos and mano fragments were collected from Falcon Landing (Table 28). Only 310 of them could be dated to between the early Chiricahua phase and the pre-Classic period, and of those, 258 were recovered from early Chiricahua phase features or deposits. The densest concentration of manos was collected from Feature 2602, an activity area originally interpreted to be a large Chiricahua phase house-in-pit (see Chapter 4, Volume 1). That feature contained 5 complete manos and 96 fragments associated with its 14 intramural pits and 45 postholes. The next-densest concentration, an Archaic period nonthermal pit, included 2 complete and 15 fragmented manos. Only the late Chiricahua phase sample numbering 16 manos

---

[1] Based on simple multiplication of surface width by surface length.

Table 28. Summary Information Recorded on Manos, by Temporal Component, Falcon Landing

Characteristics	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Red Mountain	Pre-Classic	Cochise[a]	Cochise to Historical	Not Dated	Total
Type										
Cobble mano	214	8	2	22	7	1	149	155	105	663
Loaf-shaped mano	—	—	1	—	—	—	—	1	—	2
Flat mano	1	—	—	—	—	—	—	—	—	1
Indeterminate	43	8	3	—	—	—	21	18	1	94
Number of specimens	258	16	6	22	7	1	170	174	106	760
Condition										
Complete	90	3	1	13	2	1	81	83	31	305
Fragment	168	13	5	9	5	—	89	91	75	455
Material Texture										
Nonvesicular	253	16	6	22	7	1	169	174	105	753
Vesicular	5	—	—	—	—	—	1	—	1	7
Thermally Altered										
No	78	3	1	12	1	—	77	75	54	301
Yes	180	13	5	10	6	1	93	99	52	459
Residue										
No	255	16	6	22	7	1	168	172	105	752
Yes	3	—	—	—	—	—	2	2	1	8

Characteristics	**Early Chiricahua**	**Late Chiricahua**	**San Pedro**	**Cienega**	**Red Mountain**	**Pre-Classic**	**Cochise**[a]	**Cochise to Historical**	**Not Dated**	**Total**
					Manufacturing Investment					
High	133	5	—	10	4	1	84	89	64	390
Indeterminate	55	2	—	5	1	—	23	24	25	135
Low	70	1	2	7	2	—	42	42	16	182
					Metrics					
Length (mm)										
Average	119	107	130	119	116	114	120	119	114	119
SD	17	22	n/a	18	16	n/a	17	14	17	16
n	92	3	1	11	2	1	85	87	40	323
Width (mm)										
Average	92	76	94	89	78	104	94	91	88	91
SD	11	18	n/a	12	15	n/a	12	10	11	11
n	94	3	1	11	2	1	85	88	49	335
Thickness (mm)										
Average	61	55	43	59	63	63	62	62	62	61
SD	10	4	n/a	10	13	n/a	10	9	9	10
n	94	3	1	11	2	1	85	87	44	329
Weight (g)										
Average	1,047	771	900	864	732	900	1,054	995	943	1,011
SD	429	326	n/a	440	398	n/a	379	327	343	380
n	87	3	1	13	2	1	80	81	31	300
					Recovery Context					
Activity area	9	—	—	1	—	—	4	4	—	18
Cache	—	—	—	—	—	—	5	7	—	12
Charcoal/ash lens	—	—	—	—	—	—	—	1	—	1
FAR concentration	5	—	—	—	—	—	15	22	—	42
House-in-pit	38	9	4	—	6	—	2	3	—	62
Midden	1	—	1	—	—	—	—	—	—	2
Noncultural	1	—	—	—	—	—	—	1	—	2
Nonthermal pit	22	7	1	—	1	—	56	53	—	140
Nonthermal pit (bell shaped)	8	—	—	—	—	—	1	—	—	9
Posthole	2	—	—	—	—	1	—	—	—	3
Thermal pit	102	—	—	1	—	—	18	18	—	139
CBS/mixed	70	—	—	20	—	—	68	65	86	309
Isolate surface	—	—	—	—	—	—	1	—	20	21
Total	258	16	6	22	7	1	170	174	106	760

Key: CBS = culture-bearing sediment; n/a = not applicable; SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

and the Cienega phase sample numbering 22 manos provided opportunities for comparison to the early Chiricahua phase tools. Cienega phase manos tended to be complete more often than their Chiricahua phase counterparts (see Table 28). Cienega phase manos were also less likely to have been thermally altered, and only one was found in a thermal pit, compared to 44 percent of the early Chiricahua phase collection from pits. Because manos and mano fragments were common, their numbers in post–Chiricahua phase features were anomalously low. As a group, the mano collection was highly fragmented. Broken and fragmented portions of manos constituted 60 percent of the Falcon Landing mano sample, and 85 percent of the fragmented specimens displayed obvious thermal alteration. In addition, 23 percent of the complete specimens also showed signs of thermal alteration.

The variety of manos in the type collection (Figures 55 and 56) included 2 specimens from early Chiricahua phase thermal-pit features: Feature 1523 and 14740 each contained a cobble mano (see Figures 55a and c). The overwhelming majority of the collection was composed of large, oval-shaped cobble manos averaging around 12 cm in maximum length. One complete loaf mano, undated, was quite long (16 cm) relative to the standard cobble manos. Cobble manos uniformly appeared to have been used in shallow basins or on flat surfaces that led to very little wear on the tools' lateral surfaces. Many manos exhibited pecked margins and no signs of grinding. Among the 300 complete cobble manos from Falcon Landing, 79 percent had been utilized on both surfaces (see Appendix 3.2). As few as 6 manos, all cobble type, had more than two working surfaces each. Most of the cobble manos were convex, but 31 percent had flat working surfaces. Slightly more than half of the cobble manos still retained some evidence of pecking in addition to evidence of grinding from use. Many of them had probably been episodically repecked during use, but they were generally discarded with smoothly worn surfaces. Many types of raw materials were used as manos in one of two basic forms. The predominance of convex worked surfaces on minimally shaped cobbles likely reflects their use in basin metates. Flat manos articulated with flat/concave metates and netherstones. Only 16 of the convex-surface manos were worn to a state of beveling, although that could reflect deliberate stoke patterns as opposed to uniquely extensive use. In total, 21 different types and varieties of raw materials were represented in the mano collection. Despite the apparent diversity, 84 percent of the collection consisted of only 4 rock types: quartzite, basalt, granite, and schist (Table 29). There was a significant amount of variation within those rock types. Basalt manos tended to be more completely shaped, perhaps through more intensive use and/or greater tool attrition.

Mortars

The many pestles transported to Falcon Landing contrasted with the seven stone mortars recovered (Table 30). Of the mortars, one was attributed to a Cienega phase nonthermal bell-shaped pit (Feature 3551), and three were attributed to the broadly defined Archaic period. The mortars were uniformly made out of extrusive volcanic material, with one exception, and all were mafic to intermediate in composition. Most specimens were also vesicular. Exterior surfaces indicated that all specimens had been collected from river deposits. One of the mortars, a cobble mortar, was incomplete. A small, vesicular-basalt shaped mortar, described again in the Caches section below, showed signs of thermal alteration, but it was too small and too well crafted to have been intentionally repurposed as FAR. The incomplete cobble mortar was sufficiently large and durable that accidental breakage seemed unlikely, but there was no evidence of its having functioned as FAR. The remaining boulder mortars were too large to break.

The sizes of the site's stone mortars indicated big jobs; two of the items weighed more than 28.8 kg (approximately 60 pounds) each. The small, formally shaped mortar recovered from a nonfeature context in several pieces is an isolated occurrence. Boulder mortars were used in conjunction with stone pestles found at the site, and one Type I pestle was discovered associated with a boulder mortar. The cobble mortar was shallow enough that a mano could feasibly have been utilized on its surface, but a Type IX pestle would also have been feasible. The shaped mortar was recovered in proximity to a mano that articulated seamlessly with it and could also have functioned as a Type VIII pestle. Large stone mortars were presumably used to crush and trap hard materials, based on basin depth. The vesicles in some of the basalt boulders were very large and were natural traps for soft or small materials. One of the vesicular mortars quickly spilled from its bottom all of the water we poured in its basin, confirming that water was probably not a component of

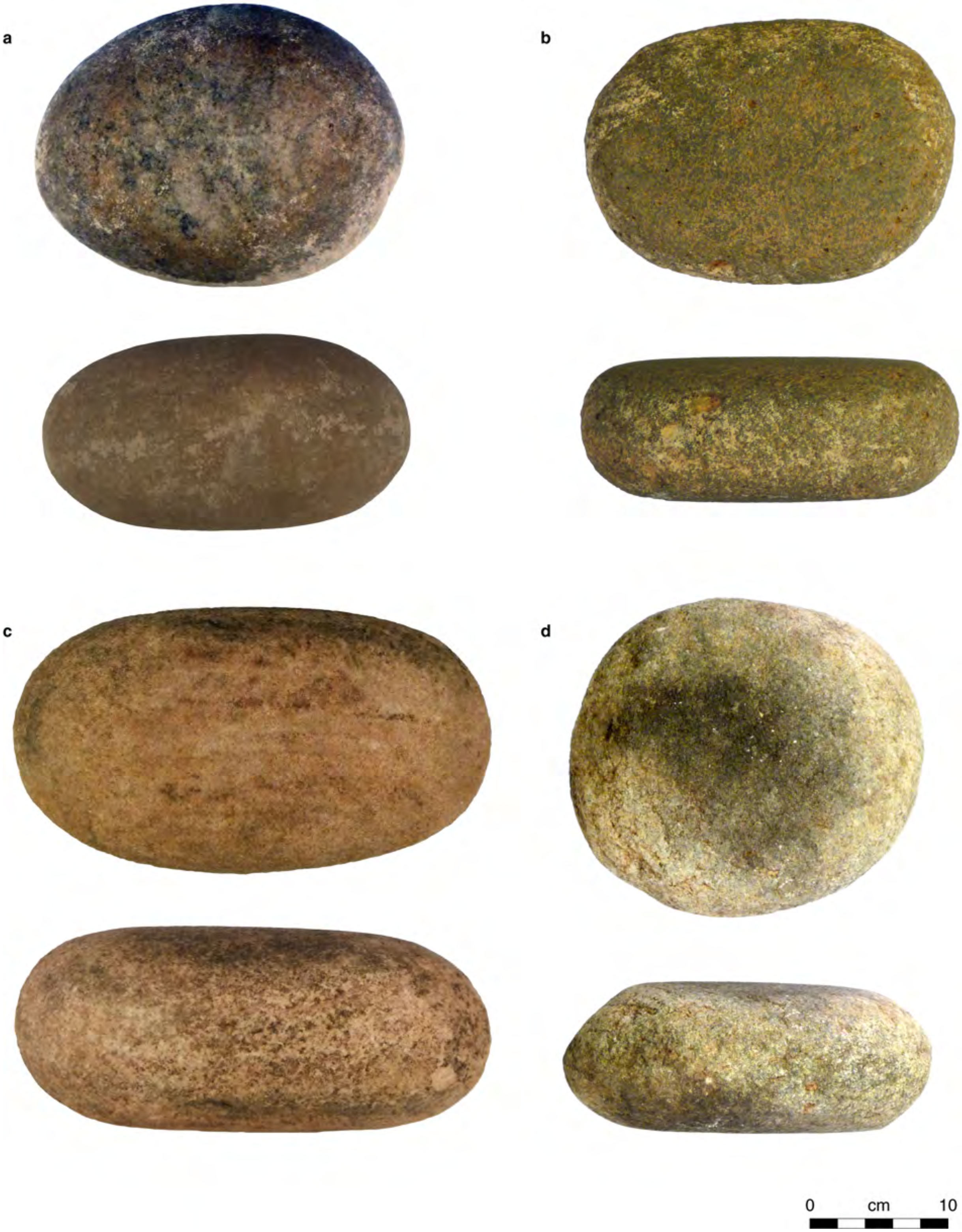


Figure 55. Cobble manos from early Chiricahua phase contexts at Falcon Landing: (*a*) quartzite, from Feature 1523, a thermal pit (Inventory No. 04000C607); (*b*) basalt, from a nonfeature context (Inventory No. 04000E410); (*c*) quartzite, from Feature 14740, a thermal pit (Inventory No. 04000F80F); and (*d*) granite, from a nonfeature context (Inventory No. 04000ED44).

Figure 56. Manos from nonfeature Cochise to Historical period contexts at Falcon Landing: (*a*) a quartzite cobble mano (Inventory No. 04000E3F4), (*b*) a basalt cobble mano (Inventory No. 04000E435), and (*c*) a quartzite loaf-shaped mano (Inventory No. 04000E430). (*Note*: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

anything mixed or crushed in the basin. Unlike most metates, the boulder mortars at Falcon Landing were not easily flipped over and handled as needed for dumping and cleaning out the contents of vesicles. Large, deep vesicles may indicate that the mortars were used to crush coarse materials. The much smoother surface of the cobble mortar suggests that a finer texture of materials was produced with that implement, but it was another isolated occurrence.

Pestles

In total, 94 pestles were identified in the Falcon Landing collection, and over 80 percent were discovered as isolates located in nonfeature contexts. At least 9 pestles were in small caches, but only a single pestle was associated with a late Chiricahua–early San Pedro phase structure (Feature 17681). Sixty-two percent of pestles had been mostly or completely shaped (pecked). The dominant pestle forms were characterized by Types V–VIII, which included cylindrical to oval forms with polished and/or pecked ends that had been

Table 29. Raw-Material-Type Information Recorded on Manos, by Temporal Component, Falcon Landing

Material Type	Complete										Fragment									Total
	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Red Mountain	Pre-Classic	Cochise[a]	Cochise to Historical	Not Dated	Complete Total	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Red Mountain	Cochise[a]	Cochise to Historical	Not Dated	Fragment Total	
Andesite	2	—	—	—	—	—	3	3	2	10	1	—	—	—	—	1	—	2	4	14
Andesite (porphyritic)	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	1	1	4	4
Aplite	1	—	—	—	1	—	—	1	—	3	3	—	—	—	—	2	—	—	5	8
Basalt	20	3		1	1		12	18	8	63	52	3	3	2	1	22	28	24	135	198
Basalt (vesicular)	—	—	—	—	—	—	—	—	1	1	5	—	—	—	—	—	—	—	5	6
Dacite	1	—	—	1	—	—	1	1	—	4	4	—	—	—	1	—	2	1	8	12
Dacite (vesicular)	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	1
Diorite	1	—	—	—	—	—	—	—	1	2	—	—	—	—	—	1	—	—	1	3
Gneiss	1	—	—	—	—	—	1	—	—	2	—	1	—	—	—	2	—	—	3	5
Granite	17	—	1	2	—	—	11	13	4	48	21	3	2	1	—	7	9	4	47	95
Granodiorite	—	—	—	—	—	—	1	—	—	1	1	—	—	—	—		2	—	3	4
Metamorphic (indeterminate)	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	2	2	2	8	8
Other	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	1
Quartz	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	1
Quartzite	33	—	—	1	—	—	40	29	10	113	27	—	—	3	3	15	15	20	83	196
Quartzite (meta)	4	—	—	—	—	1	3	1	—	9	21	1	—	—	—	14	11	—	47	56
Rhyolite	1	—	—	2	—	—	1	—	—	4	10	2	—	2	—	4	10	2	30	34
Rhyolite (porphyritic)	—	—	—	—	—	—	—	—	—		2	1	—	—	—	6	2	1	12	12
Sandstone	—	—	—	—	—	—	—	—	—		8	—	—	—	—	2	1	—	11	11
Schist	9	—	—	6	—	—	7	17	5	44	11	1	—	1	—	8	8	17	46	90
Tuff (rhyolitic)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1
Total	90	3	1	13	2	1	81	83	31	305	168	13	5	9	5	89	91	75	455	760

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

Table 30. Summary Information Recorded on Mortars, by Temporal Component, Falcon Landing

Characteristics	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Total
Type					
Boulder mortar	1	3	1	—	5
Shaped mortar	—	—	1	—	1
Cobble mortar	—	—	—	1	1
Total number of specimens	1	3	2	1	7
Condition					
Complete	1	3	2	—	6
Fragment	—	—	—	1	1
Material Texture					
Nonvesicular	—	2	—	1	3
Vesicular	1	1	2	—	4
Thermally Altered					
No	1	3	2	1	7
Yes	—	—	—	—	—
Residue					
No	1	3	2	1	7
Yes	—	—	—	—	—
Manufacturing Investment					
High	—	3	2	1	6
Low	1	—	—	—	1
Surface Texture					
Coarse /resharpened	—	1	—	1	2
Smooth	1	2	2	—	5
Metrics					
Length (mm)					
Average	390	354.7	252.5	135	326.5
SD			166		101.7
n	1	3	2	—	6
Width (mm)					
Average	275	256.3	222.5	215	246
SD		18.6	123.7		57.3
n	1	3	2	1	7
Thickness (mm)					
Average	240	158.7	155	120	163.7
SD		28.7	63.6		47.7
n	1	3	2	1	7
Surface length (mm)					
Average	170	307.7	146.5	93	231
SD		54.4	75.6		97.2
n	1	3	2	1	7
Surface width (mm)					
Average	170	227.7	141.5	145	183
SD		26.6	68.6		53.5
n	1	3	2	1	7

Characteristics	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Total
Surface depth (mm)					
Average	121	44	104	30	70.1
SD		7.5	65		46.3
n	1	3	2	1	7
Sump surface depth (mm)					
Average		50.1		30	50.7
SD		15			15
n	—	3	—	1	3
Total surface depth (mm)					
Average	121	94.6	104	30	91.9
SD		12.7	65		39.9
n	1	3	2	1	7
Weight (g)					
Average	30,825	12,150	15,075		16,237
SD		3,683	19,410		11,572
n	1	3	2	—	6
	Recovery Context				
Nonthermal pit (bell shaped)	—	1	—	—	1
CBS/mixed	1	2	2	1	6
Total	1	3	2	1	7
	Raw Material				
Material type					
Andesite (porphyritic)	—	1	—	—	1
Basalt (vesicular)	1	1	2	—	4
Dacite	—	1	—	—	1
Ignimbrite	—	—	—	1	1
Total	1	3	2	1	7

Key: CBS = culture-bearing sediment; SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

round but became beveled with use (32 percent) and sometimes smaller, conical- and barrel-shaped pestles with flat ends (29 percent). Examples of the dominant types are shown in Figures 57–60. Some conical pestles had been created on-site by the percussion removal of one polar end of an elongated cobble, as evidenced by 2 "pestle ends" set aside in the reference collection. Again, one of the remarkable attributes of the pestles was their robustness. The average complete pestle at Falcon Landing weighed around 3,000 g (or about $6^{1}/_{2}$ pounds), and most measured 30–40 cm in length (roughly 12–16 inches) (Table 31). The length distribution of elongated pestles had a positive skew with a major drop in frequency at around 25 cm. The mean pestle maximum diameter (width) was approximately 8.8 cm.

Of the 76 pestles recovered from dated contexts, only 2 were recovered from a directly radiocarbon-dated feature, a Snaketown phase cache (Feature 3372) (see Chapter 4, Volume 1) (see Figure 60c). However, 9 pestles were associated with early Chiricahua phase sediments and surfaces, indicating that diverse pounding tools were intimately linked to site function throughout site occupation. Conical pestles of Types VIII and IX were represented in the early Chiricahua phase collection. The large pestle/basin-metate form (Type X) included in the Snaketown phase cache was one of only two such forms included in the collection. The pestle types featured in the collection included 4 examples from features

A diverse range of raw materials was employed in the manufacture of pestles (Table 32). In contrast to materials used for implements in most other ground stone classes, foliated metamorphic rocks were popular. A high-grade form of quartzite with incipient foliation was heavily employed in the manufacture of

Figure 57. Type V pestles from Falcon Landing: (*a*) quartzite, from a nonfeature context (Inventory No. 04000D69C, Cochise), and (*b*) vesicular basalt, from Feature 4664, a nonthermal pit (Inventory No. 04000C73, Protohistoric period). (*Note*: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

Figure 58. Type VI and VII pestles from nonfeature contexts at Falcon Landing. Type VI: (*a*) basalt (Inventory No. 04000C7C4, Cochise to Historical period). Type VII: (*b*) metaquartzite (Inventory No. 04000C2F0, Cienega phase) and (*c*) diorite (Inventory No. 04000CD3C, Cochise). (***Note***: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

Figure 59. Type VIII basalt pestles from nonfeature contexts at Falcon Landing: (*a*) Inventory No. 04000E3F1, Cochise to Historical period, and (*b*) Inventory No. 4000E613, Cochise. (*Note*: “Cochise” indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

Figure 60. Type IX and X pestles at Falcon Landing. Type IX: (*a*) granite, from a nonfeature context (Inventory No. 04000BFF5, Cochise), and (*b*) metaquartzite, from a nonfeature context (Inventory No. 04000E40F, Cochise to Historical period). Type X: (*c*) rhyolite, from Feature 3372, a cache (Inventory No. 04000D49B, Snaketown phase). (*Note*: “Cochise” indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

Table 31. Summary Information Recorded on Pestles, by Temporal Component, Falcon Landing

Characteristics	Early Chiricahua	Cienega	Pre-Classic	Protohistoric	Cochise[a]	Cochise to Historical	Not Dated	Total
Type								
Type I	—	2	—	1	2	—	—	5
Type II	1	2	1	—	—	2	1	7
Type III	1	—	—	—	2	2	1	6
Type IV	2	—	—	—	1	1	1	5
Type V	—	1	—	1	6	6	4	18
Type VI	—	1	—	—	5	2	4	12
Type VII	2	2	—	—	7	4	1	16
Type VIII	1	—	—	—	4	4	2	11
Type IX	2	—	—	—	2	2	1	7
Type X	—	—	1	—	—	—	1	2
Indeterminate	—	—	—	—	2	1	2	5
Number of specimens	9	8	2	2	31	24	18	94
Condition								
Complete	9	8	2	2	27	22	7	77
Fragment					4	2	11	17
Material Texture								
Nonvesicular	5	5	1	2	23	15	11	62
Vesicular	4	3	1	—	8	9	7	32
Thermally Altered								
No	9	8	2	2	27	21	15	84
Yes	—	—	—	—	4	3	3	10
Residue								
No	9	8	2	2	31	24	18	94
Yes	—	—	—	—	—	—	—	
Manufacturing Investment								
High	4	2	1	1	20	18	12	58
Low	5	6	1	1	11	6	6	36
Surface Count								
1	5	6	—	1	19	11	11	53
2	3	2	1	—	11	12	6	35
3	1		1	1	—	1	—	4
4	—	—	—	—	1	—	1	2
Metrics[b]								
Length (mm)								
Average	383.2	318.1	377.5	377.5	307.0	308.6	295.0	306.4
SD	77.5	38.5	46.0	46.0	74.8	80.9	62.0	70.8
n	9	8	2	2	27	22	7	81
Width (mm)								
Average	82	95.9	101.5	101.7	87.0	83.4	82.1	85.9
n	9	8	2	2	28	22	15	86
SD	11.8	8.9	12.0	12.3	13.8	10.0	11.3	12.3
Thickness (mm)								
Average	65.7	73.4	79.5	79.3	67.2	66.9	66.3	67.9
SD	7.7	10.3	0.7	1.0	10.9	9.7	9.4	9.9
n	9	8	2	2	28	21	15	85

Characteristics	Early Chiricahua	Cienega	Pre-Classic	Protohistoric	Cochise[a]	Cochise to Historical	Not Dated	Total
Proximal end surface length (mm)								
Average	36.7	58.3	77.5	—	47.2	52.2	45.6	49.1
SD	17.6	28.4	10.6		26.3	28.6	24.8	26.1
n	3	3	2		13	13	8	43
Distal end surface length (mm)								
Average	25	41.7	57.5	—	43.9	35.5	39.7	39.7
SD	7.1	15.3	24.7		28.5	16	24.4	21.7
n	2	3	2		13	14	7	42
Weight (g)								
Average	2,400	3,488	4,950	3,094	3,046	2,884	2,989	3,016
SD	1,001	492.0	636.4	557.2	1,167	983	1,203	1,075
n	9	8	2	2	27	22	7	77
				Recovery Context				
Activity area	—	—	—	—	—	1	—	1
Cache	—	2	2	2	1	2	—	9
FAR concentration	—	—	—	—	1	—	—	1
House-in-pit	—	—	—	—	1	—	—	1
Nonthermal pit	—	—	—	—	3	1	—	4
CBS/mixed	9	6	—	—	25	20	18	78
Total	9	8	2	2	31	24	18	94

Key: CBS = culture-bearing sediment; SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

[b] Measurements performed on intact specimens only.

Type V pestles. Basalt was also fairly ubiquitous but was mostly preferred for Types VI and VIII. The prevalence of foliated materials was partially a function of the tendency of these material types to break along linear planes, making naturally elongate cobbles more common in stream deposits. Remnant cortex on pestle implements was invariably secondary water wear attributable to the cobble origin of the tools. The lack of vesicular volcanic materials more likely reflects performance criteria. In general, basalt clasts used as pestles tended to be shorter than metamorphic examples. The only large-vesicle specimen (see Figure 57b) was recovered from a Protohistoric period cache (Feature 4664).

Fragmented specimens composed approximately 18 percent of the pestle sample. Given the unique morphological qualities of pestles and the high surface-area-to-volume ratios of the implements, fragmented pieces were highly identifiable, suggesting that relatively few of the indeterminate ground stone fragments were broken pestles. The relatively low breakage rate of pestles relative to that of grinding stones was likely a function of several variables. First, although many of the pestles at Falcon Landing experienced extensive pecking on their bodies and ends, cylindrical metamorphic cobbles were more rugged than the tabular rocks typically used in grinding tools. The highly developed polish on Type V pestles indicates that many pestles required little or no end maintenance. Perhaps more importantly, traditional pounding tools are known to have included wooden mortars, which, unlike grinding stones—which typically experienced rock-on-rock contact, including resharpening/pecking—would have significantly reduced the risk of pestle breakage, as discussed in more detail below. Also, the raw materials preferred for many pestle types may have spared them from being repurposed as thermal mass.

Like manos that can be used to crack, crush, and grind plants, animals, and minerals (Adams 2002), ancient and contemporary pestle designs graded from long, round-ended pestles designed for pounding to short, flat-ended pestles that mashed and ground more like special manos than pestles. These fundamental differences in design reflect different spectrums of a pounding-to-grinding process. The 10 various types of pestles isolated in the Falcon Landing analysis clearly incorporated use-life and functional variation in

Table 32. Raw-Material-Type Information Recorded on Pestles, by Temporal Component, Falcon Landing

Material Type	Complete								Fragment				Total
	Early Chiricahua	Cienega	Pre-Classic	Prehistoric	Cochise[a]	Poorly Dated	Not Dated	Complete Total	Cochise[a]	Poorly Dated	Not Dated	Fragment Total	
Andesite	1	1	—	—	—	3	—	5	—	—	—	—	5
Andesite (porphyritic)	—	—	1	—	—	—	1	2	—	1	—	1	3
Basalt	3	2	—	—	6	5	3	19	2	—	3	5	24
Basalt (vesicular)	—	1	—	1	—	2	—	4	—	1	1	2	6
Dacite	—	—	—	—	1	—	1	2	1	—	2	3	5
Diorite	—	—	—	—	1	—	—	1	—	—	—	—	1
Gneiss	1	—	—	1	1	1	—	4	—	—	2	2	6
Granite	—	—	—	—	2	—	—	2	—	—	—	—	2
Granodiorite	—	—	—	—	1	—	—	1	—	—	—	—	1
Quartzite	2	—	—	—	6	5	—	13	—	—	1	1	14
Quartzite (meta)	1	3	—	—	4	1	1	10	—	—	1	1	11
Rhyolite	—	—	1	—	—	1	—	2	1	—	—	1	3
Schist	1	1	—	—	4	4	1	11	—	—	1	1	12
Tuff (rhyolitic)	—	—	—	—	1	—	—	1	—	—	—	—	1
Total	9	8	2	2	27	22	7	77	4	2	11	17	94

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

morphology and surface texture, but a minimum of three functional varieties of pestles could be inferred based on the obvious design criterion of end shape.

The pestles depicted in Figure 38 can be divided into three coarser groups: (1) round-ended pestles, (2) flat-ended pestles, and (3) irregular-ended pestles. The irregular-ended pestles may have functioned in any number of ways, but one globular example was discovered paired with a boulder mortar (see Caches section). Pestles used in stone mortars can be expected to have slightly irregular, coarse-textured ends and indicate the cracking or crushing of hard materials. Flat-ended pestles assumed a wide range of sizes, presumably for different tasks, and were designed for a somewhat-flat-bottomed mortar. Haury (1950:321) suspected that flat-ended pestles were used in the bedrock mortars found at Ventana Cave. Conical, flat-ended pestles, typically made of basalt, are wide and ideal for mashing and stirring, whereas barrel-shaped pestles have small, flat ends that concentrated the tool's mass on a small area, which was better for crushing. Long, round-ended pestles with smoothly polished and sometimes beveled ends were suited to pounding soft materials in a round to conical mortar basin and are generally associated with wooden mortars (Adams 2002:138).

The extensive pecking that covered the bodies of many pestles (62 percent of sample) showed no evidence of subsequent grinding. The amount of shaping achieved by pecking the pestles was minimal. Rather, that modification is interpreted to have accommodated the prehension of alluvial cobbles. Russell (1908:109–110) noted that among the Pima, "[t]he pestle varies in size from the small stone the size of one's finger to the great cylinder weighing 20 pounds that requires both hands to wield it. Many of these are obtained from the ruins, but some are shaped by pecking. This is not all done at once, but, a suitable stone having been selected, it is shaped little by little, day by day, as the owner has leisure for the work." The pestles from Falcon Landing indicated a similar casual investment in their design and functionality.

The 13:1 ratio of pestles to mortars at Falcon Landing is intuitive evidence that wooden mortars were utilized there. Haury (1950:320) also speculated that a wooden-mortar technology explained the disparity between pestles and mortars at Ventana Cave and noted that the round-ended pestles there lacked evidence of having hit a resistant surface. It is not possible to isolate wood polish, but it is possible to identify the damage caused by contact with sand, grit, or rock.

Select pestles from the Luke Solar project collection were microscopically examined for physical evidence of use with a variable-magnification binocular microscope at the University of Arizona School of Anthropology Multipurpose Laboratory. The inspected portions of ground stone tools were first soaked in a 1 percent solution of hydrochloric acid to remove calcium-carbonate deposits and then rinsed thoroughly and allowed to dry. The polished pestles characterized by Types II and V at Falcon Landing (Figure 61) matched Adams's (2002:33–39) description of ground stone surfaces used against pliable materials. Low-power magnification did not reveal the gouging and scratches that would be expected if the pestles had been used in combination with the large stone mortars at the site. Several implements had a sheen that extended an average of 5 cm up the bodies of the implements, indicating habitual contact with the sides of a steep-walled mortar rather than expedient use of the ground or a wide, shallow pit. Lastly, a few implements (Type X) evidenced unique patterns of use wear, such as grinding on lateral surfaces or pointed ends with chipping indicative of use as a pick.

Lukeoliths

As a group, these implements were generally subrectangular to almond shaped and had convex to slightly concave faces. Most forms had minimally shaped ends (Type 1) (see Figure 39), but extensively pecked specimens (Type 2) were also common. In addition to end wear, approximately 31 percent of the implements showed evidence of light to moderate grinding on one or both faces (Type 3). The metric data in Table 33 reflect a collection that was fairly homogeneous in size. Implement weight, length, and width were all essentially normally distributed about their respective means, but thickness was somewhat more erratic.

The Lukeolith collection consisted of 68 implements, all from Falcon Landing, many of which were recovered from features. Two Lukeoliths were recovered from a structure (Feature 1313), and a small number were associated with thermal (n = 2) and nonthermal (n = 5) pits, FAR concentrations (n = 1), and caches (n = 5). Essentially, they showed up everywhere at the site and were common implements. The floor of Feature 1313 contained 2 complete specimens and a separate manuport likely intended for the same purpose

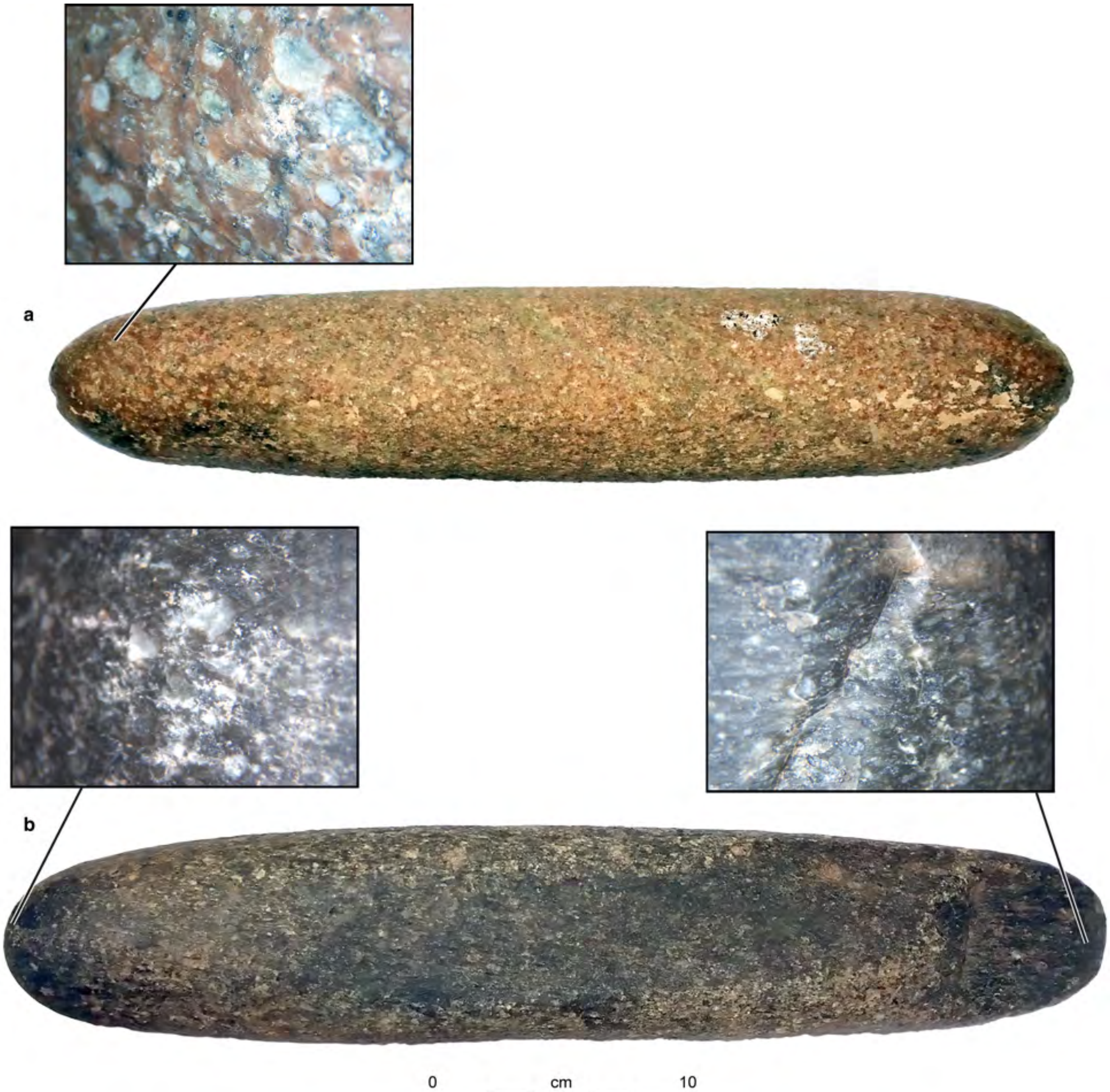


Figure 61. Type V pestles exhibiting use wear, from nonfeature contexts at Falcon Landing: (*a*) schist (Inventory No. 04000C2EF, Cochise) and (*b*) gneiss (Inventory No. 0400119E1, Cochise to Historical period). (*Note*: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

(see Chapter 4, Volume 1) but no other tools. Fifty-three Lukeoliths were encountered as isolates in nonfeature contexts (see Table 33).

A broken and burned specimen of this type found in a thermal pit (Feature 15317) was one of the earliest artifacts at Falcon Landing that were directly radiocarbon dated (3340–3030 B.C.). Only 22 examples were reasonably well dated, but 18 of them were from early Chiricahua phase deposits. Lukeoliths were also directly radiocarbon dated to the early San Pedro phase (1270–1110 cal. B.C.) in Feature 11389, included in the Cochise group, and were also found in Cienega phase contexts. One example was recovered from Pioneer to Classic period sediments (cal. A.D. 610–1220) but was included in the poorly dated group. Lukeoliths may have been distinctly common during the Middle Archaic period at Falcon Landing, but they continued to be used, if not manufactured, throughout the sequence.

Table 33. Summary Information Recorded on Lukeoliths, by Temporal Component, Falcon Landing

Characteristics	Early Chiricahua	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Total
Type						
Type 1	8	4	8	6	7	33
Type 2	4	—	3	1	2	10
Type 3	6	—	10	1	4	21
Indeterminate	—	—	2	1	1	4
Number of specimens	18	4	23	9	14	68
Condition						
Complete	16	3	21	6	4	50
Fragment	2	1	2	3	10	18
Material Texture						
Nonvesicular	11	2	16	3	11	43
Vesicular	7	2	7	6	3	25
Thermally Altered						
No	16	3	21	5	13	58
Yes	2	1	2	4	1	10
Residue						
No	17	4	17	9	13	60
Yes	1	—	6	—	1	8
Manufacturing Investment						
High	13	4	19	8	8	52
Low	5	—	4	1	5	15
Indeterminate	—	—	—	—	1	1
Metrics						
Length (mm)						
Average	350	305	314.6	280.4	315	305.7
SD	56.5	21.8	40.6	62	42.3	42.7
n	8	3	8	5	5	53
Width (mm)						
Average	149.4	139.5	138.6	131.8	150	139.8
SD	18	5.3	15.6	23.8	13.4	18.3
n	8	4	8	6	6	62
Thickness (mm)						
Average	50.6	52.8	55.9	60	50.5	54
SD	14.3	9	7.6	11.7	7	9.8
n	8	4	8	5	6	60
Weight (g)						
Average	3,727	2,850	3,628	3,015	3,431	3,434
SD	543	260	723	704	672	732
n	8	3	8	5	4	50
Proximal End Wear Length (mm)						
Average	52.5	55	37.5	70	55	46.7
SD	16.5	18	21.2	28.1	28.1	21.7
n	8	3	8	5	6	51

continued on next page

Characteristics	Early Chiricahua	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Total
			Distal End Wear Length (mm)			
Average	46.3	42.5	40.6	52.5	49	44.3
SD	16.2	8.7	24.3	33.3	10.2	17.8
n	8	4	8	6	5	50
			Proximal End Wear			
Heavy	4	1	6	3	5	19
Light	7	—	6	—	2	15
Moderate	5	2	5	3	2	17
Unused	—	—	5	1	3	9
Indeterminate	2	1	1	2	2	8
			Distal End Wear			
Heavy	6	2	7	1	7	23
Light	3	—	3	2	—	8
Moderate	6	1	8	2	—	17
Unused	2	—	3	2	1	8
Indeterminate	1	1	2	2	6	12
			Face 1 Wear			
Heavy	3	—	3	1	1	8
Light	—	—	5	—	1	6
Moderate	5	1	5	2	3	16
Unused	9	3	10	5	9	36
Indeterminate	1	—	—	1	—	2
			Face 2 Wear			
Heavy	1	—	—	—	1	2
Light	—	—	2	—	—	2
Moderate	—	1	1	—	—	2
Unused	17	3	20	8	12	60
Indeterminate	—	—	—	1	1	2
			Recovery Context			
Cache	—	—	1	4	—	5
FAR concentration	1	—	—	—	—	1
House-in-pit	—	—	2	—	—	2
Nonthermal pit	—	1	3	1	—	5
Thermal pit	1	—	1	—	—	2
CBS/mixed	16	3	16	4	14	53
Total	18	4	23	9	14	68

Key: CBS = culture-bearing sediment; n/a = not applicable; SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

Lukeoliths were executed on a diverse array of raw materials, including a variety of volcanic, plutonic, and nonfoliated metamorphic rocks (Table 34). Secondary water-wear cortex was present on most specimens, suggesting that the raw materials for Lukeoliths were invariably drawn from alluvial-cobble sources. The recovery of a number of manuports very similar in form to Lukeoliths indicates the selection of raw materials that required little modification. There was a pronounced preference for volcanic materials with naturally coarse surfaces. Vesicular-basalt items were particularly prevalent in the collection (32 percent), and basalt of all types composed just over half the collection of complete specimens. Most of the andesites, dacites, and rhyolites were nonvesicular and aphanitic but coarse textured. A limited number of granite,

Table 34. Raw-Material-Type Information Recorded on Lukeoliths, by Temporal Component, Falcon Landing

Material Type	Complete						Fragment						Total
	Early Chiricahua	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Complete Total	Early Chiricahua	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Fragment Total	
Andesite	1	—	1	1	—	3	—	—	—	—	—	—	3
Andesite (porphyritic)	—	—	2	1	—	3	—	—	—	—	1	1	4
Basalt	3	1	3	—	3	10	2	1	—	—	4	7	17
Basalt (vesicular)	5	2	6	4	—	17	—	—	—	2	3	5	22
Dacite	1	—	1	—	—	2	—	—	—	—	—	—	2
Dacite (vesicular)	1	—	1	—	—	2	—	—	—	—	—	—	2
Granite	1	—	2	—	—	3	—	—	—	—	—	—	3
Quartzite	—	—	2	—	—	2	—	—	—	—	—	—	2
Rhyolite	3	—	3	—	—	6	—	—	2	1	2	5	11
Rhyolite (vesicular)	1	—	—	—	—	1	—	—	—	—	—	—	1
Tuff	—	—	—	—	1	1	—	—	—	—	—	—	1
Total	16	3	21	6	4	50	2	1	2	3	10	18	68

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

porphyritic-andesite, quartzite, and nonvesicular-basalt specimens had smooth surface textures, but their surfaces were invariably roughened/pecked.

Eighteen of the 68 recorded Lukeoliths were fragments. Because the surfaces of most Lukeoliths were not necessarily diagnostic of the type, many fragments were likely classified as indeterminate ground stone. All of the fragmented specimens were volcanic, with a predominance of basalt. Half the fragmented assemblage had been thermally altered, but only 3 pieces were recovered from thermal pits or FAR concentrations (see Table 33). The high heat-retention capacity of volcanic rocks, and basalt in particular, likely made many Lukeoliths common for use in thermal features. It is also possible that vesicular-basalt tools were maintained longer and broke more often than other tools, increasing the likelihood of recycling.

Several of the better Lukeolith examples from the reference collection, almost exclusively recovered from nonfeature contexts, were digitally enhanced to show their wear patterns (Figures 62–66), which is sometimes hidden on proximal and distal tool edges. The ubiquity of use wear on various surfaces precludes the possibility that these forms represent trade blanks or preforms for some other implements—one of the many interpretations of the photographs sent out for peer review by SRI (see Lukeoliths section, above). Use wear on Lukeoliths always included end polish or pecking and sometimes included grinding on one or both faces. In other words, the implement alternated in function between a top stone and a bottom stone—the height of multifunctionality among typical ground stone tools.

The end wear on Lukeoliths extended a short distance up the faces but often progressed much higher on the margins. The height of margin wear was not always symmetrical from margin to margin on a given tool. This indicates that the tools came in contact with the sides of a bottom implement and often made contact with one side. No evidence of gyration was observed on the specimens. As noted above, end pecking of nonvolcanic specimens included pecked ends that had been subsequently polished and pecked bodies that received no use. Based on overlapping pecking and polishing, end pecking was clearly related to tool maintenance; body roughening, again, may have related to prehension.

The morphology and use wear of pestles and Lukeoliths indicate that they were closely related. The average extents of use wear up the shafts and margins were nearly identical, at 4.5 cm (Figure 67), and there was a steep drop-off in wear heights at around 7 cm. To further evaluate the relationship, samples of Lukeoliths and pestles with highly polished surfaces were compared at the University of Arizona School of Anthropology Multipurpose Laboratory, using the methods described for pestles. The smooth, shallow rounding and polish typical of many pestles could not be distinguished from the wear on the sampled Lukeoliths. Vesicular-basalt specimens with visibly heavy polish showed wear that rounded but did not crush high crystals and extended a short distance into vesicles without affecting the sharp, crystalline edges visible in some vesicle bottoms (Figure 68a and b). Some nonvesicular Lukeoliths showed pecked ends with high crystals that were rounded from minor use (Figure 69a). An unusual Type 3 example from a nonthermal pit (Feature 18368) exhibited a pecked and polished end and a lightly ground face with ocher and soot staining but no shaping of the natural cobble form (see Figure 69b). The limited penetration of use wear into vesicles is taken as evidence that the contact material was wood or bone rather than hide (Adams 2002:37–39). The most parsimonious explanation is that Lukeoliths represent a distinct variety of pestle that was used to process mesquite in large wooden mortars. A handful of ethnohistoric images have shown the use of flat pestles (Kroeber 1953:Plate 45; Hrdlička 1906:Plate VIII; Felger 1977:157) with bedrock, wooden, and earthen mortars.

Eight additional Lukeoliths retained residues consisting of red ocher and/or black soot on one or both faces. Pigment processing is typically associated with lapstones and palettes in later contexts (Adams 2002:116). Pigment stained between 36 and 44 percent of the San Pedro phase ground stone artifacts from southern Arizona surveyed by Adams (2005:108). It signals a wide range of socially important customs and is ubiquitous in the archaeological record. Traditional use of pigment entailed the production of pigment "cakes" for trade and transport (Eiselt et al. 2011); so, it is possible that pigment was not processed at Falcon Landing but was reconstituted from cake stocks. Based on its association with soot, it may have been heated, perhaps using embers—a commonplace practice for controlling the color of iron oxides.

Figure 62. Type 1 Lukeoliths from early Chiricahua phase nonfeature contexts at Falcon Landing: (*a*) granite (Inventory No. 040011972) and (*b*) basalt (Inventory No. 04000FC24).

Figure 63. A Type 2 basalt Lukeolith from an undated nonfeature context at Falcon Landing (Inventory No. 04000C374).

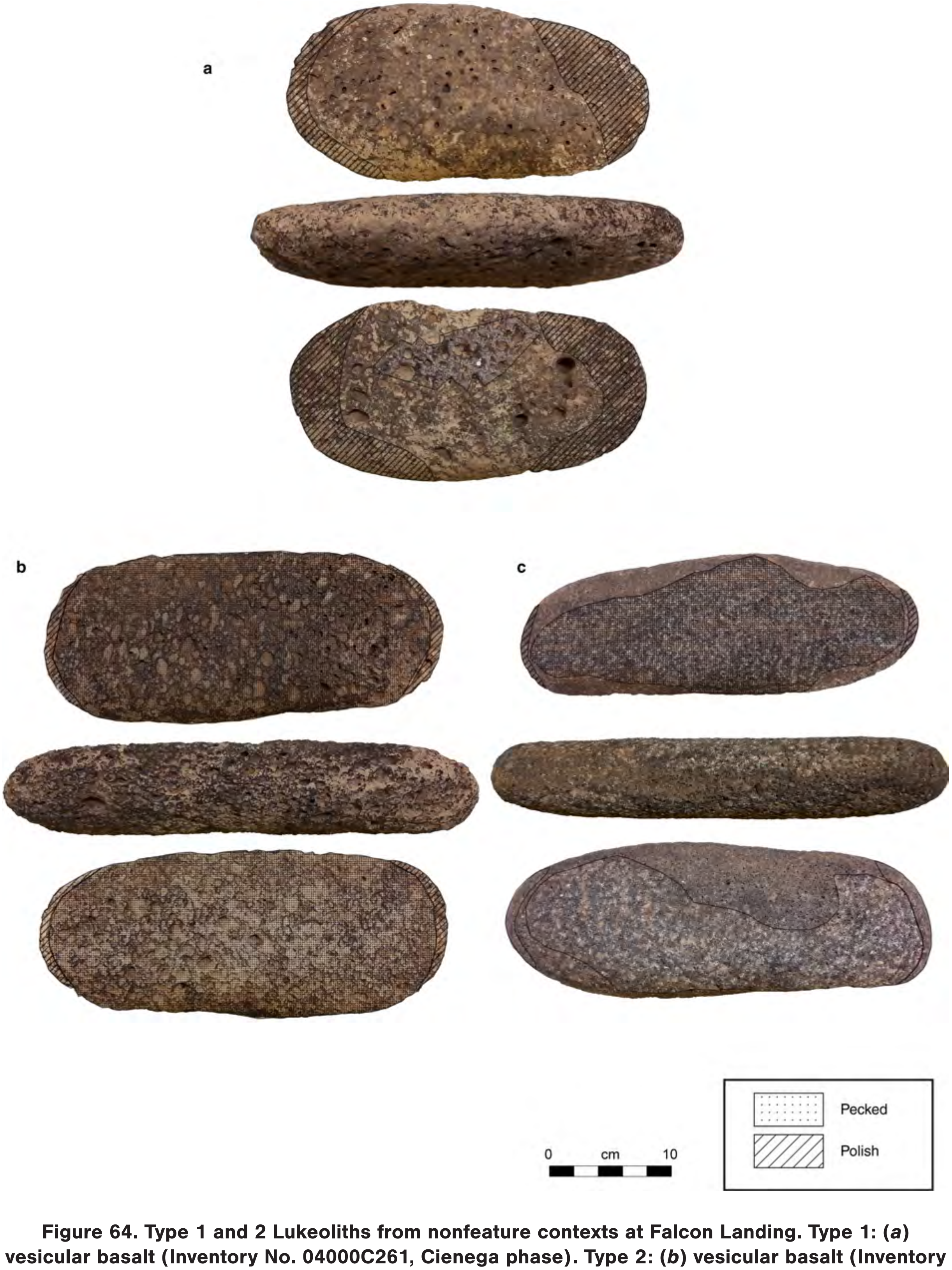


Figure 64. Type 1 and 2 Lukeoliths from nonfeature contexts at Falcon Landing. Type 1: (*a*) vesicular basalt (Inventory No. 04000C261, Cienega phase). Type 2: (*b*) vesicular basalt (Inventory No. 04000C015, Cienega phase) and (*c*) basalt (Inventory No. 04000FDFA, not dated).

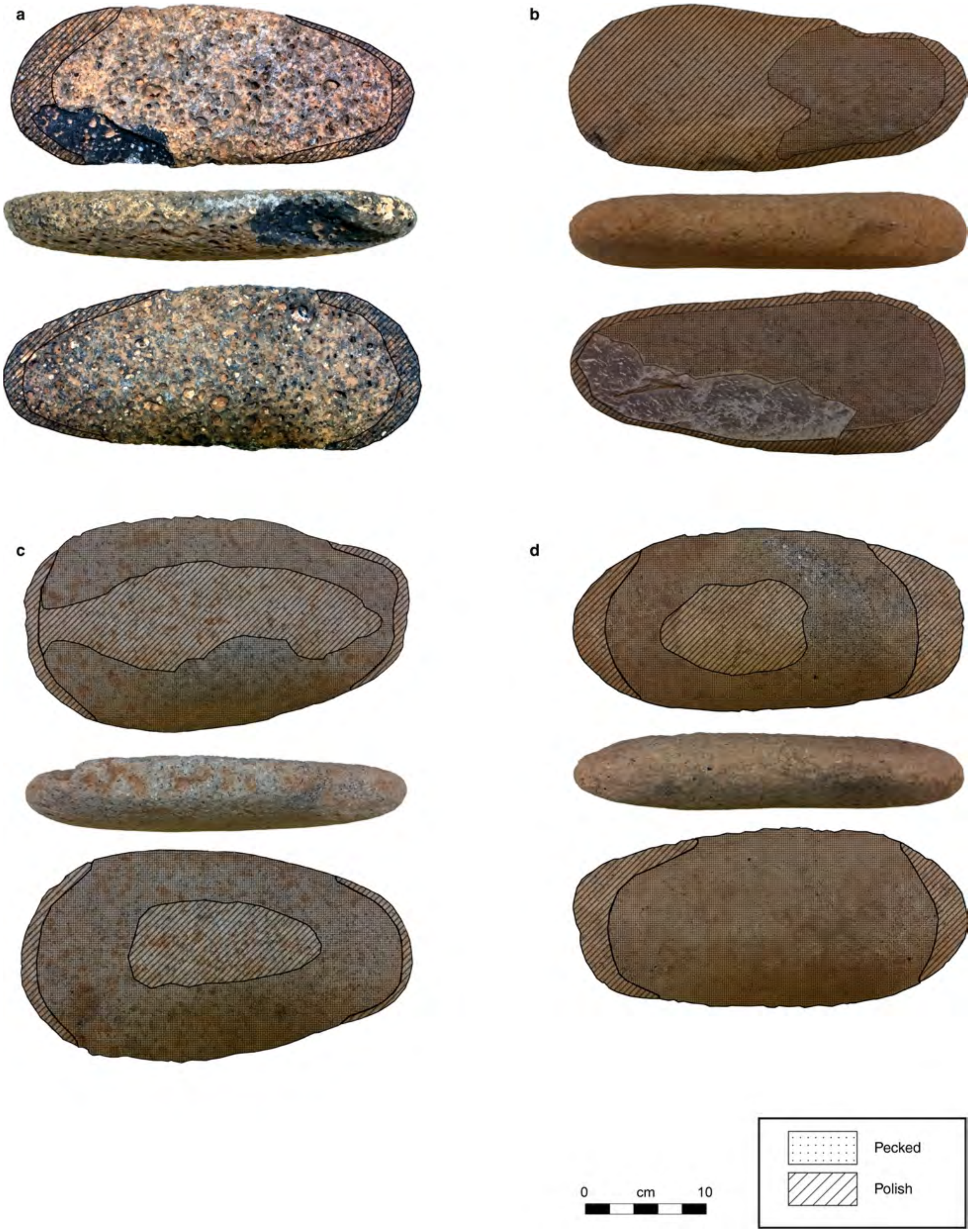


Figure 65. Type 2 and 3 Lukeoliths from early Chiricahua phase nonfeature contexts at Falcon Landing. Type 2: (*a*) vesicular basalt (Inventory No. 04000ED50). Type 3: (*b*) rhyolite (Inventory No. 04000E3EF), (*c*) rhyolite (Inventory No. 040010012), and (*d*) andesite (Inventory No. 040010019).

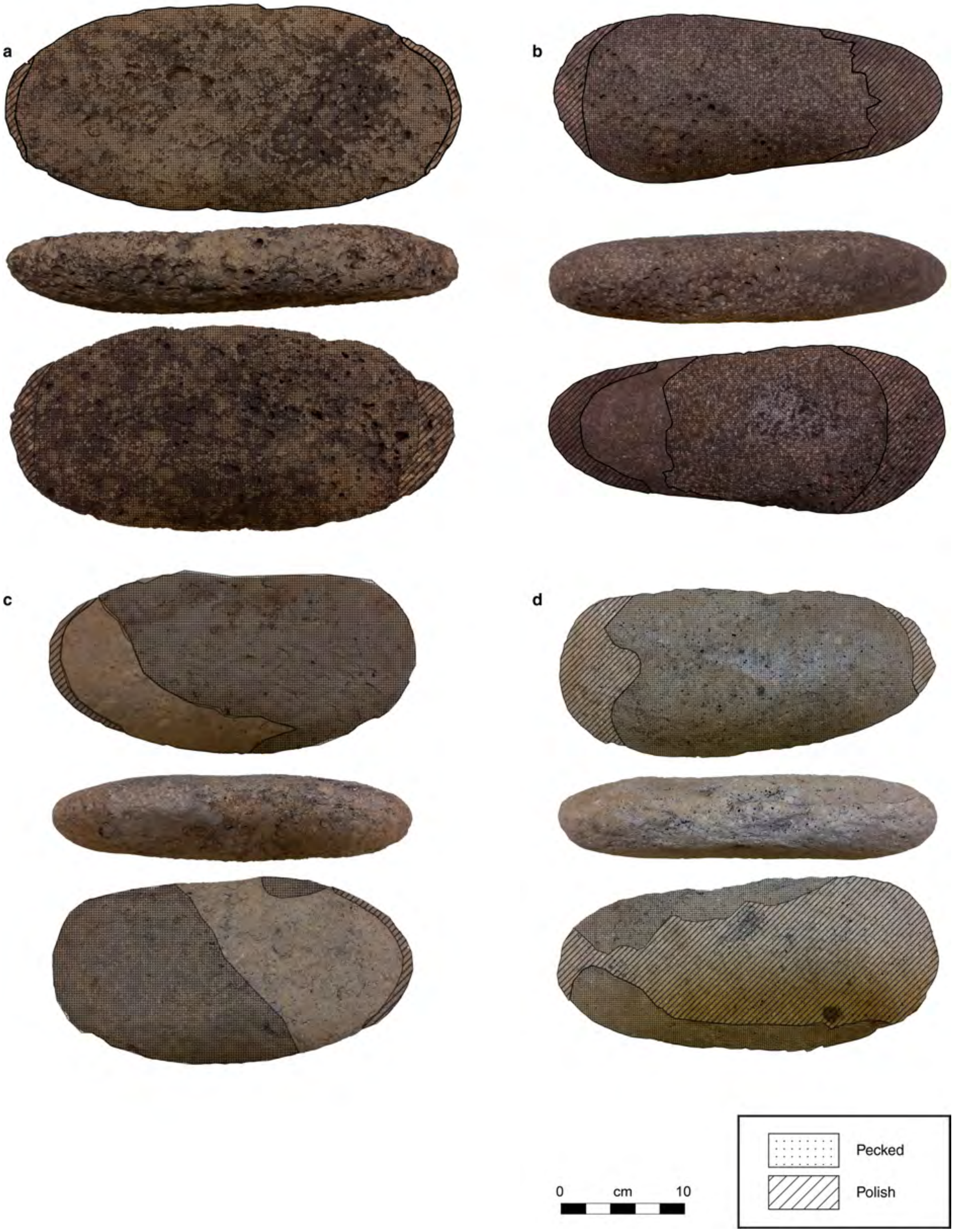


Figure 66. Type 2 and 3 Lukeoliths from Cochise contexts at Falcon Landing. Type 2: (*a*) vesicular basalt, from a nonfeature context (Inventory No. 04000C264); (*b*) vesicular basalt, from a nonfeature context (Inventory No. 04000C25C); and (*c*) andesite, from Feature 1313, a structure (Inventory No. 04000C6C5). Type 3: (*d*) rhyolite, from a nonfeature context (Inventory No. 04000C037). (*Note*: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

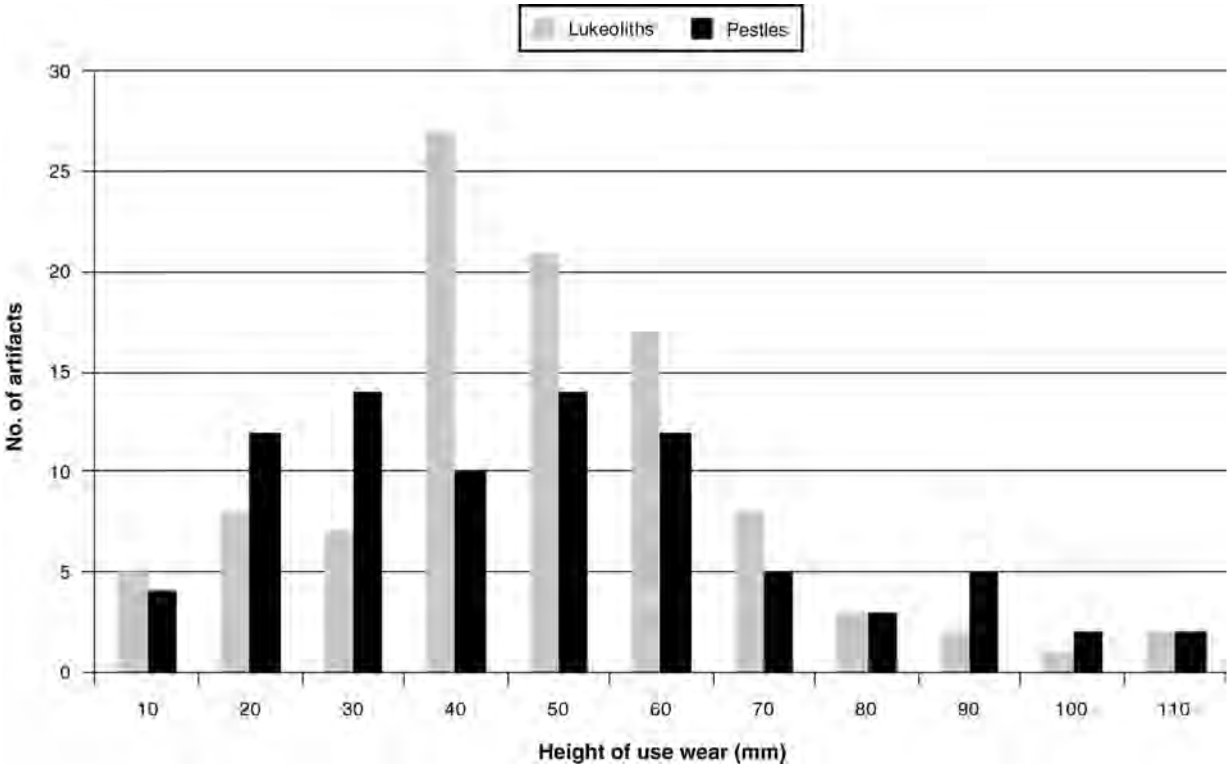


Figure 67. Heights of use wear on pestle shafts and Lukeolith margins (Pestle sample: n = 83; mean = 44.8 mm; standard deviation = 24.5. Lukeolith sample: n = 101; mean = 45.5 mm; standard deviation = 20).

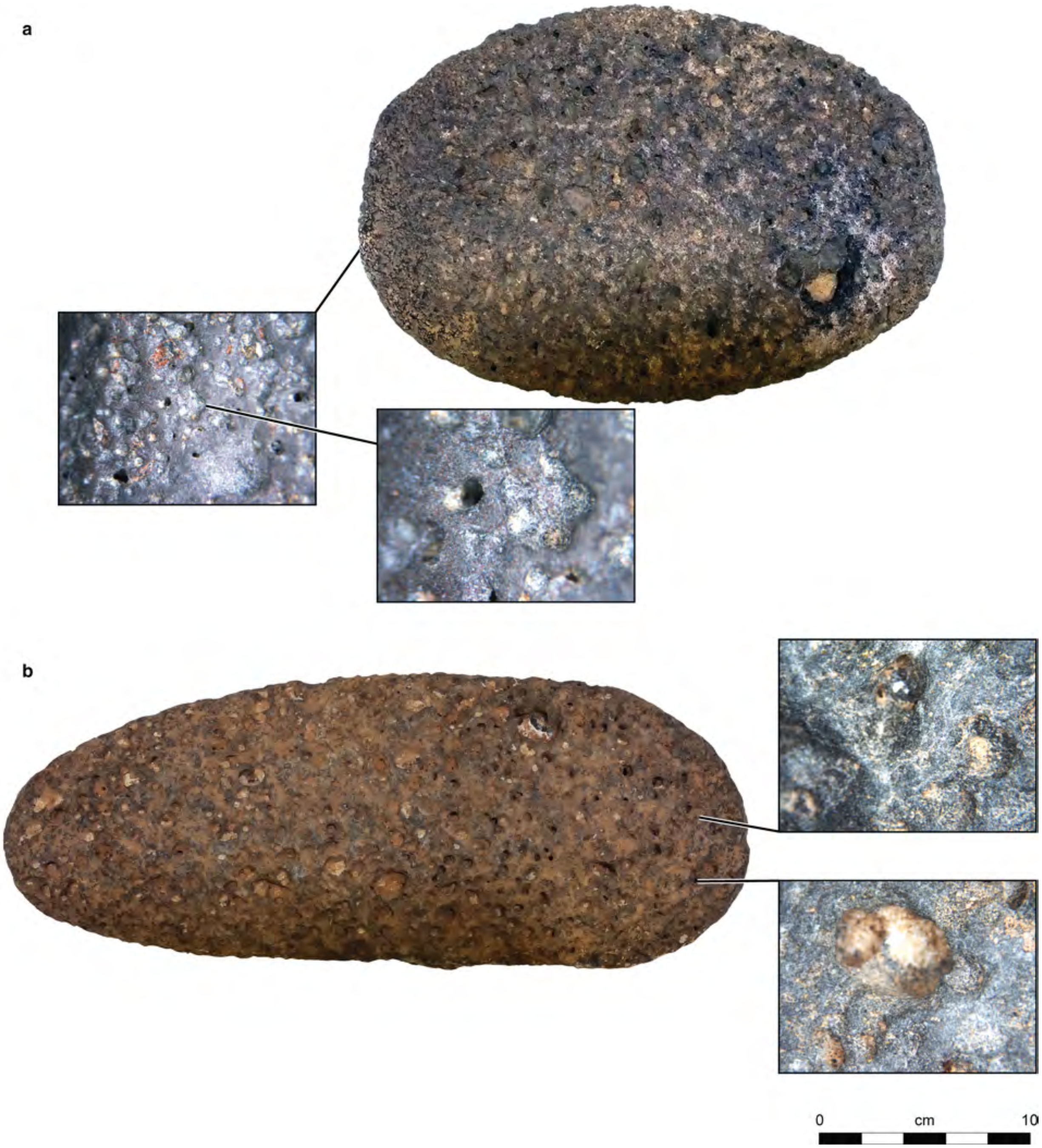


Figure 68. Use wear on vesicular-basalt Lukeoliths from nonfeature contexts at Falcon Landing: (*a*) Type 2 (Inventory No. 04000E3F9, early Chiricahua phase) and (*b*) Type 1 (Inventory No. 04000ED50, not dated). Magnification at 75×.

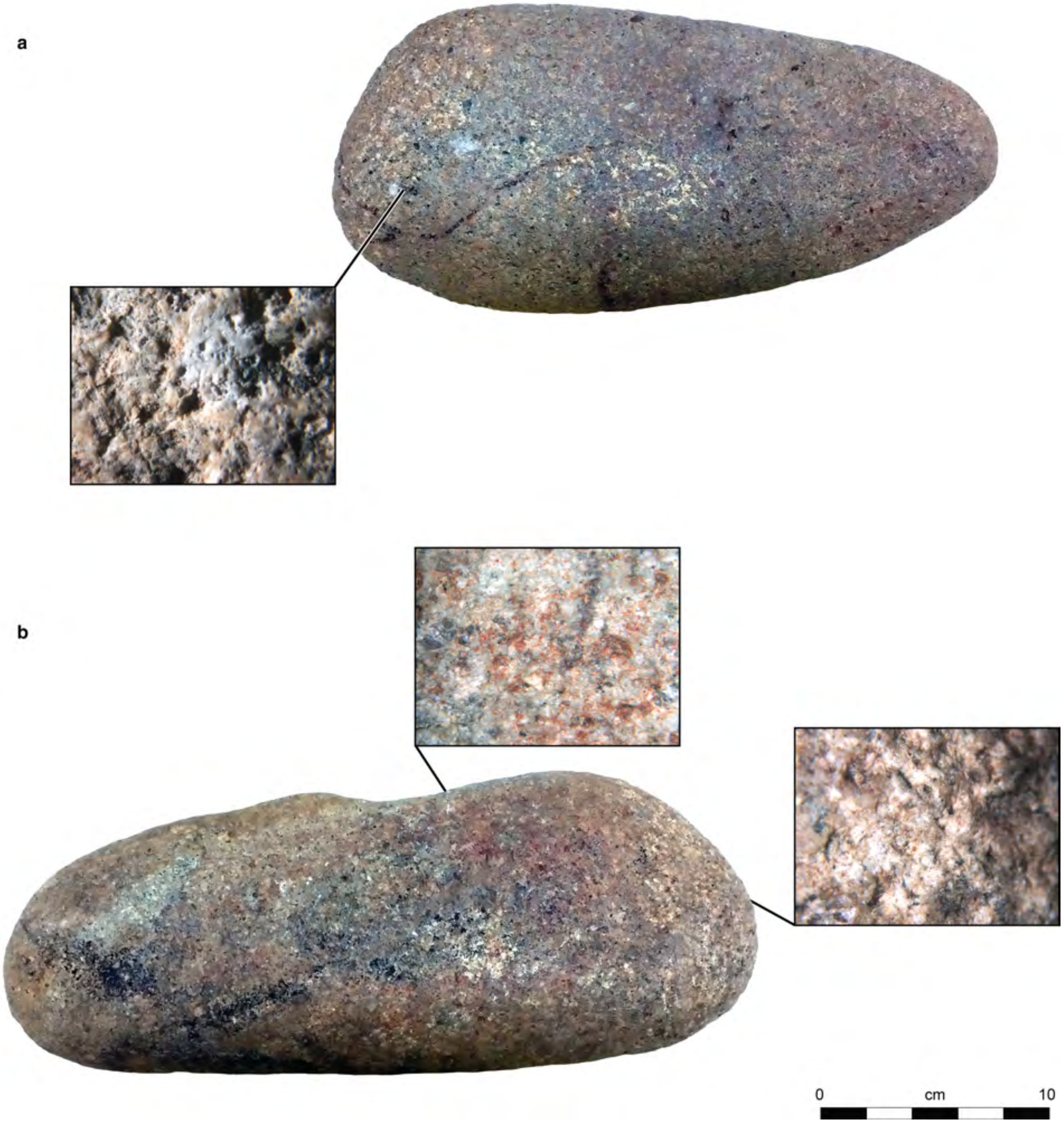


Figure 69. Use wear on granite Lukeoliths from Falcon Landing: (*a*) Type 1, from a nonfeature context (Inventory No. 040011972, early Chiricahua phase), and (*b*) Type 3, from Feature 18368, a nonthermal pit (Inventory No. 040010793, Cochise). Magnification at 75×. (*Note*: “Cochise” indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

Netherstones

This category included 43 items that were characterized by their moderate size (an average weight of 7,156 g) and having had little or no manufacturing investment (pecking). Metric observations of netherstone sizes are provided in Table 35. Length and width axes were fairly normally distributed. Thickness had a nearly uniform distribution. These patterns informed the sizes and shapes of objects considered by the analysts to be netherstones. They were generally informal bottom stones that probably fulfilled an assortment of common tasks—chief among them, grinding. Single netherstones were recovered from several extramural contexts (see Table 35), but multiple netherstones were limited to a cache (n = 2) and a small number of thermal pits (n = 6). In total, 31 netherstones were discovered as isolated artifacts in extramural spaces. Netherstones were probably in use throughout the occupational history of the site. Limiting ages were available for only 9 specimens dating to the early Chiricahua phase and 5 specimens dating to the Cienega phase.

A diverse range of raw materials was employed in the production of netherstones (Table 36). Volcanic materials of highly variable chemical composition and texture were the most common rocks. Foliated metamorphic rocks and plutonic rocks were approximately equally represented, followed by a few rare quartzite implements. There was no apparent patterning between implement form or function and material type. Items described as netherstones were complete, as opposed to fragmented, by a ratio of nearly 3:1. The predominance of complete pieces was probably a reflection of the fact that netherstones rarely show evidence of substantial use, decreasing the likelihood that fragmented pieces will be recognized as tools during analysis.

Netherstones did not experience the common uses experienced by metates or pestles, but they did not show specialized use. Four specimens retained some ocher or soot residue, but that did not set them apart from other tool classes. There was no evidence that other implements had been manufactured using netherstones. Some of the netherstones may represent early-stage metates that were deemed too small or otherwise insufficient. The netherstones at Falcon Landing provided grinding/working surfaces, but it is impossible to know whether they were transported to the site for such purposes or opportunistically used in those ways when they did not suit formal tasks.

Indeterminate Ground Stone

The indeterminate ground stone pieces recovered from Falcon Landing included 537 fragments recovered from every recorded context (Table 37). The largest excavated samples were collected from thermal pits (n = 133), structures (n = 122), nonthermal pits (n = 118), and FAR concentrations (n = 48). Not surprisingly, nearly 83 percent of the indeterminate ground stone from the site had been fire affected, indicating that most of it had been derived from ground stone tools that were recycled as thermal mass. Many of the implements experienced formal use before breaking or being broken as FAR, based on the high number of shaped pieces. Indeterminate ground stone was underrepresented in the Chiricahua phase midden (Feature 14587), indicating that recycling was intensive.

The average size of indeterminate ground stone was small, about one-quarter as large as the typical mano, but the total weight of the collection was 82,285 g (roughly 180 pounds). That is equivalent to about five or six respectable Chiricahua phase metates in mass but certainly represents many times more, because only a portion of a complete metate is a grinding surface, but all indeterminate fragments possessed grinding surfaces. The fracturing of ground stone tools made from natural cobbles would have led to many pieces that would be unidentifiable as ground stone during analysis. A significant portion of the FAR collection was likely composed of such specimens.

The indeterminate ground stone at Falcon Landing was just that: fragments, mostly of metates and netherstones. The percentage of vesicular basalt in the indeterminate ground stone was nearly identical to that of broken and complete metates at the site, around 20 percent.

Manuports

In total, 121 manuports were recovered from Falcon Landing, mostly from structures (n = 10) and thermal pits (n = 7). Eighty-six manuports were located in extramural spaces (Table 38). Only a small number of specimens were dated, including 20 items from early Chiricahua phase features and sediments. The intended functions of the manuports were sometimes evident based on raw material, size, and shape, such as a small

Table 35. Summary Information Recorded on Netherstones, by Temporal Component, Falcon Landing

Characteristics	Early Chiricahua	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Total
Number of specimens	9	5	11	8	10	43
			Condition			
Complete	5	5	6	8	7	31
Fragment	4	—	5	—	3	12
			Material Texture			
Other	8	5	9	8	9	39
Vesicular	1	—	2	—	1	4
			Thermally Altered			
No	6	5	6	8	9	34
Yes	3	—	5	—	1	9
			Residue			
No	9	5	10	8	7	39
Yes	—	—	1	—	3	4
			Manufacturing Investment			
High	2	—	—	—	—	2
Low	7	5	11	8	10	41
			Surface Count			
1	9	5	10	8	9	41
2	—	—	1	—	1	2
			Primary Surface Texture			
Coarse/resharpened	—	—	1	—	—	1
Smooth	9	5	10	8	10	42
			Metrics			
Length (mm)						
Average	294	283	269.3	355	306.1	304.9
SD	55	83.9	70.6	114.2	69.4	83.8
n	5	5	7	8	9	34
Width (mm)						
Average	221	181	169.3	233.8	225.6	208.2
SD	34.4	77.3	40.4	78	57	62.9
n	5	5	7	8	8	33
Thickness (mm)						
Average	70.2	68	70.6	68.8	90	74.9
SD	28.7	31.7	31.8	23	33.8	29.7
n	5	5	7	8	9	34
Surface length (mm)						
Average	216.7	183	154.3	203.8	202.8	192.9
SD	57.2	57.8	34.1	37.9	44	48.0
n	6	5	7	8	9	35
Surface width (mm)						
Average	155	135	105.7	141.3	136.9	133.8
SD	20.6	50.2	27	16.2	37.9	33.7
n	5	5	7	8	8	33

continued on next page

Characteristics	Early Chiricahua	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Total
Surface depth (mm)						
Average	1.2	0	4	0	3.9	5.6
SD	2.7	0	5.7	0	4.5	4.0
n	5	5	4	8	8	8
Weight (g)						
Average	6,097	6,863	4,500	9,886	7,280	7,156
SD	1,388	4,328	2,916	8,820	3,105	5,278
n	5	5	6	8	7	31
	Recovery Context					
Cache	—	—	2	—	—	2
FAR concentration	—	—	1	—	—	1
Nonthermal pit	—	—	1	—	—	1
Nonthermal pit (bell shaped)	1	—	—	—	—	1
Posthole	1	—	—	—	—	1
Thermal pit	2	—	4	—	—	6
CBS/mixed	5	5	3	8	10	31
Total	9	5	11	8	10	43

Key: CBS = culture-bearing sediment; SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

Table 36. Raw-Material-Type Information Recorded on Netherstones, by Temporal Component, Falcon Landing

Material Type	Complete						Fragment				Total
	Early Chiricahua	Cienega	Cochise[a]	Poorly Dated	Not Dated	Complete Total	Early Chiricahua	Cochise[a]	Not Dated	Fragment Total	
Andesite	—	1	1	1	2	5	—	—	—	—	5
Andesite (porphyritic)	1	1	—	—	1	3	1	—	—	1	4
Basalt	1	1	—	1	—	3	—	—	—	—	3
Basalt (vesicular)	1	—	1	—	1	3	—	1	—	1	4
Dacite	—	—	1	—	2	3	—	—	—	—	3
Gneiss	1	—	—	1	—	2	—	1	—	1	3
Granite	—	1	2	—	—	3	2	—	1	3	6
Phyllite	—	—	—	—	—	—	1	—	—	1	1
Quartzite	—	—	—	3	1	4	—	—	—	—	4
Rhyolite	1	—	—	1	—	2	—	—	1	1	3
Rhyolite (porphyritic)	—	—	—	—	—	—	—	2	1	3	3
Schist	—	1	1	1		3	—	1	—	1	4
Total	5	5	6	8	7	31	4	5	3	12	43

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

Table 37. Summary Information Recorded on Indeterminate Ground Stone, by Temporal Component, Falcon Landing

Characteristics	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Red Mountain	Cochise[a]	Cochise to Historical	Not Dated	Total
Number of specimens	220	8	17	11	4	113	90	74	537
					Material Texture				
Nonvesicular	161	7	17	9	4	92	78	69	437
Vesicular	59	1	—	2		21	12	5	100
					Thermally Altered				
No	45	—	1	2	—	2	5	38	93
Yes	175	8	16	9	4	111	85	36	444
					Manufacturing Investment				
High	32	—	—	2	—	11	12	4	61
Indeterminate	156	4	13	8	4	88	69	68	410
Low	32	4	4	1	—	14	9	2	66
					Weight[b]				
Average (g)	272	64	127	168	176	142	157	224	205
SD	509	48	116	177	89	123	115	414	360
n	144	8	11	11	4	102	62	59	401
					Recovery Context				
Activity area	3	—	—	—	—	12	—	—	15
Charcoal/ash lens	—	—	—	—	—	2	1	—	3
FAR concentration	1	—	—	—	—	17	30	—	48
House-in-pit	90	5	11	—	3	6	5	—	120
Midden	3	—	1	—		—	—	—	4
Nonthermal pit	6	3	4	1	1	61	39	—	115
Nonthermal pit (bell shaped)	1	—	—	2	—	—	—	—	3
Posthole	8	—	1	—	—	—	—	—	9
Surface structure	—	—	—	2	—	—	—	—	2
Thermal pit	104	—	—	1	—	14	14	—	133
CBS/mixed	4	—	—	5	—	1	1	24	35
Site surface	—	—	—	—	—	—	—	50	50
Total	220	8	17	11	4	113	90	74	537
					Raw Material				
Andesite	3	—	1	1	1	4	2	2	14
Andesite (porphyritic)	2	—	—	—	—	3	—	2	7
Aplite	1	—	—	—	—	1	1	—	3
Basalt	53	3	5	2	1	13	13	25	115
Basalt (vesicular)	59	1	—	2	—	16	12	5	95
Dacite	—	—	—	2	—	3	11	2	18
Diorite	1	—	—	—	—	—	—	1	2
Gabbro	1	—	—	—	—	—	—	2	3
Gneiss	2	—	—	—	—	2	3	—	7
Granite	29	2	1	1	—	4	11	3	51
Granodiorite	1	—	—	—	—	—	1	—	2
Igneous (fine grained)	2	—	—	—	—	—	—	—	2
Indeterminate	—	—	—	—	—	—	—	15	15
Metamorphic (indeterminate)	—	1	1	—	—	5	1	—	8

Characteristics	Early Chiricahua	Late Chiricahua	San Pedro	Cienega	Red Mountain	Cochise[a]	Cochise to Historical	Not Dated	Total
Phyllite	3	—	—	—	—	—	—	—	3
Quartz	—	—	—	—	—	—	1	—	1
Quartzite (meta)	11		2	1	1	9	9	3	36
Rhyolite	32	1	3	—	1	32	15	8	92
Rhyolite (porphyritic)	13	—	—	—	—	2	4	—	19
Rhyolite (vesicular)	—	—	—	—	—	5	—	—	5
Sandstone	—	—	2	—	—	3	2	1	8
Schist	4	—	2	2	—	9	4	4	25
Tuff	3	—	—	—	—	2	—	1	6
Total	220	8	17	11	4	113	90	74	537

Key: CBS = culture-bearing sediment; SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

[b] Not all specimens had weight recorded, therefore only a sample is included in this category.

number of Lukeolith-shaped rocks. The material-type frequencies also suggest provisioning for manos or hammerstones (quartzite) and grinding slabs (foliated metamorphic). However, weight data indicated that large metate blanks were not included in the manuport sample. The presence of unmodified rocks shows a heavy investment in the provisioning of raw materials at Falcon Landing. One incomplete cobble manuport in the collection was collected from the wall of TR 10065, in a nonsite area of the APE.

FAR

FAR was by far the most ubiquitous artifact class recovered from Falcon Landing. In total, 10,192 pieces of FAR, a small sample, were collected from select features and analyzed. Raw material was determined for approximately 44 percent (n = 4,460) of the sample. A significant number (n = 948) were from one feature and were very small pieces. Removing those from the sample, 38 percent of the collection was analyzed. The FAR collection from controlled excavations of dated features (n = 1,866) is summarized in Table 39.

Of the FAR-bearing features included in Table 39, nearly 45 percent contained ground stone fragments. Again, the FAR at Falcon Landing was probably composed almost exclusively of recycled ground stone tools, but that assertion is impossible to test. The largest concentrations of FAR were collected from nonthermal pits, thermal pits, structures, and the Chiricahua phase midden (Feature 14587). Figure 70 shows the total number of pieces of FAR per feature class as well as the total per feature class divided by the number of excavated features. FAR is expected in its places of use (in roasting pits or hearths) and as secondary refuse (in abandoned pits or middens). At Falcon Landing, some nonthermal pits contained more FAR per feature than FAR concentrations did and nearly as much FAR per feature as did thermal pits, suggesting that FAR was occasionally managed in piles and pits for site organization and cleanliness or in anticipation of future needs, rather than transferred to a midden or allowed to scatter.

A comparison of the distributions of material types in the FAR and the ground stone indicated substantial differences. Both plutonic rocks and rhyolite were far overrepresented in the FAR collection, but basalt was significantly underrepresented relative to other material types. That relationship is surprising, considering that basalt's thermal properties exceed those of rhyolite, and it may reflect the greater durability of basalt tools.

Tray

One ground stone object from an undated and unassociated context was classified as a tray. It was a fragment of a highly shaped implement that likely served as a bottom stone for grinding small amounts of materials, but the implement was incomplete, and its complete size is unknown. The fragment measured 12 cm in width, 10 cm in length (incomplete), and approximately 3 cm in thickness. The diminutive size and the thinness of the basin indicated that it did not serve the same function as other grinding stones in the collection. It was executed on a pink quartzite and was concave in profile. The preparation of pigment or some

Table 38. Summary Information Recorded on Manuports, by Temporal Component, Falcon Landing

Characteristics	Early Chiricahua	Cienega	Cochise[a]	Cochise to Historical	Not Dated	Total
Type						
Cobble manuport	16	3	7	5	69	100
Tabular manuport	2	1	—	1	11	15
Indeterminate	2	—	3	—	1	6
Number of specimens	20	4	10	6	81	121
Weight (g)[b]						
Average	450	1,926	1,053	2,137	2,904	2,481
SD	453	1,490	1,074	516	3,732	3,374
n	8	4	8	4	74	98
Recovery Context						
Activity area	—	—	2	—	—	2
Cache	—	—	1	—	—	1
FAR concentration	3	—	—	2	—	5
House-in-pit	9	—	1	—	—	10
Nonthermal pit	1	—	4	—	—	5
Nonthermal pit (bell shaped)	1	1	—	—	—	2
Thermal pit	3	2	—	2	—	7
Thermal pit (bell shaped)	1	—	—	—	—	1
CBS/mixed	2	1	2	2	79	86
Site surface	—	—	—	—	2	2
Total	20	4	10	6	81	121
Raw Material						
Andesite	—	—	—	—	6	6
Andesite (porphyritic)	—	—	—	1	—	1
Basalt	2	—	1	—	10	13
Basalt (vesicular)	2	—	—	—	2	4
Dacite	—	1	—	—	1	2
Diorite	—	—	—	—	1	1
Gabbro	1	—	—	—	1	2
Gneiss	—	1	1	—	10	12
Granite	6	—	1	—	1	8
Granodiorite	—	—	—	1	—	1
Metamorphic (indeterminate)	—	—	1	—	—	1
Phyllite	2	—	—	1	—	3
Quartzite (meta)	3	—	2	—	26	31
Rhyolite	3	1	3	—	11	18
Rhyolite (vesicular)	—	—	1	—	—	1
Schist	1	1	—	3	10	15
Tuff	—	—	—	—	2	2
Total	20	4	10	6	81	121

Key: CBS = culture-bearing sediment; SD = standard deviation.

[a] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

[b] Not all specimens had weight recorded, therefore only a sample is included in this category.

Table 39. Attributes Recorded on FAR from Controlled Excavations of Dated Features, by Temporal Component, Falcon Landing

Characteristics	Chircahua		San Pedro		Cienega		Red Mountain		Total Features	Total FAR
	No. Features	No. FAR	No. Features	No. FAR	No. Features	No. FAR	No. Features	No. FAR		
Total	85	1,244	12	194	15	266	6	162	118	1,866
Feature Excavation Level of Effort										
Complete	36	145	11	191	6	190	6	162	59	688
Partial	49	1,099	1	3	9	76	—	—	59	1,178
Ground Stone Present										
Yes	35	—	8	—	6	—	4	—	53	—
No	50	—	4	—	9	—	2	—	65	—
Recovery Context										
Activity area	2	47	—	—	1	2	—	—	3	49
Charcoal/ash lens	2	14	—	—	—	—	—	—	2	14
Hearth			1	4	—	—	—	—	1	4
FAR concentration	5	37	—	—	—	—	—	—	5	37
House-in-pit	3	41	7	175	—	—	4	151	15	367
Midden	1	318	—	—	—	—	—	—	1	318
Noncultural	1	27	—	—	—	—	—	—	1	27
Nonthermal pit	38	252	3	8	11	253	2	11	54	524
Nonthermal pit (bell shaped)	—	—	1	7	1	7	—	—	2	7
Posthole	2	2	—	—	—	—	—	—	2	2
Surface structure	—	—	—	—	1	3	—	—	1	3
Structure (possible)	2	2	—	—	—	—	—	—	2	2
Thermal pit	29	504	1	7	1	1	—	—	30	512
Total	85	1,244	12	194	15	266	6	162	118	1,866
Raw Material[a]										
Andesite	—	5	—	1	—	2	—	—	—	8
Andesite (porphyritic)	—	2	—	—	—	—	—	—	—	2
Aplite	—	2	—	—	—	—	—	—	—	2
Basalt	—	35	—	23	—	9	—	13	—	80
Basalt (vesicular)	—	37	—	4	—	1	—	1	—	43
Conglomerate	—	—	—	—	—	1	—	—	—	1
Dacite	—	3	—	2	—	—	—	1	—	6

continued on next page

Characteristics	Chircahua		San Pedro		Cienega		Red Mountain		Total Features	Total FAR
	No. Features	No. FAR	No. Features	No. FAR	No. Features	No. FAR	No. Features	No. FAR		
Dacite (vesicular)	—	1	—	—	—	—	—	—	—	1
Gabbro	—	1	—	—	—	—	—	—	—	1
Gneiss	—	2	—	1	—	—	—	1	—	4
Granite	—	56	—	39	—	14	—	6	—	115
Granodiorite	—	3	—	1	—	—	—	1	—	5
Igneous (coarse grained)	—	—	—	—	—	16	—	—	—	16
Igneous (fine grained)	—	—	—	2	—	—	—	—	—	2
Indeterminate	—	1	—	1	—	—	—	—	—	2
Limestone	—	2	—	1	—	—	—	—	—	3
Metamorphic (indeterminate)	—	1	—	—	—	1	—	—	—	2
Phyllite	—	6	—	—	—	—	—	2	—	8
Quartz	—	1	—	1	—	2	—	—	—	4
Quartzite	—	10	—	2	—	—	—	1	—	13
Quartzite (meta)	—	18	—	3	—	8	—	1	—	30
Rhyolite	—	116	—	97	—	26	—	31	—	270
Rhyolite (porphyritic)	—	10	—	6	—	—	—	—	—	16
Rhyolite (vesicular)	—	8	—	3	—	—	—	1	—	12
Sandstone	—	1	—	1	—	—	—	1	—	3
Schist	—	21	—	—	—	2	—	1	—	24
Scoria	—	1	—	—	—	—	—	—	—	1
Tuff	—	1	—	—	—	2	—	—	—	3
Tuff (rhyolitic)	—	3	—	—	—	—	—	—	—	3
Total	—	347	—	188	—	84	—	61	—	680

[a] Not all specimens were identified for raw-material type.

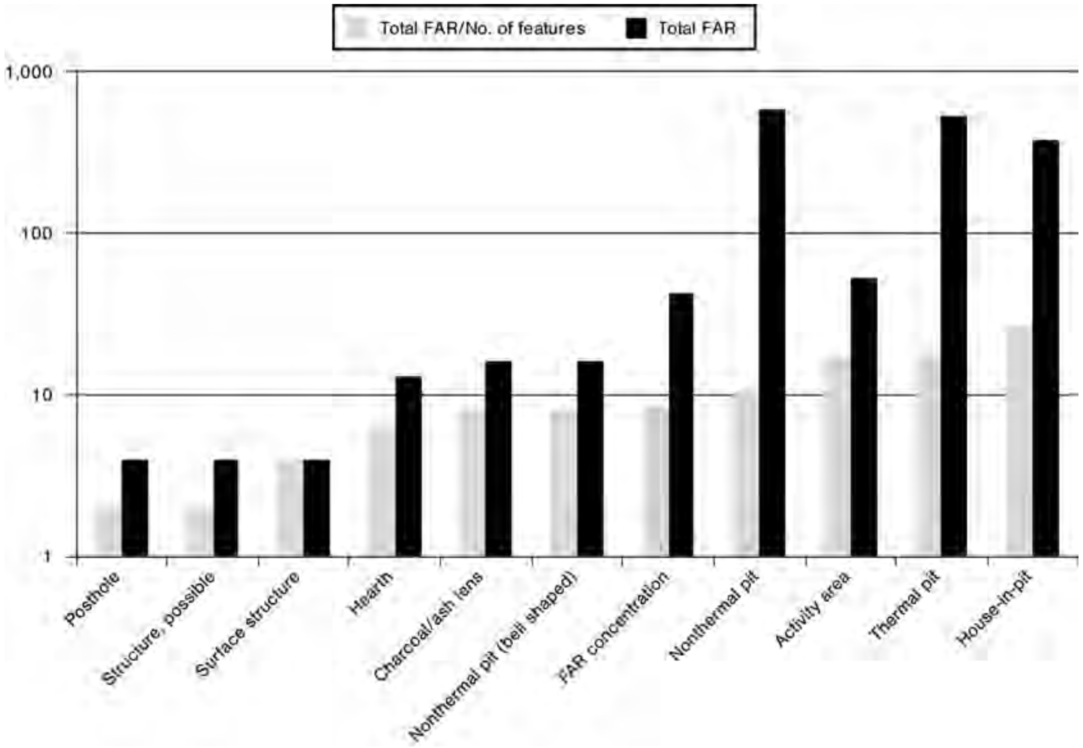


Figure 70. Absolute and relative frequencies of FAR from various recovery contexts, based on a subsample (n = 1,866).

other material prepared only in small quantities is the most intuitive functional explanation, but there was no use wear or residue to provide a more informed assessment of its use.

Polisher

One artifact showed clear signs of having been used as a polisher or having developed a polish from some other use. Recovered from Feature 14906, a Chiricahua–San Pedro phase thermal pit, the quartzite cobble measured 5 cm in diameter, exhibited a ubiquitous physical or chemical sheen, and was stained with soot. No equally large polished items were recovered from the site, and the tool's function is unknown.

Donut Stone

A "donut stone" made from basalt was recovered from an Archaic period nonfeature context. The implement was not highly symmetrical and had a diameter that varied between 7.5 and 8.4 cm. The stone measured 2 cm thick, and the small perforation was approximately 0.5 cm in diameter (Figure 71). There was no evident use wear in the perforated area. The functions imagined for donut stones are numerous, but digging-stick stone, net weight, spindle whorl, and sling stone are common analogs. They are found broken, but typically do not show wear patterns indicative of their use. Koerper et al. (2010) distinguished formal, magico-religious donut stones from utilitarian digging-stick stones at mostly Late period sites in California. Although commonplace at archaeological sites in southern Arizona (Adams 2002), the function of so-called donut stones is a mystery. Their antiquity is likewise poorly documented. Haury (1950:332) only reported two donut stones from the top level at Ventana Cave, but Adams (2002:112) described one found in an undated intramural pit at Los Pozos and mentioned their presence during Cienega phase occupations in the middle Santa Cruz River valley. The presence of a single donut stone at Falcon Landing indicates that donut stones were rarely used and lost at the site, but that is typical of the type.

Figure 71. A basalt donut stone from a nonfeature Cochise context at Falcon Landing (Inventory No. 04000C363). (*Note*: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

Disk Beads

Thirteen stone-disk beads were found intermingled with 249 *Olivella*-shell beads in Feature 18880, an extramural pit (see Chapter 4, Volume 1). The beads were made from a slightly glossy white stone, possibly steatite (Figure 72). The stone beads were the same color as the shell beads, but the shell colors may have faded over time. The stone beads were all complete and had central, cylindrically drilled perforations. With the shell beads, they may represent a single artifact, such as a long necklace, or several smaller pieces. Grinding striations were visible on the edges, but few other manufacturing traces remained. The beads were standard in size and shape, and there was very little variation in their overall diameters. The 13 beads ranged from 10.3 to 10.7 mm across and were very even in overall shape; when laid one on top of the other, the edges matched one another closely. There was slightly more variation in thickness, with a range of 3.3–5.4 mm (Table 40), and the perforations ranged from 4.4 to 5.5 mm across. No stone-bead-manufacturing debris was identified.

In an overview of San Pedro phase technologies, Mabry (2008) suggested that although larger stone disks have been found in Late Archaic/Early Agricultural period contexts, stone-disk beads were uncommon in that time period. Bone and tortoise-shell disk beads and beads of other shapes made of bone, tortoise shell, marine shell, mica disks, and fired clay were present. Drilled stone pendants and other stone ornaments have been found in low numbers (Ferg 1998), but stone does not appear to have been the preferred material for most personal ornaments in the Late Archaic/Early Agricultural period. Preferences in ornaments change over time. Bone beads and drilled bones have occasionally been found in Middle Archaic period contexts (Bayham 1986a; see also Chapter 4). A single shell bead was recovered from a Middle Archaic period context at Falcon Landing, and a tubular bone bead was also found at the site (see Chapter 4). Shell beads were common in the Early Agricultural period, but shell bracelets were more popular in later periods (Vokes 2003), and stone-disk beads also seem to have become more common in later times.

Figure 72. Steatite stone beads from Cochise Feature 18880, a nonthermal pit at Falcon Landing (Inventory Nos. 04001008C, 0400102F7, 040010806, 040010B8E, 0400124DF, 0400125DB, and 0400125E3–0400125E9. (*Note*: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

Table 40. Summary Information on Stone Beads from Feature 18880, Falcon Landing

Level	Context	Length (mm)	Width (mm)	Thickness (mm)	Perforation Diameter (mm)	Weight (g)
1	fill	10.4	10.3	4.6	4.4	0.7
		10.4	10.3	3.8	5	0.5
		10.7	10.5	3.7	5.5	0.5
		10.3	10.3	4.2	4.6	0.7
		10.6	10.5	3.5	5	0.5
		10.4	10.3	3.3	4.7	0.5
2	fill	10.4	10.3	4.6	4.8	0.7
		10.6	10.6	4.7	4.7	0.7
		10.7	10.6	4.7	5	0.8
3	mixed	10.4	10.4	3.9	4.5	0.6
		10.4	10.4	4.6	4.5	0.7
5	mixed	10.5	10.4	5.4	4.5	0.8
		10.3	10.2	4.7	4.8	0.6

Stone disk beads were recovered at Snaketown from all contexts but increased in frequencies from the Estrella phase to the Sacaton phase (Gladwin et al. 1965; Haury 1976). The Snaketown beads ranged in size from 0.1 to 1.9 cm. Steatite ornaments from Snaketown were dated mostly to the Sacaton phase, but the material appeared to be dark gray or bright green, rather than the white that was found at Falcon Landing. Disk beads were identified at sites excavated during the Tonto Creek Archaeological Project (TCAP) (Vokes 2001a). The beads had been made from several materials and were found in a variety of contexts, but most were found in mortuary contexts. Vokes found that the TCAP beads fell into two size ranges. Beads found in groups tended to be smaller than those found individually (including one group associated with shell-disk beads). The beads from Falcon Landing were more in line with the larger individual beads than the smaller beads. Stone ornaments from the Early Ceramic period were entirely absent from the Roosevelt Community Development Study (Adams and Elson 1995). The highest proportion of disk beads from that project was from the Sedentary period, and the proportion of disk beads decreased again during the Classic period. Farther to the south of the Luke Solar project area, one disk bead, a square bead, and a disk-bead blank made from turquoise were recovered from Tortolita phase contexts at the Valencia Vieja site in the Tucson Basin (Vokes 2003).

Disk beads are not limited to the Hohokam area, and excavations at the Mogollon Tla Kii Ruin, Forestdale, produced finished beads and debitage of black steatite showing stages of manufacture (Haury 1985:120). At that site, manufacturing began by incising squares into one face of a sheet of steatite. Haury suggested that after the incised sheets were broken into square blanks, the blanks were drilled and rounded, strung together, and ground into final shape on a grooved abrader. Bead manufacture observed during the TCAP was consistent with that described by Haury (Vokes 2001a), and researchers have suggested that a stone whorl in a feature interpreted as a bead-manufacturing location may have been part of a pump drill. If the beads from Falcon Landing were manufactured using processes similar to those described by Haury, and the beads were strung together before being ground into final shape, then that would account for the extremely even shape of the beads and would also suggest that the 13 stone beads were made at the same time and obtained from one source.

As noted above, stone-disk beads are generally associated with later times. Most of the shell beads from Feature 18880 were the simple spire-lopped *Olivella*-shell beads found in quantities from the Late Archaic/Early Agricultural period and later times, but three *Olivella*-shell barrel beads were also identified (see Chapter 4). Barrel beads are more often found at Sedentary through Classic period sites (Vokes 2001b). In addition, nine shell beads were made from *Olivella fletcherae*, a species usually found in contexts representing later times (see Chapter 4). Together, these various observations may indicate that the composite artifact or artifacts from Feature 18880 may belong to a later time than many of the surrounding features or that Middle Archaic period sites have been poorly sampled for rare exchange items.

Pipe

A stone pipe was recovered from Feature 4370, a nonthermal pit (Figure 73) dating to the San Pedro phase. The pipe was conical and nearly complete and had breakage along one side of its wider end. It measured 9.7 cm in length and 2 cm in width and had an interior-hole diameter of just over 1 cm that tapered to 0.6 cm at the narrow end. It was made from a very fine-grained, light-gray porphyritic tuff and had a clear soot line showing where the wide end had been filled and burned. A few lines had been scratched into the surface of the smaller end, two of them forming a Y shape (not shown in Figure 73). Two shallower, shorter lines may have been present above the Y shape, but they were much harder to see and could have resulted from inadvertent scratches or gouges.

Although conical and/or tubular pipes are often referred to as “cloud blowers” because ethnographic studies have described them as having been used to blow smoke clouds during ceremonies, Ferg (1998) recommended that this term be avoided, because it implies a specific, intended use. Moreover, such an activity does not in fact require a specific shape of pipe. In addition, inconsistent use among researchers makes the term less useful, because some have used it in reference to conical pipes, others have used it in reference to tubular pipes, and for some, it can mean either tubular or conical pipes (Ferg 1998). Therefore, the term is avoided in the present discussion.

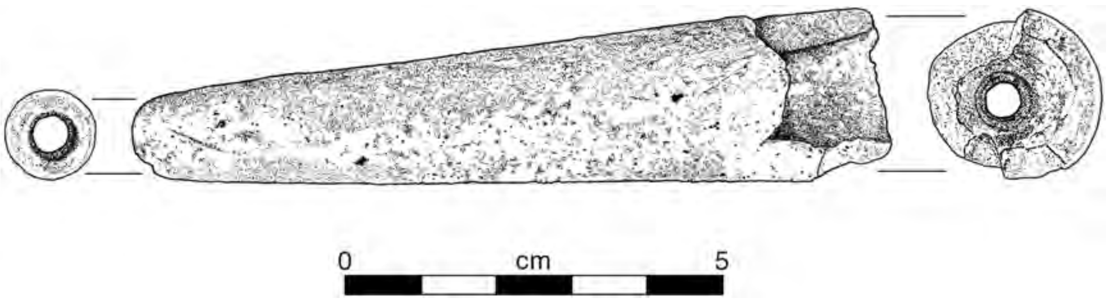


Figure 73. A tuff stone pipe from San Pedro phase Feature 4370, a nonthermal pit at Falcon Landing (Inventory No. 04000C2B9).

Ferg (1998) provided an extensive overview of pipe use among ethnographic accounts and archaeological specimens. Soot lines present on the pipe from Falcon Landing and other pipes confirmed that these objects likely were smoking equipment, but what exact materials were smoked during the Middle Archaic period is unknown, although there are some clues. Tobacco seeds were found in sediments surrounding a stone pipe from Cienega phase contexts at the Stone Pipe site and in four other features or subfeatures (L. Huckell 1998). Those seeds were tentatively identified as belonging to two species native to Southern Arizona. The bowls of a double-ended pipe from Ventana Cave retained material suggested to be tobacco (Haury 1950), but that identification has been called into question (Ferg 1998). The presence of tobacco at Stone Pipe indicates that tobacco use has been practiced since the Cienega phase, but it does not guarantee that the pipe from Falcon Landing was a tobacco pipe. During the Historical period, people of the U.S. Southwest smoked the stems, seeds, and leaves of many other plants and even smoked some nonplant materials (Ferg and Mead 1993; L. Huckell 1998; Jones 1944; Rainey and Adams 1994), and any of these could have been mixed with tobacco or smoked alone.

Ferg (1998) found that most stone pipes from the Archaic and Early Agricultural periods in the U.S. Southwest have dated to the Cienega phase, although a few Middle Archaic period specimens have been found in California, and one pipe from Ventana cave was assigned to Chiricahua–Amargosa II. He noted that Middle Archaic period pipes tend to be short, large mouthed, and conical, but by the Cienega phase, pipes had become much more variable in form. Since the time of Ferg's summary, conical stone and clay pipes and bulbous pipes with bone stems have been seen in San Pedro phase contexts at Las Capas (Mabry 2008). SWCA archaeologists recovered a fragmentary conical argillite pipe from an early San Pedro phase context (Hesse 2010). Although many of the known pipes from the Late Archaic/Early Agricultural period were recovered in the Tucson Basin, one fragmentary pipe was recovered northwest of Phoenix, at AZ T:2:1 (ASU) (Rice and Dobbins 1981). Two conical vesicular-basalt pipes were also found in Cienega and Red Mountain phase inhumations at Finch Camp (Ballenger et al. 2011). The pipe from Falcon Landing was long and slender and, when compared to pipes illustrated in Ferg's overview (1998:589–599), was most like one from the Wetlands site (Ferg 1998). It was shorter than the pipe from Stone Pipe but longer than the pipes from Finch Camp (Ballenger et al. 2011) and Cienega Creek and the measurable pieces from the SU site (Ferg 1998). Pipes seem to have been more common in the Early Agricultural period, but few have been found at Hohokam sites (Ferg 1998; Haury 1976), and Haury (1976) suggested that the dearth of pipes at Hohokam sites indicates that tobacco was consumed in cane-cigarette form.

Caches

Caches were previously defined as concentrations containing complete, serviceable stone tools (see Chapter 4, Volume 1). Most caches containing large pieces of ground stone were easily detected. Other probable caches were encountered as extramural artifacts that were usually partially exposed by mechanical excavations and not in a discernible pit. These extramural artifacts were typically collected without a formal excavation process and therefore were never assigned feature numbers. During Phase 2 fieldwork, several concentrations of ground stone items were excavated as formal features. In total, 19 such caches were identified and excavated at Falcon Landing (see Chapter 4, Volume 1). Two of the caches (Features 3598 and 3611) reported in Volume 1, however, were poor candidates for caches. For example, Feature 3598 contained a single metate, but it was fragmented into nine pieces that appeared to have been fire affected. Feature 3611 only contained one hammerstone and one mano fragment. These two features are not considered in this discussion.

The stone-artifact analysis provided an opportunity to reevaluate concentrations of ground stone items that were not identified as cache features in the field. In all, 36 possible caches were recognized at Falcon Landing: 17 of the cache features described in Volume 1, 13 additional extramural caches recovered from MSUs and not assigned feature numbers, and 6 features that contained possible caches but were assigned to different feature types (i.e., nonthermal pit, thermal pit, or FAR concentration). The caches identified in Figure 74 are discussed in more detail below, but the distribution of caches relative to manos, metates, pestles, and mortars shows that caches generally were found in contexts similar to those of isolated, extramural tools: within clusters and as isolates. Collapsing all time onto one plane, the distributions of tools and caches included obvious concentrations of multiple tools, concentrations of specific tools, and open spaces containing no isolates or caches. The spatial arrangement of plant-food-processing tools reflected the locations of former plants and other people, among other things, and the integrity of the clusters bears witness to long-term ecological and historical circumstances that gradually imparted structure to the site.

Nearly 100 tools were represented in these caches (Table 41), ranging from 2 to 6 objects per cache. Combinations of tools in the caches included multiple variations, and mano and metate groups occurred most frequently (n = 10). Multiple metates and Lukeoliths were also common (n = 7). Five caches contained only manos, and five caches consisted of pairs of pestles. Only one mortar-and-pestle pair was recovered. Caches that did not have feature numbers assigned in the field are identified here by their provenience-designation (PD) numbers.

PD 1391

PD 1391 was a large mortar-and-pestle pair (Figure 75a) at the southern end of Falcon Landing. The artifacts were stratigraphically dated to the Cienega phase. The vesicular-basalt boulder mortar had been shaped by pecking and grinding. Immediately adjacent to the mortar was a Type I pestle of the same material that had been minimally shaped by grinding and showed very light use wear.

PD 1532

PD 1532 was an Early to Late Archaic period artifact cluster in the southeastern part of the site. The cache consisted of two quartzite cobble manos. Both had been completely shaped by pecking and grinding.

Feature 3074

Feature 3074 was a possible cache of ground and flaked stone artifacts dating to the Late Archaic to Protohistoric period. The cache was located in the southern portion of the site and contained two complete ground stone artifacts: a shaped Lukeolith stacked on a gneiss grinding slab. A schist grinding-slab fragment and a basalt cobble-mano fragment were also in the pit. The flaked stone artifacts included a piece of basalt shatter and a rhyolite biface fragment.

Feature 3190

Feature 3190 was a possible Middle Archaic to Pioneer period cache located in the southwestern portion of the site. Feature 3190 contained one complete dacite flat/concave metate that had been placed vertically within the center of a nonthermal pit.

Feature 3330

Feature 3330 was a possible ground stone cache and a nonthermal pit on the eastern edge of Falcon Landing. The feature dated to the Pioneer to Classic period and included a cache of four complete ground stone artifacts. A face-down, flat andesite metate and an andesite cobble mano were immediately next to each

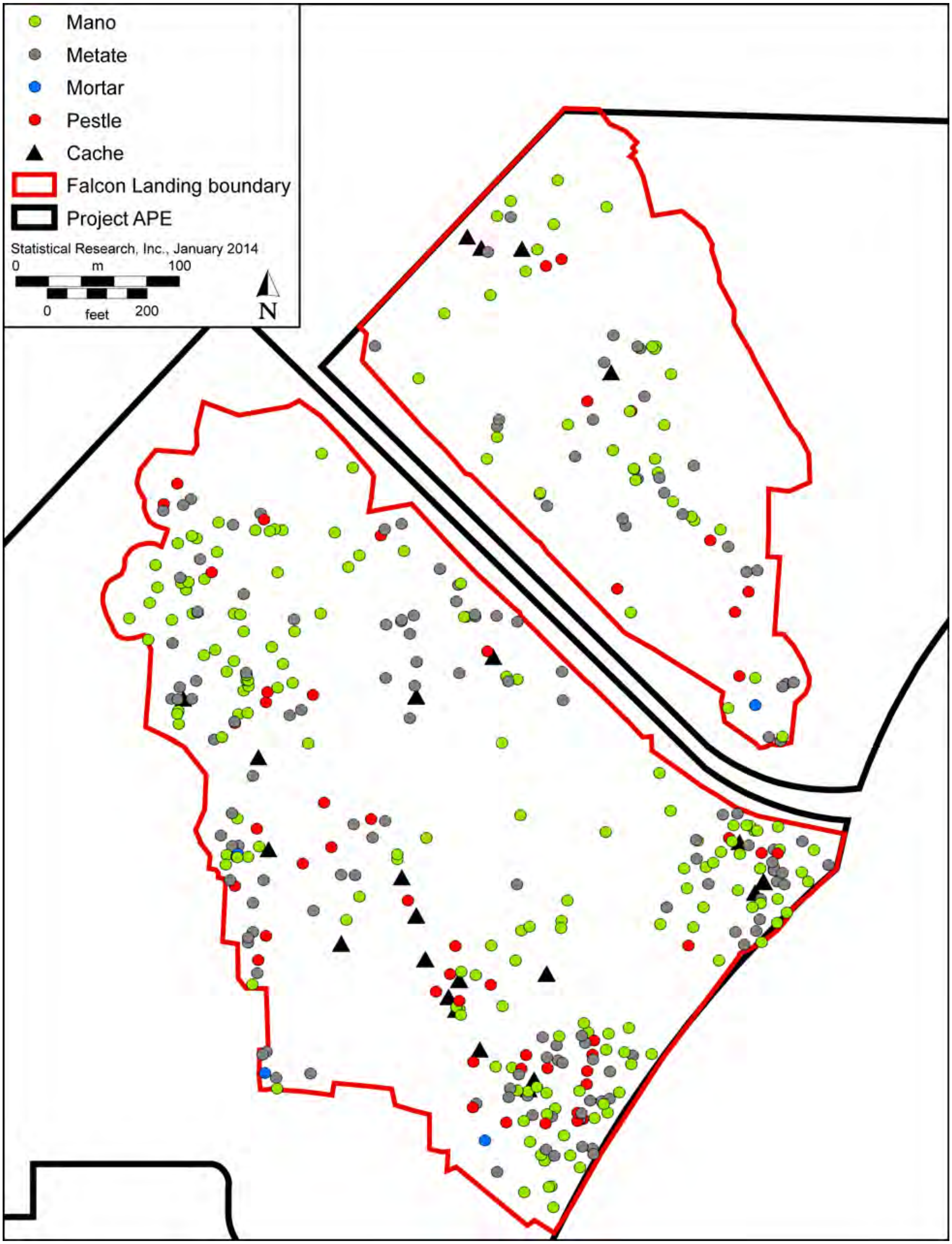


Figure 74. Map showing the distributions of complete ground stone manos, metates, mortars, and pestles in relation to caches at Falcon Landing.

Table 41. Contents of Stone Tool Caches Recognized at Falcon Landing

Feature/ PD No.	Feature Type	No. Complete Cached Items	Other Artifacts Present	Complete Items	Incomplete Items
1391	n/a	2	no	1 mortar and 1 pestle (Type I)	
1532	n/a	2	no	2 manos	
3074	cache	2	yes	1 Lukeolith and 1 grinding slab	1 grinding-slab fragment and 1 mano fragment
3190	cache	1	no	1 flat/concave metate	
3330	nonthermal pit	4	yes	1 flat/concave metate, 3 manos	2 mano fragments
3372	cache	2	yes	2 pestles (Type II and Type X)	
3547	FAR concentration	3	yes	3 manos	
3733	cache	2	no	1 basin metate and 1 mano	
3775	cache	2	no	2 pestles (Type V and Type VI)	
3792	cache	3	no	1 grinding slab, 1 basin metate, and 1 mano	
3802	cache	2	no	2 pestles (Type VI and Type VII)	
3817	cache	3	no	1 multidirectional core, 1 uniface, and 1 hammerstone	
3894	cache	1	yes	1 Lukeolith	2 Lukeolith fragments
3902	cache	2	yes	1 grinding slab, 1 mano	
3993	cache	4	yes	1 mano, 1 pestle (Type IX), 1 multidirectional core, and 1 manuport	
4664	cache	2	no	2 pestles (Type I and Type V)	
5185	cache	3	no	1 Lukeolith, 2 netherstones	
5945	cache	3	yes	1 basin metate, 2 manos	
10931	cache	2	no	1 flat/concave metate, 1 mano	
10934	cache	3	no	1 flat/concave metate, 2 manos	
11375 and 11376	n/a	2	no	1 basin metate, 1 mano	
11379	n/a	2	no	2 pestles (Type VII)	
11433	n/a	2	yes	1 flat/concave metate, 1 Lukeolith	1 mano fragment
11456	n/a	2	no	1 mortar, 1 mano	
11463	n/a	4	no	4 manos	
14550	n/a	2	no	2 Lukeolith	
14920	FAR concentration	6	yes	5 core-reduction flakes, 1 edge-modified flake	indeterminate ground stone fragment
14938	nonthermal pit	2	yes	1 Lukeolith, 1 hammerstone	
15093	n/a	2	no	1 netherstone	1 basin-metate fragment
15139	cache	3	no	1 flat/concave metate, 1 basin metate, 1 mano	

Feature/ PD No.	Feature Type	No. Complete Cached Items	Other Artifacts Present	Complete Items	Incomplete Items
15158	n/a	2	no	2 manos	
15251 and 15252	n/a	2	no	1 pestle (Type IX), 1 basin metate	
15317	thermal pit	3	yes	1 basin metate, 1 flat/concave metate, 1 mano	1 Lukeolith fragment, 2 pieces of faunal bone, 24 pieces of debitage
16663	nonthermal pit	6	yes	6 manos	1 hammerstone fragment, 1 metate fragment, 8 pieces of FAR
18185	n/a	2	no	2 Lukeoliths	
18341	n/a	2	no	1 Lukeolith, 1 hammerstone	

Key: n/a = not applicable, defined postfield and not assigned a feature number.

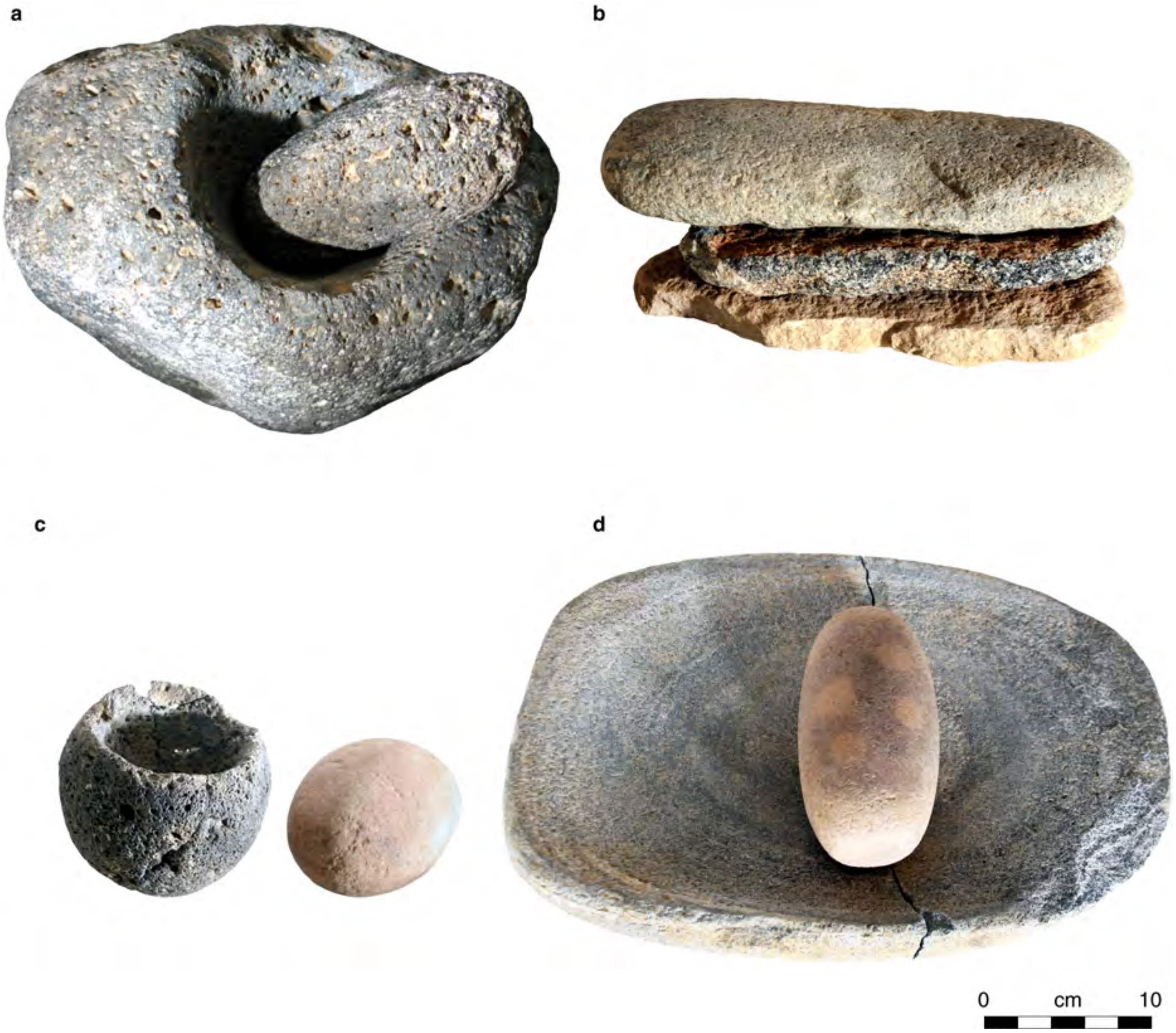


Figure 75. Caches at Falcon Landing: (*a*) a cache containing a vesicular-basalt mortar (Inventory No. 04000BFFF) and a basalt pestle (Inventory No. 04000C031) found in a nonfeature context, PD 1391 (Cienega phase); (*b*) a reconstructed cache containing two granite netherstones (Inventory Nos. 04000F4A6 [smaller] and 04000F4A3 [larger]) and a granite Lukeolith (Inventory No. 04000AB42) that were stacked within Feature 5185 (Cochise); (*c*) a cache containing a small basalt mortar and a quartzite mano (Inventory No. 04000E740 and Inventory No. 040011B2C, Cochise to Historical period); and (*d*) a cache containing a schist metate (Inventory No. 04000F2A3) and a quartzite pestle (Inventory No. 04000F203) (no feature number, Cochise to Historical period). (*Note*: "Cochise" indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.)

other. Two quartzite manos were displaced during mechanical stripping and were not relocated. The ground stone was immediately adjacent to a possibly unrelated nonthermal pit.

Feature 3372

Feature 3372 was a possible artifact cache located in the eastern-central portion of Falcon Landing (see Chapter 4, Volume 1). Ground stone artifacts in the cache were two large, complete pestles lying next to each other at the base of a pit (see Figure 142, Volume 1). The Type X rhyolite pestle had been completely shaped by pecking and grinding and had a concave, ground lateral surface. The Type II pestle was porphyritic andesite and had been minimally altered by grinding. The only other artifact in the pit was a rhyolite core flake. A piece of charred mesquite wood from the feature was radiocarbon dated to A.D. 650–770.

Feature 3547

Feature 3547 was a possible Early to Late Archaic period FAR concentration located in the southern portion of the site. Three complete cobble manos were clustered together; two were granite, one was quartzite. All had been minimally altered. A fragment of basalt debitage was also recovered from the feature.

Feature 3733

Feature 3733 was a possible post–Late Archaic period cache in the southeastern part of the site. A broken basalt metate was located next to a quartzite mano. The metate was an indeterminate-basin type and was nearly exhausted. The cobble mano had been pecked and ground into shape.

Feature 3775

Feature 3775 was a possible Cienega phase ground stone cache in the southern portion of the site. The cache consisted of two complete pestles: a Type V pestle of schist and a Type VI pestle of basalt. Both pestles had been completely shaped by pecking and grinding. A pollen sample obtained from the fill next to the pestles contained pollens of mesquite, cheno-am, sunflower, grass, Indianwheat, globemallow, spiderling, and evening primrose.

Feature 3792

Feature 3792 was a possible Late Archaic to Protohistoric period cache of three ground stone artifacts in the southern end of the site (see Chapter 4, Volume 1). It consisted of a complete gneiss grinding slab stacked on a rhyolite closed-basin metate. A basalt cobble mano was a few centimeters to the west (see Figure 140, Volume 1). Both the metate and the mano had been shaped. A pollen sample was recovered from beneath the lower metate and included pollens of cheno-am, sunflower, and large pine.

Feature 3802

Feature 3802 was a possible ground stone cache in the southern portion of the site. The feature dated to the Late Archaic to Protohistoric period. The cache contained two complete pestles, both of which had been shaped by pecking and grinding. One was a Type VI quartzite pestle; the other was a Type VII pestle of vesicular basalt.

Feature 3817

Feature 3817 was a possible Late Archaic to Protohistoric period artifact cache in the southern part of the site. The cache contained a large (>170-mm), multidirectional rhyolite core; a rhyolite cobble uniface; and an andesite hammerstone with desert varnish. The multidirectional core and the uniface were next to each other; the hammerstone was about 20 cm away.

Feature 3894

Feature 3894 was a possible Middle Archaic to Protohistoric period Lukeolith cache in the southern/central portion of the site. One complete and two incomplete Lukeoliths were clustered together.

Feature 3902

Feature 3902 was a possible Middle to Late Archaic period ground stone cache located in the central portion of the site. The cache contained a schist grinding slab, upright on its side, with a complete gneiss cobble mano next to it, at the base of the pit. Other artifacts in the pit fill included a long-bone-shaft fragment from a small mammal and a long-bone-shaft fragment and a phalanx from a medium-sized mammal.

Feature 3993

Feature 3993 was a possible artifact cache from the Middle to Late Archaic period located in the southern portion of the site. The cached ground stone artifacts included a quartzite cobble mano that had been minimally altered by pecking and a Type IX pestle of granodiorite that had been completely shaped by pecking and grinding. A quartzite cobble manuport and a basalt core were also in the feature. Five pieces of faunal bone were recovered, including a metapodial fragment, two metatarsal fragments, and one tarsal from a jackrabbit, as well as one long-bone-shaft fragment from a medium-sized mammal.

Feature 4664

Feature 4664 was a possible Pioneer to Classic period cache in the northern portion of the site. Two complete pestles were next to each other within a nonthermal pit. The pestles were a Type V vesicular-basalt pestle that had been completely shaped by pecking and grinding and a minimally shaped Type I gneiss pestle.

Feature 5185

Feature 5185 was a stack of three complete ground stone artifacts in the central portion of the site. The feature dated to the Middle to Late Archaic period and consisted of a granite Lukeolith stacked on two granite netherstones (see Figure 75b). The Lukeolith had been completely shaped by pecking and had flaking along one margin and both black and ocher residue on two faces. The two netherstones had been shaped by pecking; the bottom netherstone had been minimally shaped.

Feature 5945

Feature 5945 was a possible Early to Late Archaic period cache in the southern portion of the site (see Chapter 4, Volume 1). It contained three complete ground stone artifacts: a schist closed-basin metate and two quartzite cobble manos. The metate was situated face-up, with the manos at one end (see Figure 138, Volume 1). Nine pieces of debitage and five faunal specimens were also recovered from the feature. The faunal items were two long-bone fragments from medium-size mammals (one burned), a metapodial fragment from a medium-sized mammal, a burned jackrabbit-radius fragment, and a jackrabbit-humerus fragment.

Feature 10931

Feature 10931 was a possible Pioneer to Classic period ground stone cache in the northern portion of the site. The cache contained a granite flat/concave metate and a schist cobble mano.

Feature 10934

Feature 10934 was a possible Late Archaic to Pioneer period ground stone cache in the northern part of the site. Three complete artifacts were in the feature. An aplite cobble mano and a minimally altered quartzite cobble mano were located along one edge of a flat-lying flat/concave granite metate.

PDs 11375 and 11376

PDs 11375 and 11376 were located in the southwestern portion of the site and dated to the Late Cienega to Red Mountain phase. The artifacts were a rhyolite basin metate and a quartzite cobble mano located 0.5 m apart.

PD 11379

PD 11379 was a possible Late Cienega to Red Mountain phase cache of two complete pestles in the southwestern part of the site. Both were Type VII pestles that had been pecked into shape; one was quartzite, and the other was rhyolitic tuff.

PD 11433

PD 11433 was a possible Early Archaic to Pioneer period cache in the southwestern corner of the site. It consisted of a well-shaped andesite flat/concave metate and a vesicular-basalt Lukeolith. A rhyolite cobble-mano fragment was also present.

PD 11456

PD 11456 was an Early Archaic to Pioneer period ground stone cache in the southwestern portion of the site. The artifacts included a formal, small vesicular-basalt mortar that had been pecked and ground into shape and a quartzite cobble mano that had been well shaped by pecking and grinding. The mano articulated with the orifice and basin of the mortar and may have broken it during use (see Figure 75c).

PD 11463

PD 11463 was a ground stone cache in the south-central part of the site that dated to the post–Middle Archaic period. The artifacts were four complete cobble manos, one each of andesite, quartzite, basalt, and schist. The andesite and quartzite manos had been shaped by pecking and grinding, and the basalt and schist manos had been shaped by grinding.

PD 14550

PD 14550 was a Chiricahua phase Lukeolith cache in the northern part of the site. The artifacts were a dacite Lukeolith that had been completely shaped by pecking and a vesicular-basalt Lukeolith that had been completely shaped by pecking and grinding.

Feature 14920

Feature 14920 was a Late Cienega to Red Mountain phase FAR concentration in the southwestern portion of the site. Artifacts recovered from the feature included seven pieces of FAR, five pieces of flaked stone debitage, one EMF, one indeterminate ground stone fragment, and a bone fragment from a medium-sized mammal. The flaked stone consisted of one rhyolite core flake, four large chalcedony core flakes, and one large chalcedony EMF. The five chalcedony flakes were all between 50 and 90 mm in length and had probably been removed from the same core.

Feature 14938

Feature 14938 was a Middle to Late Archaic period extramural pit on the eastern edge of the site. It consisted of a vesicular dacite Lukeolith that had been pecked into shape and a small basalt cobble hammerstone. A piece of quartzite microdebitage was also collected.

PD 15093

PD 15093 was a Late Archaic to Pioneer period ground stone cache in the center of the site. It consisted of a gneiss netherstone that had been ground into shape and a fragment of a basalt basin metate that had been shaped by pecking and grinding.

Feature 15139

Feature 15139 was a Late Archaic to Pioneer period cache in the central portion of the site. Three complete ground stone artifacts were displaced from their original locations by mechanical stripping but appeared to have been stacked. They included a rhyolite flat metate with two faces, an andesite closed-basin metate, and a quartzite cobble mano. All had been completely shaped by pecking and grinding.

PD 15158

PD 15158 was a Middle to Late Archaic period cache located near the center of the site. The cache consisted of two complete quartzite cobble manos that had been shaped by pecking and grinding.

PDs 15251 and 15252

This pestle-and-metate set was an extramural ground stone cache in the southern portion of the site. Located less than 1 m from each other, they appeared to have been used together (see Figure 75d). The pestle was a Type IX quartzite pestle. The metate was a schist closed-basin metate. Both artifacts had been completely shaped by pecking and grinding. The artifacts dated to the Middle Archaic to Protohistoric period.

Feature 15317

Feature 15317 was a Chiricahua phase thermal feature on the western side of the site. Three complete pieces of ground stone were recovered from this thermal pit, among other artifacts. The ground stone included a basalt closed-basin metate, a dacite flat/concave metate, and a schist cobble mano. The pit also contained a basalt Lukeolith fragment, 24 pieces of debitage, and 2 burned bone fragments from medium-sized mammals. Pollen samples were collected from under the metates, both of which were upside-down near the base of the pit. Pollens in the metate samples included cheno-am, sunflower, grass, globemallow, spiderling, and small pine. Control pollen samples taken from within the pit were identified as palo verde, mesquite, cheno-am, sunflower, grass, Indianwheat, pea, evening primrose, and large pine. A burned *Trianthema* sp. seed was also recovered from the fill.

Feature 16663

Feature 16663 was a Chiricahua phase nonthermal pit in the northern portion of the site. The feature contained six complete ground stone tools, among other lithic artifacts. The ground stone included a metaquartzite cobble mano, three complete granite cobble manos, one basalt cobble mano, and one gneiss cobble mano. The pit also contained a basalt hammerstone fragment, a basalt metate fragment, and eight pieces of FAR.

PD 18185

PD 18185 was a Chiricahua phase ground stone cache on the western edge of the site. The cache consisted of two complete Lukeoliths, one basalt and one granite. The basalt Lukeolith had flaking along the margins and had been shaped by pecking and grinding. The granite Lukeolith had been shaped by pecking.

PD 18341

PD 18341 was a Middle to Late Archaic period cache located in the southeastern portion of the site. The cache consisted of one dacite Lukeolith and one basalt hammerstone. The Lukeolith had been heavily pecked on the planar surface and showed evidence of end modification.

Site 423

Limited numbers of lithic artifacts were recovered from Site 423, a small cluster of features and artifacts utilized between the Early Archaic period and the Classic period (see Chapter 6, Volume 1). Site 423 was an extension of the small, dispersed occupations throughout much of Falcon Landing. Features at the site included three nonthermal pits and one FAR concentration. The flaked-stone-tool collection included 2 cores: 1 basalt multidirectional core and 1 rhyolite unidirectional core, both from the site surface. Fifty-six pieces of flaked stone debitage were also collected from the surface (Table 42). The FAR collection numbered 9 fragments.

Site 437

Site 437 was another extension of the activities recorded at Falcon Landing. Features at the site consisted of 17 nonthermal pits and 1 FAR concentration (see Chapter 7, Volume 1). The lithic-artifact sample included two pieces of FAR, two flakes, and one multidirectional core from features and five pieces of FAR, five flakes, and two unidirectional cores from nonfeature contexts. The two cores were both made on basalt. No

Table 42. Summary Information on Flaked Stone Debitage Collected from Surface of Site 423

Characteristics	Material Type									Total
	Basalt	Basalt 1	Basalt 2	Chalcedony	Chert	Quartz	Quartzite	Rhyolite	Rhyolite 6	
Portion										
Complete	7	—	7	1	1	1	—	2	1	20
Distal	4	2	1	—	—	3	—	3	1	14
Indeterminate	2	—	2	—	—	4	1	—	—	9
Midsection	—	—	1	1	—	1	—	1	—	4
Proximal	4	—	—	—	—	1	—	2	2	9
Total number of specimens	17	2	11	2	1	10	1	8	4	56
Size Class (mm)[a]										
10–19	1	—	—	—	—	—	—	—	—	1
20–29	2	—	3	—	1	—	—	1	1	8
30–39	—	—	2	1	—	1	—	1	—	5
40–49	3	—	1	—	—	—	—	—	—	4
50–59	—	—	1	—	—	—	—	—	—	1
60–69	—	—	—	—	—	—	—	—	—	—
70–79	—	—	—	—	—	—	—	—	—	—
80–89	1	—	—	—	—	—	—	—	—	1
Not recorded	10	2	4	1	—	9	1	6	3	36
Total	17	2	11	2	1	10	1	8	4	56
Flake Type										
Biface flake	1	—	1	2	1	2	—	2	—	9
Core flake	8	1	7	—	—	2	—	3	3	24
Indeterminate	5	1	1	—	—	2	—	3	1	13
Shatter	2	—	2	—	—	4	1	—	—	9
Tool use (percussion)	1	—	—	—	—	—	—	—	—	1
Total	17	2	11	2	1	10	1	8	4	56
Cortex										
Cortical	9	1	7	—	1	2	—	4	3	27
Noncortical	6	1	3	2	—	6	—	4	1	23
Not applicable	2	—	1	—	—	2	1	—	—	6
Total	17	2	11	2	1	10	1	8	4	56

[a] Complete flakes only.

Table 43. Summary Information on Flaked Stone Debitage Collected from Site 437

Characteristics	Material Type			Total
	Basalt 2	Rhyolite	Rhyolite 6	
Portion				
Complete	1	—	—	1
Indeterminate	2	2	2	6
Total number of specimens	3	2	2	7
Size Class (mm)[a]				
40–49	1	—	—	1
Not recorded	2	2	2	6
Total	3	2	2	7
Flake Type				
Core flake	1	—	—	1
Shatter	2	2	2	6
Total	3	2	2	7
Cortex				
Noncortical	—	1	—	1
Not applicable	3	1	2	6
Total	3	2	2	7
Platform Type				
Absent	2	1	—	3
Cortical	1	—	—	1
Not applicable	—	1	2	3
Total	3	2	2	7
Recovery Context				
Nonthermal pit (Cochise[b])	—	—	2	2
CBS (not dated)	3	2	—	5
Total	3	2	2	7

Key: CBS = culture-bearing sediment.

[a] Complete flakes only.

[b] Cochise indicates a context directly or indirectly dated to more than one phase of the Cochise chronology or more than one Archaic period.

stone artifacts were associated with the Sulphur Spring phase feature at Site 437 (Feature 10307). The attributes and variables recorded for the site collection are presented in Table 43.

Site 68

Site 68 also indicated a continuation of the Middle Archaic to possible Protohistoric period foraging activities adjacent to Falcon Landing (see Chapter 5, Volume 1). SRI investigated 33 nonthermal pits, 1 Middle to Late Archaic period structure (Feature 88), 1 Snaketown phase structure (Feature 13), 1 cache (Feature 82), and 1 human burial (Feature 106). No lithic artifacts were associated with the structures. The cache included one mano, five pieces of indeterminate ground stone, and one flake. Artifacts not associated with features included three pieces of debitage, two informal cores, two basin metates, two cobble manos, and a piece of indeterminate ground stone (see Appendix 3.2).

At maximum, five projectile points were located in the immediate vicinity of the disturbed burial (Feature 106) (see Chapter 5, Volume 1). The projectile points included multiple types, and the collection likely included the contents of mixed deposits. It was difficult to determine the precise number of specimens represented. The fragments included one Elko Corner-notched point base, one obsidian side-notched San Pedro point in four pieces, the midsection and base of an indeterminate lanceolate point, a portion of a possible synoptic-series-point base, an indeterminate dart-point tip, and an indeterminate, small basal fragment (Table 44). These items were described by John Hall, who examined the artifacts at LAFB. The side-notched San Pedro example was the only projectile point in the Luke Solar Project collection that was made from obsidian. Other tools possibly associated with Feature 106 were a complete basalt side scraper and an incomplete cobble mano. A field analysis of the debitage associated with Feature 106 is presented in Table 45 and shows the collection to have been dominated by basalt microflakes and shatter debris; there was also a small sample of chert but no obsidian.

Discussion

The amount of information provided by the lithic collection is substantial on multiple levels. This is true despite the fact that some portions of the collection are numerically insignificant, and still fewer are precisely dated. One of the major goals of the project was to measure cultural and adaptive change through time. Special attention was afforded to the middle of the Chiricahua phase, around 2100 B.C., as marking the early widespread availability of maize. Unfortunately, the stone tools from Falcon Landing did not lend themselves to time-resolved, quantitative analysis, because only a small number of artifacts were found at the site, and too few of them were precisely dated. Additionally, compelling evidence for the use of maize was not found at the site (see Chapter 6).

The research questions asked of the stone tools were demanding of them, but whatever the collection lacked in size or chronological resolution, it made up for in eloquence. It was not a bewildering assortment of different times and technologies. Rather, the redeeming value of the site collection is its low diversity—an attribute that ultimately speaks to the long-term, behaviorally redundant, and highly focused activities there, independent of changes in occupational intensity and other social dynamics. This section discusses the Luke Solar project collection, especially from Falcon Landing, in the context of the project research questions posed in Chapter 2, Volume 1 and outlined in this chapter.

Chronology

Chronology was identified as the project's primary research theme. The stone-tool collection is of little chronological value, because the number of temporally sensitive artifacts collected from Falcon Landing was fewer than the number of radiocarbon-dated features there, and features bearing temporally sensitive artifacts were selectively radiocarbon dated (see Chapter 2). However, two aspects of the lithic collection do warrant mention in regard to the site's occupational and cultural chronology. First among them is the fact that the frequencies of artifacts dated to between the Chiricahua phase and the pre-Classic period did not concord with the frequency distribution of radiocarbon-dated features. The radiocarbon sample indicated continued episodes of intense use after the Chiricahua phase (see Chapters 2 and 10), but those occupations appear to have been underrepresented in the stone-tool sample.

Figure 76 shows the frequencies of features, all flaked stone artifacts, and all ground stone artifacts at Falcon Landing, in each age group between the Chiricahua phase and the pre-Classic period, scaled to the amount of time represented by each age group. For example, for the Chiricahua phase, between approximately 3300 and 1200 B.C., the frequency of features was roughly 0.4 per year, as it happened to be for flaked stone and ground stone artifacts. The graph represents a first look at the occupational intensity and major lithic industries at the site through time, tabulated from the perspective of the lithic artifacts.

As highlighted in the debitage analysis, the flaked stone collection from the site was mainly derived from features, whereas the ground stone sample was collected mostly independent of features; so, all things being equal, flaked stone artifacts and features should have co-varied in numbers, but ground stone artifacts should not have. Figure 76 shows that the opposite was the case. The frequencies of both features and ground stone artifacts decreased to less than 0.07 per year during the San Pedro phase, but flaked stone

Table 44. Flaked Stone Tools Possibly Associated with Feature 106, Recovered from Hand-Stripping Unit 137, Site 68

Catalog No.	Type	Portion	Material Type	Max. Length (mm)	Max. Width (mm)	Max. Thickness (mm)	Basal Width (mm)	Piercing Tip	Serrations	Reworked	Beveling	Burned	Comments
040011D31a	ind.	midsection	chert	22	21	4		ind.	no	ind.	ind.	yes	Refits with 040011D50.
040011D31b	ind.	proximal	chert	8	14	3		ind.	no	ind.	ind.	yes	
040011D4E	ind.	proximal	chert	8	15	4		ind.	ind.	ind.	ind.	no	Possible synoptic series base.
040011D50	ind.	proximal	chert	12	19	5		ind.	no	none	no	yes	Refits with 040011D31; Cortaro-shape.
040011D57	Elko Corner-notched	proximal	chert	19	26	4	20	ind.	ind.	ind.	ind.	yes	
040011D5A	ind.	distal	chert	28	14	4		ind.	yes	none	no	yes	Possible tip of 040011D57.
040011D5F	Sudden Side-notched	proximal, distal	obsidian		19	4	18	ind.	no	blade/ base	no	no	Four fragments.

Key: ind. = indeterminate.

Table 45. Summary Information Recorded on Debitage Possibly Associated with Feature 106, Site 68

Characteristics	Material Type							Total
	Basalt	Chalcedony	Chert	Quartz	Quartzite	Rhyolite	Indeterminate	
				Portion				
Complete	112	7	20	—	5	3	—	147
Distal	—	—	—	—	—	—	—	—
Indeterminate	22	2	3	2	—	—	45	74
Midsection	—	—	—	—	—	—		—
Proximal	—	—	—	—	—	—		—
Total number of specimens	134	9	23	2	5	3	45	221
				Size Class (mm)[a]				
<10	56	3	11	—	3	—	—	73
10–19	49	4	9	—	2	3	—	67
20–29	6	—	—	—	—	—	—	6
30–39	—	—	—	—	—	—	—	—
40–49	1	—	—	—	—	—	—	1
50–59	—	—	—	—	—	—	—	—
60–69	—	—	—	—	—	—	—	—
70–79	—	—	—	—	—	—	—	—
80–89	—	—	—	—	—	—	—	—
Subtotal	112	7	20	—	5	3	—	147
				Flake Type				
Biface flake	111	7	20	—	5	3	—	146
Core flake	1	—	—	—	—	—	—	1
Subtotal	112	7	20	—	5	3	—	147

[a] Complete flakes only.

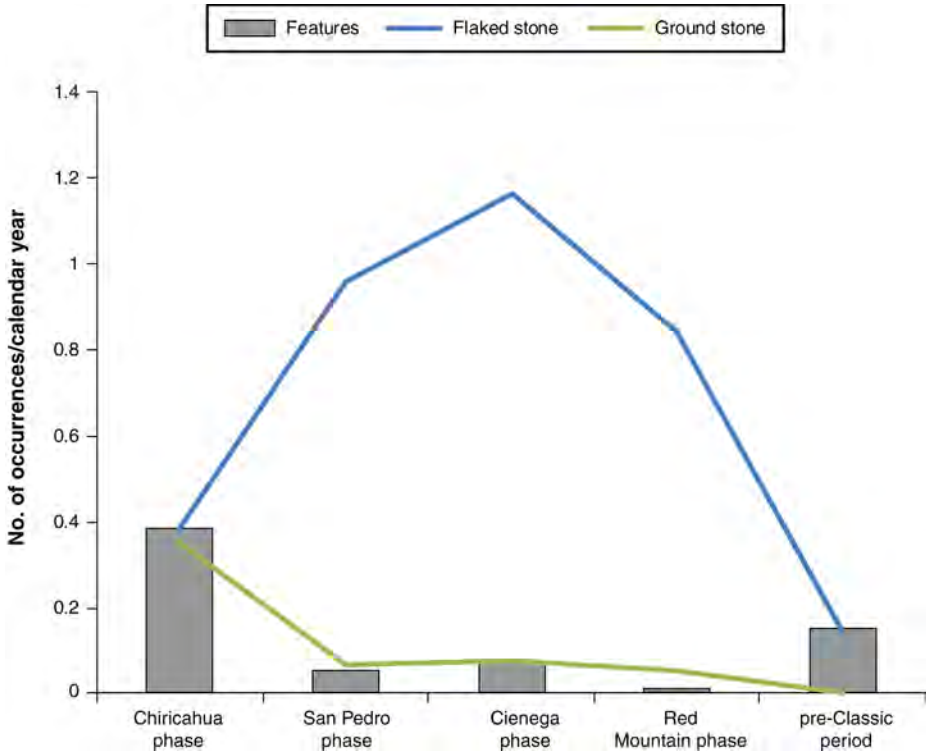


Figure 76. Relative frequency of features and flaked stone and ground stone artifacts in the Falcon Landing collection, by time period.

values increased to greater than 1 artifact per year. These data might be used to argue that the site witnessed "intense" occupation by hunters and plant gatherers during the Chiricahua phase but was only sporadically occupied by hunters thereafter. That interpretation would find support (Bayham 1982; Szuter and Bayham 1989) and may be correct, but the strength of the evidence in favor of it presented in Figure 76 is possibly spurious. The flaked stone sample per feature was skewed by a small number of rich features (and the numbers of flakes sampled from nonfeature test pits), and the Chiricahua phase ground stone artifacts from the Unit I/II boundary were more readily dated using stratigraphic correlation than were those from shallower, thinner, discontinuous units (see Chapter 2). Many of the undated or loosely dated features and artifacts were probably post–Chiricahua phase, and the true relationship of time, features, and technology is probably somewhere between the extremes portrayed in Figure 76. The topics of occupational intensity and duration are discussed in more detail in the following sections.

One of the questions asked about the Middle and Late Archaic periods is whether there was continuity between them. Mabry (2005a:62) pointed out that with the possible exception of Ventana Cave and Bat Cave, San Pedro points do not directly overlie Chiricahua phase occupations. A second contribution of the Luke Solar project on the topic of chronology is in the direct radiocarbon dates on type-quality projectile points. A date on a Chiricahua phase point (see Figure 48i) from a nonthermal pit (Feature 1334) extended the style to as late as 1440–1310 B.C. The San Pedro phase, as marked by a side-notched point (see Figure 48k) in a nonthermal pit (Feature 14755), began by 1260–1050 B.C. The latest San Pedro point, found in a structure (Feature 17908), was no younger than about A.D. 330. These dates provide important new chronological reference points for the respective types, and they close the gap between Chiricahua points and the beginning of the San Pedro phase at 1200 B.C. to a matter of generations (between about 100 and 200 calendar years).

Site Function

Descriptions of site function rely on a typology to indicate the major activities, duration, and social organization of a site. Mabry (1998a:111) outlined a dozen site types that capture the expected range of site activities between the Paleoindian and Late Archaic/Early Agricultural periods. At the short-term end of the scale are lithic-quarry sites, kill/butchering sites, and plant-gathering/-processing sites. Habitation-site types organized according to occupational duration and the diversity of activities performed there include single-use sites, short-term base camps, seasonal settlements, multiseasonal settlements, and permanent settlements. Within this construct, the prehistoric sites investigated during the Luke Solar project certainly included "plant-gathering/–processing sites." However, the presence of ephemeral structures and possible storage pits at Falcon Landing indicate habitation, as well. Falcon Landing corrupts the typology, because the chronology and archaeology show that it was more than a single-use campsite but was possibly not a base camp or a short-term "settlement." The "function" of Falcon Landing can be explored from many directions, but this summary focuses on the major activities indicated by the stone tools and debris.

The Falcon Landing lithic collection showed three major activities: (1) plant processing, (2) the production of small bifaces, and (3) cooking and roasting. If FAR were considered a "tool," then cooking and roasting would appear to be much more important than biface manufacture (cooking technologies at Falcon Landing are discussed by Vanderpot in Chapter 9). Evidence that plant collecting and processing were the primary reasons for the site's location, and therefore its primary functions, was provided by the ground stone tools, which were emplaced and used at the location of a former plant community (see Chapters 6 and 7). The ground and battered stone collection represented two basic modes of plant processing: pounding and grinding. Pounding was represented by nearly 100 pestles or fragments as well as many additional Lukeoliths. The diversity of pounding tools, including irregular, round-bottomed, and flat-bottomed pestles of various sizes, indicates that multiple steps were involved in the food recipes prepared at the site. Flaked stone industries at the site were almost entirely dedicated to biface manufacture and tool retouch.

Major components of the food-pounding technology, wooden mortars, were presumed to be missing because of decay or transport. Knowledge about prehistoric wooden mortars is essentially nonexistent in the archaeological literature, although their popular use in history and prehistory is widely acknowledged (Adams 2002:140; Hayden 1976:284). The ethnographic record of wooden mortars is rich with details, however, that provide a foundation for discussing the function of Falcon Landing.

Wooden Mortars, Mesquite, and Labor

Mortars and pestles constitute a universal and ancient household technology, and in the U.S. Southwest, they have played an iconic role in ethnographic and ethnohistoric accounts of women's activities. Stone mortars are extremely rare in the archaeological record. Heilen and Vanderpot (2013a:5.120) reported the occurrence of stone mortars at less than 1 percent of more than 1,300 sites across more than 200,000 acres on the Barry M. Goldwater Range (BMGR) East. O'odham ethnographies, however, have provided many references to wooden mortars and their primary function. Castetter and Bell (1942:198) documented that mesquite was ground in wooden mortars with wooden pestles, as were parched cotton seeds. Russell (1908:75) likewise noted that mesquite beans were prepared in a stone mortar with a stone pestle or, if a large quantity was required, in a wooden mortar.[2] Rea (1997) documented that both mesquite and cottonwood were suitable materials for wooden mortars and were required for mesquite-pod grinding, to avoid breaking the undesired hard seeds. Pfefferkorn (1949:72), a contact-period Jesuit, reported that roasted mesquite was ground using stone-stone systems, whereas unroasted pods were ground using wood-stone systems.

Spier (1978:79) noted that wooden mortars were present among the Yuman tribes of the Gila River but were utilized far less than stone metates for processing mesquite pods. Mesquite trunks were preferred for

---

[2] Russell does not specify "mortar"; we assume he was not describing a large wooden pestle.

their hardness, but cottonwood was considered suitable (Spier 1978:128). Both were manufactured by burning a cavity in a log, usually in the end. The large wooden mortars maintained at settlements were up to 16 inches in diameter by 20 inches in length, with roughly 6 inches sunk into the ground for stabilization. The working cavity was approximately 9 inches wide by 4.5 inches deep, and accompanying pestles were 10–16 inches in length (Spier 1978:128). Field processing at mesquite-collection sites utilized no more than a hole excavated into the soil and fortified with the sticky hulls of the processed mesquite (Spier 1978:128). A transportable mortar made of arrowweed fastened in a conical form and utilized in an excavated pit was also manufactured for use at collection sites (Spier 1978:129). Similar uses of wooden mortars for mesquite have been described for lower Colorado River Yuman groups (see Hodgson 2001).

Wooden mortars were also utilized by the Northern Paiute to process both mesquite and the stalks of *Phragmites,* a type of reed (Kroeber 1953:592). The Cahuilla used a system very similar to that described by Spier along the Gila. A deep wooden mortar was sunk into the ground to process mesquite and "other foods" (Kroeber 1953:697; see also Barrows 1900). This system required a slender stone pestle up to 2 feet in length. The Mohave also utilized wooden pestles with both stone and wooden mortars to process mesquite (Kroeber 1953:736–737; Stewart 1965), as did the Southern Paiute (Fowler 1995). Schneider (1996:303) showed a Mohave family equipped with a deep cottonwood mortar and a stone pestle. Mesquite harvests were so valuable to the Mohave that individual trees were considered private property; in other cases, yields were often claimed in advance of maturity with a marker hung in the tree (Kroeber 1953:737). References for wooden mortars and mesquite use can be found as far south as the Sonoran Central Coast, among the Comcaac (Felger and Moser 1971, 1985). To the east, Prewitt (1981) documented a Late Archaic period wooden mortar from the Trans-Pecos region.

The range of plants processed at Falcon Landing is unknown. The metates were likely used to process small seeds from a relatively narrow range of local edible plants, compared to the ranges in the adjacent floodplains and the upper *bajada* (Chapters 6 and 7). The principal activity was mesquite processing, which was underway at the site by the early Chiricahua phase. "Gyratory crushers," assumed to have functioned as part of an ancient and specialized mesquite-processing system (Hayden 1969), were not located at Falcon Landing. The mesquite-processing activities at Falcon Landing were summer labor; so, heavy work may have been scheduled to avoid the heat of the afternoon.

Mortars and pestles happen to be famously poor examples of gender-coding artifacts, because in prehistoric coastal California, they have been found with both male and female burials (Buonasera 2012:132; Hole and Heizer 1973:397); however, the ethnographic link between women, mesquite, and mortars is strong in the U.S. Southwest. Roth (2006:518) reviewed ethnographic descriptions of a strong division of labor according to sex and age in which Tohono O'odham women were committed to harvesting maize before gathering and processing large quantities of late-summer mesquite for storage. The increases in food processing that characterize the Middle Archaic period signal a change in labor investment toward female-oriented subsistence contributions. Ground stone technologies were among the earliest artifacts to show up at multicomponent sites that supported foraging populations for thousands of years thereafter, and they played an important role in the creation of places by mapping tools onto resources (Basso 1996). Russell (1908:110) noted the Historical period O'odham practice of retrieving stone pestles from archaeological sites for reuse. Gatherers and hunters alike have emplaced knowledge on the landscape in the form of traditional technologies (Zedeño et al. 2014). The ethnographically documented practice of Native Americans' "scavenging" of ground stone tools from archaeological and historical sites is testimony to multigenerational connections linking specific tools to specific places.

The antiquity and distribution of the mortar-and-pestle use in the U.S. Southwest are important because it is considered diagnostic of the Middle Archaic period (Sayles 1983:114). Spier (1978:179) noted that the Yuman terms for *mano* and *pestle* were derived from the term for *mortar*, perhaps suggesting that it was the progenitor form of all seed-grinding technologies. Glassow (1996:20) commented that the basin-metate shape of Chiricahua phase mortars and the use of manos as pestles reflect the creation of an in situ technological development; however, mortars and pestles were probably situational rather than developmental. The distribution of pestles at Middle and Late Archaic/Early Agricultural period sites shows a strong east–west gradient. Ventana Cave contained a total of 114 pestles (Haury 1950:321), and the late Cienega phase component at Los Pozos included 24 pestles (Adams 2005:Table 4.3), but pestles have been "conspicuously absent" from Archaic period sites in the Chihuahuan Desert of southeastern Arizona (Whalen 1971:191).

Site function is intimately connected not only to the activities performed at a site but also to the site's place in a web of seasonal resources exploited by foragers. Because the mobility of individuals varied according to age and sex (Kelly 1992), male and female technologies at the site offer a chance to examine variation in forager tools that is related to differences in individual mobility.

Land Use

Because well-documented Middle Archaic period sites are extremely rare, land-use studies have traditionally relied on a small number of anecdotal sites to verify or refute generic models of seasonal transhumance between upland and riverine environments. The Late Archaic period has been represented by more sites but is not drastically better understood away from the floodplains. Falcon Landing informed on the socioeconomic structure and settlement patterns of foragers extending back to the Middle Archaic period, but the "landscape" perspective provided by any one site is tenuous, and the amount of information gleaned from site typologies is often trivial at the level of individual sites.

One way to get at the prehistoric landscape from the perspective of Falcon Landing is to ask a series of questions about the movement of people to and from the site. The questions of where people arrived from, where they were going to, how far they went, and if and when they planned to return to Falcon Landing lead to several important pieces of information about how hunter-gatherers organized themselves around the environment. For example, the stone tools at Falcon Landing had a strongly local quality. The river cobbles suggested that people were intimately connected to the Agua Fria River. There is no evidence that upper-*bajada* succulents or game was routinely brought to the site (see Chapters 4, 6, and 7). The biface technology informed on where some people were planning to go next. Hunting preparations indicated movement into the upper piedmonts and mountains, where hunting opportunities could be anticipated (Roth and Freeman 2008). Whether or not we can predict where people went from Falcon Landing and whether or not we can reconstruct the information at hand in terms of the settlement organization and mobility of prehistoric groups who visited Falcon Landing are issues discussed within a framework of technological organization and provisioning strategies.

Male and Female Curation Strategies

Curated tools are modeled after long-distance excursions by men and are defined as tools that were transported and maintained in anticipation of use (Binford 1977, 1980). Several attributes contributed to a curated tool's usefulness, but primary among them were transportability and maintainability (Bleed 1986; M. Nelson 1991). Expedient tools were made, used, and abandoned in their places of use and are modeled after settlements. They had no physical requirements other than to be useful at a place and time. The risk or energy trade-offs between curated and expedient tools correlated to resource structure and mobility (Binford 1977) and raw-material availability (Bamforth 1986), but they also obviously correlated to use, which occurred during the performance of a task, which required labor. Sassaman (1998) suggested that the sexual division of labor distinguishes curated and expedient core technologies. In that context, expedient tools were not "unplanned," but they demanded more guarantees than curated tools, such as the availability of suitable materials or the time and labor needed to obtain raw materials, if none were available. Expedient tools therefore favored well-provisioned places. In well-provisioned environments, expedient tools would have accumulated in proportion to activities and would quickly have overshadowed the labor dedicated to curated tools (Kuhn 1995; Parry and Kelly 1987; Surovell 2009).

Falcon Landing showed a range of more- and less-curated tools that reflect the mobility of group members, raw-material availability, and future place needs. Disk/biface cores (see Figure 47b) represent the apex of "mobile" tools (Kelly 1988), and they were found in relatively small numbers at the site. In the middle of the spectrum were cobble unifaces (see Figure 40b), elongated cobbles that were reduced in a systematic manner to create wide flakes. Another set of cores was made up of informal unidirectional and multidirectional cores. Basalt and rhyolites probably obtained a minimum of 7 km away from the site overwhelmingly dominated the core sample. Cobbles and finished tools alike were transported to Falcon Landing. The question of which forager carried a core and which forager carried a tool was posed by Kuhn (1994), who argued that if efficiency was the goal, then it would always have made better sense to carry a small, finished tool or a blank rather than a core, because the core always included waste. This is a useful statement for evaluating the rocks transported to Falcon Landing, but not without first clarifying that provisioning strategies represent a range of options rather than mutually exclusive choices (Kuhn 1995:26). That is, the people who arrived with disk/biface cores and finished points were the same people who transported bulky cobbles to the site and the same people who winnowed down a set of mobile disk/biface cores, finished points, and tool blanks at the site before they departed. The procurement strategies of hunter-gatherers can be expected to have followed some general principles (Bamforth 2006; Binford 1979) that can be used to model how raw materials arrived at Falcon Landing.

Lithic-procurement strategies occurred along a continuum between lower-cost embedded strategies and higher-cost direct procurement. Embedded procurement minimized energy investments by incorporating multiple resources into one effort. Direct procurement strategies incurred an independent cost (Bamforth 2006). The cores at Falcon Landing may reflect the acquisition of river cobbles en route to the site (embedded) or a logistical back-and-forth (direct) movement between Falcon Landing and the river. Surovell (2009:131) showed that when resources are close to a site, direct procurement is most expensive, and embedded procurement is least expensive. It is possible that residential foragers or logistical task groups arrived at Falcon Landing short-handed and made back-and-forth logistical trips to the Agua Fria River, but it is more reasonable to expect that people arrived at Falcon Landing with the raw materials and tools they needed. The distance to the Agua Fria River is inexpensive by forager standards, but rocks are heavy, and some of the ground stone tools were too large to have been casually picked up and transported. Whether the groups who frequented Falcon Landing were entire families or special-task groups, getting there was a logistical operation.

The flaked stone artifacts at Falcon Landing indicated that some of the cobbles were made into disk/biface cores, some were systematically reduced to create wide flakes, and others were opportunistically reduced into informal cores. Importantly, Falcon Landing did not have an expedient-flake-tool collection sufficient to account for the nearly 100 informal cores left at the site; rather, the collection was dominated by small biface-thinning flakes. This pattern was extended across the site collection: large flakes were underrepresented relative to the number of cores at the site. Three inferences can be drawn from this information. First, men did not enjoy appreciably greater mobility than women while at the site. Second, if women were responsible for creating the informal cores, then they generally did not use them in an expedient-flake-tool technology at the site. Third, foragers arrived at the site with tools, mobile cores, and potential cores but departed with refurbished tools, new tools, and mobile cores.

Preceramic women's technologies were organic based, and the expressive basketry and other tools that would have been responsive to environmental and social dynamics were missing from the site, including wooden mortars, the fate of which are unknown. However, the ground stone tools "curated" at the site showed a disregard for transport costs that might have been associated with quarry sites or permanent habitation sites (Beck et al. 2002). As pointed out by Buonasera (2012:33), however, the incredible utility of ground stone tools always made it worthwhile to invest in their procurement, manufacture, and design functions. Ground stone utility (surface area) scales differently than flaked stone utility (available edge), making ground stone tools inherently heavy. The curated tools of men were generally short-term investments compared to those of women, and the energy dedicated to emplacing ground stone equipment provided strong motivation for site reuse. Other objects that would have seen frequent use by women are the hammerstones used to peck the various tools identified in the analysis. The flaked stone debitage was mostly biface-reduction debris that was probably created using wooden or antler billets.

Provisioning Strategies and Mobility

The tools at Falcon Landing represent a solution to the incongruence between resources and tools. The bulky cores and grinding tools left behind at Falcon Landing and the lightweight tools manufactured and transported away from the site signal the economic distinction between the provisioning of places and the provisioning of individuals (Kuhn 1995). The provisioning of places is expected for logistically organized groups, whereas the provisioning of individuals is expected for situations of increased residential mobility. The beginnings of the occupations at Falcon Landing were logistical operations dedicated to provisioning the place. Downtime at the site was focused on provisioning the individual. Unexpectedly, the well-provisioned Falcon Landing site did not produce a recognizable flake technology (see Parry and Kelly 1987), as evidenced by retouch or macroscopic use-wear. Routine daily tasks should have generated more informal edge tools than we found in the collection. A major distinction between Falcon Landing and the Chiricahua and Chiricahua–Amargosa II type sites is the enormous number and variety of formal and informal scrapers and informal edge tools at the latter sites (Haury 1950; Sayles and Antevs 1941). One of the qualities expected of provisioned places is time for expedient tools to accumulate, however, and the work tempo and duration of stays at Falcon Landing may have cut short the demand for expedient tools.

The expectations Kuhn (1995) outlined for provisioned places included the procurement of local raw materials; informal, large cores; expedient core and tool use; and the discard of tools before they became unserviceable. Setting aside the lack of expedient tools, Falcon Landing lived up to all of those expectations but the last one. The extreme amount of resharpening observed on a few of the Chiricahua phase projectile points (see Figure 48e–h) would be interesting if they were isolated occurrences, but the phenomenon has been well documented (Bayham et al. 1986:429; Dick 1965:30; Lorentzen 1998:146; Sayles 1983:75). There was no evidence that the projectile points were used at the site, and it is reasonable to assume that they arrived at the site in that condition. None of the San Pedro projectile points had been extensively resharpened.

What did Chiricahua phase groups do differently from San Pedro groups? Conventional archaeological theory says that their projectile points were heavily curated, and therefore, they must have been foragers, whereas the later San Pedro phase groups were collectors who were quicker to discard projectile points that showed wear and tear (Kuhn 1989:42). The Chiricahua and San Pedro phase assemblages were difficult to compare beyond the projectile points, but core-decortication and biface-production percentages were both highest in the San Pedro phase sample (see Figure 43). Regardless, Chiricahua and San Pedro phase groups had comparable raw-material diversities (see Figure 45), and they appear to have performed the same tasks at Falcon Landing.

Site Furniture and Caches

Falcon Landing contained large numbers of complete ground stone artifacts and large ground stone blanks as well as 183 cores. Binford (1978) distinguished "site furniture" as site-specific facilities characterized by long use lives. Site furniture was emplaced to be a component of a site and may have been communal (e.g., a hearth) or intended for a single user (e.g., a metate) (Torrence 1989). Site furniture differed from caches in that it was intended for immediate use at its location, whereas caches were stored away, often far away, for future use. And site furniture is made up of visible, isolated facilities, whereas caches are found in concealed, tight clusters. Surovell (2009:117) argued that stockpiling is not expected in situations of high mobility and brief site occupation, but it became affordable as occupation span increased. Though not necessarily "stockpiles," the tools at Falcon Landing occasionally were found in small piles, and they showed that site-provisioning efforts were more intense than is typically expected of mobile groups. In total, 442 individual and complete ground stone tools were found during mechanical stripping. The number of ground stone tools found in extramural spaces was dramatically higher for the Chiricahua phase deposits, but caching persisted until the Classic/Protohistoric period. The Cienega and Red Mountain phase deposits also contained moderate amounts of extramural ground stone.

Caches and other concentrations of resources play an important role in the interpretation of land-use and provisioning strategies but also reveal concepts of property and ritual. An impressive ritual display was uncovered in a Late Archaic period structure at Los Pozos in the Tucson Basin (Gregory 2001). The feature was described by Gregory (2001:Appendix B) as a floor assemblage array that included 13 projectile points, 2 large pieces of basalt, a fossil horse tooth, a mammoth vertebra, 2 polished pebbles, 6 stone balls, a marekanite, a hematite concretion, 3 flakes, and 3 geode fragments. Gregory compared the arrangement to Archaic period–style rock-art motifs, suggesting that it embodied a symbolic representation of Archaic period ritual practices. Possible ritual material culture at the Luke Solar project sites was limited to a broken conical stone pipe from a San Pedro phase nonthermal feature at Falcon Landing (Feature 4370). Also, a death assemblage probably associated with an Elko Corner-notched point and a San Pedro side-notched point (Feature 106) was recovered from Site 68.

Several Late Archaic period utilitarian caches were identified at the Fairchild site, located along Whitewater Draw in southeastern Arizona (Windmiller 1973). The Fairchild site caches included 8 pit features containing manos associated with various other tools, including metates, a pestle, an abrader, and 2 scrapers. Four Late Archaic period caches were identified at Las Capas, located in the Tucson Basin (Whittlesey et al. 2010), and consisted of bell-shaped pits containing overturned, upright, or broken metates. One of the metates covered a concentration of *Chenopodium* seeds at the base of the pit. Another cache contained a metate covered with pigment that overlay a polished-clay spinning weight (Lascaux et al. 2010:153). Halbirt and Henderson (1993) found several caches at Coffee Camp, a Late Archaic period site located along the lower Santa Cruz River flats. The 29 caches identified at Coffee Camp contained 90 artifacts, primarily manos, metates, pestles, grinding slabs, and hammerstones. Other cached items included 5 cores, a stone ball, a San Pedro projectile point, and an antler fragment. Halbirt et al. (1993:94) interpreted the Coffee Camp caches as "insurance gear," places where Late Archaic period groups intentionally stored useful ground stone tools for intended reuse.

Large flaked stone caches containing bifaces or cores represent the provisioning of a place, but they are temporary, and the places are unpredictable. Large Archaic period flaked stone caches have not been reported in the U.S. Southwest. Falcon Landing contained only two small caches. Feature 3817, not dated, contained a large (>170-mm) multidirectional core and a large (>100-mm) cobble uniface, both made of rhyolite, and a hammerstone. Another cache (Feature 14920) represented a late Cienega to Red Mountain phase collection of large (50–90-mm) chalcedony core flakes. The large chalcedony flakes had cortex that appeared to be from a primary geologic source that was likely not the Agua Fria River drainage, unlike most of the stone artifacts recovered from Falcon Landing. It may have been a source favored by Chiricahua-point-using groups, based on two extensively resharpened points. The flaked stone pieces from Features 3817 and 14920 were big, and they had not been struck with the intent of making bifaces from them.

Property ownership was actively suppressed in many small-scale hunter-gatherer societies (Lee 1979; Woodburn 1982). Small, mixed assemblages containing ground stone tools and occasional flaked stone tools appear to have been common during the Late Archaic period. Large riverine habitations and foraging sites alike are known for having intramural and extramural caches. Whether caching happened everywhere on the landscape is an interesting question in the context of arid lands, common-pool resource use, and territoriality (Bayman 2007). The cache inventory in Table 41 shows that many of the ground stone tools found at Falcon Landing occurred as small tool combinations, including some unpaired tools, but the caching of large, complete tools was not a common practice. This is important, because the point of hiding a large rock in the middle of the desert was not to protect the rock, necessarily, but to deny passers-by the technology to harvest a resource.

It is not known whether competition for staple resources, such as mesquite, was fierce during the Middle Archaic period or any time thereafter at the site, but ground stone tools were personal objects by Middle Archaic period times and were occasionally concealed in pits and structures (see Chapter 4, Volume 1). This was a rare practice at Falcon Landing, but houses were also rare at the site. More often, large, complete tools were left in the open. Figure 76 shows the complete ground stone artifacts of all ages that were found in clusters and lines and as isolates in open space—patterns that certainly reflect the long-term locations of trees, washes, and the emplaced facilities, themselves. The distributions of pestles, metates, and manos did not suggest that the tools had been used in separate pursuits. The number of Middle Archaic period ground stone artifacts emplaced at the site is impressive, but site furniture does not necessarily correlate to occupational intensity (Torrence 1989).

Occupational Intensity and Duration

Based on ethnographic accounts of mesquite-collecting forays by Maricopa, Mohave, Yuma, and Cocopa groups in western Arizona, site occupations may have been limited to a matter of days. Roth (2006:519) summarized that women would occasionally camp for several days at mesquite-gathering locales. Men would sometimes accompany them, as protection, and would hunt rabbits. Importantly, the mesquite beans were taken to the village in large nets, were processed by women using mortars and pestles, and were then stored. Mesquite pods were evidently processed at Falcon Landing and would have required longer site occupations, but archaeological correlates for occupational duration indicated brief stays.

One of the things that make Falcon Landing interesting is the "discard" of ground stone tools as rocks for hearths and roasting pits. More than 80 percent of features containing FAR included recycled ground stone tools, mostly metates and manos (see Table 39). This indicates that the level of rock consumption was high. The utility of complete metates was curiously similar through time (see Table 26) and showed that complete basin metates had about 70 percent of their maximum utility (thickness). Even moderately exhausted tools were absent from the collection. FAR was recovered from thin middens at Falcon Landing, but it was densest in structures and thermal pits (see Figure 70). Schlanger (1991) predicted that short-term, seasonal occupations would contain relatively large floor assemblages in relation to the limited number of tools accumulated in trash fills, whereas more-sedentary occupations would accumulate more debris, which eventually ended up in trash-filled pits. In other words, when occupations, structures, or work areas lasted longer than tools, discarded tools began to accumulate in fill, trash, and other settings and gradually outnumbered floor assemblages (Schlanger 1991:467).

At Falcon Landing, the houses contained more FAR than the middens or other pits, and the floor assemblages were located outside, as site furniture and small caches. The radiocarbon and geochronology indicated long-term occupation (see Chapter 2), but the lithic-accumulation rate was extremely low. The most "intense" accumulation occurred during the San Pedro phase, when nearly one artifact accumulated per year (see Figure 76). However, Falcon Landing occupations did not generate significant occupational debris, for the reasons discussed above. Site furniture lasts a long time, usable flakes were curated, and the remaining lithic debris included microflakes and small biface-thinning flakes, many of which were probably located in extramural space and were undersampled. Potentially, large numbers of people were accommodated at the site, assuming that occupations were highly focused and brief.

The topic of artifact repurposing and FAR is of special interest, because it relates to wood. The use of rock in cooking features is universal and can serve several functions, but it maximizes the energy of the fuel. One of the technologies missing from the Falcon Landing collection was woodworking tools, such as axes or planes, although a single broken plane was eventually identified. Even the many large cobble unifaces lacked evidence of having been used as chopping tools. That is peculiar, in light of the demand for fuel at the site, and it possibly indicates that ample deadwood was available or that, like rocks, wood was transported to the site. Traditional management practices may have also discouraged the felling of mesquite trees at the site (Anderson and Moratto 1996). Consequently, it can also be posited that wooden mortars were not manufactured at Falcon Landing and required transport.

Mobility and Interaction

It is not difficult to defend the assertion that human populations expanded drastically during the late Middle Archaic period, because it followed a hiatus (Haury 1950; Sayles 1983; Waters 1986), and sites appeared everywhere on the landscape (Roth and Freeman 2008; Whalen 1971). One explanation that accounts for the distribution of Late Archaic/Early Agricultural period sites is the presence of logistically organized farmers in the river valleys and displaced hunter-gatherers in the surrounding piedmonts and mountains (see Premo and Mabry 2003). Falcon Landing indicated a flexible but expensive technological solution whereby hunter-gatherers provisioned a plant-processing site with large cobbles. Site provisioning is linked to expedient tool use, but at Falcon Landing, "expedient" cores were used to fashion portable men's and women's tools or tool blanks. Although it is difficult to reconstruct what people carried with them when they departed from Falcon Landing, it is possible that groups arrived at the site outfitted as low-mobility residential foragers but departed with the equipment expected of highly mobile collectors.

It is possible that Falcon Landing functioned as a springboard for long-distance forays into the mountains. The site was probably not used as a daily foraging site by groups occupying the valley, because suitable amounts of mesquite could have been procured closer to home at less cost. The specialized, low-diversity tools at Falcon Landing were also not what one would expect from residential foragers who generally pursued a wide range of subsistence options using informal tools. Whether they spent more time organized as collectors or foragers, women were among them and processed the food procured from the site, possibly to support seasonal movements out of the valley and into winter base camps.

Jones (1996) predicted that the marriage of Middle Archaic period females would have played an important part in offsetting local shortfalls in productivity if Middle Archaic period groups were circumscribed within defended territories. No evidence for territoriality among Middle and Late Archaic period groups has been found in the U.S. Southwest. Rather, Falcon Landing indicated the same Middle and Late Archaic period social landscapes as the Cochise-culture "core" in southeastern Arizona, including the extension of Cortaro-point-using groups into the Phoenix basin (Huckell 1996:328). The emphasis placed on local volcanic materials did not indicate frequent long-distance mobility, and that was supported by the amount, provenience, and provenance of the obsidian left at the site.

The Luke Solar project collection attested to the use of three obsidian sources, although one of them is unidentified and was represented by only a single flake. The San Pedro side-notched projectile point attributed to a disturbed cremation burial (Feature 106) at Site 68 was not subjected to EDXRF analysis. Among the other artifacts, the most common source (represented by 17 specimens) was Government Mountain, located in the Kaibab National Forest on the Coconino Plateau, approximately 200 km northeast of LAFB. The Government Mountain rhyolite domes contain large nodules (up to 30 cm in diameter) suitable for the manufacture of any flaked stone tool; Government Mountain is one of the best-known obsidian sources in the U.S. Southwest (Shackley 2005:32). Vulture obsidian was represented by only 9 specimens. The Vulture source, located approximately 45 km west of the Luke Solar project area, is also characterized by relatively large nodules (up to 10 cm in diameter). These may be found at least 20 km south and east of the source, in the Hassayampa Plain and possibly the Gila River valley (Shackley 2005:40). Of the Middle and Late Archaic period sites summarized by Shackley (2005:Table 6.3), only the New River site contained obsidian from both the Government Mountain and Vulture sources.

Obsidian-provenance studies provide a valuable opportunity to reconstruct Middle and Late Archaic period land use in the Sonoran Desert. In contrast to later times, when Classic period Hohokam groups capitalized on the use of volcanic glass for the production of projectile points, Archaic period obsidian use appears to have been highly opportunistic. Mitchell and Shackley (1995) described this using a distance-decay model of obsidian procurement and use that showed obsidian rapidly decreasing in abundance with increased distance from the respective source. However, Late Archaic/Early Agricultural period groups in the vicinity of the Superior obsidian source appeared to have avoided the use of obsidian, despite its close proximity (Ballenger and Hall 2011). One reason offered for why obsidian was not highly prized during the Archaic period is that Tertiary period marekanites typical of the Sonoran Desert were generally too small for Archaic period projectile point production (Shackley 2005:117). The two known obsidian sources represented at Falcon Landing would have provided appropriately large nodules to make the projectile points in the site collection, however; so, that does not explain the low frequency of obsidian at the site.

Shackley (2005:131) suspected that obsidian procurement was embedded in complex mobility strategies focused on social interaction and subsistence pursuits, especially the pursuit of mates and the fall acquisition of piñon, deer, elk, and pronghorn from nearby upland environments. If so, obsidian was highly curated at

Middle and Late Archaic period sites. The frequency of obsidian has constituted less than 1 percent of Archaic period flaked stone collections in the Sonoran Desert, and the Falcon Landing collection was equally dismal. Less than 0.005 percent of the flaked stone artifacts in the Luke Solar project collection were made from obsidian, and the mass of the entire sample was equal to a single typical marekanite.

The technological character of obsidian recovered from Falcon Landing revealed small-biface production and retouch, a theme that extended across multiple material types at the site. Based on the source provenance of two small-biface fragments, that was true of both Government Mountain and Vulture materials. Importantly, the majority of the obsidian sample (88 percent) was microdebitage collected from a 50-by-40-m area in the southeastern corner of the site. This indicates that (1) the majority of the obsidian sample accumulated during a single occupation, (2) obsidian consumption was extremely rare, (3) obsidian tools were highly curated, and (4) the lithic footprint of the individual or group was relatively small. By extension, it cannot be argued that the site was occupied by groups whose seasonal rounds provided regular access to obsidian.

Roth (2000:311) assumed that obsidian materials were procured directly from their respective sources, but it is not possible to distinguish direct procurement from long-distance exchange with any certainty (Shackley 2005:120). If Falcon Landing was used by foragers who regularly visited the Coconino Plateau, then we would expect that material to have been more ubiquitously distributed at the site. The rare and episodic occurrence of obsidian indicates exchange opportunities rather than direct acquisition. The co-occurrence of long-distance and semilocal obsidian in the same possible “tool kit” at Falcon Landing might also have taken place because someone who was uniquely fond of the material went out of his (or her) way to obtain it, both directly and indirectly.

The Late Archaic/Early Agricultural period is characterized by increased sedentism as agricultural villages flourished in the floodplains of southeastern Arizona (Huckell 1995; Mabry 1998a). The obsidian evidence of shrinking procurement ranges during the Middle Archaic to Early Agricultural period, as summarized by Roth (2000), includes 48 pieces of obsidian collected from nine sites in southeastern Arizona. Middle Archaic period sites contained evidence of 8 different obsidian sources, and Late Archaic/Early Agricultural period sites contained evidence of 10 separate sources. Roth asserted that these data pointed to a greater diversity of raw-material sources during the Middle Archaic period that was possibly related to larger procurement ranges and greater residential mobility. That argument is not valid, however, because the Middle Archaic period sites in her sample clearly contained obsidian from fewer sources than did Late Archaic/Early Agricultural period sites. The conflict between the interpretation and the data is apparent in Figure 3 of Roth’s (2000) report; it appears that the y axis was mislabeled. Shackley’s (2005:125) analysis of the data is more compelling. From a sample of three sites located in south-central Arizona, including Hankat Cave, Ventana Cave, and the Buried Dune site, Shackley (2005:Figures 6.2, 6.3) showed the use of Mogollon Highlands, Sonoran Desert, and Chihuahuan Desert sources during the Middle Archaic period, in contrast to the use of only Sonoran Desert sources during the Late Archaic/Early Agricultural period. Shackley (1990:352) argued that obsidian discarded at the Buried Dune and Arroyo sites revealed that two separate Middle Archaic period groups operated in overlapping but different territories. The obsidian sample from Falcon Landing showed acquisition of both long-distance and semilocal obsidian, both of which were probably used by one individual or a common group. The presence of Elko Corner-notched projectile points may indicate relationships with groups on the southern Colorado Plateau.

Conclusions

The Falcon Landing stone-tool collection represents hunter-gatherer technologies that developed before the appearance of maize in the U.S. Southwest and persisted into the Ceramic period. It is compelling evidence of long-term continuity in traditional subsistence strategies. Ethnographic comparisons have shown that women’s technologies, focused on the processing of mesquite, were used extensively but not intensively during brief, laborious occupations, possibly during the late summer, to finance upland hunting forays. The energy invested in women’s technologies and the labor dedicated to using them indicate that large returns were anticipated. The Lukeolith and pestle collections point to a highly specialized, cobble-based technology paired with large wooden mortars, an assertion that is difficult to make based on negative evidence. Contrasted by a strong emphasis on the production of hunting equipment, the Falcon Landing collection indicates that a pronounced division of male and female labor was in place by the early Chiricahua phase.

The Falcon Landing collection reinforces the importance of place in the study of provisioning strategies. The emplacement of massive processing tools and the low-level stockpiling of raw materials at the site created a special circumstance for evaluating how hunter-gatherers used the full range of “forager” and “collector” behaviors to meet the balance between the provisioning of places and the provisioning of people. How that strategy changed through time elsewhere on the landscape is in debate, but the available samples indicate that it persisted into the Ceramic period at Falcon Landing. However, it is possible that stone-tool inputs diminished significantly after the San Pedro phase, and the lack of post–San Pedro projectile points is problematic.

Articulating the biface technology with the obvious plant-oriented function of Falcon Landing is an interesting problem. The flaked stone sample had all the vestiges of a “gearing-up” site (Binford 1977). What is curious is that “gearing up” was a downtime task that required raw materials. In the case of Falcon Landing, people chose to “gear up” at a labor-intensive food-processing site that had no rocks. Basalt and rhyolite cobbles transported from the Agua Fria River made the largest contributions to the biface-thinning-flake sample (see Figure 44). The emphasis placed on working bifaces from local volcanic gravels transported several kilometers to the site indicates that ample opportunities for biface manufacture were ensured. By the same token, Russell (1908:109–110) showed an association between ground stone shaping and women’s downtime. The ground stone items at Falcon Landing had, in some cases, been extensively pecked, but those modifications were mostly surficial and appeared to relate to prehension and immediate functional requirements. In other words, the ground stone collection suggests that the function of the site was to harvest and process mesquite, but the flaked stone collection suggests that not everyone functioned equally to accomplish that task.

CHAPTER 4

Faunal Remains and Bone and Shell Artifacts

Janet L. Griffitts, Robert M. Wegener, and Karen R. Swope

The Luke Solar project recovered 4,732 faunal bones, mollusk shells, and bone and shell artifacts from four sites with contexts dating from the Early Archaic period to the early twentieth century (Table 46). The vertebrate fauna included 4,445 specimens assigned to 4 classes and 12 orders; 3 orders were represented among the invertebrate fauna, including both local land snails and imported marine shell (Table 47). Analysis focused on identifying taxa; recording any traces relevant to butchering, food processing, or other human activities; identifying taphonomic processes; and documenting any temporal changes in the use of faunal resources. Most of the faunal bone (99 percent) was recovered from one site, AZ T:7:419 (ASM); only a few specimens were found at AZ T:7:68 (ASM), AZ T:7:423 (ASM), and AZ T:7:437 (ASM) (hereafter referred to as Falcon Landing, and Sites 68, 423, and 437, respectively). An additional 635 fragments of bone and land snails were recovered from flotation samples from Falcon Landing, but these specimens did not undergo detailed analysis.

The Middle and Late Archaic period deposits are especially important because they provide much-needed data for understanding Archaic period subsistence practices on the lower *bajada* of the Phoenix Basin. In all, nearly 45 percent of the faunal bone was recovered from Archaic contexts. Some bone could be securely dated to the Chiricahua phase or the San Pedro or Cienega phases, but the dates of others spanned the transition between the Chiricahua phase and the San Pedro phase. Others could only be assigned to broader time ranges extending across periods, such as the Early to Middle Archaic, or the Early to Late Archaic. Those Archaic period specimens that could not be assigned to a specific phase were classified as Cochise in accordance with the project culture history presented in Chapter 2 of Volume 1. Less than 2 percent of the faunal bone was recovered from contexts dated to the pre-Classic or Classic periods.

Although faunal analysis generally focuses on identifying human subsistence patterns, careful examination of animal remains can also provide insights on other important aspects of past life. For example, faunal remains can potentially provide information on past environments. Certain taxa are restricted to specific environments and can therefore aid environmental reconstruction. Faunal analysis can also provide clues on land use and how prehistoric peoples exploited local and nonlocal resources over time. The analysis of faunal remains can also help inform on more-recent times. Over a third of the bone was recovered from a single Historical period pit, Feature 1664. This feature provided a glimpse into a sometimes-forgotten aspect of early-twentieth-century farming and ranching in southern Arizona, when human and leporid interests and land use competed and collided.

This chapter begins with a brief discussion of the principal research themes for this study and follows with a summary of methods used to analyze and record information on the vertebrate faunal material. This is followed by a description of the identified vertebrate taxa, including aspects of their life history and known ethnographic importance. The next section discusses terrestrial and marine shell, the former providing information on environmental conditions and the latter on prehistoric trade. Following the discussion of shell is a detailed discussion of the bone artifacts. Two historical-period features contained faunal remains; these are discussed in the next section. A brief overview of the vertebrate material from each site follows this section, including summary information on the kinds and amounts of taxa recovered from each temporal context and feature. The resultant taxonomic and distributional data are then used to infer and discuss butchery, transport, and processing, comparing data over time with a particular focus on the bone and shell recovered from Middle and Late Archaic period contexts. Additional data concerning taxon, element, taphonomy, and dating can be found in Appendix 4.1 (on CD).

Table 46. Number and Frequency of Faunal Specimens from the Luke Solar Project, by Site and Temporal Period

Temporal Period	Site				Total	% of All Sites	% of Falcon Landing	% of Falcon Landing, Feature 1664 Removed
	AZ T:7:68 (ASM)	AZ T:7:423 (ASM)	AZ T:7:437 (ASM)	Falcon Landing	n			
Sulphur Spring	—	—	5	—	5	0.1		
Early Chiricahua	—	—	—	497	497	10.5	10.6	17.4
Late Chiricahua	—	—	—	31	31	0.7	0.7	1.1
San Pedro	—	—	—	109	109	2.3	2.3	3.8
Cienega	—	—	—	547	547	11.6	11.7	19.1
Red Mountain	—	—	—	38	38	0.8	0.8	1
Pre-Classic	14	—	—	43	57	1.2	0.9	1.5
Classic	—	—	—	5	5	0.1	0.1	0.2
Protohistoric	—	—	—	9	9	0.2	0.2	0.3
Historical period (post-1700)	—	—	—	25	25	0.5	0.5	0.9
Historical period (early twentieth century, Feature 1664)	—	—	—	1,827	1,827	38.6	39	n/a
Cochise[a]	14	1	—	913	928	19.6	19.5	32
Poorly dated	7	—	—	614	621	13.1	13.1	21.4
Not dated	1	—	—	32	33	0.7	0.7	1.1
Total	36	1	5	4,690	4,732	100	100	100

[a] Archaic-aged material that could not be assigned to a specific phase was classified as Cochise.

Table 47. Number and Frequency of Faunal Specimens from the Luke Solar Project, by Site, Taxon, and Body-Size Class

Scientific Name	Body Size	Common Name	Site								Total	
			AZ T:7:68 (ASM)		AZ T:7:419 (ASM) Falcon Landing		AZ T:7:423 (ASM)		AZ T:7:437 (ASM)			
			n	%	n	%	n	%	n	%	n	%
	Vertebrata											
Amphibia												
Anura	small	frogs and toads	—		19	0.41	—		—		19	0.40
Anura	medium	frogs and toads	—		4	0.09	—		—		4	0.08
Reptilia/Amphibia												
Reptilia/Amphibia (small)	small	reptiles/amphibians (small)	—		2	0.04	—		—		2	0.04
Reptilia/Amphibia (large)	large	reptiles/amphibians (large)	—		2	0.04	—		—		2	0.04
	small	reptiles/amphibians (small)	—		2	0.04	—		—		2	0.04
Reptilia												
Colubridae	small	nonvenomous snakes	1	3	6	0.1	—		—		7	0.15
Serpentes	small	snakes	—		17	0.4	1	100	—		18	0.38
Squamata (small)	small	lizards	—		14	0.3	—		—		14	0.30
Squamata (small)	small	lizards, snakes, and amphisbaenians	1	3			—		—		1	0.02
Testudines (small)	small	turtles, tortoises, terrapins	—		5	0.1	—		—		5	0.11
Crotalus	medium	rattlesnakes	1	3	10	0.2	—		—		11	0.23
Crotaphytus	medium	collared lizards	—		1	0.02	—		—		1	0.02
Colubridae	medium	nonvenomous snakes	—		1	0.02	—		—		1	0.02
Iguanidae	medium	American arboreal lizards	—		2	0.04	—		—		2	0.04
Viperidae	medium	pit vipers	—		2	0.04	—		—		2	0.04
Serpentes (large)	medium	snakes	—		6	0.1	—		—		6	0.13
Squamata	medium	lizards, snakes, and amphisbaenians	—		3	0.06	—		—		3	0.06

continued on next page

Scientific Name	Body Size	Common Name	Site								Total	
			AZ T:7:68 (ASM)		AZ T:7:419 (ASM) Falcon Landing		AZ T:7:423 (ASM)		AZ T:7:437 (ASM)			
			n	%	n	%	n	%	n	%	n	%
Squamata (large)	medium	lizards	—		4	0.09	—		—		4	0.08
Testudines (large)	large	turtles, tortoises, terrapins	—		1	0.02	—		—		1	0.02
Aves												
Callipepla	small	crested quails	—		5	0.1	—		—		5	0.11
Sphyrapicus	small	sapsuckers	—		1	0.02	—		—		1	0.02
Turdus	small	robins	—		1	0.02	—		—		1	0.02
Aves (small)	small	birds (pigeon sized or smaller)	—		24	0.5	—		—		24	0.51
Accipitridae	medium	eagles, hawks, and kites	—		3	0.06	—		—		3	0.06
Aves (medium sized)	medium	birds (chicken or hawk sized)	—		17	0.4	—		—		17	0.36
Aves (indeterminate size)	indeterminate	birds (indeterminate sized)	—		19	0.4	—		—		19	0.40
Mammalia/Aves												
Mammalia/Aves (small)	small	mammals/bird (squirrel- or pigeon-sized)	—		32	0.7	—		—		32	0.68
Mammalia/Aves (medium)	medium	mammals/bird (rabbit or chicken sized)	—		15	0.3	—		—		15	0.32
Mammalia												
Ammospermophilus	very small	antelope squirrels	—		1	0.02	—		—		1	0.02
Dipodomys	very small	kangaroo rats	—		14	0.3	—		—		14	0.30
Perognathus	very small	pocket mice	—		18	0.4	—		—		18	0.38
Peromyscus	very small	deer and white-footed mice	1	3	2	0.04	—		—		3	0.06
Muridae (very small)	very small	mice and rats (mouse sized)	—		12	0.3	—		—		12	0.25
Rodentia (very small)	very small	rodents (mouse sized)	2	6	29	0.6	—		—		31	0.66

Scientific Name	Body Size	Common Name	Site								Total	
			AZ T:7:68 (ASM)		AZ T:7:419 (ASM) Falcon Landing		AZ T:7:423 (ASM)		AZ T:7:437 (ASM)			
			n	%	n	%	n	%	n	%	n	%
Sciuridae (very small)	very small	squirrels, chipmunks, and marmots	—		2	0.04	—		—		2	0.04
Mammalia (very small)	very small	mammals (mouse sized)	8	22	109	2.3	—		—		117	2.47
Neotoma	small	wood rats	—		34	0.7	—		—		34	0.72
Sigmodon	small	cotton rats	—		7	0.1	—		—		7	0.15
Spermophilus	small	ground squirrels	—		1	0.02	—		—		1	0.02
Thomomys	small	pocket gophers	—		3	0.06	—		—		3	0.06
Muridae (small)	small	mice and rats (squirrel sized)	—		1	0.02	—		—		1	0.02
Sciuridae	small	squirrels, chipmunks, and marmots	1	3	10	0.2	—		—		11	0.23
Rodentia (small)	small	rodents (squirrel sized)	1	3	19	0.4	—		—		20	0.42
Mammalia (small)	small	mammals (squirrel sized)	6	17	734	15.7	—		—		740	15.64
Lepus alleni	medium	antelope jackrabbit	—		4	0.09	—		—		4	0.08
Lepus californicus	medium	black-tailed jackrabbit	—		9	0.2	—		—		9	0.19
Lepus	medium	hares and jackrabbits	—		277	5.9	—		—		277	5.85
Sylvilagus	medium	cottontails	—		200	4.3	—		—		200	4.23
Sylvilagus (smaller individuals)	medium	cottontails (smaller individuals)	—		29	0.6	—		—		29	0.61
Leporidae	medium	rabbits and hares	—		72	1.5	—		—		72	1.52
Leporidae/Rodentia	medium	leporids or rodents	—		9	0.2	—		—		9	0.19
Mammalia (medium sized)	medium	mammals (rabbit sized)	8	22	1,478	31.5	—		5	100	1,491	31.51
Vulpes macrotis	large	kit fox	—		2	0.04	—		—		2	0.04

continued on next page

Scientific Name	**Body Size**	**Common Name**	**Site**								**Total**	
			AZ T:7:68 (ASM)		**AZ T:7:419 (ASM) Falcon Landing**		**AZ T:7:423 (ASM)**		**AZ T:7:437 (ASM)**			
			n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Canis	large	dogs, coyotes, and wolves	—		4	0.09	—		—		4	0.08
Canidae	large	dogs, coyotes, wolves, foxes, and jackals	1	3	3	0.06	—		—		4	0.08
Carnivora	large	carnivores	—		3	0.06	—		—		3	0.06
Mammalia (large)	large	mammals (coyote sized)	1	3	41	0.9	—		—		42	0.89
Odocoileus	very large	mule or white-tailed deer	—		3	0.06	—		—		3	0.06
Ovis/Capra	very large	sheep/goat	—		2	0.04	—		—		2	0.04
Cervidae	very large	deer, elk, and moose	—		3	0.06	—		—		3	0.06
Artiodactyla	very large	artiodactyls (deer sized)	—		10	0.2	—		—		10	0.21
Mammalia (very large)	very large	mammals (deer sized)	1	3	140	3.0	—		—		141	2.98
Artiodactyla (extra large)	extra large	artiodactyls (cow sized)	—		1	0.02	—		—		1	0.02
Mammalia (indeterminate sized)	indeterminate	mammals (indeterminate sized)	—		5	0.1	—		—		5	0.11
Vertebrata (indeterminate)												
Vertebrata (very small)	very small	vertebrate (mouse sized)	—		36	0.8	—		—		36	0.76
Vertebrata (small)	small	vertebrate (squirrel sized)	—		46	1.0	—		—		46	0.97
Vertebrata (medium)	medium	vertebrate (rabbit sized)	—		17	0.4	—		—		17	0.36
Vertebrata (indeterminate)	indeterminate	vertebrate (indeterminate sized)	—		800	17.1	—		—		800	16.91

Scientific Name	Body Size	Common Name	Site								Total	
			AZ T:7:68 (ASM)		AZ T:7:419 (ASM) Falcon Landing		AZ T:7:423 (ASM)		AZ T:7:437 (ASM)			
			n	%	n	%	n	%	n	%	n	%
	Mollusca											
Bivalvia												
Glycymeris	n/a	bittersweet	—		1	0.02	—		—		1	0.02
Gastropoda												
Olivella	n/a	dwarf olive	—		183	3.9	—		—		183	3.87
Olivella dama	n/a	dama dwarf olive	—		58	1.2	—		—		58	1.23
Olivella fletcherae	n/a	no common name found	—		9	0.2	—		—		9	0.19
Succinea	n/a	amber snail	1	3	19	0.4	—		—		20	0.42
Gastropoda (indeterminate)	n/a	mollusks (indeterminate land snail)	2	6	12	0.3	—		—		14	0.30
Mollusks (nacre)	n/a	nacreous mollusk	—		2	0.04	—		—		2	0.04
Total			36	0.8	4,690	99	1	0.02	5	0.11	4,732	100

Research Goals

Analysis of animal remains can help reconstruct diet and past subsistence strategies, including hunting practices and changing patterns of resource use and processing. Faunal analysis can also provide information on environmental zones. The following discussion focuses most heavily on the Middle and Late Archaic period, because, as noted above, the greatest proportion of the prehistoric bone was recovered from Archaic period contexts. The large proportion of bone from this period is unusual in southern Arizona, where faunal collections from Middle Archaic period sites are often quite sparse. The large collection from the Middle Archaic period contexts at Falcon Landing therefore provides an exceptional opportunity to examine animal use during this poorly understood period.

Archaic period sites are known in Paradise Valley (Hackbarth 1998), north and east of our project area, but most tend to be surface lithic scatters, and even the extensively investigated Last Ditch site (Hackbarth 1998; Phillips et al. 2001, 2009) yielded only a few faunal bones. Consequently, the faunal data from the Luke Solar project contribute significantly toward understanding Middle and Late Archaic period resource use in a lower-*bajada* setting in the Phoenix Basin and, by extension, southern Arizona.

Additionally, the presence, abundance, or absence of certain taxa in an archaeological collection can assist reconstruction of past anthropogenic and natural landscapes. For example, certain taxa of land snail recovered in prehistoric contexts may provide information on the duration and chemistry of available moisture. Nearly all vertebrate taxa of the Sonoran Desert have specific environmental requirements that must be met in order to sustain a flourishing population. Ratios of jackrabbits (*Lepus*) to cottontails (*Sylvilagus*) and ratios of artiodactyls to leporids have been used to examine hunting patterns and changes in the landscape (Szuter and Bayham 1996). Bone and antler artifacts can provide indirect evidence on economic or other pursuits. For example, use wear on well-preserved tool surfaces may indicate if a tool was used for processing hide, making baskets, or other tasks. Bone and antler ornaments or gaming pieces can provide clues to social behaviors; and bone artifacts, or even unaltered animal remains, can reflect ritual life. For example, the O'odham accorded special treatment to certain taxa because of their symbolic value (Rea 1998, 2007). Skulls, horns, and hides of bighorn sheep (*Ovis canadensis*) required specific storage and disposal practices (Castetter and Bell 1942; Nabhan 1993; Rea 1998), sometimes resulting in large piles of skulls and horns (Hayden 1985). A number of birds were ethnographically important in the U.S. Southwest (Ferg 2007). Some, such as hawks and eagles (Accipitridae) were native, others had origins outside the region and can potentially provide information on exchange and interpersonal contacts. McKusick (2007a, b) documents trade in Mexican macaws (*Ara*) and turkeys (*Meleagris gallopavo*) in the Casas Grandes area, and in the early eighteenth century, Tohono O'odham near Tucson raised macaws for their feathers (Ferg 2007). Marine shells were traded throughout the U.S. Southwest for use as ornaments and tools and therefore can provide clues to participation in the prehistoric trade networks linking the Gulf of California and/or the Pacific Coast to the Sonoran Desert.

Previous Research

Humans are known to have occupied southern Arizona for at least 12,000 years. Much of our current knowledge of Paleoindian lifeways in southern Arizona stems from several intensively studied Clovis sites in the San Pedro Valley (Hall et al. 2011). These sites suggest a hunter-gatherer lifestyle that included very large game, although the degree to which the Clovis people truly relied on large game is debated (Faught and Freeman 1998). Clovis projectile points found near the LAFB indicate some presence in the area. The Paleoindian period was followed by the Archaic period, a time of climate change and corresponding changes in human adaptation, beginning around 10,000 years ago. The Archaic period, in particular the Middle Archaic, is of special interest for the present study because this is where the data from the Luke Solar project can potentially make the greatest contribution.

The Early Archaic is poorly understood in southern Arizona (Huckell 1996), but an increase in grinding stones and fire-affected rock (FAR) suggests changes in subsistence as the Paleoindian period drew to a close. In the present project, only a few faunal remains were identified as belonging to the Early Archaic Sulphur Spring phase at Site 437, but they were too few to contribute substantially to our knowledge of this time (see Table 46).

Among the few Middle Archaic sites with more than a few bones are the Middle Archaic components at Los Pozos (Gregory 1999; Wöcherl 1999) and El Taller (Dean 2007a), both in the Tucson Basin. Other sites include Tator Hills (Halbirt and Henderson 1993) in the Santa Cruz Flats; the Lookout site in Harquahala Valley (Bostwick and Hatch 1988); Ventana Cave (Bayham 1982) and the Buried Dune, Arroyo, and Gate sites in the Picacho Reservoir area (Bayham et al. 1986); and the Fairchild site in the Sulphur Spring Valley (Windmiller 1973). Small, fragmentary faunal collections were recovered at the Last Ditch site, the site geographically closest to the Luke Solar project area of all previously excavated and reported Middle Archaic sites (Phillips et al. 2001; Rogge 2009) (Figure 77). Other Middle Archaic sites are known in southern Arizona and in the Phoenix Basin, but many lack faunal collections, and our knowledge of Middle Archaic foodways is therefore limited. The documented faunal remains indicate a reliance on jackrabbits, cottontails, and other small taxa, with few, if any, bones from deer-sized mammals. Because of this dearth of faunal material, the bone from the Luke Solar project provides an opportunity to greatly increase our understanding of Middle Archaic foodways.

The Late Archaic period is better known, especially in riverine sites in the Tucson Basin. More Late Archaic period sites have been identified, and several have been intensively studied. Our understanding of the Late Archaic/Early Agricultural period has greatly increased over the last several decades as a result of extensive research conducted on large Early Agricultural period riverine sites in the Tucson Basin, including Las Capas and Los Pozos (Gregory 1999; Mabry, ed. 1998a), and other sites, such as La Paloma (Dart 1986), Santa Cruz Bend (Mabry, ed. 1998a). Faunal remains from these sites indicate a primary focus on leporids with much lower emphasis on artiodactyls. Late Archaic period sites have been identified outsided the Tucson Basin, but generally, less is known regarding Late Archaic subsistence outside the Tucson Basin and in more-arid environments, and therefore, the materials recovered from San Pedro and Cienega phase contexts in the present project area will help increase our knowledge of the Late Archaic in the Phoenix Basin and in nonriverine environments.

Taxonomic and Skeletal Identification

All specimens were identified to the smallest taxonomic level possible, and their attributes were entered into SRI's custom database system. The bones were analyzed at SRI's Tucson laboratory, using a collection of comparative specimens and the comparative collections in the Arizona State Museum (ASM). Published osteological references were also consulted (Gilbert 1980; Gilbert et al. 1985; Hillson 1992, 2005; Lawrence 1951; Olsen 1964, 1968, 1979; Schmid 1972; Zweifel 1994). The primary analytical unit used in this analysis was the number of identified specimens (NISP). Each specimen was included in the NISP calculation. If specimens were recently broken and could be refit to other fragments, then the reassembled specimen was counted as one. Mollusk shell identifications were made using published resources (Cheatum and Fullington 1971; Keen 1971) and were confirmed by Arthur Vokes of the Arizona State Museum.

Fauna recovered from flotation samples mostly consisted of very small, carbonate-covered, minimally identifiable fragments. Initially, all material from flotation samples was analyzed, but it became apparent that little additional information would be gained by in-depth analyses, and therefore the fauna from flotation samples were only briefly examined in order to identify (1) taxa not previously identified in the project collection and (2) exemplary specimens such as small bone or shell beads or ornament fragments. The unanalyzed specimens were not included in NISP counts in the tables and figures accompanying this chapter.

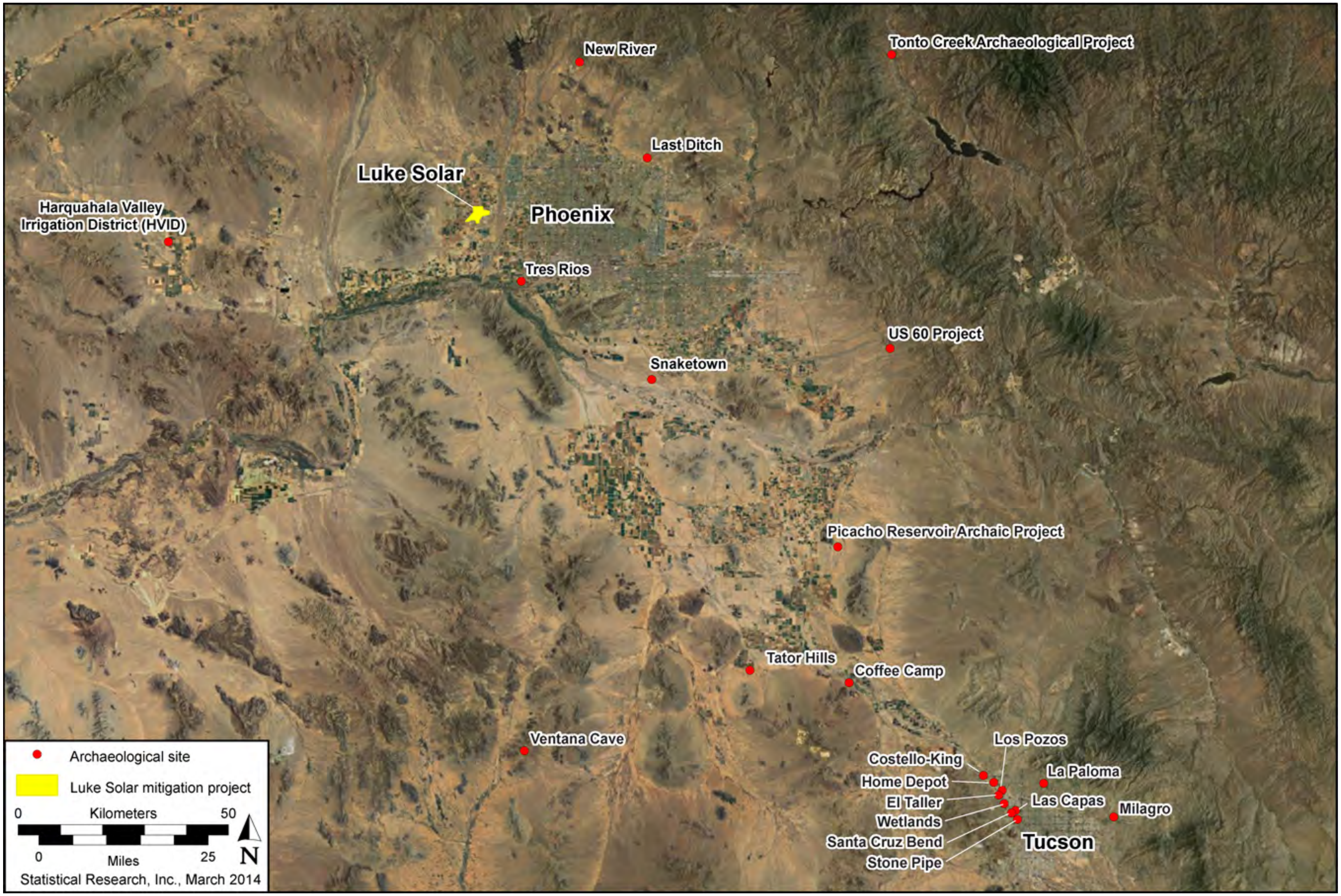


Figure 77. Locations of sites with faunal remains discussed in the text.

The most minimal level of identification was animal-size class. All specimens were assigned to general size classes based on those proposed by Thomas (1969:393) and Wegener (2009). Very small animals are those that weigh less than 100 g, such as pocket mice (*Perognathus*). Small mammals weigh between 100 and 700 g, such as wood rats (*Neotoma*) and many squirrels. Medium-sized mammals weigh between 700 g and 5 kg. Most medium-sized mammals identified in this study were leporids, specifically jackrabbits and cottontails. Animals weighing between 5 and 25 kg were classified as large mammals. Examples of animals in this size class include coyotes (*Canis latrans*) or bobcats (*Lynx rufus*). Very large mammals are those weighing over 25 kg such as deer (*Odocoileus*), pronghorn (*Antilocapra*), or sheep (*Ovis*). Finally, extra-large mammals are those animals the size of a cow (*Bos*), horse (*Equus*), or elk/wapiti (*Cervus*). Only a few bird bones were recovered in this project, and they tended to fall into two size classes: medium-sized birds that are the size of a hawk or a duck (Anatidae) and small birds, a classification that holds all smaller birds. Specimens that were too fragmentary or were too covered with carbonate to determine size class were assigned to an indeterminate size class.

This analysis did not include multiple-size groupings such as small to medium, or medium to large, and therefore bones that were unidentifiable to taxon were placed in the smallest possible size class. For example, if a fragment could have belonged to a larger squirrel-sized mammal (usually in the small mammal class) or a small leporid (medium-sized mammal) but was otherwise unidentifiable, it was assigned to the smaller size classification as a small mammal. There were exceptions to the classification system described above. Kit foxes (*Vulpes macrotis*) are tiny carnivores (members of Carnivora) weighing less than 5 kg, but they are behaviorally much more like the larger gray fox (*Urocyon cinereoargenteus*) and other larger carnivores than they are like the rabbits and hares that make up the bulk of the medium-sized mammals in this collection. Similarly, the upper weight range of the antelope jackrabbit (*Lepus alleni*) is over 5 kg, but these large hares were placed in the same size class as other rabbits rather than included with the small carnivores.

Bones and fragments were counted and identified to skeletal element, portion, and side when possible. Fragments were counted individually unless they could be refitted to one another. Several methods were employed to examine element representation. Specimens were placed in categories based on element portion (Wegener 2009). Long bones were identified as NISP/whole, NISP/shafts, or NISP/ends. Cranial and other axial bones, innominates, scapulae, and carpals and tarsals were assigned to NISP/flat. These categories were used to examine breakage patterns, in particular among long bones.

Minimum number of elements (MNE) was calculated using two systems. The first is outlined by Stiner (1994:240–242), the second by Waters (2002:764). Elements were grouped into anatomical regions. Stiner proposes 9 regions: horns and antlers, head, neck (cervical vertebrae), axial (thoracic and lumbar vertebrae, sacrum, sternum, ribs, and pelvis), upper front (scapula and humerus), upper hind (femur), lower front (radius, ulna, carpals, and metacarpals), lower hind (patella, tibia, fibula, tarsals, and metatarsals), and feet (phalanges). Waters (2002) uses only four regions: cranial, axial, upper leg (scapula, innominate, humerus, femur, and tibia), and lower leg (radius, ulna, metapodial, carpals, tarsals, and phalanges). These various systems are useful for looking at general patterns in processing and discarding carcasses, and they facilitate comparisons with published data.

Faunal specimens can potentially be identified as belonging to adult, subadult, neonatal, or fetal individuals based on the presence or absence of age indicators. Such indicators include unfused, partially fused, or fused epiphyses, erupting or heavily worn teeth, presence of antler (an indicator of gender as well as age in most cervids), or spongy fetal-appearing bone. Some species have strongly seasonal birth patterns, and therefore the presence of juveniles of these taxa can potentially provide information on seasonality of site occupations.

Bone pathologies include broken and healed bones or certain diseases. A single pathological specimen was recovered in this project; this consisted of four snake vertebrae that had fused together, likely as a result of some injury. Unfortunately, heavy carbonate deposits on many specimens in this collection limited visibility, and other pathologies, if present, may have gone unrecorded.

Because 99 percent of the faunal remains were recovered from Falcon Landing (see Tables 46 and 47), in the following discussion, features can be assumed to be from Falcon Landing unless specified otherwise. All radiocarbon dates in this chapter are presented in 2σ calibrated ranges. Dates for features and nonfeature units are presented in Appendix 4.2.

Taphonomic Processes

The bones recovered during the Luke Solar project had been subjected to both cultural and noncultural formation processes. A carbonate coating covered many bones. Sometimes it was patchy and thin, but often it was too thick to identify any but the most obvious features on a bone surface, and in some cases, bones were so thickly covered that it was difficult to identify the element or even if the specimen was indeed bone. Carbonate is the result of precipitation of calcium carbonate salts “where moisture is insufficient to flush the salts from the sedimentary matrix” (Lyman 1994:420). Carbonate deposits were noted on 26 percent of all bone, or 45 percent of the bone excluding the early-twentieth-century Feature 1664. A reddish brown stain was noted on 452 specimens (17 percent of all bone excluding Feature 1664). This staining was most often noted on the interiors of broken bones that also had some carbonate buildup. If the specimen was completely coated with carbonate, it was impossible to tell if there was staining. In addition, it was at times difficult to determine if a dark-brown specimen was lightly burned or stained.

The weathering stage records the degree of bone destruction due to exposure to changes in temperature, moisture, and other physical and chemical agents (Lyman 1994). Bones dry out over time, with corresponding changes beginning at the outermost surface and extending inwards as time goes by and weathering increases. If bone is continually exposed or is repeatedly reexposed to the elements, the weathering progresses deeper into the bone. Bone surfaces crack, the cracks become rounded, the surface becomes rough and fibrous, and then cracks progress deeper until the bone begins to splinter and finally falls apart.

Weathering was recorded using the six-stage classification system used by other researchers (Andrews 1990; Behrensmeyer 1978; Lyman 1994). When possible, each specimen was classified based on degree of surface alteration. The categories vary slightly between larger and smaller mammals. Bone weathering stages begin at Stage 0: smooth, unblemished, and still greasy, but no bones were assigned to Stage 0. Stage 1 bones from large mammals have begun to dry out and may have some longitudinal cracking with mosaic cracking on the articular surfaces. Bone and teeth from small mammals begin to split during Stage 1 (Lyman 1994:355). Stage 2 bones have begun to exfoliate and cracking continues, and in smaller mammals the teeth chip and split. The classification system was modified to incorporate specimens that seemed to be halfway between stages, introducing Stages 1.5 and 2.5. In Stage 3, the edges of cracks become rounded, and weathering penetrates up to 1–1.5 mm into the bone surface. Most bones were not highly weathered and the majority fell into Stage 1 (64 percent). No bones were placed in weathering stages over Stage 3. It was not possible to identify weathering on many of the carbonate-coated bones (34 percent), although, occasionally a gap between carbonate patches revealed enough surface to assess the state of the bone.

Root etching is indicated by round-bottomed grooves etched onto a bone surface and is produced by acids in plant roots or by fungi (Lyman 1994). Etching on bones suggests that plants must have been present at some time. Root etching was recorded on a few specimens (n = 36), but as with many other taphonomic observations, the carbonate coating on many bones made root etching impossible to detect. Rodent and carnivore gnawing were also noted on a few bone surfaces, but both were recorded in very low frequencies. Gnawing was seen on only 11 bones, all from Falcon Landing. Rodent tooth marks were noted on 7 specimens, carnivore tooth marks on 3 specimens, and an indeterminate tooth mark on 1 bone. The low frequencies may reflect poor visibility of bone surfaces rather than actual presence and absence of these traits.

Cultural formation processes include cut marks, butchery, and burning. Burning can provide information on carcass processing and discard, as well as certain cooking practices. Four burning stages were recorded: unburned, partial, blackened, and calcined. Identification of burning was based on color. Calcined bone, bone heated to above ca. 600°C (Lyman 1994:386–389), becomes blue-gray to white. Bone recorded as blackened is charred black, or dark brown, a condition indicating that the bone has been heated to about 400°C. This seemingly straightforward observation was complicated greatly in this analysis because thick layers of carbonate covered many bones and fragments. In addition, mineral staining was at times difficult to distinguish from burned bone. Burning was observed on only 25 percent of the bone, but because of poor visibility, simple comparisons of presence and absence are not meaningful.

Although it is tempting to interpret burned bone as evidence of cooking, burning can result from either cultural or noncultural processes (Schiffer 1987). Humans burn bone in a variety of ways, including discarding waste in fire, periodically burning trash, or using bone as fuel. Burning is not, in fact, reliable evidence of cooking because bones encased by muscle are protected from the heat to a certain extent, and usually the goal of cooking is to heat and soften meat, not to burn it so badly that the bone contained within is charred or calcined. This is not to say that bone never burns during cooking. Parts of the bone where muscle is thin (and therefore less protected) may burn during cooking. For example, around the turn of the century, Akimel O'odham would place pocket gophers (*Thomomys*) directly on coals to cook (Russell 1908). Cooking small mammals or birds in this way could result in charring the foot bones, crania, or other skeletal elements covered with little soft tissue, but the meatier proximal femur and proximal humerus would have been less likely to burn unless the carcass was left too long on the fire. Uniformly charred bone was rarely the desired effect of cooking. Additionally, burning is not necessarily exclusive to human activity. Wildfires, lightning strikes, or underground proximity to hearths can all inadvertently expose bones to heat and burning.

Crushing and impact marks, breakage, cut marks, and other signs of butchery can provide clues to human behavior. The maximum dimension of each specimen was recorded using seven ordinal categories (following Wegener 2011): 0–5 mm, 6–15 mm, 16–25 mm, 26–35 mm, 36–50 mm, 51–100 mm, and greater than 100 mm. These ordinal size classes provide information on fragmentation which in turn can reflect decisions made during meat processing. Fragmentation can also provide evidence regarding postdepositional processes, such as the formation history of feature fill and the extent of transformation (Schiffer 1987). When possible patterning was detected, average fragment size was calculated by determining the midpoint of each size range (e.g., the midpoint of 0–5 mm is 2.5), multiplying the midpoint by the number of observations, and then dividing by number of specimens (Thomas 1986). This technique is somewhat imprecise but served to provide a general idea of the overall size of bone from a given collection.

In sum, when possible, burning, weathering, and other taphonomic processes were recorded, but the heavy layers of carbonate made such recording impossible on many specimens. Therefore, any comparisons of burning or other taphonomic observations can only focus on presence, not absence.

Vertebrate Fauna

Faunal remains were recovered from all four sites in the project area, but the vast majority was from Falcon Landing (see Tables 46 and 47). Mammal bones were more common than those from any other vertebrates; mammals were followed, in order of abundance, by reptile, bird, bird/mammal, amphibian, and reptile/amphibian bones. Very small fragments unidentifiable below the level of phylum contributed 27 percent of the vertebrate collection. Leporids and bone from indeterminate rabbit-sized mammals made up the bulk of the collection in both prehistoric and Historical period contexts, including black-tailed (*Lepus californicus*) and antelope jackrabbits and cottontails. Rodent bones included ground squirrels (*Spermophilus*), antelope ground squirrels (*Ammospermophilus*), white-footed or deer mice (*Peromyscus*), pocket gopher, pocket mice, kangaroo rats (*Dipodomys*), wood rats, and cotton rats (*Sigmodon*). Artiodactyls and bone from artiodactyl-sized taxa were only occasionally recovered, and very few specimens were large enough to identify to taxon. Included in the few identifiable pieces were antler assigned to the deer family and deer bone. Two sheep/goat (*Ovis*/*Capra*) elements were found in a Historical period pit (Feature 1664), with a single bone from a cow-sized artiodactyl.

Amphibians

No amphibians could be positively identified below the level of Anura, the order that includes frogs and toads (see Table 47). Many amphibian long bones were broken and were missing ends, leaving the distinctive bifurcated long bones indicating their class, but little else. None were burned. Eighteen of the 23 specimens were recovered from an early-twentieth-century pit (Feature 1664), and these tended to be slightly more recognizable than bones from older features, although even in this case, the identifications were far from certain. Two of these more-recent specimens looked more like spadefoot toads (*Spea*) than any other amphibians in the ASM comparative collections, but they lacked strongly diagnostic characteristics. Two others were more like southern toad (*Anaxyrus terrestris*), but none of the identifications could be made with confidence. Anura bones represented individuals of several sizes. In addition to the Historical period pit, frog or toad bone was also found in prehistoric contexts, including a possible structure (Feature 2622) from the early Chiricahua phase (2560–2460 cal B.C.), a thermal pit (Feature 18027) dating to the Cochise (2570–790 cal B.C.), and in test-pit excavations (PD 8250) dated to the Cienega phase (720–200 cal B.C.). Anura bones were also recovered in poorly dated and undated contexts.

Reptiles

In most cases, reptile bones were unidentifiable beyond distinguishing between lizards (Squamata), snakes (Serpentes), and turtles or tortoises (Testudines), but a few genera were recognized. Carbonate deposits and fragmentation limited the identifiability of the bones, as did the very small size of some complete or nearly complete specimens. Among the 76 reptile bones was a collared lizard (*Crotaphytus*) mandible from a Historical period pit (Feature 1664), and unidentified members of Iguanidae recovered from a nonthermal pit (Feature 4370) dated to Cochise and nonfeature context (see Table 47). Rattlesnake (*Crotalus*) vertebrae were recovered from a Historical period pit at Falcon Landing and a posthole in a Snaketown phase structure at Site 68 (Feature 13, Subfeature 240). Four snake vertebrae were fused together by bone growth, suggesting that the snake had been injured but survived long enough for the bones to grow together. The fused bones, recovered from a poorly dated noncultural context, were light colored, unweathered, and had no carbonate, staining, or root etching. Therefore, they were likely intrusive. Other snake and lizard bones were found in feature and nonfeature locations. Although many snakes and lizards in archaeological sites are probably intrusive, some may have been deliberately brought to human settlements. Russell (1908:86) reported that during the Historical period, Akimel O'odham villagers captured lizards to feed the captive eagles and hawks they kept for feathers, and the same practice occurred among the Yumans (Castetter and Underhill 1935:43). Some snakes may have been drawn to the site at the time it was occupied. Human activity attracts rodents, and increased rodent populations, in turn, can attract snakes. Once there, depending on cultural attitudes and the type of snake, they may have been tolerated for pest control, killed and disposed of, killed and eaten, or even used for ceremonial purposes.

A few turtle or tortoise shells were recovered. Two specimens were found in a Cochise (Middle to Late Archaic) nonthermal pit (Feature 4329). Two other specimens were found in nonfeature contexts, one dating to the Cienega phase (PD 8231) and the other undated. Two sizes were represented. The carapace fragment from the undated context belonged to a large individual with a thick, domed shell, possibly a desert tortoise (*Gopherus agassizii*). The other specimens belonged to much smaller individuals. According to Castetter and Underhill (1935:43), the Tohono O'odham did not go out to hunt these slow-moving reptiles, but they would gather tortoises when they encountered them. Desert tortoises were prepared by first removing the entrails, then placing hot pebbles in the body cavity and roasting them on ashes (Castetter and Underhill 1935:47). This cooking method could result in burned shell exteriors, as the shell in this case served as a handy container for the meat within. The two fragments from Feature 4329 were not burned; the large, domed carapace fragment was burned; and the remaining shell fragment from the Cienega phase was too covered with carbonate to identify presence or absence of burning.

Birds

Nearly equal numbers of bird and reptile bones were identified. In all, 70 bones represented birds, and an additional 47 fragments were either birds or mammals (see Table 47). Of the 70 bird bones, 45 were recovered from one Historical period pit feature (Feature 1664) (see Appendix 4.1), along with 27 mammal/bird bones. Twelve bird bones were found in Feature 1361, a bell-shaped nonthermal pit dating to the Cienega phase; none could be identified to order. The remaining bird bones were recovered in small amounts, with 1, 2, or occasionally 3 pieces found per feature, but most could not be identified beyond size and class. The relative lack of bird bone—and the low identification rate of the bird bone that was found—may reflect poor preservation. Other bird bone may have been so encased in carbonate that it was unidentifiable or too fragmentary to be identified even to class. The only birds from prehistoric contexts that were identifiable to genus were crested quails (*Callipepla*), represented by 3 bones. Two of these, from a poorly dated natural deposit, originally interpreted as a midden (Feature 10118), may have been intrusive based on the pale color and unblemished condition of the bone. The third was from an excavation unit (Unit 8265) into nonfeature Cienega phase deposits. Other bird bone was recovered from at least six features and two nonfeatures, but the bone could not be identified below the level of class and general body size. When compared to the bird collection at the ASM, 2 carbonate-covered bones were most similar to roadrunner (*Geococcyx*), but both bones were so encased that no positive identification was possible. One of these carbonate-encrusted possible roadrunner bones was a mandible found in Feature 1361 (noted above); the other, a right coracoid, was recovered from a thermal pit dating to the Cochise (Feature 4272). No burning was seen on any bird bone, but some specimens were too encased by carbonate to tell if they were burned or stained. Twenty eggshell fragments were found in feature and nonfeature contexts.

The quail bones included an innominate and left humerus from Feature 10118; a left carpometacarpus and right humerus from Historical period Feature 1664; and another left carpometacarpus from a nonfeature context. These little birds are common today, and during our excavations, quails were frequently seen running about the site. Among the O'odham, Gambel's quails (*Callipepla gambelii*) were hunted with bows and arrows, trapped, or dispatched with branches (Rea 2007). Yumans trapped quail and other small birds with fiber nets, shot them with arrows, or captured them by hand (Castetter and Bell 1951:215–216). Some Yumans also trapped quails in cages made of saguaro ribs (Castetter and Underhill 1935:43). The average clutch size for quail is 10–12 eggs (Thomson 2001), so one or two nests would have supplied quite a few eggs. Quail eggs were boiled or buried in warm ashes in a small pit. Among the Akimel O'odham, there were certain restrictions concerning quail and quail eggs, lest quail sickness, sore eyes, or blindness strike (Rea 2007; Russell 1908). Touching the quail's topknot was taboo among O'odham groups, so it was customary to first pull off the heads before processing further to avoid touching the topknot (Rea 2007). If this belief extends deeply into the past, then one might expect to find quail heads and upper vertebrae missing.

The following birds were found only in Historical period contexts and so their Native American uses are not described here. One bone was identified as the left coracoid of a possible sapsucker (*Sphyrapicus*) or small woodpecker (Picidae). Several sapsuckers make their homes in the area, including the yellow-bellied (*S. varius*), red-naped (*S. nuchalis*), and red-breasted sapsuckers (*S. ruber*) (Arizona Bird Committee 2012). The red-naped sapsucker is a visitor to Arizona, the other two nest here. The presence of additional bird species is also possible; for example, the left coracoid might represent a Williamson's sapsucker (*S. thyroideus*), a bird that winters in Mexico (Peterson 1990) and may pass through the Luke Solar project area, or the bone could represent some other small woodpecker. Another left coracoid was identified as a possible robin (*Turdus*) bone. The American robin (*T. migratorius*) breeds in Arizona, and the rufous-backed robin (*T. rufopalliatus*), though native to Mexico, is a winter visitor (Peterson 1990). Two third phalanges and a synsacrum were identified to Accipitridae, which includes eagles, hawks, and kites. Many Accipitridae live in or pass through Arizona. The three bones recovered in Falcon Landing were from a bird or birds the size of a western marsh harrier (*Circus aeruginosus*).

Mammals

The bulk of the identifiable fauna was assigned to mammalian taxa. In all, the mammalian specimens represented at least 4 orders and 14 genera, and they included animals of a range of size and dietary preferences (see Table 47). Among mammalian orders, lagomorphs made up the greatest proportion, with rodents taking a distant second place.

Rodents

Recovered rodent bone included a variety of mice, rats, and squirrels (Heteromyidae, Muridae, and Sciuridae). Some may have been deliberately hunted by humans, some attracted to human activities, and some were likely intrusive. In all, 158 specimens were identified as rodent bone, and of these, 80 were found in an early-twentieth-century pit feature. Members of Heteromyidae and Muridae were most numerous of the identified rodents. In all, 32 specimens were assigned to Heteromyidae, which includes pocket mice and kangaroo rats (see Table 47). Kangaroo rats and pocket mice are nocturnal, seed-eating, desert-adapted burrowing rodents. All stash gathered seeds in cheek pouches to carry away and cache in their burrows. Although several species and subspecies of both heteromyid genera live in the project area, many distinguishing characteristics only are found in soft tissue and so the specimens in this study were only identified to genus. Pocket mice are small rodents, seed eaters with fur-lined cheek pouches, small ears, long tails, cusped and rooted teeth. Several species live in Arizona, and no attempt was made to identify these rodents by species. The pocket mice recorded in Maricopa County (Hoffmeister 1986) range in size from the aptly named little pocket mouse (*Perognathus longimembris*), weighing only 6–9 g, to the much larger Bailey's pocket mouse (*P. baileyi*), which at 17–42 g (Reid 2006), overlaps with smaller kangaroo rats. Some species of pocket mouse are known to reuse the abandoned burrows of kangaroo rats and pocket gophers or the abandoned nests of wood rats (Best and Skupski 1994), and some kangaroo rats and pocket mice have been observed sharing burrows. Pocket mice will also dig into the soft soil surrounding pocket gopher burrows and are often found associated with Merriam's kangaroo rat (*Dipodomys merriami*) (Burt and Grossenheider 1980; Hoffmeister 1986). Isolated specimens of pocket mice were recovered from both prehistoric and twentieth-century contexts, including thermal (Feature 11290) and nonthermal pits (Features 1664, 10774, 15191, and 15334); a reservoir (Feature 10278); a structure (Feature 17908); an activity surface (Feature 15119); and a natural deposit, originally identified as a feature (Feature 10118), but other very small mammal and rodent bones from these features may also have been from this taxon. Three specimens, although recovered from prehistoric contexts (Features 11290, 17908, and 15119), were likely intrusive, based on bone condition. One calcined femur from a pocket mouse was collected from poorly dated test-pit excavations within the general site sediments.

Kangaroo rats in the project area are most likely to have been Merriam's kangaroo rat, a small rodent weighing only 25–53 g (Reid 2006:261), or the desert kangaroo rat (*Dipodomys deserti*) weighing 73–148 g (Hoffmeister 1986; Reid 2006:270). As such, they potentially occupy both the very small and the small size classes. For consistency, because kangaroo rats could only be identified to genus, all were placed in the very small size class. Kangaroo rats were identified in nonthermal pit and nonfeature contexts in both prehistoric and Historical period contexts. Only one kangaroo rat bone was burned. This bone, a complete calcined calcaneus, was the only bone recovered from Feature 10278, a San Pedro phase reservoir. A second kangaroo rat bone recovered from a nonthermal pit (Feature 15191) dated to the Cochise, and the rest of the kangaroo rat bones were found in Historical period contexts.

Rea (1998) was told that O'odham would leave kangaroo rats alone and was unable to find anyone who considered kangaroo rats to be edible. Castetter and Underhill (1935:42) noted that among the Tohono O'odham, kangaroo rat consumption was limited to times of extreme need. Pocket mice, too, were eaten only during times of scarcity—"the hungry time" (Castetter and Underhill 1935:42). No cut marks or butchery marks were seen on any heteromyid remains, although this was not surprising. Very little butchery would be needed on such tiny mammals and processing them for food might well destroy the bones.

Muridae includes a variety of rats and mice. Muridae identified in the Luke Solar project included cotton rats (*Sigmodon* sp.), wood rats (*Neotoma* sp.), and white-footed or deer mice (*Peromyscus* sp.). Several species of cotton rat inhabit Arizona, and seven specimens could be identified to these thick-bodied, short-eared rodents (see Table 47). Cotton rats weigh about 159 g (Rea 1998) and are found in a variety of habitats. Some are xeric-adapted desert dwellers (Hoffmeister 1986), but most are especially attracted to riparian areas and irrigated fields (Merlin and Siminski 2000). They are vegetarian, feeding on green plants and grasses. Cotton rats are active during the day and night, running through grasses along protected trails or runways.

In the early 1960s, Rea (1998) was told that cotton rats were a favorite food of the Akimel O'odham, who reported that the round little rodents tasted like pork and that they were not fatty but good flavored. Cotton rats had to be gutted soon after death or the meat would spoil. They were roasted directly on coals, or skewered on a stick, and were roasted until they could be peeled, then roasted again until brown (a practice that could potentially expose bones to more direct heat and burning). Cotton rats were also stewed, and in more recent times, fried. One or two rats served for a meal (Rea 1998:177). Cotton rats were hunted using fire drives and surrounds, poked out of their holes, killed when disturbed in grain piles, and in recent times, Akimel O'odham men working in alfalfa fields would sometimes catch and cook them for lunch. Bones of cotton rat were identified in a Historical period pit (Feature 1664) and in two prehistoric contexts (Feature 3693 and Feature 10118 [later determined to be a natural deposit]), but those from the prehistoric contexts were likely intrusive based on bone condition. None were burned.

In all, 34 bones were identified as wood rat (see Table 47). Wood rats, commonly known as pack rats, are relatively large-bodied nocturnal rodents. Southern Arizona species weigh around 157g (Rea 1998). They feed on cactus, mesquite beans, creosote bush flowers and stems, and other plants, but they will also eat meat (Hoffmeister 1986). Their distinctive nests are a familiar sight to many southern Arizona residents. The nests are constructed of sticks, cholla, prickly pear or other cactus parts, and other debris, and these prickly outside nests surround smaller nests made from fine, soft materials where the young are reared. Nests are often built around bushes, trees, cacti, or sheltering rocks (Merlin and Siminski 2000; Reid 2006), or in modern times and urban areas, beneath houses or in automobiles. Their habit of collecting bits and pieces of attractive debris gives them their more common name: pack rat.

Wood rats were identified in nonthermal pits (Features 148, 1664, 4234, and 11168), a bell-shaped nonthermal pit (Feature 1361), structures (Features 2529, 2602, and 4349), thermal pits (Features 4272 and 11974), an FAR concentration (Feature 4625), a charcoal/ash concentration (Feature 3693), and an activity area (Feature 14729). They were also recovered from nonfeature and noncultural contexts. Only 1 of the 34 bone fragments was burned, although 4 other specimens were either burned or stained; all 4 of these were covered with thick carbonate layers that reduced visibility. Both adult and juvenile individuals were represented.

Some wood-rat bones probably represented intrusive individuals, but others may have been come to the site while it was occupied, attracted by changes in vegetation; discarded refuse on the surface, in pits, or abandoned structures; or by stored seeds. Humans may have hunted some of these rats. For example, Rea (1998) noted that in the Historical period, the O'odham considered wood rats probably the second-most-important rodent game animal after cotton rats. They were among the animals taken in drives (Rea 1998:182) or were pulled from their nests by tangling sticks in the wood rat's fur. Russell (1908:80) reported that the Akimel O'odham ate a rat but he did not identify the species, and Castetter and Bell (1942) also reported that wood rats were consumed by the Tohono O'odham.

To the south of the project area, the Tepehuan trapped wood rats and mice using an upside-down bowl set up over bait (Pennington 1969). Castetter and Underhill (1935) reported that the Tohono O'odham preferred to hunt smaller animals with bow and arrow, and cooked unidentified rats and birds in ashes, leaving the skin on to protect the meat. The Tohono O'odham also reportedly burned nests to chase out the occupants (Rea 1998), as did the Cocopah (Castetter and Bell 1951). Underhill (1979:39) noted that Tohono O'odham boys hit rats with sticks to kill them and then skewered and roasted them. The Chiricahua used two methods to hunt wood rats (Opler 1996:325): in pairs and individually. When two men were hunting rats, one drove the rat from its nest by poking it with a stick, and the second shot it with a wood pointed arrow. At other times, a single person drove the rat out and hit it with a stick. The Cocopa pounded the bones of wood rats and ate them (Castetter and Bell 1951). Not only were wood rats eaten, but occasionally humans raided their cached stores of mesquite beans (Rea 1998), although this is reported to have been discouraged among the O'odham. Castetter and Bell (1951:182), too, wrote that Yumans raided rodent nests for their seeds.

Three mouse bones were identified only to the genus *Peromyscus*, white-footed and deer mice. Several species of these tiny rodents live in the Sonoran Desert, including the cactus mouse (*P. eremicus*), Merriam's mouse (*P. merriami*), and the canyon mouse (*P. crinitus*). These little mice have large ears; large eyes; thick, long tails; and are nocturnal (Reid 2006). Two bones were recovered from a Historical period feature

(Feature 1664), and one carbonate-covered specimen was found in a nonthermal pit (Feature 148, Site 68) dated to the Cochise period.

Members of Sciuridae (squirrels, chipmunks, and marmots) were the third most common rodents identified in our project (see Table 47). Squirrels native to Arizona include a variety of ground squirrels, antelope ground squirrels, tree squirrels (*Sciurus*), prairie dogs (*Cynomys*), and even chipmunks (*Tamias*), but the most likely to be found in Maricopa County and the Luke Solar project area are the round-tailed ground squirrel (*Xerospermophilus tereticaudus*), antelope ground squirrel (*Ammospermophilus*), and rock squirrel (*Otospermophilus variegatus*) (Hoffmeister 1986; Maricopa County Parks and Recreation n.d.; Merlin and Siminski 2000).

Round-tailed ground squirrels are social, diurnal, desert-adapted burrowers living in colonies. They eat seeds, cacti, and green plants, and may rely more heavily on green plants than antelope ground squirrels. Round-tailed ground squirrels may hibernate October through December (Hoffmeister 1986:185), and so, if their remains are interpreted as nonintrusive in cultural contexts, their presence may provide some indications of seasonality. Rock squirrels are the largest of the three squirrels, but they are the least likely to be found in the project area. They are most common among the rocks that give them their name, but they are found in other habitats across the state, except for the driest portions in the southwestern Arizona deserts. Like the antelope ground squirrels, their diets are flexible, including seeds, fruit, nuts, agave, and carrion, and they have been observed killing and eating a captive kangaroo rat and catching and eating a robin in the wild. It is unknown if rock squirrels truly hibernate, but they become less active in the winter and only appear occasionally on sunny days (Hoffmeister1986:177).

Antelope ground squirrels are smaller than round-tailed ground squirrels. They are striped squirrels living in burrows in saltbush–creosote bush–bursage deserts and are diurnal. They do not appear to hibernate, and they have a very varied diet. Like the round-tailed ground squirrel, little antelope squirrels eat fruit, seeds, and green plants, but they also eat carrion, and will catch and eat insects and lizards, and in captivity, they have been known to kill and eat pocket mice. There are two species in Arizona, with Harris' antelope squirrel (*Ammospermophilus harrisii*) in the southern portion of the state (Hoffmeister 1986:172).

Squirrel bone was recovered in prehistoric and Historical period contexts, in house-in-pit, nonthermal pit, thermal bell-shaped pit, and nonfeature contexts, and included 15 bones from indeterminate squirrel, ground squirrel, and antelope ground squirrel. Two squirrel bones dated to the Cienega phase, both were covered with carbonate and had small conical punctures that suggested carnivore gnawing. One of these bones was from a nonthermal pit (Feature 1295), and the other was from a nonfeature context. No squirrel bones were burned and 7 had carbonate coating. Two of the squirrel bones were from taxa around the size of comparative prairie-dog specimens from Colorado (included in the ASM comparative collection); these larger individuals could represent rock squirrels. The remaining squirrel bones were from smaller taxa. Antelope ground squirrel bone was recovered from Historical period Feature 1664. Additionally, 2 very small carbonate-covered squirrel bones were recovered from nonfeature Cienega contexts. These 2 bones likely represent antelope ground squirrels as well. Others may be included among the unidentified rodent (squirrel-sized) remains.

The O'odham hunted round-tailed ground squirrels by pouring water into burrows and clubbing or shooting the fleeing squirrels (Rea 1998), and Russell (1908) reported unidentified ground squirrels were treated in the same way. Historically, squirrels were cooked on coals or were fried. Women were not allowed to eat ground squirrels because eating ground squirrels was thought to cause nosebleeds or insufficient milk (Rea 1998). O'odham formerly hunted antelope squirrels with bow and arrow, but Rea (1998:146) was told that they were very small and didn't provide much meat per squirrel. Ground squirrels were a less popular food than the larger mammals among the Tohono O'odham (Castetter and Underhill 1935:42).

Only three pocket gopher (*Thomomys* sp.) bones (two tibiae and a femur) were identified during this project, one from a Historical period pit, and the other two from nonfeature test-pit excavations (see Table 47). One dated to the early Chiricahua phase and the other was poorly dated. In spite of the paucity of identifiable bone, pocket gophers were indeed present at Falcon Landing, at least in more-recent times, as indicated by burrows running through site sediments, and the recent carcass of an unfortunate individual noted in a backdirt pile during mechanical stripping.

Pocket gophers follow a vegetarian diet, preferring roots, bulbs, and tubers. They construct extensive tunnels marked by mounded backdirt piles. These rodents are the bane of many southern Arizona gardeners and archaeologists alike as they burrow into soft garden soil and devour plants from the comfort of the burrows safely underground. Pocket gophers excavate into the strata of archaeological sites where they mix sediments, shift small objects, and occasionally die in their burrows. Pocket gopher bones are often therefore intrusive, but their presence at archaeological sites can also be the result of human activity. Reports differ concerning whether Historical period tribes ate pocket gophers. Rea (1998) reported that the pocket gopher is an active figure in O'odham emergence tradition and suggests that this may account, at least in part, for why they weren't eaten. People raided gopher caches for tubers, but the animals themselves were not consumed, although Rea (1998:158) noted that one man commented that such fat, clean, vegetarian animals likely tasted good. Social rules govern their treatment and molesting the animals is said to have serious consequences. Russell's 1908 observations contradict those of Rea. Russell reported that the Akimel O'odham roasted them after extracting them from their holes but also noted that gophers were thought to bring sickness. On the other hand, the Northern Tepehuan, although O'odham, had no such rules against injuring gophers. Members of the Northern Tepehuan killed and ate gophers, cooking them on spits or boiling them (Pennington 1969).

In summary, several types of rodents were identified in both prehistoric and Historical period contexts. Rodent bones may make their way into archaeological sites through a variety of processes. Some were likely intrusive, representing individuals who burrowed down through the strata into the archaeological site and died there. Some rodents were attracted to human activity by changes in vegetation, stored seeds, or refuse in middens and so may have been coresidents with the human inhabitants. These animals may have died of natural causes or may have been killed as pests. Russell (1908:92) noted that Akimel O'odham youngsters guarded agricultural fields with bows and arrows, and shot birds and rodents drawn to the growing crops. Some rodents may have been brought to a settlement as food for other animals; Yumans brought rats and lizards to feed captive hawks (Castetter and Underhill 1935:43). Other rodents may have been intentionally hunted and brought to the site, as with the cotton rats taken in fire drives. It would be a mistake to automatically class all rodent bones as intrusive or all as cultural, or indeed, all rodents as the same. Some native peoples preferred to eat certain rodent taxa, but other rodents may have been viewed as providers of stored seeds, some may have been avoided for ritual reasons, and others may have been considered too small to be worth the trouble, except in times of famine. None of the rodent genera identified here appears to have made an important contribution to human diet in the Luke Solar project area. That place is held by the various species of rabbits and hares.

Rabbits and Hares

Southern Arizona leporids include multiple species of jackrabbits and cottontails. Jackrabbits, cottontails, and unidentified members of Leporidae made up the bulk of the identifiable taxa recovered during the Luke Solar project. In all, 591 leporid bones were recovered (see Table 47) in a range of contexts, including activity surfaces; FAR concentrations; houses; ground stone caches; postholes; thermal, nonthermal, and bell-shaped pits; middens; and nonfeature locations. They were the most common of any taxa recovered from Chiricahua phase through early-twentieth-century contexts.

Jackrabbits and cottontails are similar in many ways. Their long ears, elongated hind legs, hopping locomotor pattern, and vegetarian diets make them instantly recognizable, but they have different habits and prefer different environments (Hoffmeister 1986). Arizona cottontails (*Sylvilagus* sp.) generally weigh under 1,140 g, and black-tailed jackrabbits (*Lepus californicus*) in southern Arizona average 2,300 g. Antelope jackrabbits (*Lepus alleni*) are restricted to south-central Arizona's deserts and grasslands. These lanky hares are larger and have longer ears than their black-tailed compatriots, and white sides that flash as they run, giving them their name. Females average 3,629 g and males 3,719 g (Hoffmeister 1986). They are desert adapted; the blood vessels in their long ears dilate in hot weather and help regulate body temperature (Whitaker 1980:363). Antelope jackrabbits may be more social than black-tailed jackrabbits. In the 1930s, groups of up to 25 antelope jackrabbits were recorded in Pima County, and when in groups they travel in single file (Hoffmeister 1986:144). These aggregated groups might have been a boon to hunters, potentially providing a greater return for expended effort; given both the larger size of these animals and their tendency to group, it might have been easier to harvest multiple individuals.

Responses to danger vary between the two genera. Cottontails tend to crouch and hide when threatened, whereas both jackrabbit species are adapted for flight when threatened. When disturbed, they may leap into the air for a better view of their surroundings before fleeing. Jackrabbits prefer habitats that allow them to see longer distances, such as deserts, grasslands, and open scrub. Cottontails prefer more vegetation to hide beneath and are therefore more often found in brushy areas, hills, and canyons rather than the more-open environments preferred by jackrabbits, although the habitats of the two genera overlap. Cottontails give birth to naked, blind young in fur- and grass-lined nests where the babies are hidden and protected until more developed. Jackrabbit young are born in open fur-lined burrows covered with fur and with eyes open. Jackrabbits dig forms, shallow depressions used as resting places (Hoffmeister 1986), and mother jackrabbits distribute the members of a litter over several forms to protect them from predation (Whitaker 1980:346; Zeveloff 1988). When possible, antelope and black-tailed jackrabbits were distinguished from one another based on measurements found in Gillespie (1988), but the carbonate coating on many of the bones limited the opportunity to obtain exact measurements.

Both eastern cottontails (*Sylvilagus floridanus*) and desert cottontails (*S. audubonii*) are found in Maricopa County, but according to Hoffmeister (1986), eastern cottontails, the larger of the two species, are only found in the northern and easternmost edges of the county. If current environmental conditions approximate the relevant paleoecology of LAFB, the cottontail remains from LAFB are most likely desert cottontails. In addition, a few specimens of much smaller cottontails were recovered. The tooth row measurements of these smaller specimens show rabbits as small as the pygmy cottontail, but this species is restricted to sagebrush areas (Hoffmeister 1986). It is possible that environmental conditions have changed over the last 5,000 years, and the population distributions may have shifted over time. These tiny rabbit specimens may represent a subspecies of the desert cottontail, e.g., the smaller *Sylvilagus audubonii minor*, found in parts of southern Arizona today, or a smaller subpopulation within the larger desert cottontails. Alternatively, they may simply represent smaller, diseased, or nutritionally stressed individuals. Although only a few of these smaller cottontails were identified, long-bone fragments from these individuals could have easily been identified as large squirrel-sized bones during analysis and gone unrecognized.

Ethnographic accounts of Historical period Akimel O'odham report that there was no designated season for rabbit hunting and that they were hunted year-round (Rea 1998:66). Jackrabbits were taken by individuals and communally in drives by the Akimel O'odham and Yumans, using bow and arrow, net, or a special curved hunting stick (Castetter and Bell 1951:216; Rea 1998; Russell 1908). Fire was sometimes employed in the drives, as were nets (Spier 1978); rabbits were also hunted individually using arrows or other projectiles (Rea 1998:136). Cottontails were hunted either by individuals using arrows or communally (Rea 1998:132). Cottontails also may have been attracted to gardens where they could have been opportunistically hunted. When the Akimel O'odham went on raiding parties, they were required to kill game without using bows, arrows, or clubs, and so leporids had to be captured and killed by hand. Rabbits killed in this way were only slightly cooked (Rea 1998:58), in contrast to those hunted at other times. Small cottontails could be killed with blunt arrows (Russell 1908), dug or pulled from their burrows by twisting an arow in their fur (Spier 1978), and were taken in rabbit drives along with the larger jackrabbits (Russell 1908). Leporids were fond of raiding tepary plantings, and so Yumans protected their gardens by setting traps made from a bent willow sapling and wild hemp noose (Castetter and Bell 1951:153).

People prefer different leporid genera for eating, and these preferences are often influenced by both culture and the environment. For example, Yumans preferred cottontails to jackrabbits, but jackrabbits were more common (Castetter and Underhill 1935:42). Among the O'odham, however, many preferred jackrabbits to cottontails for their size and flavor (Rea 1998:133). Leporids were roasted in pits, cooked on a stick, or stewed (Castetter and Underhill 1935:47; Rea 1998). These different cooking practices potentially result in different archaeological patterns. When leporids or rodents are spitted on a stick and cooked over a fire, the connective tissue of the small bones of the extremities may burn or loosen, and these small bones may fall into the fire and be lost (Szuter 1989:221). In the Historical period, the Akimel O'odham prepared rabbits for roasting by removing the intestines but leaving on the skins; they were then buried in a trench and covered in hot ashes and coals (Webb 1959:15). In a recent account of Akimel O'odham roasting jackrabbits in pits, Rea (1998:88–89) noted that after the entrails were removed, the fur was singed off, and the carcass was buried in hot ashes. The front and back legs were broken to make it lie properly. The broken limbs of the pit-cooked rabbit might be recovered, but it would be difficult to identify isolated fractured long bones as having been broken for this purpose and not simply for marrow extraction. Burning was recorded on 42 leporid bones, but an additional 134 specimens were so coated with carbonate or stained that it was not possible to identify presence or absence of burning. The meat, skins, and bones were all important. The Northern Tepehuan made sleeping mats from rabbit skins (Pennington 1969), and the Yuma and Akimel O'odham cut skins into strips and wove them into blankets (Rea 1998:141; Spier 1978). Rabbit long bones were made into beads, tubes, whistles, or other artifacts, and their tails were used for curing in O'odham traditions (Rea 1998).

Carnivores

Carnivores were represented by dog/coyote, kit fox, and indeterminate carnivores (see Table 47). Dogs, coyotes, and wolves are all members of the genus *Canis*, and it is often difficult to identify fragmentary canid bones to species, and particularly difficult to distinguish between domestic dogs and coyotes. Four dog/coyote bones were identified, and four canid (a family containing coyote, wolves, dogs, foxes, and jackals. although the last is not indigenous to North America) bones were found. Female coyotes in central Arizona average from 17.5 pounds (7.94 kg), and males average 21 pounds (9.53 kg) (Hoffmeister 1986:461).

Most of the coyote diet comes from meat, including rodents, rabbits, carrion, young artiodactyls, and birds, but they can and do eat plants as well. They live in many environments, adapting to deserts, grasslands, mountains, and to urban environments today. Coyotes are important in O'odham stories and myths, and are moiety mascots. Among the O'odham, coyotes could be killed but not eaten, and various elements of the carcass were used in curing (Rea 1998:197). Some were kept as pets among Tohono O'odham (Castetter and Underhill 1935:43).

Dog or indeterminate canid burials have been found in various contexts in southern Arizona sites (Waters 2005a). Dogs served multiple functions, as companions and in assisting hunters. Omnivorous and social like their wild relatives, dogs also acted as scavengers around households or villages, gobbling down organic waste and keeping areas relatively clean. They also warned villagers of the presence of enemies (Russell 1908:84). They are important in O'odham creation stories, and they may have had a ritual role (Rea 1998).

Dog or coyote and indeterminate canid remains were found in nonthermal pits and in nonfeature Historical period and prehistoric contexts at LAFB. Four were found in Feature 1664, a Historical period pit. One isolated skull of a juvenile dog or coyote was found in a nonfeature location (discussed below). More bones from carnivores or coyote-sized mammals were recovered from Chiricahua phase contexts (36 percent) than any other phase or time period, and most of the Chiricahua phase canid specimens were found in Feature 4235, a nonthermal pit. This relatively greater quantity of bone may in part be related to the much greater time span of the Chiricahua phase (2,300 years) compared to the other phases investigated here. The fragmentary carnivore remains included one burned carnassial fragment. This piece matched that of a coyote but was too small to identify with any confidence. The remaining bones were all burned and less than 15 mm in maximum dimension. A distal phalanx was found, but no other bone could be identified to element (beyond long or flat bone), or to taxon. There was other bone in this Chiricahua phase pit; it was assigned to rabbit-sized mammals but was highly fragmented and largely unidentifiable beyond the most general categories. The exception was a single vertebra of a medium-to-large-sized mammal. All but one piece was burned. An unidentified canid radius was found in an undated, nonfeature location, and a proximal metacarpal was found in Feature 4370, a nonthermal pit dated to the Cochise period. This piece, covered with carbonate and mineral stains, was found with a cranial fragment from a similar-sized mammal, along with 98 pieces of bone, including cottontail, jackrabbit, Iguanidae, snake, deer-sized mammal, squirrel-sized mammal, and indeterminate leporid. A carnivore ulna fragment was found in Feature 14587, a midden dated to the early Chiricahua phase. This bone was a close match with a comparative coyote skeleton housed at the ASM, but the fragment was too small and fragmentary to rule out similar-sized carnivores such as bobcats, and so it cannot be confidently identified below the level of family with any certainty.

Kit foxes live in the desert scrub and grasslands. They typically weigh less than 2 kg and are small, light-colored foxes that feed on kangaroo rats and other rodents, rabbits, insects, lizards, and birds. They dig dens with multiple openings, with bits of fur, bone, and feathers scattered nearby (Hoffmeister 1986). Fox bones assigned to the Chiricahua phase were limited to a whole right unburned calcaneus found in Feature 14764, an early Chiricahua phase FAR concentration. No other faunal remains were in this feature. A partially burned left mandible was found in a poorly dated nonthermal pit (Feature 14932).

Artiodactyls

Three artiodactyl taxa were identified in this project (see Table 47). Two were recovered from Historical period contexts, and the third from prehistoric and undated features. Southern Arizona artiodactyls include four similarly sized species: mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), bighorn sheep (*Ovis canadensis*), and pronghorn (*Antilocapra americana*). Each has preferred habits and habitats (Burt and Grossenheider 1980; Merlin and Siminski 2000). Bighorn sheep, denizens of largely inaccessible rocky areas in upland settings, would have been available through long-distance hunting, while pronghorns prefer open grasslands. No mountain sheep or pronghorn bones were identified. Deer bone and cervid antler were identified in prehistoric contexts, and sheep/goat and possible cow bone were recovered from Historical period contexts. The deer bone was either mule or white-tailed deer. Mule deer live in lower elevations and canyons, and white-tailed deer are generally found at elevations above 1,000 m, but their ranges overlap and hybrids have been recorded (Hoffmeister 1986). Mule deer migrate seasonally, up and down in elevation to find forage, and they are more tolerant of arid conditions than their white-tailed counterparts. They can survive without drinking water for several days (Rea 1998; Wallmo 1972). White-tailed deer are unable to do so and therefore are more likely to be found at higher elevations. Adult mule deer average 45.5–52.3 kg (Rea 1998:238). When startled, mule deer bound with stiff legs. White-tailed deer run away. Mule deer have branched antlers, and those of white-tailed deer have a main beam. Desert white-tailed deer are smaller than mule deer (Rea 1998). Mule deer occupy a special place in Akimel O'odham mythology and, like many animals, are thought to cause sickness if treated improperly (Rea 1998).

Only 157 bones from artiodactyls and deer-sized mammals were recovered, and fewer could be identified below the level of order. Bone from deer-sized taxa was usually highly fragmented, and only a few pieces could be identified to genus. Deer bone was identified exclusively in prehistoric or undated contexts and all were from Falcon Landing, although a single unidentifiable fragment of bone from a deer-sized mammal was found in Feature 13 (a house-in-pit) at Site 68. Unlike much of the bone from smaller taxa, some of the artiodactyl bone may have been curated bone or antler tools, moved from place to place and may not actually reflect the presence of an animal killed and brought to the site. Shed antler can be picked up and carried home to make into tools without the human ever coming into contact with the rest of the deer. A tool handle made from a deer metapodial was recovered from nonfeature contexts, an unmodified distal tibia was found in Red Mountain phase nonfeature contexts, and a proximal ulna was found in an FAR concentration (Feature 10773) that dated to the Cochise. No deer bone could be identified to species. In addition to the prehistoric deer bone, a proximal metacarpal fragment from a cow-sized artiodactyl and a right tibia and calcaneus from sheep were found in a Historical period pit (Feature 1664) at Falcon Landing.

Invertebrate Fauna

Invertebrate remains included both native land snails and imported marine shell. Land snails likely represent intrusive individuals or individuals inadvertently brought to the site clinging to vegetation. These tiny mollusks are unlikely to have been sought out as food sources, and the intact condition of their fragile shells also suggests that no effort was made to extract the snails from their shells. Marine shells must have been brought to the site by humans. Identified marine shells included at least two genera as well as fragmentary, unidentifiable specimens.

Land Snails

Thirty-one land-snail shells and shell fragments were recovered from Falcon Landing. Of these, 19 were identified as *Succinea*, and the others were unidentifiable fragments (Table 48; see Table 47). The unidentifiable fragments could easily represent *Succinea*, but their shells were too fragmentary to make that determination. *Succinea* are widespread land snails that prefer "moist, well vegetated habitats adjacent to marshes and watercourses" (Vokes and Miksicek 1987:178). Because of this preference, they can be used as local environmental indicators. *Succinea* shells were recovered in structures, intramural and extramural nonthermal pits, and in nonfeature contexts. Most were found in the northwestern end of Falcon Landing and may have been drawn to the increased moisture in or near the paleochannels/swales (Figure 78). As with the overall faunal collection, most of the identified specimens of land snails dated to the Middle or Late Archaic periods, including the early Chiricahua phase and Cienega phase. Only a few were attributed to the Historical period.

Table 48. Land Snail Shells from the Luke Solar Project

Feature	Subfeature	Provenience	Feature Type	Level	Date	Taxon	Count	Faunal Element Notes
					AZ T:7:68 (ASM)			
80		284	noncultural	1	n/a	Mollusca	1	fragment of land snail shell, similar to large *Succenia*
87		165	nonthermal pit	1	Cochise[a]	Mollusca	1	fragment of land snail shell, similar to *Succenia*
87		165	nonthermal pit	1	Cochise	*Succinea*	1	
					AZ T:7:419 (ASM)			
1664		1677	nonthermal pit	1	Historical period	*Succinea*	1	
2529		20308	house-in-pit	1	Red Mountain	*Succinea.*	1	
2602		7572	house-in-pit	1	early Chiricahua	*Succinea*	1	
2602		7573	house-in-pit	1	early Chiricahua	*Succinea*	1	
2602	8430	8431	nonthermal pit	1	early Chiricahua	Mollusca	1	fragment of land snail shell
2602	8430	8431	nonthermal pit	1	early Chiricahua	*Succinea*	1	
2605	7777	7810	nonthermal pit	1	early Chiricahua	Mollusca	1	fragment of land snail shell
2605	7777	7810	nonthermal pit	1	early Chiricahua	*Succinea*	1	
2622		2853	structure - possible	1	early Chiricahua	Mollusca	1	fragment of land snail shell
4647		9765	nonthermal pit	1	early Chiricahua	Mollusca	1	fragment of land snail shell

continued on next page

Feature	Subfeature	Provenience	Feature Type	Level	Date	Taxon	Count	Faunal Element Notes
10118		1940	noncultural	2	poorly dated	Mollusca	2	fragment of land snail shell
10600		14219	nonthermal pit	1	poorly dated	*Succinea*	1	
10951		16585	noncultural	1	early Chiricahua	Mollusca	3	fragment of land snail shell
10951		16585	noncultural	1	early Chiricahua	Mollusca	1	fragment of land snail shell
13018		16165	nonthermal pit	1	poorly dated	*Succinea*	1	
14765		18865	nonthermal pit	1	Cienega	Mollusca	1	fragment of land snail shell
15448		20125	nonthermal pit	1	early Chiricahua	*Succinea*	1	
18880		18872	nonthermal pit	1	Cochise	*Succinea*	1	
18880		18872	nonthermal pit	1	Cochise	*Succinea*	1	
18880		18873	nonthermal pit	1	Cochise	*Succinea*	1	
18880		18873	nonthermal pit	1	Cochise	*Succinea*	1	
18880		18873	nonthermal pit	1	Cochise	*Succinea*	1	
18880		18912	nonthermal pit	1	Cochise	*Succinea*	1	
		18848		1	Cochise	Mollusca	1	fragment of land snail shell
		18848		1	Cochise	*Succinea*	1	
		18848		1	Cochise	*Succinea*	1	
		18848		1	Cochise	*Succinea*	1	
		18848		1	Cochise	*Succinea*	1	

[a] Archaic-aged material that could not be assigned to a specific phase was classified as Cochise.

Shell Artifacts

Shell artifacts and unworked marine shell fragments included 200 *Olivella*-shell beads, a single fragment of *Glycymeris*, as well as unidentified nacreous shell (Figure 79; Appendix 4.3). All of the marine shell was recovered from Falcon Landing. Taxonomic identifications were verified by Mr. Arthur Vokes of the ASM. *Olivella* beads were classified following the typology developed by Bennyhoff and Hughes (1987).

Beads

By far, the greatest portion of the shell collection from the Luke Solar project consisted of *Olivella* spp. beads, representing at least two species (*O. dama* and *O. fletcherae*), as well as indeterminate *Olivella*. *Olivella dama* live in Gulf of California tide pools, and *O. fletcherae* reside in the northern Gulf of California (Keen 1971; Vokes 2001a, personal communication 2013).

One spire-lopped *Olivella* bead was found in the floor fill of Feature 4302, a structure dated to the San Pedro phase (1130–1000 cal B.C.). The remaining shell artifacts consisted of 250 beads recovered from the fill and mixed sediments of a single nonthermal pit (Feature 18880) and adjacent test-pit excavations (TPs 18816 and 18847). Intermingled with the Feature 18880 shell beads were 13 disk beads cut from white stone (see Chapter 3, Volume 2). This feature produced a 2σ calibrated age range of 1260–1040 cal B.C. This bead-filled feature also contained a few bones of cottontail and wood rat, and a fragment of a bone artifact (with grinding traces along one edge) that had been made from a long bone of a deer-sized mammal. The *Olivella* beads from Feature 18880 were not standardized in size, taxa, or overall bead shape. Most were identified only as *Olivella* spp.; at least two species were present, including *O. dama* and the smaller, more slender *O. fletcherae*.

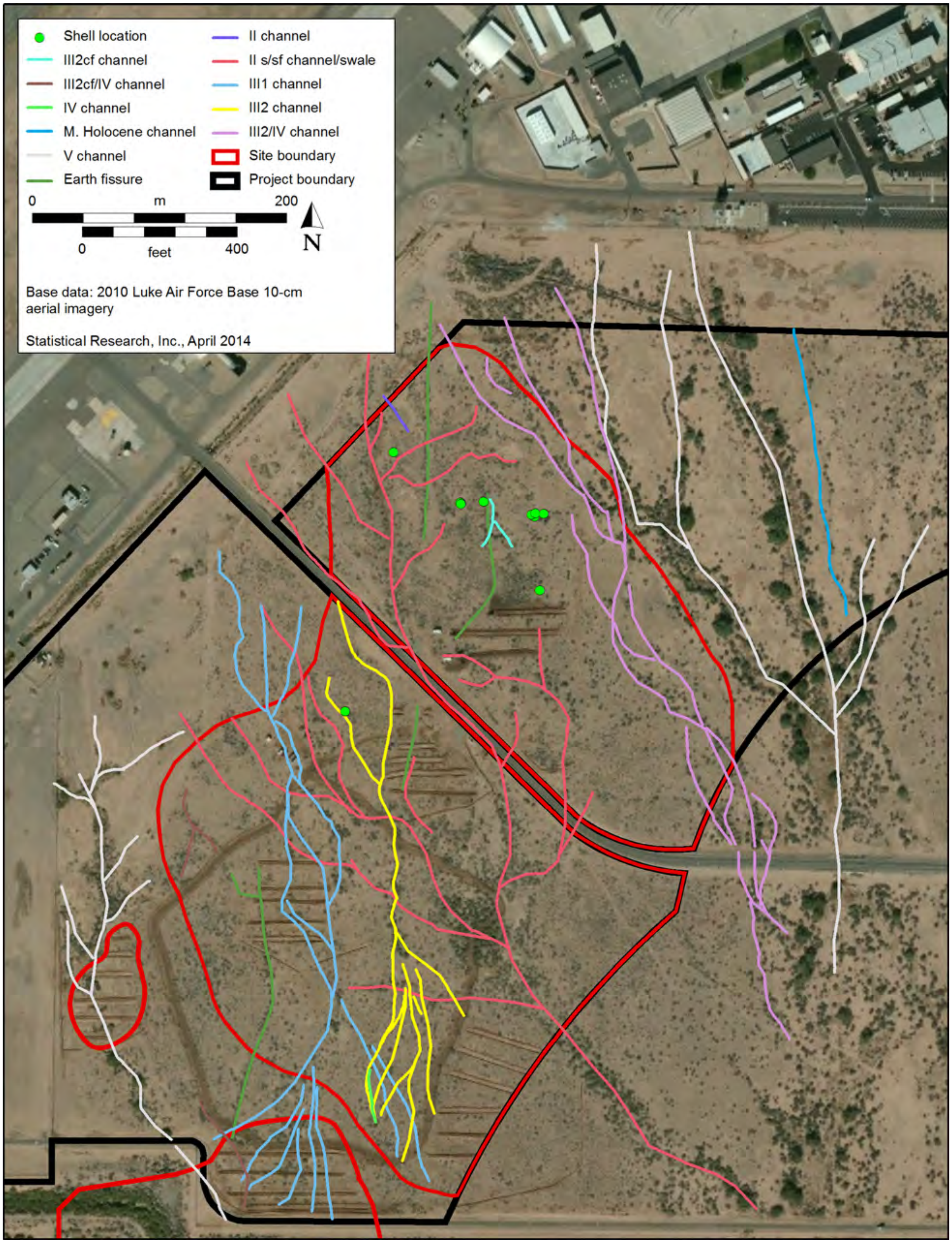


Figure 78. Distribution of land snails and channels.

Figure 79. ***Olivella dama*** **spire-lopped beads: (*a*) Catalog No. 040010BAF, (*b*) Catalog No. 040010BAB, (*c*) Catalog No. 040010BBB, (*d*) Catalog No. 040010BFA, (*e*) Catalog No. 040010BAD, (*f*) Catalog No. 040010BBA, (*g*) Catalog No. 040010BAC, (*h*) Catalog No. 040010BAE, and (*i*) Catalog No. 040010BAA; O. *fletcherae* spire-lopped beads: (*j*) Catalog No. 040010BB2, (*k*) Catalog No. 040010BB3, (*l*) Catalog No. 040010BE2, (*m*) Catalog No. 040010AF2, (*n*) Catalog No. 040010819, (*o*) Catalog No. 04001031A, (*p*) Catalog No. 040010AE6, and (*q*) Catalog No. 040010AF3; and barrel beads: (*r*) Catalog No. 04001008E, (*s*) Catalog No. 0400102F8, and (*t*) Catalog No. 040010B7E. All beads were recovered from Feature 18880, Falcon Landing.**

Most were spire-lopped beads (see Figure 79a–q), manufactured by cutting, grinding, or breaking away the pointed spire but leaving the shells otherwise nearly complete. Caution must be applied in reconstructing the manufacturing stages because the spires of some shells may have broken away before the shells were retrieved by humans (Rosenthal 2006). Among the spire-lopped beads were three barrel beads (see Figure 79r–t). Spire-lopped beads were modified at only one end, but barrel beads were modified at both ends; the spire was removed, and the opposite end was also ground down producing a shorter, wider bead compared to the simple spire-lopped beads. One barrel bead was made from an *O. dama* shell, the other two could not be identified to species. The shell and stone beads may have represented a single artifact, such as a complete necklace, or several smaller artifacts such as multiple strands. Unfortunately, there was no evidence to further identify the type or number of artifacts. The lengths of the spire-lopped beads ranged from 6.1 to 19.4 mm, and the lengths of the few barrel beads ranged from 5.9 to 7.9 mm. Interestingly, the stone beads from Feature 18880 were much more standardized than the shell; because they were cut from stone, the craftsperson may have had more control over bead shape than did the shell worker who was dependent on the size and shape of the animal shell. The shell condition was also quite variable. All of the shells from this feature were the same white color as the stone beads, but a few *O. dama* beads from this feature retained faint shadowy traces of their original color and patterning. The natural gloss remained on a few shells, providing a surface shine that suggested polishing at first glance, but others were worn, pitted, and eroded and were likely rolled, worn, bleached, and battered by waves, sand, and sun for a time before the shell was picked up for human use along the shoreline. There was no evidence for the on-site manufacture of shell artifacts.

Other Shell Artifacts

One small *Glycymeris* shell was recovered from a Cienega phase (720–200 cal B.C.) nonfeature context. These bivalves live in the Gulf of California (Vokes 2006), and the Hohokam commonly made them into bracelets (Vokes 2006). This piece, however, was broken on all sides and no cut marks or signs of manufacture remained. It could not be determined if this represented an artifact (e.g., a bracelet), unworked shell, or manufacturing debris. A few deteriorated, delaminated nacre fragments were recovered from an extramural thermal pit (Feature 10131), which produced a 2σ calibrated age range of 1260–1040 cal B.C. Very little can be interpreted from these tiny pieces, and no other fauna was found in this pit. Another, slightly larger fragment of nacre was found in the artifact-rich deposits of TP 8230, dating to the Cienega phase (720–200 cal B.C.). These fragments could have been either a nacreous marine shell representing *Haliotis* or *Anodonta*, the local freshwater mussel shell. Prehistoric residents of southern Arizona made artifacts from both local and imported taxa (Vokes 2005).

Chronology and Comparison with other Sites

Shell artifacts are relatively common in the large Late Archaic/Early Agricultural period sites in the Santa Cruz floodplain but are found in smaller quantities and with less variety of form in smaller sites. Desert Archaeology's excavation of San Pedro phase contexts at Las Capas produced a collection of 78 marine or freshwater shells, artifacts, or fragments, dominated by *Laevicardium*, *Olivella*, and unidentified nacreous shell, a few *Pteria/Pinctada,* and one specimen each of *Trachycardium, Sonorella, Agaronia,* Vermetidae*,* and *Anodonta* (Vokes 2005). The collection included cut-ring beads, geometric pendants from nacreous shell, and *Olivella* spire-lopped beads. Excavations by SWCA Environmental Consultants (SWCA) at the same site recovered 6 *Olivella* barrel beads dating to the early San Pedro phase, as well as nacreous shell beads, and a single piece each of *Laevicardium*, *Trachycardium*, and *Vermetus* (Urban and Whittlesey 2010).

The Cienega phase deposits at Los Pozos contained 764 shell artifacts. *Olivella* and *Laevicardium* shell remained common in the Cienega phase at Los Pozos (Vokes 2001c). Vokes (2005) notes that the end of the Early Agricultural period brought a number of changes to the shell artifacts in southern Arizona. Late Cienega phase shell from Los Pozos included a wider variety of taxa and artifact types than were seen in San Pedro phase contexts, and it is in these Late Cienega phase contexts that *Glycymeris* artifacts are more likely to be found, although *Glycymeris* shell bracelets did not become common until later times (Vokes 2005).

Vokes (2001c) compared ratios of nacreous to non-nacreous shell in Middle to Late Archaic and Early Ceramic period contexts from the Milagro, Wetlands, Santa Cruz Bend, Stone Pipe, and Los Pozos sites and found that nacreous shell made up a larger proportion of the shell in the Early Agricultural period compared to the Early Ceramic, pre-Classic, and Classic periods. The nacreous shell from these sites, as well as Las Capas, were *Haliotis* from the California coast and *Anodonta* (Vokes 2001c, 2005). Vokes also observed that as the frequency of nacreous shell decreased the frequency of whole-shell beads increased. Overall, the use of nacreous shell declined in the Early Ceramic period (Vokes 2005), but it did not completely disappear, and its use continued into the Historical period. In 1700, Father Kino recorded *Haliotis* shell among the Yuma and Cocomaricopa, who reported that they acquired the shell over trade routes linking them with the Pacific Coast (Di Peso 1956). The marine shell from Early Agricultural period villages may indicate that the people of the Tucson Basin also participated in these, or similar, exchange systems (Vokes 2001c). Several other artifact types were recovered at the large Early Agricultural period sites in the Tucson Basin but were not found in the Luke Solar project area, including pendants cut from unidentified nacreous shell, as well as *Laevicardium*, *Acmaea*, and *Sonorella* (Vokes 2005).

Not surprisingly, shell artifacts are less abundant at smaller sites. The shell artifact collection from El Taller is relatively scanty (Vokes 2007). This multicomponent site, located on the middle Santa Cruz floodplain in Tucson, produced only one shell artifact: an *Olivella dama* bead recovered from an early San Pedro–aged pit. An additional 11 shells and shell fragments from San Pedro phase contexts were identified as *Helisoma*, a freshwater snail.

The quantities of shell ornaments increased over time in sites in the Queen Valley–Queen Creek portion of the U.S. 60 project (Griffitts 2011a), with a single specimen dated to the Cienega phase, more dated to the Red Mountain phase, and the greatest number dated to the Sacaton phase. Artifacts of *Olivella fletcherae* may also be associated with later time periods in southern Arizona, especially the Classic period (Arthur Vokes, personal communication 2013). A few shell beads were found during the U.S. 60 project, including spire-lopped beads found in Red Mountain phase and indeterminate prehistoric contexts at Finch Camp. Four *Olivella* barrel-shaped beads and one spire-lopped bead were also found in the fill and floor fill of a Sacaton phase structure at Carbonate Copy, another site excavated during the U.S. 60 project (Griffitts 2011a). Shell beads also were recovered from Santa Cruz and Sacaton phase contexts at Snaketown (Gladwin et al. 1965).

The popularity of various types of shell artifacts waxed and waned over time in southern Arizona. Although *Olivella* spire-lopped beads are found in Late Archaic/Early Agricultural period contexts, other artifact types are often more numerous. Simple spire-lopped *Olivella* beads, such as those recovered at Falcon Landing, made up 18 percent of the shell from San Pedro phase contexts in combined collections from Desert Archaeology and SWCA excavations at Las Capas (Vokes 2005), and a spire-lopped *O. dama* bead was the only shell artifact recovered from the San Pedro phase at the El Taller site (Vokes 2007:152). *Olivella* whole-shell beads were found in Cienega phase contexts at the Stone Pipe and Santa Cruz Bend sites along the middle Santa Cruz River in Tucson (Vokes 1998). But, despite their presence during the Late Archaic/Early Agricultural period, *Olivella* spire-lopped beads by themselves are not time diagnostic in the Tucson Basin. They appear early, but are present in varying proportions into the Classic period (Vokes 2001). *Olivella* barrel beads are more commonly associated with later times, in particular the middle Sedentary through Classic periods (Vokes 2001; personal communication 2013). However, fewer whole-shell beads have been found in southern Arizona sites outside of the large sites in the Tucson Basin floodplain (Vokes 2005).

Olivella beads are common outside of southern Arizona as well. R. Nelson (1991:58–59) reviewed shell collections from 123 sites in his study of Hohokam marine shell. *Olivella* beads were recovered from between 77 and 92 sites in the U.S. Southwest and northern Mexico. Although he focused on Hohokam sites, Nelson found *Olivella* beads from Basketmaker II to Pueblo IV contexts across the Colorado Plateau. In southern Arizona, he noted Hohokam use of *Olivella* started during the Vahki phase and persisted into the Civano phase but that barrel beads were only recovered from Santa Cruz phase and later contexts. Barrel beads were found in 11 sites, and nearly all were found in mortuary contexts. In the middle Santa Cruz River valley, and possibly near Gila Bend, the greatest numbers were recovered from Classic period contexts. Spire-lopped beads were found at more sites than barrel beads, but there were about four times as many barrel beads as spire-lopped. In contrast to the barrel beads, less than half of the spire-lopped beads were found in mortuary contexts. Nelson's comprehensive study, though, focused on sites dating to the Pioneer period or later and, moreover, was conducted before many Late Archaic/Early Agricultural and Middle Archaic sites were excavated. Artifacts made from *O. fletcherae* are uncommon in the Luke Solar project area, and Vokes (2001a:355) noted that the 15 shell beads found in the Tonto Creek Archaeological Project excavations marked the first identification of this species in the U.S. Southwest. *Olivella fletcherae* artifacts were identified in Sedentary and Classic period contexts by the Tonto Creek Archaeological Project, and at least one *O. fletcherae* shell was found among the beads in a Classic period inhumation (Clark et al. 1998; Vokes 2001a).

The *Olivella* and indeterminate nacreous shell from Falcon Landing were consistent with shell from the Early Agricultural period sites along the middle Santa Cruz River, although *O. fletcherae* was an unusual species for this time. The few barrel beads from Falcon Landing were also uncommon, although not unknown, during earlier periods. The Cienega phase date of the single *Glycymeris* specimen from Falcon Landing was in line with previous observations from the Tucson Basin, where this taxon was more common during the Cienega than San Pedro phase.

The *Glycymeris* shell fragment from Falcon Landing may indicate participation in the trade routes that extended inland from the Pacific Coast (Vokes 2005). The fragments of nacreous shell could represent marine taxa, but they could also have been more locally available *Anodonta*. If it represents the latter, the mobile residents of these sites may have harvested the shellfish for food and raw materials from the nearby Agua Fria River or other appropriate waterways. Alternatively, such freshwater shell could have been acquired by trade. If these nacreous shell fragments represent marine taxa, any meat, unless dried, would have had to have been consumed long before the shells reached the Phoenix Basin. In Historical period times, the Tohono O'odham and Akimel O'odham travelled to the Gulf of California for salt and shell (Vokes 1998), and it is possible that some of the Middle Archaic period occupants of Falcon Landing also made their way to the Gulf of California, or the shell may represent participation in a regional exchange network. Whatever the means of shell transportation, the marine shell recovered from the Luke Solar project area is evidence of some sort of contact between the people of the Sonoran Desert and the Gulf of California or Pacific Coast. Even the single bead from Middle Archaic period contexts indicates some connection with the Gulf of California, although whether that connection occurred as person-to-person contact, personal pilgrimages or other journeys to the ocean, or through trade is unknown.

Bone Artifacts

Bone artifacts from the Middle Archaic period tend to be few and fragmentary, and consequently, use of bone tools during this period is poorly documented. When found, collections of bone tools are generally composed of a few awl fragments, bead/tubes, and an occasional tip of an antler flaker. During the present project, 12 bone artifacts were recovered (Figure 80; Table 49), although only a few could be securely dated. Bone artifacts were found only at Falcon Landing and included both utilitarian and nonutilitarian artifacts. Use-wear analysis was conducted on a few specimens using high-power optical microscopy with an Olympus OHM-J metallurgical microscope, but most pieces were too covered with carbonate or otherwise damaged for use-wear analysis to be productive. In those cases where use-wear analysis could be conducted, patterns seen were compared with those on a reference collection of approximately 200 specimens with replicated wear patterns and a few ethnographic specimens (for further details, see Griffitts 2006, 2011a).

Beads

Two fragments of tubular bead were recovered, both from poorly dated contexts. Although both were recovered from extramural thermal pits, Features 3109 (920 cal B.C.–cal A.D. 1520) and 18177 (A.D. 610–1220), neither was burned. Both were lightly polished. Both were made from mammal bone, but neither could be identified to taxon beyond the general size class of squirrel-sized and rabbit-sized mammal (see Table 49). One, from Feature 18177, was split lengthwise, but retained both ends, showing that it was originally a short wide bead (see Figure 80a). Both ends were beveled and seem to have been ground and rounded, although a light, patchy covering of carbonate limited visibility. The other bead was more fragmentary (see Figure 80b). The remaining end, too, was beveled, but the edge was sharper and retained the shape left by cutting using the groove-and-snap process. Other beads or small artifacts and fragments may have been present but were invisible under the heavy layer of carbonate that coated many bones.

Utilitarian Artifacts

Utilitarian artifacts included three awl tips made from artiodactyl long bones. Two were covered with carbonate to the extent that use-wear analysis was impossible. Two had sharp tips and round cross sections. One was found in Cochise contexts in activity area Feature 10599 (2570–790 cal B.C.), and another was from a nonfeature context dating to the Cienega phase (720–200 cal B.C.) (see Figure 80c, d). The third awl tip, more fragmentary than the others, was from Feature 4625, a poorly dated FAR concentration (cal A.D. 1220–1520). This piece was split longitudinally so the original cross section could not be determined. It was unburned and lacked the heavy carbonate that covered the others, so it was possible to examine it for microwear. Use wear was visible at 100× and included fine, long, longitudinal (that is, oriented along the long axis of the tool) striations in a light polish. The appearance was somewhat like that formed through contact with softer materials such as leather or hide (see Griffitts [2006] for discussion of levels of magnification and identifiability of manufacturing and use traces). Unfortunately, the exact uses of the two more-complete pieces could not be determined because they were covered with carbonate.

A probable flaker made of antler tine was recovered from a charcoal or ash lens (Feature 19503, 2400 cal B.C.–A.D. 610) (see Figure 80e). This poorly dated piece was unburned but deteriorated, with rodent gnawing crossing the remaining battered and polished cancellous surfaces above the tip. The tip itself

Figure 80. Bone and antler artifacts from Falcon Landing: (*a*) bead fragment (Catalog No. 04001016C) from Feature 18177, (*b*) bead fragment (Catalog No. 04000CFD9) from Feature 3109, (*c*) awl tip (Catalog No. 04000F244) from Feature 10599, (*d*) awl tip (Catalog No. 04000C4AB) PD 5346, (*e*) probable flaker (Catalog No. 04000FABA) from Feature 19503, (*f*) tool handle and shaft (Catalog No. 04000EB54) from Feature 12294, and (*g*) possibly polished bone fragment (Catalog No. 04000C5FA) from Feature 5509.

Table 49. Bone and Antler Artifacts from the Luke Solar Project

Location			Feature Type	Period or Phase	Names and Element			Artifact		Measurements			Tip Measurement (5 mm from tip)		Notes
Feature/ Subfeature	Provenience	Level			Scientific Name	Common Name	Element	Bone Artifact Type	Bone Artifact Portion	Length (mm)	Width (mm)	Thickness (mm)	Tip Width (mm)	Tip Thickness (mm)	
	2020				Artiodactyla (deer size)	deer-sized, even-toed, hoofed mammal	metatarsal	indeterminate	fragment	29.7	6.5	9.0			Cut/sawn on one edge; could be shaft/handle or manufacturing debris.
	2399				*Odocoileus*	mule- or white-tailed deer	metapodial condyle	handle	base only	25.4	18.9	16.3			Light grinding on edges.
	5346	1		Cienega	Mammalia (deer size)	deer-sized mammal	undiagnosed	awl	tip fragment	17.8	5.7	5.9	3.6	3.6	Covered with carbonate, tapered point, round cross section.
Feature 1244/ Subfeature 5509	5510	1	bell-shaped non-thermal pit	late Chiricahua	Mammalia (deer size)	deer-sized mammal	long bone	indeterminate	fragment	53.4	14.7	2.5			Polish on high points across cortical side, additive "polish" on cancellous side; possible tool.
3109	8616	1	thermal pit	poorly dated	Mammalia/Aves (squirrel-size)	squirrel-sized mammal	long bone	bead	fragment	10.5	2.3	5.9			Very thin walled, polished, one end is beveled, carbonate present; 2 pieces fit together,
4625	6869	1	FAR concentration	poorly dated	Mammalia (deer size)	deer-sized mammal	long bone	awl	tip fragment	18.3	3.8	2.6			Fine longitudinal grinding on one side, split longitudinally, light carbonate deposits, use wear includes fine, closely packed longitudinal striations visible at 100×; possibly used with a soft material.
10599	16913	1	activity surface	Cochise[a]	Mammalia (deer size)	deer-sized mammal	long bone	awl	tip fragment	33.2	6.4	5.9	2.6	2.6	Awl tip, fine point, tapered tip, round cross section, covered with carbonate; exact measurements not possible.
12294	16220	1	thermal pit	poorly dated	Mammalia (deer size)	deer-sized mammal	long bone	handle/shaft	medial only	81.9	7.4	10.8			Groove and snap along one side, too much carbonate to see other manufacturing traces, shaft/ handle, tapers slightly to broken end; likely awl or narrow spatulate tool.
18177	20982	1	thermal pit	poorly dated	Mammalia (rabbit size)	rabbit-sized mammal	long bone	bead	fragment	10.1	7.2	3.6			Short tubular bead, split in half longitudinally but both ends present.
18203	20806	1	nonthermal pit	poorly dated	Mammalia (deer size)	deer-sized mammal	long bone	indeterminate	fragment	13.5	4.3	2.6			Fragment is burned and shiny but retains a few longitudinal grinding marks.
18880	18873	3	nonthermal pit	Cochise	Mammalia (deer size)	deer-sized mammal	long bone	indeterminate, possible awl	fragment	12.3	2	1.8			Grinding patches, one area of longitudinal striations and polish visible at 100×, carbonate present in patches.
19503	19522	1	charcoal/ash lens	poorly dated	Cervidae (deer size)	deer family	antler	flaking tool	tip	21.3	4.8	7.8	4.8	4.2	Probable flaker tip, rodent gnawing present, more or less round cross section.

Key: FAR = fire-affected rock

[a] Archaic-aged material that could not be assigned to a specific phase was classified as Cochise.

was largely undamaged, as were a few patches above the tip. When viewed under magnification, the tip was gouged, with large, wide, shallow, sharp-edge striations running irregularly longitudinally and diagonally, and with flat-edge gouges at the end of the tip similar to those produced by flaking. Deer use their antlers for a variety of tasks and can create battered, broken ends as well (Olsen 1989), but the pattern seen on the archaeological specimen strongly suggested pressure flaking. The piece was too small and damaged for a definitive interpretation, so the identification remains tentative.

A few other fragmentary artifacts were recovered. One was probably an awl handle and shaft, or perhaps the handle/shaft of a very narrow spatulate tool (see Figure 80f). Although other studies have shown that the shafts of many awls received some use, the carbonate covering this piece precluded use-wear examination. A second fragment was too small to identify the original shape but it retained slight lipping from groove-and-snap cutting along one side and a few longitudinal grinding traces. This piece was recovered from an undated nonfeature context. An artiodactyl metapodial condyle, also from an undated nonfeature context, was slightly ground on one edge and was probably the handle end of a tool. Two more pieces had to be scrutinized closely to identify that they had been shaped. A small burned fragment from Feature 18203 (a poorly dated nonthermal pit, 2400 cal B.C.–cal A.D. 610) was identified as a probable artifact, retaining very faint grinding traces along one side. Another fragment had a few small patches of grinding that were visible between areas of carbonate and one polished area with longitudinal striations visible at 100×. This piece may have been a fragment of an awl tip and was recovered from Feature 18880, which produced a 2σ calibrated age range of 1260–1040 cal B.C. It was associated with more than 200 shell beads.

Finally, an intriguing but ultimately baffling specimen was recovered from Subfeature 5509, a bell-shaped intramural pit from a late Chiricahua phase structure (Feature 1244) that produced a 2σ calibrated age range of 1390–1210 cal B.C. (see Figure 80g). This specimen consisted of a flat-sided, broken section of long bone, possibly a tibia, with what appeared to be "polish" on high points of the cortical surface, edges, and over much of the cancellous surface. No definite cutting, grinding, or other signs of manufacture were visible. The polish differed in appearance under magnification. In some areas, it appeared to be much like heavy use wear, with striations running transverse in some areas, in particular near the wider end, and longitudinally in others. But, over much of the object, the polish consisted of a thick, shiny additive substance. The additive quality of this polish was apparent under magnification where it could be seen to fill in cracks in the bone. The coating was noted also during excavation. Longitudinal and diagonal striations appeared on top of the additive polish. Heavy additive coatings were produced experimentally during tasks involving juicy silica-rich plants, such as husking fresh corn and then leaving the tools to dry without washing. Under magnification, this bone surface was similar to such coatings. It could be that the site's residents used this bone for some task involving juicy plants or plant sap. But, it is unknown whether such deposits would have preserved through centuries underground. It is unlikely to represent a gaming piece, based on the lack of manufacturing marks. No effort was made to scrub away the coating in the field, and in fact, it was wrapped in cotton and placed in a vial for protection. The bone was stained on the cortical side and the two ends, although more heavily stained on the narrower, beveled end. This could have been an artifact, or it is possible that some unknown noncultural formation process deposited the coating on the bone. At this time, the identification remains unknown. No other faunal bones were recovered from this feature.

Archaic Period Bone Artifacts

The use of bone tools during the Middle Archaic period is poorly understood. As noted above, evidence of bone technology has been found only rarely, and when found, the collections tend to be small and fragmentary. Unfortunately, during the present project, only one artifact, an indeterminate tool fragment with a strange additive polish could be securely dated to the Chiricahua phase, although most of the other bone artifacts fell into time ranges that included both the Middle and Late Archaic. A few bone tools have been found in the Tucson Basin, and seven bone tools were recovered from the Middle Archaic components at Los Pozos (Gregory et al. 1999), including three indeterminate fragments, two tool midsections, an awl tip, and a possible antler flaker. A few bone artifacts were also found in Middle Archaic contexts at Las Capas

(Chapin-Pyritz 2007:311), including one awl and one indeterminate bone artifact recovered from Middle Preceramic contexts, and another awl found in Middle Preceramic/early San Pedro deposits.

Even less is known about the use of bone tools during the Archaic period in the Phoenix Basin. Excavations at the Archaic sites nearest to the Luke Solar project area have generally produced fewer bone artifacts than the larger excavations at the Early Agricultural period sites along the middle Santa Cruz River in the Tucson Basin. No bone artifacts were reported in the highly fragmented bone from the Middle and Late Archaic period and Red Mountain phase deposits of the Last Ditch site (Hunter 1998; Phillips et al. 2001; Rogge 2009). The Last Ditch site is interpreted as a plant-processing camp located on the lower *bajada* of Paradise Valley in the Phoenix Basin. Nor were bone artifacts reported at site AZ T:4:122 (ASM) (Potter 2000; Potter and Fox 2000), located on Deadman Wash about 19 km (12 miles) north of Glendale, Arizona. This site contained Archaic/Red Mountain phase and Hohokam components. As with Falcon Landing, ground stone artifacts were common, and the site is interpreted as a campsite where people procured and processed plant resources. Site AZ T:11:94 (ASM), located near the confluence of the Salt and Gila Rivers in the Phoenix Basin, contained Early Archaic period and Hohokam components, and it is also interpreted as a locale for collecting and processing plant foods. A few faunal bones and three *Glycymeris* shells were found, but no bone artifacts were recovered (Graves et al. 2009; Graves et al. 2011). Nor were any bone artifacts recovered in the Archaic/Red Mountain phase contexts excavated at the Phoenix Convention Center/Pueblo Patricio (Hackbarth 2010).

Archaic contexts examined in the Picacho Reservoir Archaic Project produced a few artifacts, including two possible awl fragments from the Buried Dune site, a drilled jackrabbit calcaneus from the Arroyo site, and an awl tip from AA:3:1 (Bayham 1986b). No bone artifacts were reported from several Archaic sites in the Harquahala Valley investigated in the 1980s (Bostwick and Hatch 1988). Further to the south, three awl fragments and an unidentified cut and polished bone were recovered at the Fairchild site (Windmiller 1973), a transitional Chiricahua–San Pedro campsite in the Sulphur Spring Valley.

Bone artifacts have been encountered more frequently in the larger Late Archaic/Early Agricultural period sites along the middle Santa Cruz River in Tucson, where literally hundreds of artifacts were recovered. Awls and beads remain among the most frequently identified, although the proportions of beads to awls and other artifacts vary considerably from site to site. Beads, tubes, and manufacturing debris made up only 4 percent of the 291 bone artifacts from the Late Cienega phase at Los Pozos, compared to 106 awls and awl tips (36 percent). Tubular beads made up 10 percent (n = 18) of the 190 bone artifacts from San Pedro phase contexts at Las Capas compared to 73 awls or awl tips (38 percent) (Griffitts and Waters 2005; Waters 2005b), but the proportion of beads rises to 14 percent when 10 disk beads are included. Other major artifact types from these sites include spatulate tools (found largely but not exclusively in Los Pozos), bone and tortoise-shell disks, edge-used tools, socket handles, and enigmatic balls made from femur heads.

Beads, tubes, and bead/tube manufacturing debris made up 20 percent of all bone and antler artifacts from early San Pedro phase contexts at Las Capas in SWCA's excavations (Chapin-Pyritz 2007). In all, SWCA recovered 84 bone and antler artifacts associated with the early San Pedro phase component, including 17 awls, 2 spatulas and a possible third spatula, 3 possible scrapers, 2 possible chisels, 37 antler tools, 10 beads and fragments, 1 tube, 6 pieces of bead stock or manufacturing debris, 1 shaped animal tooth, and 4 unknown. Awls made up 19 percent of the early San Pedro phase bone and antler artifacts, and the combined category of beads, tubes, and bead/tube manufacturing debris contributed another 19 percent. Forty-one percent of the collection was antler artifacts. Eleven of the antler artifacts were shaped into possible spatulate tools, and the others were unidentified.

Three beads and 4 tubes were recovered from Cienega phase contexts at the Santa Cruz Bend site, making up 10 percent of the total worked antler and bone artifacts, which included 39 pointed tools, 2 spatulas, a rasp, 2 socket handles, 14 indeterminate-shaped bones, and 4 shaped antlers (Mabry, ed. 1998a; Thiel 1998). The faunal collection at Stone Pipe, dating to the Cienega/Agua Caliente phases, was smaller, with only 24 artifacts, including only 1 tube, but 10 pointed tools, and 13 indeterminate pieces (Thiel 1998). In contrast, Late Archaic period contexts at Coffee Camp yielded 14 artifacts, including 5 tubes, a tube blank, 2 awl fragments, and a shaped deer antler fragment (James 1993), reversing the previous pattern with 43 percent tubes compared to 11 percent awls. Tubular beads outnumbered other artifacts at El Taller, where tubular beads and manufacturing debris greatly outnumbered awl fragments in San Pedro phase deposits (Dean 2007a). One awl fragment was recovered from Middle Archaic period contexts at El Taller (Dean 2007a), and this single artifact made up the extent of the Middle Archaic period bone artifacts from this site. Two more awls were found in early San Pedro phase contexts at El Taller, which contained a total of 2 awls, 1 bell-shaped bead or pipe bowl, 9 beads or bead fragments, and a piece of bead-manufacturing debris.

In the U.S. 60 project, archaeologists recovered small bone and antler artifact collections from Cienega and Red Mountain phase contexts. Eighteen bone artifacts were recovered from Late Cienega phase features at Finch Camp (Griffitts 2011a), including eight awls or awl fragments, one tube, and one tube notched on the side to produce a whistle. Other objects included two spatulate tools, an edge-used tool, and broken handles and shafts. Six more artifacts from Late Cienega to Red Mountain phase contexts included two additional awls but no beads or tubes. Red Mountain phase contexts at Finch Camp produced 17 artifacts, including 5 awls and 2 tubes, and Red Mountain phase contexts at Bighorn Wash included a single awl, two spatulate tools, and two handle and shaft fragments.

Although small collections of bone artifacts often tend to have similar composition—a few awls, beads, a flaker, some indeterminate bone—larger collections indicate that the tools were far from standardized. In larger collections, we find awls, beads, and flakers, but other objects as well. Some are unique to particular sites or components, e.g., the balls made from femoral heads that were recovered at Los Pozos; others are found across sites but are less common. The differences in artifact types between sites or components suggest some variation in importance. As noted above, the Early Agricultural period component at Los Pozos contained dozens (n = 40) of balls made from femoral heads, enigmatic objects produced by removing the heads from artiodactyl femora and carefully grinding them into round balls, but none were recovered in the earlier Middle Archaic period contexts at this site, and only one was found in late San Pedro phase contexts at Las Capas. Antler artifacts take the lead in the early San Pedro phase component excavated by SWCA at Las Capas, but they were much less important in the earlier excavations by Desert Archaeology, which included some early San Pedro phase, but a higher proportion of late San Pedro phase contexts (Griffitts and Waters 2005). Chisel-ended tools, many of which retained wear suggesting woodworking, were more common in Los Pozos than at Las Capas.

Bone artifacts were uncommon at Falcon Landing, but given the amount of bone that was recovered, it seems unlikely that the paucity of bone artifacts was entirely caused by lack of preservation. Artiodactyls often make up only a very small fraction of Middle Archaic period faunal collections, and perhaps the paucity of bone tools may in part be related to the availability of raw material. Bones of larger taxa are needed for certain tools, and if the raw material was not available, then the Middle Archaic people may have chosen other materials for their awls, beads, and scrapers. Haury (1976) suggested that the Hohokam may have relied on desert hardwoods for their awls, and these may well have been an adequate substitute for the rarer artiodactyl bone for at least some tasks. Additionally, the artifacts left behind in a temporary habitation may not be a representative sample of the technology in use by the people. They may represent only those objects broken, lost, worn out, or otherwise discarded during the period of occupation. Ethnographic studies indicate that some bone tools could be curated for years, or even decades (Hiller 1948; Steinbring 1966). If good raw materials were in short supply, then tools could be curated and carried from place to place over time, leaving only those pieces broken beyond repair. In special-use sites, the women and men performing their particular tasks may not have had the need to use every piece in their tool kits. For example, at sites that people customarily revisited yearly to process quantities of mesquite beans, they may have only rarely needed their equipment to process hides, and so these tools would have been less likely to wear out or break than those that they used every day. In short-term habitation sites, there may have been less opportunity for tools to break and be left behind than at a longer-term occupation, and artifacts left behind may not indicate the importance of particular technologies in everyday life.

Isolated Canid Skull

One isolated cranium from an immature canid was recovered in a nonfeature context at Falcon Landing during mechanical stripping. The mandible was absent, and no postcranial remains were found with or near the skull. The skull was hit by the backhoe, and given the fragmentation and the young age of the animal, it was not possible to confidently identify at the species level. The first permanent molar was in the process of erupting, the fourth premolar was visible beneath the deciduous premolar, and deciduous canine roots were resorbing. If this individual represented a domestic dog, it would have been aged around 5 months old, or a little less, based on tooth eruption ages (Hillson 2005). Coyote teeth appear to erupt on a similar, or slightly earlier eruption schedule (La Croix et al. 2011). This skull was compared to a 6-month-old coyote skull at the ASM zooarchaeological collection and it had a shorter, wider face than the coyote, as one would expect with a domestic dog. Although it looked somewhat more like a dog than a coyote, no definitive determination was possible and it was classified as an indeterminate canid. If this cranium represents a cultural event, it may be an early example of a burial of a canid skull, similar to those noted in later periods; however, it was found in a nonfeature location. The skull most likely originated from Stratum IIA (2870–2400 cal B.C.), dating it to the Chiricahua phase.

This skull is of particular interest because canid burials and isolated canid skulls have been found occasionally in Late Archaic/Early Agricultural period and later sites (Waters 2005a), and it is not clear when such practices began in southern Arizona. Some burials and crania have been recovered in what seem to be special contexts and may represent ritual deposits, other individuals may represent pets or companions, and some may simply reflect carcass disposal in trash pits or middens. An adult dog cranium was found in a pit in San Pedro phase contexts at the Costello-King site (AZ AA:12:503 [ASM]) (Ezzo and Stiner 2000; Waters 2005a). Isolated canid skulls were also recovered at Las Capas. Two skulls from Las Capas were found in an extramural pit, and two others from nonfeature locations, as was this canid from the present project. The four Las Capas skulls were fragmentary and could not be firmly identified to species (Waters 2005a). Dog or canid burials have been reported in Cienega phase contexts at Santa Cruz Bend (AZ AA:12:746 [ASM]) and the Donaldson site (AZ EE:2:30 [ASM]), and in Early Ceramic contexts at Houghton Road (Cairns and Ciolek-Torello 1998:175–179). Two possible canid burials were identified at Finch Camp. One was found in indeterminate Cienega/Red Mountain phase contexts, and the other was assigned to the Red Mountain phase (Griffitts 2011). The context of the Falcon Landing skull is unclear. It was not located near any structure or other features, and it could not be determined if it represented a special deposit, a skull that was discarded by humans, or simply a young canid that died naturally and was disarticulated and buried by noncultural processes.

Vertebrate Fauna from Site 68

Vertebrate faunal remains were dominated by mammal bones, although amphibian, reptile, and bird bones were also present. The bones represented at least 12 orders and 19 identified genera (see Tables 46 and 47; Appendix 4.1).

Thirty-three pieces of bone and 3 land-snail shells or shell fragments from Site 68 were analyzed. Vertebrate fauna consisted mostly of small taxa, but a few larger species were identified. Analyzed bone was fragmentary, with only one piece measuring more than 15 mm in maximum dimension, and 13 of the 36 faunal specimens measured less than 5 mm. Equal numbers were recovered from Cochise and pre-Classic contexts, with a few pieces dating to the general Late Archaic to Protohistoric period, and a single piece from undated contexts.

One feature contained 14 specimens, all others contained 8 or fewer. The largest feature, a Snaketown phase house-in-pit (Feature 13), and one of its postholes (Subfeature 240) contained the most diverse faunal collection on this site. Faunal specimens from these two features included a few specimens each of rattlesnake and unidentified snake bone, mouse- and squirrel-sized rodent, rabbit-sized mammal bone, and a small splinter of the only bone from a deer-sized mammal identified at Site 68. Another fragment represented an alveolus of a probable canid. This last individual was the size of a small coyote or dog. Six pieces of bone were burned, including one snake bone, four of the five bones from squirrel-sized taxa, and one of the bones from mouse-sized rodents. However, the burning may not reflect human action. A large root burn intruded into this structure and some rodents and snakes may well have been caught in their burrows when the root burned.

The fauna from other features was far less diverse, but the lack of diversity was doubtless related to their small numbers. Most had only one or two specimens. Feature 88, a house-in-pit that dated to a calibrated 2σ date range of 1380–920 cal B.C., had the second highest bone count with eight specimens that represented nonpoisonous snake, coyote-sized and rabbit-sized mammals, and squirrel; five of the eight specimens represented rabbit-sized mammals. The only other feature with more than two bones (aside from Feature 106, see below), was nonthermal pit Feature 206, with one bone from a rabbit-sized mammal and four from mouse-sized mammals. Feature 206 could only be geologically dated to 920 cal B.C.–cal A.D. 1520.

Several hundred pieces of highly fragmented, charred or calcined, small-to-medium-sized mammal bone were found associated with Feature 106, a secondary human cremation (see Chapter 8, this volume). Examination of this feature's stratigraphic position indicates that this feature and these associated faunal remains dated to 1380–920 cal B.C.

Vertebrate Fauna from Site 423

The faunal collection from Site 423 (see Tables 46 and 47; Appendix 4.1) consisted of a single fragmentary vertebra from an indeterminate snake. Although this bone was recovered from Feature 111, a bell-shaped nonthermal pit geologically dated broadly to the Early to Late Archaic period, the bone was pale in color, suggesting that it may have belonged to a recent, intrusive individual. The bone was slightly eroded all over and may have passed through the digestive tract of some other animal.

Vertebrate Fauna from Site 437

Excavators at Site 437 recovered five fragmentary long bones of rabbit-sized mammals from Feature 10307, a thermal pit dating to the Sulphur Spring phase that produced a 2σ calibrated date range of 7040–6690 cal B.C. (see Tables 46 and 47; Appendix 4.1). These five pieces represent the entire Early Archaic period faunal collection from the Luke Solar project, although some specimens from Falcon Landing date to more-general periods such as the Early to Middle Archaic or Early to Late Archaic period. All of the Site 437 specimens were unburned and displayed recent breaks, and the largest piece was stained by minerals and covered with carbonate. The five pieces were all from the same-sized element and may have been part of the same bone, but none of the pieces could be refit.

Vertebrate Fauna from Falcon Landing

The collection from Falcon Landing included 4,690 analyzed specimens, including bone and shell artifacts (see Tables 46 and 47; Appendix 4.1). Of these, 284 were mollusk shell and shell fragments, and most of these shells were found in one feature. Most of the bone represented mammalian taxa, but amphibian, reptile, and bird bones were also present. More than a third of the specimens were recovered from a single Historical period feature, and the remainder came from prehistoric and undated contexts.

Historical Period Fauna

Among the thousands of features dating to the Archaic period, Red Mountain phase, pre-Classic, Classic and Protohistoric periods at Falcon Landing, there were only two Historical period features: Feature 3767, a thermal pit, and Feature 1664, a nonthermal pit (Table 50). The contents of these two pits varied considerably from one another in abundance and type of taxa and appear to represent very different human behaviors. Feature 3767 could be dated only to post-1700, whereas Feature 1664 dated to the early twentieth century.

Table 50. Number of Faunal Specimens from Early-Twentieth-Century Feature 1664, Falcon Landing, by Taxon and Body-Size Class

Scientific Name	Body Size Class	Common Name	n	Percent	Comments
		Amphibia			
Anura (small)	small	frogs or toads	14	0.8	
Anura (medium sized)	medium	frogs or toads	4	0.2	
		Reptilia/Amphibia			
Reptilia/Amphibia	small	reptiles or amphibians	2	0.1	
		Reptilia			
Crotalus	small	rattlesnakes	10	0.5	
Colubridae	small	nonvenomous snakes	6	0.3	
Serpentes	small	snakes	8	0.4	
Squamata	small	lizards	3	0.2	
Crotaphytus	medium	collared lizards	1	0.1	
Viperidae	medium	venomous snakes	2	0.1	
Serpentes	medium	snakes	1	0.1	
Squamata	medium	lizards	3	0.2	
Testudines	indeterminate	tortoises, turtles	2	0.1	
		Aves			
Callipepla	small	crested quails	2	0.1	
Sphyrapicus	small	sapsuckers	1	0.1	cf. sapsucker or small woodpecker
Turdus	small	robins	1	0.1	
Accipitridae	medium	hawks, eagles, kites	3	0.2	all from raptor the size of western marsh harrier
Aves (small)	small	birds (songbird sized)	11	0.6	
Aves (medium sized)	medium	birds (chicken sized)	15	0.8	
Aves	indeterminate	birds	12	0.7	
		Mammalia/Aves			
Mammalia/Aves (medium sized)	medium	bird or mammal (rabbit sized)	12	0.7	
Mammalia/Aves (small)	small	bird or mammal (squirrel or songbird sized)	15	0.8	
		Mammalia			
Ammospermophilus	very small	antelope ground squirrels	1	0.1	
Dipodomys	very small	kangaroo rat	12	0.7	
Perognathus	very small	pocket mouse	12	0.7	

continued on next page

Scientific Name	Body Size Class	Common Name	n	Percent	Comments
Peromyscus	very small	white-footed or deer mice	2	0.1	
Muridae	very small	rats and mice	3	0.2	
Rodentia	very small	rodents (mouse sized)	16	0.9	
Mammalia	very small	mammals (mouse sized)	34	1.9	
Neotoma	small	wood rats	16	0.9	
Sigmodon	small	cotton rats	5	0.3	
Sylvilagus	small	very small cottontails	14	0.8	
Thomomys	small	pocket gophers	1	0.1	
Sciuridae	small	squirrels	1	0.1	
Rodentia	small	rodents (squirrel sized)	9	0.5	
Mammalia	small	mammals (squirrel sized)	192	10.5	
Lepus alleni	medium	antelope jackrabbits	1	0.1	
Lepus californicus	medium	black-tailed jackrabbits	8	0.4	
Lepus	medium	jackrabbits	101	5.5	
Sylvilagus	medium	cottontails	88	4.8	
Leporidae	medium	rabbits and hares	33	1.8	
Mammalia	medium	mammals (rabbit sized)	319	17.5	
Vertebrata	medium	vertebrates (rabbit sized)	17	0.9	
Canis	large	dogs, coyotes, wolves	3	0.2	dog or coyote sized
Canidae	large	canids	1	0.1	
Mammalia	large	mammals (coyote sized)	2	0.1	
Ovis/Capra	very large	sheep/goats	2	0.1	
Mammalia	very large	mammals (sheep sized)	11	0.6	
Artiodactyla	extra large	mammals (cow sized, even-toed hoofed)	1	0.1	
Vertebrata	indeterminate	vertebrates	793	43.4	
		Gastropoda			
Succinea	indeterminate	amber snails	1	0.1	
Total			1,827	100	

Feature 1664

Feature 1664 was a pit filled with a diverse faunal collection that included mammals, birds, reptiles, and amphibians (see Table 50). Over a thousand pieces of bone were recovered from this pit. Shotgun shells intermixed with the bones provided a well-defined date of deposition for the feature. The 12-gauge shotgun shells from the feature were heavily corroded. Only one headstamp remained partially legible; it read "[WINCHESTER/LEADER]/No 12." The "1901 Leader" was produced by the Winchester Repeating Arms Company beginning in the 1900s and continued in production for many decades. This particular headstamp, however, was produced only until 1920 (Farrar 2005).

A large rodent burrow intruded into the upper portion of the pit, disturbing the fill and displacing some of the bones and shotgun shells to the adjacent Hand Stripping Unit 1666, a unit excavated to help define the extent of the feature. According to the field notes, the tunneling appeared recent and some burrows were still void of fill at the time of excavation. Rodent bone was found in the upper portion of the unit, and bones of larger taxa were located in the lower area. Some of the bones, in particular the nearly complete rodent remains found in the tunneling, likely represent intrusive individuals; others were probably placed in the pit by human intent. Most of the bones in this feature were identified as leporids or from rabbit-sized taxa. The leporid remains represented at least one antelope jackrabbit, at least one black-tailed jackrabbit, four indeterminate jackrabbits, at least six cottontails, and two much smaller cottontails.

The bones in this feature were well preserved and many were intact. None were burned. All body regions for leporids and rabbit-sized mammals were represented, from head to tail, or crania to caudal vertebrae, and even tiny sesamoids and patellae were present. Articulated portions were noted during excavation, and such completeness suggests that many carcasses were interred without extensive processing. There may have been slight differences in element representation between the two leporid genera. The two genera did not have quite the same representation of body parts. Six percent of all jackrabbit bones were identified as belonging to the lower front limb, but 26 percent of the cottontail bones were from this region. This may reflect preservation issues, if articulated cottontails happened to be in the area removed by mechanical stripping, or the hunters may have selected the parts they preferred (e.g., rabbit's feet) prior to discarding the cottontails.

Other taxa found either in Feature 1664 or in the intrusive rodent burrow included frog or toad, dog or coyote, a hawk the size of a western marsh harrier, quail, possible robin, possible sapsucker or small woodpecker, pocket gopher, wood rat, cotton rat, antelope ground squirrel and bone from a larger but indeterminate squirrel, kangaroo rats, pocket mice, deer or white-footed mice, collared lizard, rattlesnake, nonvenomous snake (Colubridae), turtle or tortoise shell, and eggshell. A tiny *Succinea* land snail was almost certainly intrusive. Squirrel-sized mammals were relatively complete, with bones representing body parts from head to tail, including sesamoids, carpals, tarsals, a patella, and caudal vertebrae. Mouse-sized mammals were similarly represented, but lacked many very tiny bones that would have been easily lost during excavation (e.g., sesamoids, carpals, patellae, and caudal vertebrae). The carcasses of nonmammal taxa were somewhat less complete, but the missing portions may be related to the small size of many of these taxa. The small frog or toad bone that was recovered included femur, humerus, innominate, radio-ulna, scapula, and vertebral fragments; and a larger frog or toad was represented by a hind limb (femur and tibia), right innominate, and long-bone fragments. Only a few elements were present for any of the bird taxa. More than 800 recently broken bone fragments could not be identified even to the level of class and were unidentifiable to element as well. All measured less than 15 mm in maximum dimension, and it is likely that many of the missing elements are visible among these unidentifiable fragments.

Why were the jackrabbit carcasses so complete in this feature? Why were so many leporids killed but not consumed? A look at early-twentieth-century interactions between humans and leporids offers a possible explanation for this feature. Jackrabbit drives are not only a part of Arizona's prehistory. In the late nineteenth into the first third of the twentieth century, periodic localized peaks in leporid populations caused great damage to crops and created competition with cattle for forage. Rabbit drives were organized, with as many participants as possible recruited to drive the animals out of hiding, after which they could be shot or clubbed; hundreds of animals could be taken in a day (Figure 81). A 5-cent bounty for each pair of rabbit ears was paid by the territory in 1905 and by the state in 1912, and similar bounties existed for gophers and prairie dogs (Brown 2008). No cut marks indicating ear removal were seen on leporid crania recovered from Feature 1664, but most skulls were fragmentary.

Large communal rabbit drives were announced in newspapers. For example, a July 1920 headline proclaiming that a "plague of jackrabbits threaten crops" announced a rabbit drive to be held the following Saturday in Casa Grande (*Tucson Citizen*, 8 July 1920). The same newspaper announced another drive in December of the same year (*Tucson Citizen*, 24 December 1920). The article announcing the December drive noted that a drive held in Allendale the previous month (November 14, 1920) included more than 200 people with 150 shotguns and that more than 1,200 rabbits had been taken. Fewer individual animals were killed in a combined coyote-jackrabbit drive held in 1901 in Scottsdale when "a crowd of young men" and "a young lady friend from Phoenix" began the coyote hunt (*Republican Herald* 1901:3). The participants were joined by about 150 residents of the Salt River reservation, and eventually 5 or 6 coyotes and about 100 jackrabbits were killed. Near the project area, in 1906, Ellison Wilcox turned in 715 jackrabbits for bounty and stated that the rabbit colony near Peoria and Glendale continued to increase (Brown 2008: 204).

Cottontails were regarded by some hunters as better meat, and some drive participants donated the jackrabbits to charity while keeping cottontails for their personal consumption (see Figure 81). Other hunters found other uses for their surplus jackrabbits.

Figure 81. A 1930s Salvation Army jackrabbit hunt. Photograph shows the Stone Avenue Church, Tucson, Arizona (photograph courtesy of the Arizona Historical Society, Call No. B29259).

Some enterprising landowners were able to turn a profit by shipping the luckless leporids to West Coast markets (Brown 2008). For example, *The Tucson Citizen* reported on March 29, 1912, that F. J. List of Peoria had sold 2,600 dressed jackrabbit carcasses to the Zeisel Produce Company of Los Angeles, where they were sold to restaurants and served as Belgian hares or made into tamales. List made from $2.50 to 3.00 a dozen for his Arizona jackrabbits and was also able to turn in the ears for the 5-cent bounty from the state for an additional $130 (*Arizona Daily Star* 2013). Northern Arizona landowners shipped jackrabbits to Los Angeles, as well. In January, 1909, Judge O'Toole of Canyon Diablo commented that his region had shipped 38,331 rabbits to Los Angeles thus far that winter (Brown 2008:205). Not all rabbits were consumed in Los Angeles, and not all were eaten by humans. Jackrabbits sold for 10 cents each in Portland in 1916 (Vorhies and Taylor 1933), and some people supplemented their chicken feed with rabbit protein (Los Angeles Times 1920).

We found no records concerning rates of rabbits on this particular property, but jackrabbit predation was said to be very bad in the Casa Grande area in fall 1917 (Brown 2008:206). Pemma filed homestead on the property that year and it is possible that the local jackrabbit populations contributed to his poor crop yields. As indicated by local newspapers, jackrabbits were considered to be a problem in nearby Peoria and Glendale a few years before and after he began to try to work the land. Feature 1664 may reflect a similar hunting episode.

Fluctuations in jackrabbit populations occurred through the late nineteenth and early twentieth centuries, and jackrabbit predation in the Casa Grande area was said to be very bad in the fall of 1917, especially for small farmers whose fields were overrun by hungry jackrabbits (Brown 2008:206). The ranchers' fears of leporids outcompeting their livestock were not unfounded. Studies conducted by the University of Arizona Agricultural Experiment Station observed that 15 antelope jackrabbits ate as much forage as 1 sheep, and 74 consumed the same amount as would 1 cow (Vorhies and Taylor 1933). Moreover, they suggested that rabbits were better able than sheep or cattle to feed on the forage that was available on overgrazed or otherwise poor ranges. These studies also found that jackrabbits were more likely to be a problem in areas already damaged by overgrazing or drought, or areas recovering from damage, because the leporids were more attracted to open weedy areas than to areas with better vegetation and cover (Vorhies and Taylor 1933). The local peak in the fall of 1917 was the year and the season that Teddy Louis Pemma filed his homestead on the property, and it is possible that the soaring local jackrabbit populations contributed to his poor crop yields in subsequent years.

The shells and bones from Feature 1664 could represent local efforts to control booming leporid populations, or it could represent less-organized hunting by one or a few individuals. As noted above, smaller taxa were often taken in communal drives by O'odham (Rea 1998), so it would not be surprising for large rodents such as wood rats and cotton rats to be startled into the open and killed in Euro-American rabbit drives. Unlike the Akimel O'odham drives, the wood rats and cotton rats were not consumed in the Euro-American drives, and it seems that after the hunt, the area was cleaned up and the remains of many hunted animals were buried in a pit.

The dog or coyote bones from this feature probably represented a coyote taken at the same time as the leporids. Coyotes were often considered to be enemies of ranchers, and the State of Arizona paid a $2.00 bounty for each coyote pelt (Brown 2008:397), and as noted above, these canids were also targeted during hunting drives at least occasionally. Vorhies and Taylor (1933:544) report that the supervisor of Crook National Forest, Arizona, noted that jackrabbit populations increased after coyote drives, and at least one rancher recommended that the bounty for coyotes be removed to help reduce rabbit populations (Tucson Citizen 1905). Interestingly, the rancher in question had brought in eight coyote and two wolf skins for bounty and made his comments while the skins were being inspected. Many of the other taxa could easily have been caught in a rabbit hunt or have been targeted as undesirable species, including the snakes and raptors. Wood rats, cotton rats, and antelope ground squirrels would have been large enough to be visible to hunters. The omnivorous little antelope ground squirrel may even have been attracted to the carrion if the pit was left open for any length of time.

Not all of the bone in the feature was necessarily related to hunting. A large burrow began in the upper portion of the pit and ran through the central and southeastern portions, as well as south of the pit. The bone was densest at the base of the pit, the larger bones were found below the burrow, and the smaller rodent bone in the burrow above. Kangaroo rats, white-footed mice, and pocket mice are more likely to be intrusive. Pocket and white-footed mice, especially, are too small to be highly visible to hunters, and unlikely to remain recognizable if hit by a shotgun blast. Kangaroo rats and pocket mice are known to share burrows, and much of the rodent burrowing was clearly intrusive to the filling of the pit. Immature specimens of both species were present and may represent burrow deaths.

The few bones from the sheep/goat and cow-sized artiodactyl categories were a sheep/goat tibia and calcaneus and a distal metapodial of a larger artiodactyl. These lower leg bones likely represent the remains of the hunter's meal, perhaps as a stew or similar concoction, as these cuts are often cooked for extended periods to tenderize the meat. The pit may represent an overnight camp used before Teddy Louis Pemma built his house on the property about 1918, or a day camp used by hunters during his tenure there.

The State Senate passed an act in 1912 regulating and licensing hunting and establishing hunting seasons. Hunters were required to obtain a bird license (costing $10–25) for quail, although during the hunting season (between October 15 and February 1) it was legal to take 25 quail per day (Brown 2008:385–386). If the quail were legally hunted, their presence in Feature 1664 would place the event in the fall; however, the quail recovered from this pit could easily represent animals simply caught up in the hunt. Songbirds were also protected in this legislation and had no hunting season, but hawks were not protected. This feature therefore contained a mix of protected, semiprotected, and unprotected taxa, reflecting the cultural values of the era.

Feature 3767

Feature 3767 dated to post-A.D. 1700. All bones from this thermal pit were unburned. The fauna consisted of 25 fragmentary specimens, all from rabbit-sized mammals, although at least some could have been from a jackrabbit to small-coyote-sized mammal or mammals. Crania, appendicular, and indeterminate cancellous bone were represented, as were fragments of bone unidentifiable to element. All specimens were less than 15 mm in maximum dimension. There were no indications that more than one individual was represented. No commercially manufactured Historical period artifacts were found associated with the fauna, but a core flake and a flake fragment were found with the fauna. In contrast to Feature 1664, the contents of this pit were comparable with many other pits investigated in the LAFB that contained fragmented bone from rabbit-sized taxa and probably represented food remains discarded in a hearth.

Fauna from Prehistoric, Protohistoric, and Undated Contexts

The following discussion focuses on the material from Falcon Landing found outside of the Historical period features described above. Faunal bone was recovered from contexts ranging from the Early Archaic to the Protohistoric periods, but most was assigned to the Middle or Late Archaic periods, and this discussion therefore focuses most heavily on the Archaic period fauna. Additional bone could only be dated to more-general time ranges.

Archaic Period Fauna

Most of the faunal bone (71 percent) outside of the Historical period features was recovered from Archaic period contexts, which included the Chiricahua phase and San Pedro and Cienega phases, as well as contexts dated to more-general Early to Middle, Early to Late, and Middle to Late Archaic periods. These latter three general periods are grouped and classified as Cochise in Table 46 and in Appendixes 4.1 and 4.2. The highest proportion of bone dated to a specific phase was assigned to the Chiricahua phase and the Cienega phase, a combination that allowed comparisons of the Middle Archaic with the end of the Late Archaic. Bones from all prehistoric time periods were highly fragmented, with over 50 percent of all faunal remains measuring less than 15 mm in maximum dimension, and 75 percent measuring less than 25 mm (Table 51). In all, 79 percent of the faunal bone from the Luke Solar project could not be identified to the level of order because of fragmentation or heavy carbonate deposits. The early Chiricahua phase bone was especially fragmentary; 47 percent of bone from this time measured less than 5 mm, and 39 percent measured 5–15 mm. In most of the other phases and periods represented, the greatest proportion of bone measured 5–15 mm, with the exception of the Red Mountain phase, in which 49 percent of the bone measured 15–25 mm in maximum dimension. The Red Mountain phase collection, though, was much smaller than those of the early Chiricahua phase and San Pedro and Cienega phases. The general trend to slightly larger specimens was also evident in the 145 specimens that were only assigned to the more-general Late Cienega to Red Mountain phases, with only 4 percent measuring less than 5 mm, 48 percent measuring 5–15 mm, and 35 percent measuring 15–25 mm (see Appendix 4.1 for complete data). Bone from the Historical period contained a high proportion of recently broken bones, the result of mechanical stripping.

The Cochise sample included specimens assigned to broader time ranges but still within the Archaic, including the Middle to Late Archaic, and the Early to Middle Archaic. Nearly a quarter of the bone was assigned to the general Middle to Late Archaic time. Fewer bones were assigned to the Early to Middle Archaic and Early to Late Archaic, but still, each of these general categories contained nearly 90 specimens. Faunal materials of this age are scarce throughout southern Arizona and so some discussion of these more-general time groups is included.

The Early to Middle Archaic period included a single bone each from a coyote-sized mammal, artiodactyl, and lizard, as well as bone from unidentified mouse- and squirrel-sized taxa. Most, though, were from

Table 51. Number of Faunal Specimens by Bone-Fragment Size and Temporal Period, for All Sites

Temporal Period	Bone Maximum Dimension (shell excluded)																
	< 5 mm		5–15 mm		15–25 mm		25–35 mm		35–50 mm		50–100 mm		> 100 mm		Unknown		Total
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n
Sulphur Spring	—		4	80	—		1	20	—		—		—		—		5
Early Chiricahua	227	47	188	39	54	11	10	2	5	1	—		—		—		484
Late Chiricahua	7	23	17	55	3	10	1	3	1	3	2	6	—		—		31
San Pedro	22	20	51	47	24	22	11	10	—		—		—		—		108
Cienega	33	6	371	68	103	19	25	5	5	1	6	1	—		1	0.2	544
Red Mountain	4	11	12	32	18	49	2	5	1	3	—		—		—		37
Pre-Classic	18	32	33	58	6	11	—		—		—		—		—		57
Classic	—		4	80	1	20	—		—		—		—		—		5
Protohistoric	7	78	2	22	—		—		—		—		—		—		9
Historical period	93	5	682	37	157	8	66	4	29	2	30	2	1	0.05	793	43	1,851
Cochise[a]	126	18	319	46	176	26	53	8	11	2	3	0.4	—		—		688
Poorly dated	32	5	300	50	203	34	43	7	13	2	4	1	—		1	0.2	596
Not dated	10	33	5	17	9	30	3	10	1	3	2	7	—		—		30
Total	579	13	1,988	45	754	17	215	5	66	1	47	1	1	0.02	795	18	4,445

[a] Archaic-aged material that could not be assigned to a specific phase was classified as Cochise.

leporids and rabbit-sized taxa. All were recovered from four nonthermal and two thermal pits. Most were found in one nonthermal pit, Feature 5215, which yielded 79 bones from squirrel-sized mammals, rabbit-sized mammals, jackrabbits, and a piece of lizard bone. Eighty-six percent of these bones measured less than 15 mm in maximum dimension. The remaining features contained only 1 or 2 specimens each. Burning was noted on 39 percent of the bone from this general time period, and 39 percent of Feature 5215 as well.

Specimens recovered from Early to Late Archaic period contexts tended to be larger and therefore more identifiable to taxon than many of those from the Early to Middle Archaic. The average fragment size for Early to Late Archaic bone was 17 mm, in comparison to only 10 mm for the Early to Middle Archaic bone. The 89 bones and fragments were distributed across 21 features and 3 nonfeature contexts and therefore were generally found in very small quantities in most features. Jackrabbits, cottontails, wood rats, squirrel, artiodactyl, indeterminate rabbit-sized, squirrel-sized, and coyote-sized mammals, indeterminate rodents, and indeterminate vertebrates were all recovered, but rabbit-sized mammals and leporids contributed nearly 70 percent of the overall bone count. Burning was seen on 22 percent of the bone from this time, but 33 percent of the bone was so covered with carbonate or stained that burning could not be identified.

The Middle to Late Archaic included more than 600 pieces of bone and shell and made up more than 15 percent of the Luke Solar project fauna. With this much larger collection, it is not surprising that correspondingly more-diverse fauna were represented, including kangaroo rats, pocket mice, lizards, snakes, turtle or tortoise, Iguanidae, antelope jackrabbits, cottontails, Canidae, frogs, birds, and deer-sized mammals. As noted previously, over 200 specimens were *Olivella*-shell beads found in a single feature, and 2 of the 24 fragments of deer-sized bone were artifacts. Fully 26 percent of the bone was burned and 25 percent was either stained or so coated with carbonate that it was not possible to identify burning. Bone fragment size was more or less in line with those found in Early to Late Archaic contexts and averaged 17 mm.

These three general Archaic period groupings show an overall pattern of high fragmentation. Although fragment size varied somewhat among the groups, none of the three contained any bone fragments greater than 50 mm in maximum dimension. Leporids or rabbit-sized mammals were the dominant taxa, and burning was seen on at least 20 percent of the bone.

Chiricahua Phase

In all, 18 percent of the bone and shell were recovered from Chiricahua phase contexts, including 497 specimens assigned to the early Chiricahua phase and 31 to the late Chiricahua phase (see Table 46; Appendix 4.2). Most were highly fragmentary, averaging 9 mm in maximum dimension. Just over half (51 percent) of the total bone sample from the Chiricahua phase was recovered from Feature 4235, a nonthermal pit that produced a 2σ calibrated age range of 3340–3090 cal B.C. All bone from this feature was burned, ranging from blackened to calcined white, checked and spalled, and highly fragmented, with most (70 percent) of the 270 bone fragments measuring 5 mm or less. Most Chiricahua phase features contained only a few specimens. Of 47 features, 37 had 5 or fewer pieces, and 11 had only 1 bone, fragment, or piece of shell.

Mammalian bone dominated the Chiricahua phase fauna. No bird bone was identified, and only a single frog or toad bone was found. Reptile bone consisted of five snake vertebrae and two damaged vertebrae that could have been either snake or lizard. Mammals recovered from Chiricahua phase contexts included leporids, carnivores, and rodents, as well as unidentified deer-sized taxa. A fragment of a carnassial—the specialized high-cusped shearing teeth that form many carnivore premolars or molars—was also recovered. This tooth fragment was a good match to a modern coyote, but the fragment was too small to rule out large felids, so it was identified only as a carnivore. A distal phalanx of a coyote-sized mammal was also present. The remaining bone consisted of long bones, indeterminate bones, flat bone, and a vertebral fragment from coyote-sized, rabbit-to-coyote-sized, rabbit-sized, and squirrel-sized mammals. Although there were many burned bones, no burning or oxidation was noted on the pit walls of Feature 4235 or in the fill during excavation, and Feature 4235 is therefore thought to have been a repository of previously burned bone.

Burning was seen on 64 percent of the bone from the early Chiricahua phase, and on only 6.5 percent of the late Chiricahua bone. At Falcon Landing, burning does not seem to be correlated with recovery context in the Chiricahua phase. Only 22 percent of the bone from thermal pits was burned, and 87 percent from nonthermal pits was burned (counting Feature 4235 described above). But, if Feature 4235 is removed, burning was seen on only 15 percent of the bone from nonthermal pits. Carbonate or staining limited visibility on only 10 percent of the bone from the Chiricahua phase. Visibility was much poorer on the bones from the more-general Archaic period category.

In all, 18 percent of the bone from rabbit-sized mammals was burned, and 6 percent had been covered by too much carbonate or stains to identify burning. Burning did not seem to be strongly patterned on leporid bones during the Chiricahua phase. The maxilla fragment was burned, one mandible fragment was not burned, and the second mandible fragment was indeterminate. The single vertebra fragment was burned, as were some scapula fragments, 35 percent of the indeterminate long bones, some of the foot and lower leg bones, and some of the upper leg bones.

During the Chiricahua phase, 19 percent of the bone from squirrel-sized mammals was burned, and 17 percent was too covered with carbonate or stains to identify burning. No bone from mouse-sized taxa was burned. A tibia from an immature wood rat was burned. Burning was most common on the extremities and long-bone fragments, and 25 percent of the indeterminate long bones were burned, along with the single identified rib fragment.

Only 21 bones and fragments of deer-sized mammals were from Chiricahua phase contexts, and of those, only one was an artifact. More than half (57 percent) of the bone from deer-sized mammals was so broken that it could not be identified to element. One scapula fragment was identified, and the remainder could only be identified as rib or vertebral spine (4 percent), long bone (28 percent), or cancellous bone (4 percent), and so no clear pattern for body-part representation could be identified. Burning was seen on 24 percent of the deer-sized bone, and the same proportion of bone was too covered with carbonate or staining to identify burning. Bone from deer-sized mammals was found in small quantities across feature types—in activity areas, FAR concentrations, house-in-pits, nonthermal pits, thermal pits, bell-shaped pits, and nonfeature locations—but always as 3 specimens or fewer per feature, including bone artifacts.

No nonthermal pit other than Feature 4235 contained more than 6 bones, fragments, or shell. Thermal pits were more variable, and each contained 1–20 bones or bone fragments. Three pits held 17, 19, and 20 specimens; one held 7; and all other thermal pits held only 1, 2, or 3 specimens each. Altogether, the thermal pits averaged 6.5 bones each, but this average was overly influenced by the few pits with larger collections.

The two thermal bell-shaped pits held 1 and 4 fragments. Chiricahua phase houses, too, generally held only a few faunal specimens each; six of the seven houses contained 5 or less pieces, and the seventh house contained 15 pieces. Aside from the anomalous Feature 4235, no clear difference was seen in the kinds or amounts of faunal remains in different features or feature types.

San Pedro Phase

The San Pedro phase faunal collection from Falcon Landing was much smaller than that for the Chiricahua phase and Cienega phase (see Table 46; Appendix 4.2), and sample sizes were consequently problematic. Only two bones from deer-sized mammals were identified from San Pedro phase contexts, and although both were long bones, few, if any conclusions could be drawn from so small a sample. Even with the small sample size, leporid body-part representation was very similar to that seen for the Chiricahua phase. Lower leg bones and indeterminate long bones made up the greatest proportion. A single cranial bone was recovered, and axial bones were present but underrepresented relative to the frequencies in the living body. Higher proportions of leporid and medium-sized-mammal foot bones were present in San Pedro phase contexts compared to the Chiricahua phase.

Burning was present on 23 percent of the rabbit-sized taxa from San Pedro phase contexts, and 47 percent were unburned. The remainder of the bones were too covered with carbonate or stains to identify burning. Burning was most frequently observed on the lower leg bones but was also noted on upper legs; the cranial fragment was also burned. Unlike what was seen in the Chiricahua phase rodent remains—where leporids and rabbit-sized mammals and squirrel-sized rodents and mammals seem to have been treated in similar ways—in the San Pedro phase, body-part representation of squirrel-sized taxa contrasted strongly with that of the rabbit-sized mammals. Most of the San Pedro phase bones of both squirrel-sized (75 percent) and rabbit-sized (86 percent) mammals were so fragmentary as to be unidentifiable to region. Cranial bones made up 1 percent of the rabbit-sized mammal bone and 2 percent of the squirrel-sized mammal bone, lower limb bones contributed 8 percent to the rabbit-sized mammal bone and 11 percent to the squirrel-sized, and upper limb bones were 4 and 5 percent of the rabbit and squirrel-sized mammal bone. The difference was seen in the axial bones. Axial bone made up only 0.5 percent of the rabbit-sized but 6 percent of the squirrel-sized mammal bone. Because the bone identified as from rabbit-sized mammals is larger than that of the squirrels, it should actually be more identifiable to element. This disparity suggests that rabbit vertebrae may have been preferentially destroyed compared to those of the smaller mammals. Perhaps they were crushed and processed for fat, or it may be that the smaller vertebrae were more likely to pass unmodified through a carnivore digestive system.

Most bone was indeterminate long bone or unidentifiable, but axial bones and fragments made up the largest proportion of identifiable bones. In all, 27 percent of the bone from rodent-sized mammals was burned, and 19 percent of squirrel-sized and 4 percent of mouse-sized mammal bone was burned. Presence or absence of burning could not be seen on 29 percent of the small and very small mammal bone and 38 percent of the bone from squirrel-sized taxa.

Cienega Phase

More specimens dated to the Cienega phase at Falcon Landing than to any other prehistoric component (see Table 46; Appendix 4.2). The fauna included frog or toad, quail, two sizes of squirrel, mouse or rat, deer, wood rat, antelope jackrabbit, cottontail, turtle or tortoise, lizard, and snake bone, although once again, the collection was dominated by leporids and rabbit-sized mammals, which made up 39 percent of the total vertebrate collection. Evidence of burning was present on 5 percent of the bone from rabbit-sized mammals, 67 percent were unburned, and 27 percent of the bones were so covered with carbonate it was impossible to identify burning. Most bone (76 percent) was recovered from nonfeature contexts, and with two exceptions, when bone was recovered in features, it was found in small quantities. Seventeen features contained bone; of these, 12 have 5 or fewer specimens, 3 have 6–10 specimens, 1 has 15, and 1 has 63.

In all, 20 bones (3 percent) from deer-sized mammals dated to the Cienega phase, 1 of which was an artifact. All were fragmentary, and 68 percent were less than 25 mm in maximum dimension. These elements included axial, tooth, and antler, as well as long bone, flat bone, and indeterminate. Only 1 was burned, but the presence or absence of burning could not be determined on 9 specimens.

Late Cienega to Red Mountain Phase and Red Mountain Phase

Only 38 specimens were securely dated to the Red Mountain phase. An additional 131 specimens dated to the Late Cienega to Red Mountain phase (400 B.C.–A.D. 450). The Late Cienega to Red Mountain phase is a chronological component defined in Chapter 1, which dates to 400 B.C. to A.D. 400 (see Appendix 4.2; for further discussion of chronological groupings see Chapter 1, this volume). Leporids and rabbit-sized taxa made up just over half of the bone (56 percent) from the total vertebrate faunal collection, and of these, 34 percent were burned and 21 percent unburned, and the rest were too covered with carbonate or stains to identify burning. In contrast to the Cienega phase, leporids and rabbit-sized taxa made up 69 percent of the fauna from the Late Cienega to Red Mountain phase, but 58 percent of that bone was too covered with carbonate to identify burning, and fewer burned specimens (21 percent) could be identified. Red Mountain phase bone from rabbit-size taxa represented all body regions with nearly half assigned to appendicular indeterminate. Most of the Late Cienega to Red Mountain phase bone from rabbit-sized taxa that could be identified to body region was from the lower legs, in particular, the lower hind limbs and foot bones, although 49 percent could only be identified as long bone. More axial bones (19 percent) were present in the Red Mountain phase deposits than were found in Chiricahua and San Pedro contexts, but the proportion of axial bone to other body regions was much lower in the more-general Late Cienega to Red Mountain phase bone (3 percent). Burning was present on most bones, from most of the body regions, in the Late Cienega to Red Mountain phase bones.

Squirrel-sized mammals made up 19 percent of the Red Mountain phase bone but only 10 percent of the Late Cienega to Red Mountain phase bone, and 57 percent of the Red Mountain phase bone from squirrel-sized mammals was burned. Burning was present on squirrel-sized and mouse-sized mammal bone from the Late Cienega to Red Mountain phase as well.

Bone from deer-sized mammals made up 10 percent of the specimens from both the Red Mountain phase and the Late Cienega to Red Mountain fauna. One deer tibia, one artiodactyl phalanx, and two long-bone fragments from deer-sized taxa were found in contexts securely dated to the Red Mountain phase. In addition, a deer ulna, artiodactyl cheek tooth, and deer-sized mammal rib, tibia, long bone, and unidentified fragments were found in Late Cienega to Red Mountain phase contexts. The proportions of burned bone were similar between the Red Mountain phase (25 percent) and Late Cienega to Red Mountain phase bone (23 percent) collections. Only five Red Mountain phase features contained faunal remains, but those that did tended to have higher NISP counts than found in Chiricahua features. Two features held 10 specimens, two had 6, and one had 5 specimens. A single piece was found in nonfeature contexts.

Cochise

The Cochise included bone and shell that could be identified to the Archaic period but not to any particular individual Archaic period or phase, and 913 specimens from Falcon Landing were assigned to the Cochise category (see Table 46; Appendix 4.2). Animals found in Cochise contexts included an unidentified canid, represented by a second metacarpal. Bone from indeterminate coyote-sized mammal included a cancellous bone, cranial, flat bone, and radius fragment, two long bones, and two unidentifiable fragments. Rodents were well represented in these deposits. A few specimens were identified as kangaroo rats and pocket mice, indeterminate mouse-sized Muridae, and cranial, axial, long bone, flat bone, tibia, and foot bones of mouse-sized mammals. Wood rat, cotton rat, squirrel, squirrel-sized rodent and squirrel-sized mammal were also present and included at least a few pieces of most body regions.

Nearly all portions of jackrabbit, cottontail, and rabbit-sized mammals were represented in the Cochise collection. Medium-sized mammals included both antelope and black-tailed jackrabbits and cottontail, including a few pieces of bone from smaller cottontails. Deer-sized mammals were represented by a deer ulna, artiodactyl innominate, tooth fragment, and a phalanx, as well as 2 flat bones, 10 long bones, rib, tibia, and indeterminate bone from deer-sized mammals.

Burning was noted on 19 percent of all bone from Cochise contexts, and on nearly all size classes. The sole exception was carnivore bone and bone of coyote-sized mammals. In all, 36 percent of the bone from deer-sized mammals was burned, and an additional 18 percent were too covered with carbonate or stains to identify burning. The proportion of identifiable burning on rabbit-sized mammals was slightly lower, at 26 percent, but 37 percent of the bone had heavy carbonate covering or staining that limited surface visibility. Thirty percent of the bone from squirrel-sized mammals was burned with 18 percent unidentifiable. Even a few pieces of bone from mouse-sized mammals were burned, with seven burned bones making up 39 percent of the collection.

Pre-Classic Period and Later

The pre-Classic period was represented in Falcon Landing and included 56 bones assigned to Snaketown, and 1 bone assigned to the Sacaton phase (see Table 46; Appendix 4.2). No shell was identified from pre-Classic period contexts. The bone from Snaketown phase contexts included jackrabbit and cottontail bones, indeterminate leporid, squirrel-sized rodent, mouse-sized mammal, bone from deer-sized taxa, indeterminate snake or lizard bone, and indeterminate vertebrate. The reptile, 2 of the 3 pieces of mouse-sized mammal bone, and 4 of the 8 indeterminate mouse-sized mammal bone were likely intrusive, based on the light color and unblemished condition of the bone. All bone from leporids and rabbit-sized mammals represented limbs or teeth. No axial bone was found. A single small, unidentifiable fragment represented a deer-sized mammal. The other time phases/periods such as the Sulphur Spring and Classic had far too few specimens to draw any real conclusions concerning behavior. Only a few specimens were found in Protohistoric period contexts, and the condition of all 9 specimens suggested that they were intrusive. All were lizard bone, possibttly from a collared lizard.

Analysis

Leporids, and to a much lesser extent, artiodactyls made up the primary game animals in the project area, and therefore, the analysis focused on these taxa. Body-part representation, abundance of particular taxa, and carcass processing can help reveal prehistoric hunting methods and human decision making.

Examining Taxonomic Abundance: NSP, NISP, and MNI

The most basic unit of measurement used in this analysis was the NISP. This measurement counts each bone, tooth, antler, or fragment thereof as one, although if pieces were recently broken and could be refitted, the refitted fragments were counted as a single specimen. Highly fragmented bones from only one individual can greatly inflate NISP counts and may consequently overemphasize particular taxa, and therefore, this measure was supplemented by the MNI. The MNI is based upon the most frequent nonduplicated skeletal part for each taxon. For example, barring an extremely pathological birth, one jackrabbit cannot have more than one right femur, and so if two right femora and a handful of bone fragments are recovered from a pit, they can be interpreted as representing at least two individual jackrabbits. The MNI also has problems (see Lyman 2008 for a discussion of advantages and drawbacks to various measurements of faunal abundance), and the uncritical use of MNI has been criticized, but it nevertheless serves a useful function, and in this case was used as one of several measures of faunal abundance. The MNI can be calculated in several different ways (Lyman 2008). One of the primary criticisms of the MNI is related to problems resulting from aggregation, that is, the way in which the analyst chooses to combine and separate fauna according to levels, features, or site components can have a pronounced effect on the estimates of minimum numbers. If MNI is calculated for an entire site, it will likely be much lower than if MNI is calculated for each feature and then summed for each time period at the site. The MNI is included here to be consistent with earlier studies.

Leporids and rabbit-sized mammals made up 71 percent of the Luke Solar project Chiricahua phase vertebrate fauna, but only 49 percent of the San Pedro phase and 39 percent of the Cienega phase specimens. Rodents, and squirrel- or mouse-sized mammals contributed only 17 percent of the Chiricahua phase vertebrate fauna (obviously intrusive specimens removed), but were 39 percent of the San Pedro phase and 52 percent of the Cienega phase nonintrusive vertebrate fauna. The NISP for the Red Mountain phase was very low (see Table 46; Appendix 4.2). Leporids and rabbit-sized mammals made up 73 percent of the combined Late Cienega to Red Mountain phase fauna, and squirrel- or mouse-sized mammals made up only 15 percent. Rabbit-sized mammal bone was dominated by lower leg and appendicular indeterminate bone. Ratios between rabbit and rodent-sized taxa in this combined time differed from the Cienega phase and were more consistent with the Chiricahua phase fauna.

Very few birds or other nonmammals were identified in the faunal specimens analyzed from Falcon Landing. Low numbers of frog or toad bones were found and a few turtle or tortoise shells were recovered. Leporids were consistently the most common identified taxa from Falcon Landing, for individual phases, and for many features. Of the three Archaic phases, the Cienega phase collection was the most diverse with 12 vertebrate taxa, followed by the Chiricahua phase with 8 taxa, and the San Pedro phase with only 6 vertebrate taxa. The low diversity of the San Pedro phase was likely influenced to some extent by the much smaller sample size (NISP = 109) compared to the Chiricahua phase and Cienega phase. The Chiricahua phase and Cienega phases were much more comparable on sample size, with NISPs of 528 and 547 respectively. Some of the differences in diversity may also be explained by fragmentation. The average fragment size of vertebrate faunal remains in the Chiricahua phase was 9 mm, in contrast to the San Pedro and Cienega phases, which both averaged 13 mm. Chiricahua phase bone was consistently more fragmentary than the two later Archaic phases, and as a result, bone identifiability was lower.

The MNI was calculated for artiodactyls and leporids for each chronological period and/or phase at each site (Table 52). Even in the largest samples, the MNIs were quite small, but this probably reflects, at least partially, bone fragment size and identifiability. As fragmentation increases, the identifiability decreases, and so, accordingly does the MNI (Lyman 2008). The prehistoric and undated specimens from the Luke Solar project tended to be highly fragmented, and therefore MNI undoubtedly underrepresents the total individuals brought to the sites.

The prehistoric and undated components of Falcon Landing as a whole contained seven complete right calcanei from cottontails, and a fragment of an eighth, indicating that at least portions of eight cottontails were present. This MNI, and those that follow in this paragraph, do not include those specimens assigned to Cochise because they could represent the same individuals. Seven right scapulae were also recovered. The right calcaneus also provided the minimum number for the smaller cottontails, with one complete and one fragmentary right calcaneus present. The minimum number of jackrabbits for the site as a whole was provided once again by the right calcaneus, with five complete and four proximal calcanei, indicating portions of at least nine jackrabbits. At least one black-tailed jackrabbit and at least one antelope jackrabbit were present as well. These may be in addition to the nine indeterminate jackrabbits, or they might be included in the count of nine. At least one deer was present in the site as a whole, but specimens identified to artiodactyl or cervids were so infrequent that the MNI is essentially meaningless, especially after bone and antler artifacts are removed.

Artiodactyl remains were so few in number and fragmentary that there was no duplication of an element in any phase or more-general chronological category. At least three adult cottontails and two adult jackrabbits dated to the Chiricahua phase, along with a subadult leporid. Adult cottontail and subadult jackrabbit specimens were also recovered from San Pedro phase contexts, with an MNI of three. Although the total NISP for the Cienega phase was four times that of the San Pedro phase, the leporid MNI was smaller than was found in either of the two preceding phases.

Leporid Body Regions

Patterns in element representation can potentially provide information on prehistoric hunting, butchering, food preparation, and disposal practices. For example, fat was important nutritionally, but it had other value as well, and it was used to coat and protect people's skins, mix with paint, and to process hides. Native peoples across North America crushed bone from large and small taxa and simmered the fragments in water in pots or organic containers (Densmore 1979:44; Vehik 1977:170). As the bone fragments heated, the fat or bone grease rose to the surface and was skimmed off and collected. Once collected, it was a resource that could be stored and used or traded for other goods (Russell 1908). Other food preparation methods may result in other breakage patterns. Although marrow extraction also results in broken bones, bones broken for marrow extraction do not need to be crushed, rather they simply need to be broken open enough for the nutrient-rich fatty marrow to be removed.

Because of their small body size, differences in leporid body-part representation were not likely the result of differential transport as might have been the case with artiodactyl body parts; leporids, rodents, and other small animals did not have to be disarticulated and skinned in the field before bringing them home. But, even so, people may have removed and discarded heads in the field, or they may have taken them back to the site and opened them to extract brains. If the latter had occurred, then crania are likely to have been fragmented and would be unidentifiable to taxon.

Table 52. Minimum Number of Individuals for Primary Game Mammals from Falcon Landing, by Temporal Period

Temporal Period	Cottontail, Adult or Indeterminate	Jackrabbit		Black-Tailed Jackrabbit	Antelope Jackrabbit	Indeterminate Leporid	Deer-Sized Mammal	Deer	Total
		Adult	Subadult	Adult or Indeterminate	Adult	Subadult	Adult or Indeterminate	Adult or Indeterminate	
Chiricahua	4	2	—	—	—	1	1	—	8
San Pedro	1	1	1	—	—	—	1	—	4
Cienega	2	1	1	—	1	—	1	—	6
Red Mountain	1	1	—	—	—	—	—	1	3
Cochise[a]	3	3	1	1	1	—	—	1	10
Totals	11	8	3	1	2	1	3	2	31

[a] Archaic-aged material that could not be assigned to a specific phase was classified as Cochise.

Some forms of food processing were likely to reduce the identifiability of small bones, raising questions on body-part representation. For example, some small animals may have been roasted and consumed whole (Szuter 1984:150–151). Foot bones were more likely to burn than those of meatier portions, and small-mammal foot bones may have also remained attached to skins that were thrown into the fire during food processing (Szuter 1984). Cranial and vertebrae also may have been underrepresented because of issues of identifiability. Small cranial or vertebral fragments were unlikely to preserve landmarks diagnostic to genus or even to family. Additionally, it should be remembered that humans may not have been directly responsible for what was present; some unburned rodent bone in pit fill may have represented intrusive pests, rather than prey (Wöcherl 2001:213).

This study used two additional methods to examine skeletal representation in leporids. Waters (2005b) divides the carcass into four large portions: cranial (not including teeth), axial, upper leg, and lower leg. These units can be used to investigate overall differences in body-part representation, and these were used in the present study (Table 53). If patterns were seen between these four units, then a second scheme was used in which the body was divided into smaller portions. As described earlier, specimens were also assigned to MNE regions similar to those proposed by Stiner (1994), including head, neck, axial, upper front, upper rear, lower front, lower rear, and feet (Table 54). Because of the highly fragmentary nature of southern Arizona faunal collections, two additional categories were added; appendicular indeterminate and axial indeterminate.

Leporid body-part representation in Chiricahua phase contexts was largely constant for cottontails, jackrabbits, and indeterminate leporids, and therefore all rabbits and hares were grouped together in this discussion. Rabbit-sized mammals, a category that tends to accumulate the less identifiable or highly fragmented elements included mostly fragments from long bones, with a few other indeterminate elements. However, even when leporids and rabbit-sized mammals were combined, cranial, rib, and vertebral fragments were lacking (Figure 82). Only one cranial, one maxilla fragment, and three flat bones were found. No innominates, ribs, or rib fragments were identified. The largest portion of the Chiricahua phase bone was made up of very small, unidentified fragments, nearly 200 of which measured less than 5 mm in maximum dimension. It was highly fragmentary, 86 percent were identified only as long bone, flat bone, or entirely unidentifiable. The fauna was investigated first using regions defined by Waters (2005b). Most were indeterminate, but among the identifiable bone, lower leg bones far outnumbered those from all other regions (see Table 53). However, only some parts of the lower legs were present. When the lower leg bones were divided into lower front, lower hind, and feet (see Table 54) foot bones seemed underrepresented. Tibia, radius, ulna, and the calcaneus were represented, but carpals were absent and phalanges underrepresented. This could be related to recovery bias, small phalanges and carpals could slip easily through a screen. Appendicular indeterminate made up 15 percent, and many of the upper hind and forelimb bones may have been in this category. Some metapodials were likely also hidden in the general appendicular indeterminate group. Axial elements were rare.

Far fewer leporid and rabbit-sized mammal bones were recovered from San Pedro phase contexts than from Chiricahua phase and Cienega phase contexts, and any patterns may have been heavily influenced by the smaller sample size (Figure 83; see Tables 53 and 54). Identifiability was slightly better for the San Pedro phase bone than it was for the Chiricahua phase bone. As with the latter, cranial bones remained underrepresented, but there was a higher proportion of axial bones. The biggest difference, when examined using Waters (2002) regions, was found in the upper and lower leg representation, with San Pedro phase bone having higher proportions of upper leg than lower leg bones than seen in the earlier phase and the Cienega phase.

When examined with the more-detailed Stiner (1994) regions, it appears that more lower-front bones were present than other limb bones in the Cienega phase. More bones could be assigned to body regions in the Cienega phase leporids and rabbit-sized mammals compared to those found in Chiricahua phase contexts (Figure 84; see Tables 53 and 54). Lower leg bones made up the largest proportion of identified bone, in particular the bones of the lower front limb (see Table 53). Cranial and axial bones each contributed 10 percent. There were more grouped lower-leg bones than other regions, but cranial and axial bones were better represented than in the Chiricahua phase bone. Overall, element identifiability of rabbit-sized mammals was highest in the Cienega compared to San Pedro and Chiricahua. Overall, more elements of rabbit-sized mammals were identifiable in the Cienega phase collection compared to those from the San Pedro and Chiricahua stage. When the lower legs were examined in more detail (see Figure 84; Table 54), it becomes apparent that much of the difference can be explained by the presence of more foot bones from Cienega phase contexts.

Table 53. Number of Leporid and Rabbit-Sized Mammal Specimens by Body Region (as defined by Waters [2002]) and Temporal Period, from Falcon Landing

Region	Chiricahua		San Pedro		Cienega		Cochise[a]	
	n	%	n	%	n	%	n	%
Indeterminate	314	86	35	65	106	50	238	58
Cranial	4	1	1	2	21	10	14	3
Axial	2	1	5	9	21	10	8	2
Upper leg	14	4	8	15	11	5	43	10
Lower leg	30	8	5	9	53	25	108	26
Total	364	100	54	100	212	100	411	100

Key: Cranial = antler/horn, maxilla, and mandible, skull; axial = ribs, vertebra, sternum, innominate, and sacrum; upper leg = scapula, humerus, femur, and tibia; and lower leg = ulna, radius, metapodicals, carpals, tarsals, phalanges, and sesamoids.

[a] Archaic-aged material that could not be assigned to a specific phase was classified as Cochise.

Table 54. Number of Leporid and Rabbit-Sized Mammal Specimens by Body Region (as defined by Stiner [1994]) and Temporal Period, from Falcon Landing

Region	Chiricahua		San Pedro		Cienega		Cochise[a]	
	n	%	n	%	n	%	n	%
Head	4	1	2	4	36	17	20	5
Neck	—		—		—		1	
Axial	1		4	7	16	8	6	1
Axial indeterminate	1		1	2	5	2	1	
Upper front	7	2	1	2	8	4	24	6
Upper hind	1		2	4	2	1	4	1
Lower front	16	4	—		24	11	16	4
Lower hind	16	4	8	15	14	7	56	14
Feet	2	1	—		11	5	30	7
Appendicular indeterminate	55	15	25	46	75	35	223	54
Indeterminate	261	72	11	20	21	10	30	7
Total	364	100	54	100	212	100	411	100

Key: Head = mandible, maxilla, and skull; neck = atlas, axis, and cervical vertebrae; axial = thoracic and lumbar vertebrae, sternum, ribs, innominate, and sacrum; upper front = scapula and humerus; lower front = carpals, tarsals, metacarpals, radius, and ulna; upper hind = femur; lower hind = tarsals, patella, metatarsals, tibia, and fibula; and feet = phalanges and sesamoids.

[a] Archaic-aged material that could not be assigned to a specific phase was classified as Cochise.

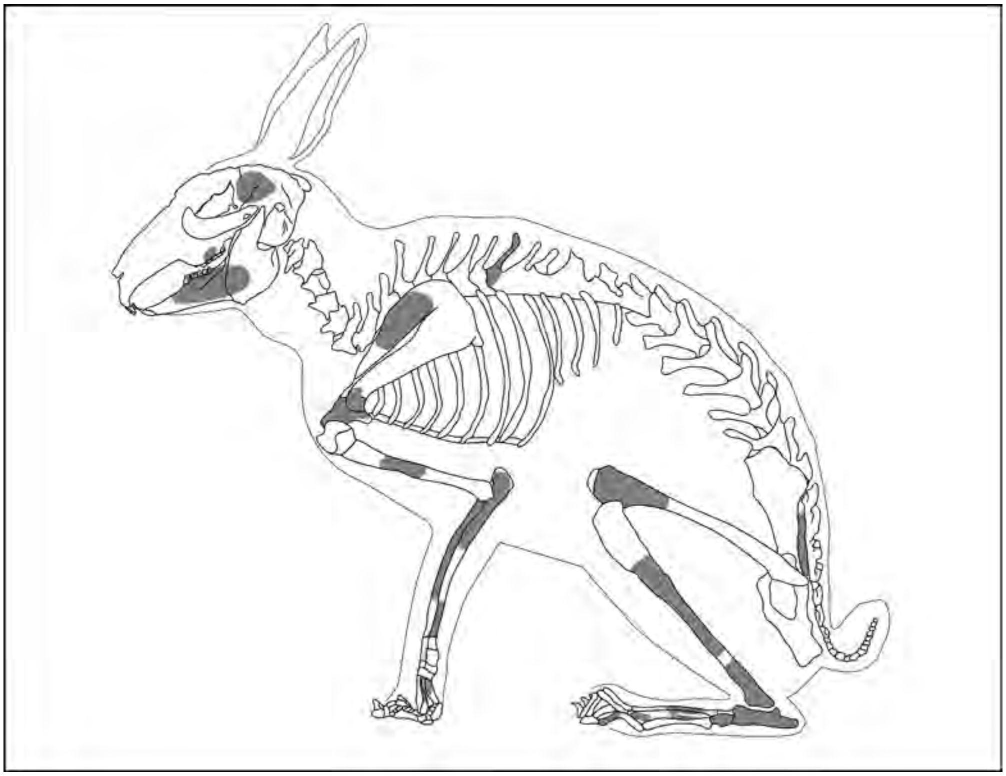


Figure 82. Leporid and unidentified rabbit-sized mammal bone recovered from Chiricahua phase contexts at Falcon Landing.

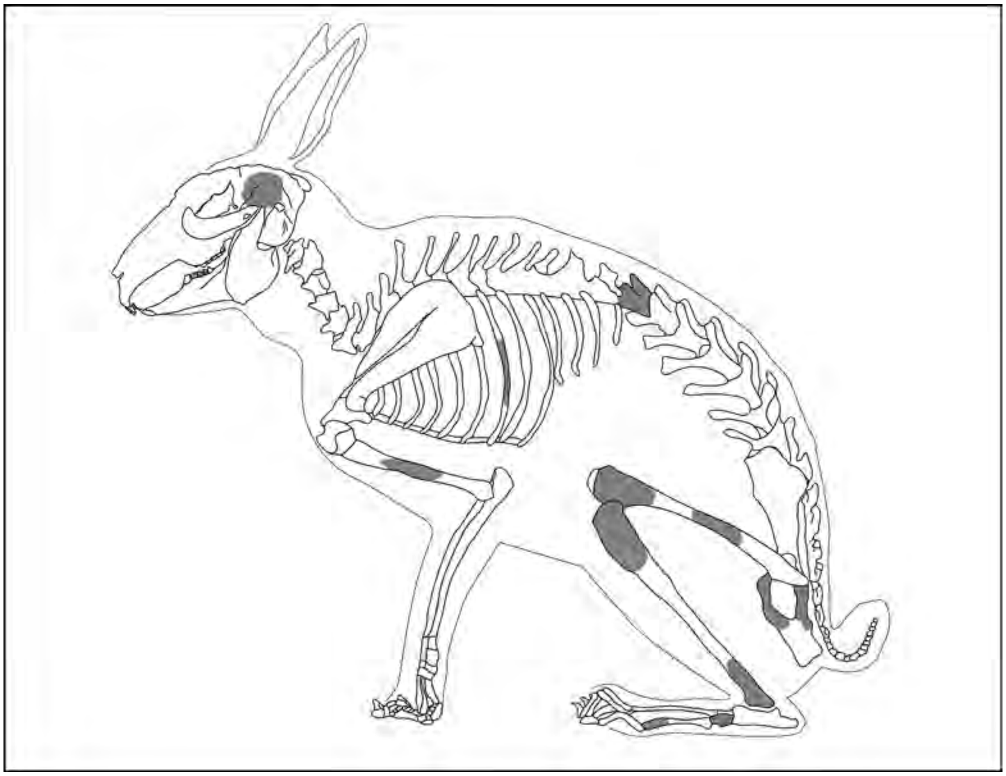


Figure 83. Leporid and unidentified rabbit-sized mammal bone recovered from San Pedro phase contexts at Falcon Landing.

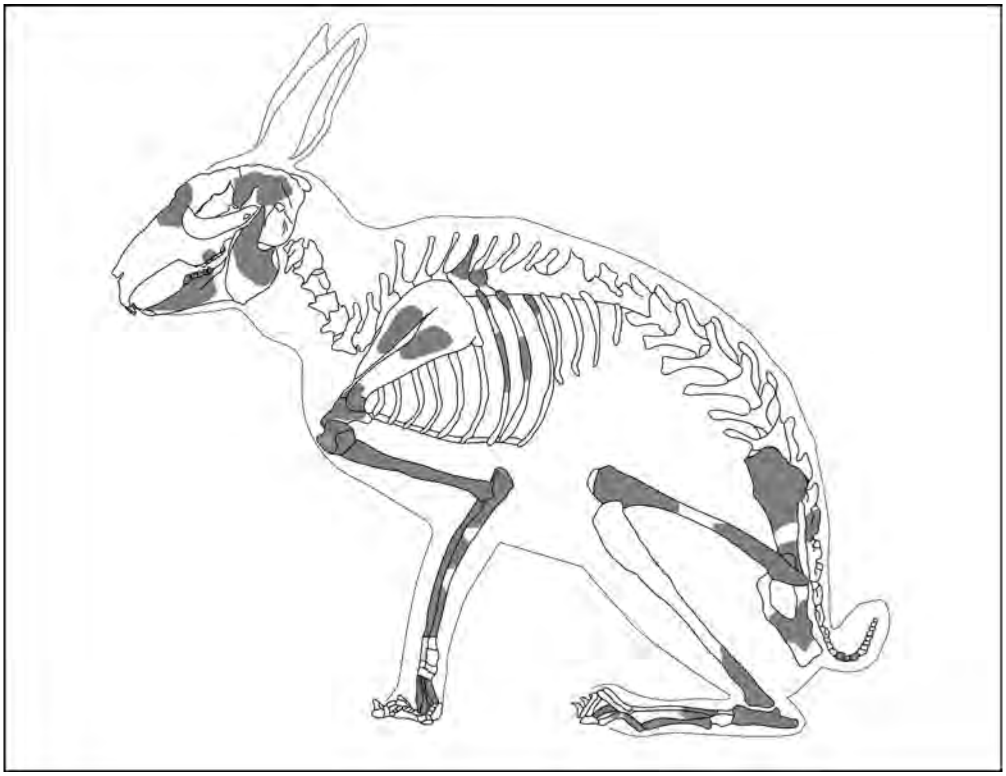


Figure 84. Leporid and unidentified rabbit-sized mammal bone recovered from Cienega phase contexts at Falcon Landing.

The proportions of long-bone ends, shafts, and complete bones were relatively consistent across time, with a few exceptions (Table 55). Ends made up between 20 and 29 percent of the Chiricahua phase and San Pedro, Cienega, and Red Mountain phases, and Cochise long bones. Shafts contributed 71–76 percent of the total count of long bones for early and late Chiricahua phase and San Pedro phase and the Cochise category, with a slightly lower proportion of shafts in Red Mountain phase contexts (67 percent). The lowest percentage of shafts was from Cienega phase contexts (58 percent). Higher percentages of whole long bones were found in the Red Mountain and Cienega phases (compared to the other prehistoric samples), although the Red Mountain phase had a small sample size. No complete long bones were recovered in San Pedro phase contexts. Whole bones from the Cienega phase were dominated by those of the foot and lower leg, but also included humerus, radius, metacarpal and metatarsals, and phalanges. A single phalanx represented the only complete long bone from Chiricahua phase contexts, and the only complete bones from the Cochise category consisted of foot and lower leg bones, metatarsals, and phalanges.

The general Cochise category included bones from all body regions, and a high proportion of bone from lower limbs, but in contrast with the Cienega phase, there were more bones from the lower hind limb.

In general, the patterns suggest that carcasses may have been more intensively processed during the Chiricahua phase compared to the Cienega phase. This is supported by higher fragmentation (see Table 51), lower identifiability, and underrepresentation of body parts such as cranial and axial bones, which may have been smashed beyond recognition during bone grease rendering. Although cranial bones are underrepresented, at least a few fragmentary cranial elements are present in Chiricahua, San Pedro, Cienega, and Cochise, and these, with lower leg and foot bones, suggest that entire carcasses were at least sometimes present, either because hunters returned with complete, minimally processed animals or because the leporids were hunted or trapped on or near the site.

Table 55. Frequencies of Ends, Shafts, and Whole Elements for Long Bones of Leporids and Rabbit-Sized Mammals, by Temporal Period for All Sites

Temporal Period	Long Bones						Total Long Bones	Total Rabbit-Sized Mammals
	End		Shaft		Whole			
	n	%	n	%	n	%	n	n
Sulphur Spring	—		5	100	—		5	5
Early Chiricahua	19	23	62	76	1	1	82	350
Late Chiricahua	1	25	3	75	—		4	14
San Pedro	10	29	25	71	—		35	54
Cienega	34	26	76	58	21	16	131	212
Red Mountain	3	20	10	67	2	13	15	21
Pre-Classic	10	59	6	35	1	6	17	20
Classic	1	50	1	50	—		2	2
Historical period	91	24	114	31	167	45	372	647
Cochise[a]	65	21	227	72	23	7	315	426
Poorly dated	48	18	201	77	13	5	262	406
Not dated	2	50	2	50	—		4	4
Total	284	23	732	59	228	18	1,244	2,161

[a] Archaic-aged material that could not be assigned to a specific phase was classified as Cochise.

Burning Patterns

Small animals may be cooked with the skin on to protect the meat from burning. This would reduce the chance that the bones beneath the meat would be burned as well. Vertebrae are covered with muscle and so would be protected from flames during cooking if the animals were roasted over a fire or cooked in the coals. The bones of the lower limbs, e.g., the radius and ulna, and tibiae and fibulae, are not meaty bones and are less protected than the more-meaty upper limbs, the humeri and femora. During cooking, the lower leg bones would have been exposed to fire more rapidly than the more-meaty, muscled portions. As might be expected, the upper leg bones recovered during the Luke Solar project exhibited lower percentages of burning. However, cranial bones in this collection, which were not protected by much muscle, and might have been expected to be burned, did not exhibit burning.

The burning patterns described here were limited by reduced visibility, and we must therefore rely much more heavily on observations of presence rather than absence, and few strong conclusions can be drawn on the limited data. The burning seen on Chiricahua, San Pedro, Cienega, and Late Cienega to Red Mountain phase leporids was not strongly patterned. Some bones with little meat covering were burned, but so were some bones that would have been more protected from flames by muscle and skin. The charring and calcination seen on meat-covered elements, such as the humerus and scapula, may indicate that these bones were deposited into the fire after the meat was removed. Some burning may reflect cooking, as with the thinly protected foot and lower leg bones and cranial fragments, but other examples of burning were likely the result from discard into fires.

Game Indexes

Some animal populations increase as humans modify the natural environment. Such species may be attracted to increased water in canals, vegetation in cultivated fields, or certain vegetation thriving on disturbed land. Other taxa become less common when the environment is disturbed by human activity. The lagomorph index was designed to investigate changing frequencies of jackrabbits to cottontails, two genera that prefer different habitats. The artiodactyl index, which compares artiodactyl and leporid ratios, is used to investigate not only the degree to which the two orders contribute to the diet, but also long-distance hunting, or use of different environmental zones over time.

Table 56. Faunal Indexes (All Sites Combined), by Temporal Period

			Taxa (n)											Indexes			
Vertebrate Fauna (n)	**Leporids (Percent of Total Vertebrates)**	**All Rabbit-Sized Mammals (Percent of Vertebrates)**	**Jackrabbits**	**Cottontails**	**Indeterminate Leporids**	**Indeterminate Rabbit-Sized Mammals**	**All Leporids**	**Artiodactyls**	**Deer-Sized Mammals**	**All Rabbit-Sized Mammals**	**All Deer-Sized Mammals**	**All Deer Size+ All Rabbit-Sized**	**Total Fauna**	**Lagomorph Index s/(s+l)**	**Artiodactyl Index A/ (A+All Leporids)**	**Large Game Index (1) Deer Sized/ (Deer+ Rabbit Sized)**	**Large Game Index (2) Deer Sized/ Rabbit Sized**
Early Chiricahua																	
484	7	72	17	15	3	315	35	—	19	350	19	369	497	0.47	0.00	0.05	0.05
Late Chiricahua																	
31	10	45	1	2	—	11	3	—	2	14	2	16	31	n/a[a]	0.00	0.13	0.14
Chiricahua (early and late combined)																	
515	7	71	18	17	3	326	38	—	21	364	21	385	525	0.49	0.00	0.05	0.06
San Pedro																	
108	9	49	8	2	—	43	10	—	2	53	2	55	109	0.20	0.00	0.04	0.04
Cienega																	
544	13	39	23	34	14	139	71	2	18	210	20	230	547	0.60	0.03	0.09	0.10
Late Cienega to Red Mountain (these specimens also included in Cochise)																	
145	18	73	18	6	2	80	26	2	12	106	14	120	146	0.25	0.07	0.12	0.13
Red Mountain[a]																	
37	14	57	1	3	1	16	5	2	2	21	4	25	38	n/a[a]	0.29	0.16	0.19
Cochise[b]																	
688	15	59	68	27	8	300	103	4	35	403	39	442	917	0.28	0.04	0.09	0.10
Pre-Classic																	
57	18	33	2	5	3	9	10	—	2	19	2	21	57	n/a[a]	0.00	0.10	0.11
Historical Period[c]																	
1851	13	32	110	102	33	344	245	3	11	589	14	603	1,852	0.48	0.01	0.02	0.02
Early Twentieth Century (Feature 1664)																	
1826	13	31	110	102	33	319	245	3	11	564	14	578	1,827	0.48	0.012	0.02	0.02

[a] Totals are too small to be reliable.

[b] Archaic-aged material that could not be assigned to a specific phase was classified as Cochise.

[c] Early-twentieth-century artiodactyls include one bone from a cow-sized artiodactyl.

For the most part, the numbers of identifiable artiodactyl bones were too few for indexes to be reliable and so the large-game index was used instead. Ratios of deer-sized mammals to rabbit-sized mammals were very low in the Chiricahua phase and San Pedro phase, increasing slightly in the Cienega, the Late Cienega to Red Mountain, and Red Mountain phases. It is clear that large-game hunting was not an important activity during the time that people occupied the Luke Solar project area, though there is the possibility that animals were killed elsewhere, and the meat dried and brought to the sites. The Luke Solar project is located at ca. 325 m (ca. 1,066 feet) AMSL, so it is well below the 800-m break noted below, and so the low artiodactyl indexes are not surprising. But, the high proportions of cottontails do not fit with predictions based on elevations.

The lagomorph index measures the percentages of cottontails to jackrabbits and is a way to interpret changing intensity of site use, site size, and duration (Szuter 1989). The lagomorph index can be calculated in different ways, for example as S/(L+S) (S for *Sylvilagus*, and L for *Lepus*) (Dean 2007b) or L/S (Thiel 1998), using either NISP or MNI. The MNIs for both genera were very low in this study and so the NISP was used. Cottontails and jackrabbits prefer different habitats and amount of ground cover, and the relative proportions of these two genera can provide clues to local environments and how these may have been impacted by human activities. Cottontails prefer to crouch under the cover of vegetation for protection, while jackrabbits prefer open environments where they can see longer distances and escape predators (Hoffmeister 1986). Whereas cottontails freeze and hide, jackrabbits flee. Decreasing lagomorph indexes indicate lower numbers of cottontails and may indicate changes in the environment, with more land cleared for growing crops (Szuter and Bayham 1989). Szuter and Bayham (1989:92) predict that there should be more cottontails relative to jackrabbits in upland environments where vegetation is denser, and that the frequencies of cottontails will decrease the longer a site is occupied. Fewer cottontails are predicted in areas of longer or more-intense site occupation, with the accompanied vegetation clearance and loss of food and protection.

Although the lagomorph index is employed to investigate environmental modification, there are other reasons why proportions of leporids may vary over time or between sites. Szuter (1989, 1991) found that the artiodactyl index increases in higher elevations, with indexes of 0–0.87 below 800 m and higher in sites above 800 m. A similar break was seen in leporid ratios, with more cottontails present in sites over 800 m in elevation than in sites below 800 m (Dean 2007b; Szuter 1989). More cottontails than jackrabbits were found in sites located along the Salt and Gila Rivers, and the cottontails increased in the pre-Classic and Classic periods. In contrast, in sites located on the Santa Cruz River, the proportions of cottontails decreased during the same periods (Dean 2007b). The lowest lagomorph indexes are found in nonriverine settings (Szuter 1989). Dean (2007b) reviewed 101 sites and compared the lagomorph indexes by site type, elevation, region, and time, and also considered prey choice, i.e., whether some species were preferred. She determined that differences in the relative proportion of jackrabbits to cottontails reflect more-complicated interactions between people and the environment than are often assumed. It is unlikely that variation in lagomorph indexes can be attributed to one cause. Of particular interest to the present project, logistic camps in nonriverine contexts tended to have higher lagomorph indexes than villages or farmstead/field houses (Dean 2007b).

At 0.20, the index calculated for the San Pedro phase indicates a higher proportion of jackrabbits to cottontails than were found in Chiricahua phase and Cienega phase contexts (Table 56), but only 10 specimens could be clearly identified to taxon from San Pedro phase contexts, and the high fragmentation and low identifiability may distort the perceived proportions. The lagomorph index for San Pedro phase contexts in the Luke Solar project collection was more or less in line with those reported for early San Pedro phase deposits at Las Capas by SWCA (Chapin-Pyritz 2007) and those reported by Desert Archaeology for the late San Pedro phase at Las Capas (Dean 2003). However, it was lower than that reported by Desert Archaeology for the early San Pedro phase at Las Capas (Dean 2003) and much lower than found at the San Pedro phase Home Depot site (Strand 1999) where the ratio was 0.58. The indexes for Middle and Late Archaic period contexts at New River (AZ T:4:122 [ASM]) (Potter 2000) were higher than those seen at Falcon Landing, at 0.52. Cienega phase contexts at Las Capas, Los Pozos, and Stone Pipe (Dean 2003) had much lower lagomorph indexes than those found in the Luke Solar project. The Luke Solar Cienega phase and Chiricahua phase lagomorph indexes were much higher than those for Middle Archaic period contexts excavated for the Picacho Reservoir project (Bayham et al. 1986).

There were higher proportions of cottontails to jackrabbits in both the Chiricahua phase and the Cienega phase at Falcon Landing (see Table 56) compared with the San Pedro phase, which had more jackrabbits than cottontails. The San Pedro phase also had less than a quarter of the number of specimens the Chiricahua phase and Cienega phase did. More cottontails were seen in the Red Mountain phase as well, but the number of identifiable specimens was far too low to be reliable. Although the ratio was high in the Cienega phase, it was lower in contexts dating to the Late Cienega to Red Mountain phases. Unfortunately, there were too few identifiable leporids to construct indexes for later time periods, so we could not determine if this indicates any chronological trend. Interestingly, the lagomorph index for early-twentieth-century Feature 1664 was consistent with that for the Chiricahua phase. This feature likely represents a very different behavior than the prehistoric features, but it may include a more representative sample of the kinds of leporids available in the immediate area. Feature 1664 appeared to contain largely unprocessed carcasses and probably reflects a sample of individual animals of various undesirable taxa that were visible to the hunters at the time. Still, it may provide a partial snapshot of some of the taxa in the area. The lagomorph index for Historical period Feature 1664 was significantly higher than that of the prehistoric logistic camps examined by Dean, suggesting that even though jackrabbits took much of the blame for crop depredations in the early twentieth century, cottontails had a significant presence at least in our area.

Humans do not always hunt game in direct proportion to their abundance in the environment. There may be cultural preference for one taxon over another, and, at least in times of relative plenty, this may affect the ratios of bones recovered in archaeological sites. Cottontail bone is smaller, and broken cottontail bones may be lost during excavation more often than jackrabbit (Waters 2002:752), and so differences in the numbers of jackrabbits and cottontails may reflect, in part, excavation bias rather than hunting. The ethnographic Akimel O'odham preferred jackrabbits to cottontails (Rea 1998:132). Jackrabbits are larger, but they are also said to taste better than the smaller rabbits. Rea (1998:143) was also told that the black-tailed jackrabbit tastes a little tenderer than the antelope jackrabbit.

Density

As noted above, the Luke Solar project Chiricahua phase features tended to have low frequencies of bone, with a few exceptions. In fact, most features of any age had very little fauna. Of 309 features and subfeatures containing bone, shell, or eggshell, 290 had less than 20 specimens and 274 less than 10. Only 4 features contained more than 100 specimens: Feature 1664 (n = 1,827), dating to the early twentieth century; Feature 18880 (n = 266), a nonthermal pit containing more than 200 shell beads dating to the transition between the Chiricahua and San Pedro stage; Feature 4235 (n = 270), a nonthermal pit dating to the Chiricahua phase; and Feature 3306 (n = 156), a poorly dated thermal pit.

The density of bone per cubic meter excavated was calculated (Table 57), excluding mollusk shell and obviously intrusive bone. The densities were compared across time, and with a few exceptions tended to fall between 7 and 12 fragments per cubic meter. The results largely supported trends seen in the number of bone fragments recovered, with the exception of the Sulphur Spring phase and Classic period, two time periods with bone counts of only 5 specimens each. Both of these showed very high densities, probably because they were artificially inflated by multiplying a small excavated volume to attain a cubic meter. For example, in the case of the Sulphur Spring phase, even if only 1 bone fragment had been recovered, the density would still be calculated to 38 specimens per cubic meter.

Bone densities may increase slightly over time from the Chiricahua phase through the Cienega phase, although the differences are slight between the San Pedro and Cienega phases. Specimens assigned to the Red Mountain phase made up only ca. 1 percent of the total fauna (see Table 46; Appendix 4.2), with less than half as much bone as was recovered from San Pedro phase contexts and less than 10 percent of the amount recovered from either the early Chiricahua phase or the Cienega phase. Just as the bone counts were lower, the density of bone in Red Mountain deposits was also much lower than the density of bone in the combined Chiricahua phase and San Pedro and Cienega phases. Bone density was very high in the Historical period, but this is a direct result of Feature 1664, which also had the highest NISP of any feature.

Table 57. Density of Bone per Cubic Meter, by Temporal Period, All Sites Combined

Temporal Period	Number of Features	Volume (m^3)	n	Density per m^3
Sulphur Spring	1	0.026	5	192.31
Early Chiricahua	39	55.582	445	8.01
Late Chiricahua	5	3.995	31	7.76
Early and late Chiricahua combined	44	59.577	476	7.99
San Pedro	15	10.125	105	10.37
Cienega	17	8.993	111	12.34
Red Mountain	5	13.327	36	2.70
Pre-Classic	4	4.935	46	9.32
Classic	2	0.069	5	72.46
Historical period	2	0.104	1,811	17,413.46
Cochise[a]	98	38.928	654	16.80
Poorly dated	86	35.995	545	15.14
Total	318	112.476	3,794	33.73

[a] Archaic-aged material that could not be assigned to a specific phase was classified as Cochise.

Waters (2005) found that bone densities at Las Capas and Los Pozos increased during site occupation, and suggests that lower densities at Las Capas indicated lower intensity human occupations, with fewer people occupying the area; hunting, processing, and consuming meat; and discarding bone. If the importance of animal foods remained constant over time, the gradual increase in bone density at Falcon Landing between the Chiricahua phase and the Cienega phase may similarly suggest that more people were present in the Cienega. Or the lower bone densities could also reflect a greater reliance on plant products and less energy devoted to hunting during the earlier times.

As an experiment, the large-game index was calculated substituting the densities of rabbit-sized and deer-sized mammals for specimen counts to create a large-game density index, with the understanding that the result, which represents a ratio of ratios, was unlikely to be directly comparable to published large-game indexes of other sites. The resultant ratios were surprisingly similar to the indexes calculated in the more usual manner. In most time periods, the ratios were usually within a few points of one another for the entirety of the Chiricahua phase, and the San Pedro and Red Mountain phases, the Cochise category, and the Historical period. The ratios differed for two time periods: the standard large-game index was 0.10 for the Cienega phase, but the index derived from densities was slightly higher at 0.14. In contrast, the large-game index derived from densities was lower for the pre-Classic period at 0.05, compared to 0.11 using the standard large-game index based on NISP (see Table 56).

Comparison with other Sites

Our understanding of Archaic hunting practices and foodways is hindered by the lack of identified sites with faunal material on the lower *bajada*. Only a few pieces of faunal bone were found in Sulphur Spring phase contexts at Tres Rios (AZ 11:94 [ASM]), including three calcined and fragmentary bones from a rabbit-sized mammal, three *Glycymeris* shells, and snail shells from the channel (Graves et al. 2009). More Middle Archaic period sites and faunal collections have been reported, but faunal collections tend to be scarce and consist of few specimens.

Deposits at the Last Ditch site (U:5:33 [ASM]) include Middle and Late Archaic period materials as well as a Hohokam surface scatter (Rogge and Phillips 2009a). Archaeologists have visited the site several times over the years. URS Corporation excavated Middle Archaic period contexts at the Last Ditch site in 2007 but only recovered 8 bone fragments and all were interpreted as likely intrusive rodent bone. In addition, 2 land snails were also found (Albush 2009). The authors suggest that plant resources were likely a focus for the occupants, and that small game was only taken opportunistically (Phillips et al. 2009). Faunal bone from Archaeological Consulting Services (ACS) excavations at the Last Ditch site yielded 146 bones and fragments, but 133 of these were small fragments recovered from flotation that were largely unidentifiable beyond general size class. All bone that could be identified to at least size class belonged to smaller taxa, with 3 jackrabbit bones, 37 small mammal, 8 rodent, and 1 bone that could have belonged to an animal larger than a jackrabbit (Phillips et al. 2001). The carbonate coating and staining seen on the bone from Falcon Landing was not mentioned for these specimens. The 1996 and 1997 excavations at Last Ditch produced only 8 faunal bones, including 2 jackrabbit bones, 4 medium-sized mammal bones from feature locations, and a jackrabbit and a kangaroo rat bone from nonfeature locations (Hunter 1998). The 3 jackrabbit specimens were all foot bones. Together, these results suggest that the faunal material from Last Ditch was generally highly fragmentary, with a focus on smaller taxa such as leporids and perhaps rodents rather than larger artiodactyls.

North of our project area but still in Maricopa County, Stratum II of AZ T:4:122 (ASM) contained a mix of Middle and Late Archaic period deposits including 67 faunal specimens (Potter 2000; Potter and Fox 2000). Although a few deer bones were found, the fauna was dominated by bone from smaller mammals such as jackrabbits, cottontails, and unidentified small mammals. A few rodent bones were also identified. Carbonate coating was seen on 13 percent of the bone.

Several Archaic period sites in the Harquahala Valley were investigated in the 1980s, and small faunal collections were recovered from four of these sites. Of these, the Lookout and the Apothecary sites contained bone in sufficient quantities to compare. The Harquahala Valley sites are located at around 372–384 m (1,220–1,260 feet) AMSL (Bostwick 1988). A strong difference between the bone from the four Harquahala sites and the sites investigated by the Luke Solar project is in the identifiability of the bones. Analysts were able to identify 62 percent of the bone to level of order from the Harquahala Valley sites. These rates of identifiability suggest that the bone from the Harquahala Valley sites was much less fragmented than the bone from the present project.

The Lookout site contained only 129 specimens, with seven distinct taxa, including sheep, jackrabbit, wood rat, cottontail, ground squirrel, badger, and fox. The lagomorph index for the San Pedro phase Lookout site was only 0.05, and the artiodactyl index less than 0.02. The faunal collection at the Middle to Late Archaic period Apothecary site was dominated by tortoise shell bone, with Testudinidae and two jackrabbit, one cottontail, and one badger (*Taxidea taxus*) bone, with a MNI of one each of tortoise, jackrabbit, cottontail, and badger (Bostwick and Hatch 1988). Other sites in the general area date to the Archaic period but had little or no fauna. For example, at AZ T:2:1 (ASM), located about 67.6 km (42 miles) northwest of Phoenix, subsurface deposits were explored, but no faunal bone was found (Rice 1981).

Fauna was recovered from Middle Archaic period deposits at the Buried Dune, Gate, and Arroyo sites, all excavated as part of the Picacho Reservoir Archaic Project (Bayham 1986b). Archaeologists recovered 449 bone fragments at the Arroyo site, but 82 percent was unidentifiable. Sixty percent of the identifiable fauna was jackrabbit, compared to 11 percent cottontails. Reptiles, including desert tortoise, horned lizard (*Phrynosoma*), and snake bones contributed 6 percent. Carnivora remains included fox, coyote, and badger. Deer and bighorn sheep bones were present as well. A few Pleistocene fossil bones were also found in this site. Fauna from the Buried Dune site (AA:3:16 [ASM]) consisted largely of leporid bone, with 1 lizard, no artiodactyl, 1 coyote, and 1 squirrel bone, but 70 percent of the 87 bones and fragments could not be identified. The fauna from the Gate site included 243 bones, but a much higher proportion could be identified than at the other two Middle Archaic sites investigated in this project. Only 49 percent of the fauna was unidentifiable. Not surprisingly, leporid bone made up a high proportion of the collection, with 84 percent of the identifiable bone assigned to jackrabbit, cottontail, or indeterminate leporid. Carnivora remains at the Gate site included coyote, kit fox, and bobcat, and wood rat, kangaroo rat, ground squirrel and antelope ground squirrel were also recovered. The low identifiability of the bone from two of the three sites at Picacho indicates high fragmentation, suggesting that the carcasses may have been heavily processed by the people of the Picacho Reservoir area. When faunal bone has been recovered in Middle Archaic period sites in the Phoenix area, it has generally been very fragmented and generally assigned to smaller taxa. Fragmentation can come about through cultural or noncultural processes. Waters (2005b) found increases in fragmentation in Los Pozos and Las Capas from the San Pedro through the Cienega phases, but this pattern was not seen at Falcon Landing. Instead, the highest fragmentation was seen in the Chiricahua phase, although this may be partially influenced by the greater likelihood that bone was broken simply because it was older.

In the Tucson Basin, Middle Archaic period components were discovered at Los Pozos (Wöcherl 1999) and Las Capas (Chapin-Pyritz 2007). The Middle Archaic period components at Los Pozos included 283 highly fragmentary faunal bones, 197 (70 percent) of which were identifiable at least to size class, but only 43 percent could be identified to the level of order. Only 2 (0.7 percent of the total) complete elements were recovered, both of which were leporid foot bones. Leporids made up 75 percent of the identifiable bone and artiodactyls contributed only 17.6 percent. Far fewer rodent bones were found at Los Pozos compared to the Luke Solar project sites. Relatively low proportions of leporid cranial and axial bones and high proportions of lower limb bones were seen in Los Pozos, Las Capas, Wetlands, and Santa Cruz Bend (Waters 2005b). Most leporid bones from the Middle Archaic period component of Los Pozos were from limbs and feet, but a few other body regions were represented. Artiodactyl bones included limb bones and antler (Wöcherl 1999).

Excavators of Middle Preceramic deposits at Las Capas recovered 38 pieces of faunal bone (Chapin-Pyritz 2007), and as usual, leporids continued to dominate the identifiable bone (n = 21; 55 percent), but artiodactyls made up a much higher proportion, represented by 10 specimens (26 percent). Reptiles were few, and included 1 tortoise bone and 1 snake bone (2 percent each). No bird, rodent, or carnivore bones were identified.

Fauna from the Fairchild site included 4,257 bones and fragments, 94 percent of which could not be identified beyond mammal size class (Windmiller 1973). Most were from small mammals; the remainder were identified as leporid, jackrabbit, cottontail, rodent, and unidentified large mammal bone. Sixty percent of the bone from the Fairchild site was burned. No other information is available, but the low identifiability reported suggests that the bone was probably highly fragmented.

The few known Middle Archaic period faunal collections from southern Arizona tend to be highly fragmented and are interpreted to have been heavily processed. The Luke Solar project fauna is no exception. Faunal diversity is harder to interpret because so many of the collections are very small, and there is some variability in the emphasis on different taxa, perhaps because of site or sample size, or site function.

Over the last few decades, several large, well-documented Late Archaic/Early Agricultural period sites have been found and investigated, greatly increasing our understanding of this time period. Many of the larger faunal collections from Tucson Basin Late Archaic/Early Agricultural contexts were found in the floodplains (Waters 2005b; Wöcherl 1999) where a variety of riparian fauna were potentially available. Comprehensive studies of these large sites show that by the Early Agricultural period, agriculture was regularly practiced in the floodplain. Maize and beans were present at Las Capas in the early San Pedro phase (Diehl 2005), although cultivars had not yet replaced wild foods in importance (Diehl, ed. 2005). Leporids made up the highest proportion of the animal-based diet throughout the Late Archaic/Early Agricultural period (Waters 2005b), but the ratios of jackrabbits to cottontails, the overall taxonomic richness, and the proportion of artiodactyls to leporids changed in response to increasing human sedentism. Environmental changes caused by variations in the size and duration of human settlements may have played a role as well. Lagomorph indexes tend to become smaller, indicating a heavier reliance on jackrabbits than cottontails. Artiodactyl and large-game indexes grow larger in the Cienega phase compared to the San Pedro phase. The gradual changes seen in the Late Archaic/Early Agricultural period have roots in the previous period. Maize was rare in the Middle Archaic, but present (Roth and Freeman 2008). As more data have been recovered, it appears that the Middle Archaic was a time of transition as some southern Arizona groups began to add a few cultivars to their subsistence strategies while retaining a focus on wild plants and animals.

Summary and Conclusions

The animal remains from Falcon Landing provide clues to the poorly understood subsistence and hunting practices of the Middle and Late Archaic periods in the Phoenix Basin. As with the nearby Last Ditch site, the faunal remains from Falcon Landing and Site 68 were consistent with a pattern expected if people were drawn regularly to the site to procure and process plant foods—not to hunt and process faunal resources. The faunal remains seem to represent opportunistic hunting. In fact, it is possible that some animals could have been trapped in snares while prehistoric residents were engaged in other tasks. Subsistence patterns appear to have been relatively stable over time, as people repeatedly returned to the area to undertake the same tasks.

Hunters focused on leporids consistently over time. The leporids were heavily processed, and bone was highly fragmented from the Middle Archaic to the early historical period, the latter as evidenced by Feature 3767. Certain differences between the Chiricahua phase and the Cienega phase were suggested in the faunal collection, but there was insufficient comparative material to determine whether these patterns were widespread or unique to Falcon Landing. The bone was more heavily processed during the Chiricahua phase than the Cienega phase, as indicated by fragment size, lack of complete bones, and underrepresentation of certain body regions in Chiricahua phase contexts. High proportions of cottontails to jackrabbits were seen in the Chiricahua phase; jackrabbits increased in the San Pedro phase but decreased again in the Cienega phase. The low density of faunal remains per volume of excavated fill generally indicates low intensity of faunal exploitation over time, as might be expected if the site population was focused on gathering or processing nonfaunal resources. There does not appear to have been any strong change over time in the preferred taxa or degree of processing that would indicate either increasing or decreasing occupational duration or intensity during the Archaic period. Future analysis may be able to confirm these patterns, as more Middle Archaic period sites with large faunal collections are discovered.

There was little faunal evidence that hunting parties traveled to higher elevations or other environmental zones to bring back deer, pronghorn, or sheep. Bird bone was rare throughout the long span of the site's occupational record, and there was no evidence for special treatment of particular taxa, with the possible exception of an isolated skull of juvenile canid. The faunal data did not provide any information on seasonality. There was no evidence for agriculture-related anthropogenic changes in the landscape in the pre-twentieth-century material, but this is not surprising because there was no evidence for on-site agriculture. Feature 1664 provided a glimpse into what appears to have been a single, short-term hunting event in the early twentieth century. In contrast to the heavily processed leporids of the earlier times, these individuals appear to have been nearly complete when interred. Fragmentation was recent, as indicated by clean, white broken surfaces. The cow and sheep bones from this feature were probably the remains of a meal or two consumed by those engaged in the hunting episode.

Faunal artifacts provided limited evidence of personal decoration (e.g., bone and shell beads) and tool use. An antler tine tool was likely used to manufacture, repair, or resharpen stone tools, and the awls could have been used to make baskets or skin containers used in processing plant resources. Use wear on one awl suggested contact with a soft material, but unfortunately, use-wear analysis was unproductive on most bone tools because of the thick carbonate layers that covered the bone. The heavy layer of possible additive polish found on one bone fragment was intriguing. In experimental work, such a polish was formed by allowing plant juices to dry on bone, but the exact cause of the shiny surface of the broken bone from Feature 5509 is unknown. The limited bone-tool collection may, at least in part, reflect the special-use and short-term occupation of the site. Marine shell indicated some contact with the Gulf of California as early as the San Pedro phase, although it is not known whether this was by trade, person-to-person contact, or if it was collected by individuals or groups travelling to the coast.

CHAPTER 5

Ceramics

William M. Graves and David E. Doyel

In this chapter, we present the results of analysis of the small collection of ceramic sherds recovered from the Luke Solar project area. Ceramics were collected from Falcon Landing, Site 423, and a trench between Falcon Landing and Site 437, in Area A (see Figure 1, Volume 1). Despite the low frequency of ceramic remains, the analyzed collection provides insight into the use of the project area and some of the activities that may have been carried out there during both the Late Archaic/Early Agricultural period (1500 B.C.–ca. A.D. 50) and the Ceramic period (ca. A.D. 50–ca. 1450). The ceramic-function-analysis data from the collection suggest occasional use of ceramic vessels in the project area to fulfill short-term liquid- or dry-storage needs and/or for cooking during the Ceramic period. Other analyses in this volume have concluded that the project area sites were not long-term or more-permanent habitations but are indicative of intermittent, short-term use of the area over time. Perhaps, inhabitants of nearby sites visited the project area to acquire resources, such as food resources or wood, and occasionally used vessels to support or provision such activities. In addition, the collection also contained two untempered rim sherds from small vessels that were recovered from buried contexts radiocarbon dated to between 1200 B.C. and 200 B.C. (the Late Archaic/Early Agricultural period). These two sherds correspond to published descriptions of the incipient plain ware that has been recovered from buried features along the Santa Cruz River in the Tucson Basin and dates to as early as 2100 B.C. (Heidke 1999, 2005, 2006; see also Garraty 2011). To our knowledge, incipient plain ware has not been described previously from Archaic period sites in the Phoenix Basin. The inclusion of these two possible incipient plain ware fragments in the project collection is remarkable and provides some clues as to the very earliest stage of the development of ceramic technology in the Phoenix Basin.

Below, we describe the ceramic collection from the Luke Solar project and briefly detail the methods used to analyze the collection. Following that is a discussion of the different varieties or types we identified of the two wares present in the collection: plain ware and Hohokam Buff Ware. We then discuss the recovery contexts of the ceramic artifacts in the collection, focusing particularly on sherds recovered from features and other buried contexts at the project sites. Finally, we end the chapter with our thoughts on what the collection can tell us about past use of the project area and the introduction of ceramic technology in the region.

The Collection and Methods

The ceramic collection consisted entirely of fragmented-vessel remains recovered mostly from the modern ground surface of the project sites. Phase 1 and 2 investigations resulted in the collection of 126 sherds from Falcon Landing, Site 423, and intersite areas within the project area. Of the 126 sherds, 125 were analyzed. In addition to the 126 collected sherds, 1 indeterminate plain ware sherd was recorded in the field, on the surface of Falcon Landing, but was not collected. Based on similarities in paste, temper, and surface color, we estimate that the maximum number of vessels represented by the analyzed collection is 111; however, the actual total number of vessels represented may be smaller.

The analysis consisted of the recording of attribute data for all sherds and was conducted in two stages (Table 58). The first stage of analysis involved the recording of a limited set of attributes. All sherds were counted and coded for ceramic unit or vessel part, ware and type, sherd size, primary and secondary inclusions

Table 58. Ceramic Variables Recorded during Analysis

Recorded Variable, by Analysis Stage	Variable Type	Comments
Initial analysis		
Count	integer	
Ceramic unit	categorical	Rim or body sherd.
Ware	categorical	Plain ware or Hohokam Buff Ware.
Type	categorical	Gila Plain, Gila variety; Gila Plain, Salt variety; indeterminate plain ware; indeterminate red-on-buff (painted); indeterminate buff ware (no paint); Sacaton Red-on-buff.
Sherd size	categorical	Rim or body sherd.
Primary-inclusion type	categorical	Rim or body sherd.
Primary-inclusion sorting	categorical	Rim or body sherd.
Primary-inclusion size	categorical	Rim or body sherd.
Secondary-inclusion type	categorical	Rim or body sherd.
Secondary-inclusion sorting	categorical	Rim or body sherd.
Secondary-inclusion size	categorical	Rim or body sherd.
Paint color (general), interior	categorical	Rim or body sherd.
Paint color (general), exterior	categorical	Rim or body sherd.
Slip color (general), interior	categorical	Rim or body sherd.
Slip color (general), exterior	categorical	Rim or body sherd.
Expanded analysis		
Vessel class	categorical	Rim or body sherd.
Vessel form	categorical	Rim sherds only.
Rim form	categorical	Rim sherds only.
Wall angle	categorical	Rim sherds only.
Rim angle	categorical	Rim sherds only.
Shoulder type	categorical	Body sherd.
Rim-orifice diameter	metric (cm)	Rim sherds only.
Percent of orifice present	percent	Rim sherds only.

(tempers), and general paint and slip color, when applicable. Ware and type assignments were made by David Doyel; inclusion types were identified by Doyel and William Graves, with assistance from Matthew Pailes and Jesse Ballenger; and all other attributes were recorded by Graves. The second stage of analysis consisted of the recording of additional data concerning aspects of vessel morphology and size for the eight recovered rim sherds. These attributes included vessel class, vessel form, rim form, wall angle, rim angle, shoulder type, rim-orifice diameter, and percent of orifice present. For analysis purposes, all conjoinable sherds were counted as one. Appendix 5.1 presents brief descriptions of the ceramic attributes recorded for this project.

The recording of vessel morphology and size attributes for rim sherds allowed for the identification of vessel-form functional categories for five of the eight rim sherds analyzed. These vessel-form functional categories were based on Braun's (1980, 1983) method of inferring vessel function based on attributes of vessel size, shape, and orifice diameter. Using Braun's methods, Heckman (2001, 2002) has developed a procedure whereby whole vessels or rim sherds can be assigned to one of Braun's 42 vessel-function categories (Table 59) using the attributes recorded during the second stage of analysis. See Heckman (2002) and Garraty et al. (2011) for more detailed discussions of vessel-function analyses utilizing Braun's (1980, 1983) functional groups.

Table 59. Braun Functional-Group Categories

Braun Code	Shape Class	Orifice-Diameter Range	General Function	Specific Function (based on Braun 1980)	Vessel Size
1	jar, necked	extremely narrow (0–2.9 cm)	storage	specialized liquid/canteen	individual
2	jar, indeterminate	extremely narrow (0–2.9 cm)	storage/transfer	short-term dry/liquid storage	individual
3	jar, recurvate	extremely narrow (0–2.9 cm)	storage/transfer	short-term dry/liquid storage	individual
4	jar, simple	extremely narrow (0–2.9 cm)	storage	specialized dry storage	
5	bowl, plain	extremely narrow (0–2.9 cm)		miniatures, specialized function	
6	plate/shallow bowl	extremely narrow (0–2.9 cm)		miniatures, specialized function	
7	jar, necked	very narrow (3–6.9 cm)	storage/transfer	short-term dry/liquid storage	individual
8	jar, indeterminate	very narrow (3–6.9 cm)	storage/transfer	short-term dry/liquid storage	individual
9	jar, recurvate	very narrow (3–6.9 cm)	storage/transfer	short-term dry/liquid storage	individual
10	jar, simple	very narrow (3–6.9 cm)	storage	specialized dry storage	
11	bowl, plain	very narrow (3–6.9 cm)		miniatures, specialized function	
12	plate/shallow bowl	very narrow (3–6.9 cm)		miniatures, specialized function	
13	jar, necked	narrow (7–12.9 cm)	storage/transfer	liquid storage/carrier	individual
14	jar, indeterminate	narrow (7–12.9 cm)	storage	liquid/dry storage	individual
15	jar, recurvate	narrow (7–12.9 cm)	storage	liquid/dry storage	individual
16	jar, simple	narrow (7–12.9 cm)	storage	specialized dry storage	
17	bowl, plain	narrow (7–12.9 cm)	processing/serving	food processing without heat/eating/serving	individual
18	plate/shallow bowl	narrow (7–12.9 cm)	processing/serving	food processing with or without heat/eating/serving	individual/small
19	jar, necked	medium (13–25.9 cm)	storage/cooking	short-term liquid storage/cooking	small
20	jar, indeterminate	medium (13–25.9 cm)	storage/cooking	short-term liquid or dry storage/cooking	small
21	jar, recurvate	medium (13–25.9 cm)	storage/cooking	short-term liquid or dry storage/cooking	small
22	jar, simple	medium (13–25.9 cm)	storage	short- or long-term dry storage	small
23	bowl, plain	medium (13–25.9 cm)	processing/serving	serving/food processing without heat	small
24	plate/shallow bowl	medium (13–25.9 cm)	processing/serving	food processing without heat/dry cooking/serving/eating	small
25	jar, necked	wide (26–31.9 cm)	storage/cooking	short- or long-term liquid or dry storage/cooking	small/medium
26	jar, indeterminate	wide (26–31.9 cm)	storage/cooking	short- or long-term, dry storage/cooking	small/medium
27	jar, recurvate	wide (26–31.9 cm)	storage/cooking	short- or long-term, dry storage/cooking	small/medium
28	jar, simple	wide (26–31.9 cm)	storage	short- or long-term dry storage	small/medium

continued on next page

Braun Code	Shape Class	Orifice-Diameter Range	General Function	Specific Function (based on Braun 1980)	Vessel Size
29	bowl, plain	wide (26–31.9 cm)	processing/serving	serving/food processing without heat	small/medium
30	plate/shallow bowl	wide (26–31.9 cm)	processing/serving	food processing without heat/dry cooking/serving/eating	small/medium
31	jar, necked	very wide (32–38.9 cm)	storage	short- or long-term liquid storage	medium/large
32	jar, indeterminate	very wide (32–38.9 cm)	storage	short- or long-term liquid or dry storage	medium/large
33	jar, recurvate	very wide (32–38.9 cm)	storage	short- or long-term liquid or dry storage	medium/large
34	jar, simple	very wide (32–38.9 cm)	storage	long-term dry storage	medium/large
35	bowl, plain	very wide (32–38.9 cm)	processing/serving	serving/food processing without heat	medium/large
36	plate/shallow bowl	very wide (32–38.9 cm)	processing/serving	food processing without heat/dry cooking/serving/eating	medium/large
37	jar, necked	extremely wide (>39 cm)	storage	short- or long-term liquid storage	large
38	jar, indeterminate	extremely wide (>39 cm)	storage	short- or long-term liquid or dry storage	large
39	jar, recurvate	extremely wide (>39 cm)	storage	short- or long-term liquid or dry storage	large
40	jar, simple	extremely wide (>39 cm)	storage	long-term dry storage	large
41	bowl, plain	extremely wide (>39 cm)	processing/serving	serving/food processing without heat	large
42	plate/shallow bowl	extremely wide (>39 cm)	processing/serving	food processing without heat/dry cooking/serving/eating	large

Note: See Heckman (2002).

Wares and Types in the Collection

Two wares, plain ware and Hohokam Buff Ware, were present in the project collection (Table 60). Each of these wares is described below. The plain ware consisted of three varieties, or "types": Gila Plain, Gila variety; Gila Plain, Salt variety; and unidentified plain ware. The remainder of the collection was Hohokam Buff Ware (both painted and unpainted sherds), and the only identifiable type in the collection was the Sedentary period type Sacaton Red-on-buff. We identified two distinctive varieties of temper in the sherds of Hohokam Buff Ware in the project collection: a sand-tempered variety and a micaceous-schist-tempered variety. Interestingly, phyllite-tempered Buff Ware, common in the Agua Fria drainage north of the Luke Solar Project, is not present in the collection.

Gila Plain

Gila Plain was the dominant plain ware throughout the Hohokam sequence (ca. A.D. 300–1450) (Garraty et al. 2011; Haury 1965, 1976), and it was the most abundant ware in the project collection. Gila Plain sherds constituted 77 percent of the analyzed sherd total. Gila Plain is commonly attributed to one of several varieties,

Table 60. Frequencies of Analyzed Wares and Types, by Site

Ceramic Unit, by Ware/Type	Falcon Landing	Site 423	Nonsite Area	Total
Gila Plain, Gila variety				
Sherd, body	9	—	—	9
Sherd, rim	1	—	—	1
Subtotal	10	—	—	10
Gila Plain, Salt variety				
Sherd, body	43	39	1	83
Sherd, rim	3	—	—	3
Subtotal	46	39	1	86
Indeterminate Hohokam buff (no paint)				
Sherd, body	12	—	—	12
Sherd, rim	1	—	—	1
Subtotal	13	—	—	13
Indeterminate plain				
Sherd, body	1	—	—	1
Sherd, rim	2	—	—	2
Subtotal	3	—	—	3
Indeterminate Hohokam red-on-buff				
Sherd, body	6	—	—	6
Subtotal	6	—	—	6
Sacaton Red-on-buff				
Sherd, body	5	—	—	5
Sherd, rim	2	—	—	2
Subtotal	7	—	—	7
Total	85	39	1	125

based on temper (see Doyel and Elson 1985; Garraty et al. 2011:336–337), and two varieties of this ware were present in the project collection: Gila variety (n = 10) and Salt variety (n = 86).

Gila Plain at Snaketown was described by Haury (1965, 1976). There, Gila Plain sherds constituted between approximately 60 and 95 percent of each phase assemblage and decreased in relative frequency through time (Haury 1965:Figure 107). Gila Plain vessels were used for cooking and storage and came in varieties of bowls, jars, and miscellaneous forms (scoops, rectangular vessels, legged vessels, colanders, and "heavy-walled" vessels) (see Haury 1976:Figure 12.58). The surfaces of Gila Plain vessels range from light brown to gray in color and often exhibit fire clouding, which resulted in variation in surface color on individual vessels (Haury 1965: 206, 1976:223). Vessel thickness is also variable, depending on where the measurement is taken (e.g., at the rim, shoulder, or base) and intended vessel function. Haury (1976:223) described Gila Plain vessels as generally not slipped and the interior and exterior vessel surfaces as often not finished or modified, other than occasional instances of the expedient polishing of some vessel exteriors. However, exterior-surface polishing (perhaps with pebbles) is more typical of both late pre-Classic period and Classic period Gila Plain.

Gila Plain, Gila Variety

Gila Plain, Gila variety, was described by Doyel and Elson (1985:452) from site collections in the New River drainage, located approximately 24 miles northeast of the Luke Solar project area. Sherds of this variety exhibited angular micaceous-schist temper with small amounts of angular quartz and muscovite particles and were not slipped. Gila Plain, Gila variety, sherds from the New River project were also rarely blackened, and polishing and smudging were not observed (Doyel and Elson 1985:452). Doyel and Elson (1985:452) reported that the Gila Plain, Gila variety, sherds recovered from the New River project were similar in temper to Gila Plain, Gila variety, sherds recovered from the Cashion site, near the confluence of the Gila, Agua Fria, and Salt Rivers, and that no micaceous-schist sources are known for the New River drainage. They further suggested that Gila variety vessels were produced in a geographically restricted area where micaceous schist was available and were imported into the New River area (Doyel and Elson 1985:452).

Gila Plain, Gila variety, sherds (n = 10) constituted 8 percent of the total analyzed Luke Solar project collection. Figure 85 presents a sample of the Gila Plain, Gila variety, sherds recovered from the project area. Gila Plain, Gila variety, sherds range from light yellowish brown (10YR 6/4) to very dark gray (10YR 3/1) in surface Munsell color and from 3 to 6 mm in sherd thickness. None of the analyzed Gila variety sherds were smudged, burned, or sooted; however, several were blackened. In total, 1 rim sherd and 9 body sherds were typed as Gila Plain, Gila variety. All Gila Plain, Gila variety, sherds contained angular micaceous-schist temper with abundant mica flecks. The inclusions were medium- to coarse-sand-sized (1/4–1-mm) particles that were medium to poorly sorted. The angularity of the particles suggests that the tempering material was crushed before it was combined with the clay. Mica flecks were also commonly observable on the surfaces of sherds. The single rim sherd was from a plate that was approximately 19 cm in diameter (see Figure 85). The plate rim was not assigned to a Braun functional group (Table 61); however, based on its form, it was likely used for food presentation or consumption.

Gila Plain, Salt Variety

Doyel and Elson (1985:451–452) also described Gila Plain, Salt variety, from New River sites, where a variety of this pottery is thought to have been produced (Doyel and Elson 1985:510–511). Salt variety sherds were the most abundant among the plain ware sherds recovered from the Luke Solar project area (see Table 60). Sherds of this variety contain temper consisting of rounded to subrounded sand and quartz particles with secondary inclusions of muscovite, biotite, plagioclase, chert, crushed sherds, and a variety of other rock and mineral inclusions (Doyel and Elson 1985:451). Salt variety sherds in the New River project collection ranged from light brown to reddish or dark brown, and fire clouds were observed on over half the sherds recovered. Sherd surfaces were smoothed and occasionally wiped, and surface finishes, such as smudging,

Figure 85. Selection of Gila Plain, Gila variety, sherds: (*a*) body sherd, Catalog No. 0400104C8; (*b*) body sherd, Catalog No. 04000BE65; (*c*) plate-rim sherd, Catalog No. 04000F9D5; and (*d*) body sherd, Catalog No. 04000F397. Sherd exteriors are shown to the left, and interiors are shown to the right.

Table 61. Rim-Sherd Data and Braun Functional-Group Categories

Ware and Type	Vessel Form	Rim-Orifice Diameter (cm)	Percent of Vessel Orifice Present	Braun Functional Group	Site Surface	Feature 15482	Feature 19067	Total
Gila Plain, Gila variety	plate	19	7	not assignable	—	—	1	1
Gila Plain, Salt variety	indeterminate	not recordable	not recordable	not assignable	1	—	—	1
Gila Plain, Salt variety	indeterminate	20	4	not assignable	1	—	—	1
Gila Plain, Salt variety	jar with neck	15	9	short-term liquid storage/cooking	1	—	—	1
Indeterminate plain ware	bowl[a]	4	20	miniatures, specialized function	1	—	—	1
Indeterminate plain ware	indeterminate[b]	8	5	not assignable	—	1	—	1
Micaceous-schist-tempered buff ware, Sacaton Red-on-buff	jar with neck	15	13	short-term liquid or dry storage/cooking	1	—	—	1
Sand-tempered buff ware, Sacaton Red-on-buff	jar with neck	20	13	short-term liquid storage/cooking	1	—	—	1
Sand-tempered buff ware, indeterminate buff ware (no paint)	jar with neck	17	16	short-term liquid storage/cooking	1	—	—	1
Total					7	1	1	9

[a] Sherd recovered from Level 3 in TP 8874 at Site 419.

[b] Sherd recovered from the fill of Feature 15482 (pit) at Site 419, which dated to 1200–1000 B.C.

polishing, and the application of slips, were observable on 5 percent or fewer of the sherds attributed to this variety (Doyel and Elson 1985:451–452).

In total, 86 sherds (or 69 percent of the analyzed sherds) in the Luke Solar project collection were typed as Gila Plain, Salt variety (Figure 86; see Table 60). We estimate that these 86 sherds represent the remains of, at most, 83 vessels, given similarities in surface color, paste color, and temper. Salt variety sherds contain either rounded quartz and feldspar inclusions or quartz inclusions only. Secondary inclusions include a variety of fine-grained volcanic stone (likely basalts), granitic particles, gold mica, and schist. Primary and secondary inclusions were poorly sorted to well sorted and were medium- to coarse-sand-sized ($^1/_4$–1-mm) particles. The rounded and subrounded shapes of the inclusions in the sherds of this variety suggest that relatively unprocessed sands were selected for tempering agents and that these sands were not crushed. Salt variety sherds range from very pale brown (10YR 7/3) to very dark grayish brown (10YR 3/2) in surface Munsell color and from 4 to 7 mm in thickness. Only 1 sherd was blackened, and none was sooted or smudged. In total, 3 rim sherds and 83 body sherds were typed as Gila Plain, Salt variety. One of the 3 Salt variety rim sherds could be assigned to the short-term liquid-storage/cooking Braun functional group.

Unidentified Plain Ware

We were not able to assign ware or variety to three plain ware sherds in the project collection (see Table 60). These sherds included a very thick and heavily tempered body sherd that measured approximately 1.4–1.8 cm in thickness. It bears a resemblance to Haury's (1965:207–209, 1976:Figure 12.58) heavy-walled Gila Plain vessels from Snaketown. The remaining two unidentified plain ware fragments were an untempered rim sherd with a small possible plagioclase inclusion and an untempered rim sherd from a miniature bowl.

The untempered rim sherd containing the plagioclase inclusion was recovered from the fill of a pit, Feature 15482 at Falcon Landing, that yielded a calibrated radiocarbon date of 1200–1000 B.C. (San Pedro phase) (see Chapter 2). It exhibited a possible incising mark on its exterior surface (Figure 87) and may represent a fragment of a vessel of an incipient plain ware described by Heidke (1999, 2005, 2006; see also Garraty 2011) from Archaic period sites in the Tucson Basin. The sherd tapers in width at the rim, and we were not able to determine the original vessel form or the Braun functional group (see Table 61). The original vessel may have been 8 cm in diameter, and we estimate that approximately 5 percent of the original vessel orifice was represented by the sherd. We discuss this sherd and its context of recovery further in later sections of this chapter.

The untempered rim sherd from a miniature bowl was recovered from TP 8874 at Falcon Landing (Figure 88). TP 8874 was excavated through Unit III2, which has been dated to the interval of 720–200 B.C. (Cienega phase). The rim-diameter measurement for this miniature-bowl fragment was 4 cm, and it had an unknown specialized function (see Table 61). Given the age of the deposit from which the bowl-rim sherd was recovered, it may be from another incipient plain ware vessel. We discuss the bowl-rim sherd and its recovery context further in later sections of this chapter.

Hohokam Buff Ware

Hohokam Buff Ware was the main decorated ceramic ware during the Hohokam pre-Classic period and was first described in detail by Haury (1965, 1976), from Gila Pueblo excavations and subsequent University of Arizona excavations at Snaketown. Hohokam Buff Ware is distributed throughout central and southern Arizona and consists of multiple red-on-buff types produced throughout the Hohokam pre-Classic period and into the early Classic period (see Heckman et al. 2000). The paste color of Hohokam Buff Ware ranged through time from brownish gray to a rosy pink to buff (Heckman et al. 2000:97–98). Hohokam Buff Ware vessels were often tempered with crushed schist or other metamorphic rock (Heckman et al. 2000:97–98). Surface finishes included incising of the exterior surfaces on earlier types, and jar exteriors and bowl interiors and exteriors were often lightly polished or hand-smoothed. Fire clouding is commonly observed on Pioneer and early Colonial period Hohokam Buff Ware sherds (Heckman et al. 2000:98), and the paint used to decorate buff ware types was "a red, ocherous hematite pigment" (Heckman et al. 2000:98). Whitish slips were used

Figure 86. Selection of Gila Plain, Salt variety, body sherds: (*a*) Catalog No. 04000C195, (*b*) Catalog No. 0400104C6, and (*c*) Catalog No. 04000EA29. Sherd exteriors are shown to the left, and interiors are shown to the right.

Figure 87. Possible incipient plain ware rim sherd from Feature 15482 at Falcon Landing (Catalog No. 0400104C9). The sherd exterior is shown to the left, and the interior is shown to the right.

Figure 88. Possible incipient plain ware bowl-rim sherd from TP 8874 at Falcon Landing (Catalog No. 04000D7F5). The sherd exterior is shown to the left, and the interior is shown to the right.

during the Colonial and Sedentary periods. Varieties of bowls, jars, and miscellaneous forms of Hohokam Buff Ware were produced; the most distinctive forms were flare-rimmed bowls and Gila-shouldered jars (Heckman et al. 2000:98).

The only identifiable type found in the Luke Solar project collection was Sacaton Red-on-buff (see Table 60). Sacaton Red-on-buff vessels were produced during the Sacaton phase or Sedentary period (ca. A.D. 950–1150), and they possess a pinkish buff-colored paste, often with complex designs utilizing a variety of different decorative motifs painted on bowl interiors and jar exteriors (Haury 1965:171; Heckman et al. 2000:103). Vessels include a variety of bowls, jars, and miscellaneous forms (Haury 1965:171).

The 26 sherds (21 percent) in the analyzed Luke Solar project collection identified as Hohokam Buff Ware were assigned to one of three categories: unpainted (n = 13), painted (n = 6), and Sacaton Red-on-buff (n = 7) (see Table 60). We estimate that these 26 sherds represent a maximum of 15 vessels, based on similarities in surface color, paste color, and inclusions. Within each of the buff ware categories, we identified three distinctive inclusion types: micaceous schist (n = 17), sand or quartz (n = 8), and granite (n = 1). The sherd with the granite inclusion was an indeterminate buff (no paint) body sherd tempered with what appeared to be medium-sorted, medium-sand-sized ($^1/_4$–$^1/_2$-mm) granitic particles. We briefly discuss the types with micaceous-schist and sand or quartz inclusions below.

Micaceous-Schist-Tempered Buff Ware

A range of inclusions was identified in what we defined as micaceous-schist-tempered buff ware sherds. Primary inclusions ranged from poorly sorted to medium-sorted fine-sand-sized ($^1/_8$–$^1/_4$-mm) to medium-sand-sized ($^1/_4$–$^1/_2$-mm) quartz or schist particles. Secondary inclusions included well-sorted fine-sand-sized mica particles with occasional medium-sorted fine-sand-sized quartz and schist. Occasionally, possible carbonate nodules were also observed as secondary inclusions. Well-sorted mica flecks were also often visible on the surfaces and in the pastes of micaceous-schist-tempered sherds. The angularity of inclusions in this category of sherds suggested that the tempering materials were crushed during the manufacturing process.

Figure 89 presents a selection of the micaceous-schist-tempered buff ware sherds from the Luke Solar project collection. The unpainted surfaces of micaceous-schist-tempered buff ware sherds range from pale yellow (2.5YR 7/4) and very pale brown (10YR 8/4) to brownish yellow (10YR 6/6) in Munsell color, and sherds range from 5 to 8 mm in thickness. In total, 1 rim sherd and 16 body sherds from the Luke Solar project were typed as micaceous-schist-tempered buff ware. The rim sherd was from a sharply everted Sacaton Red-on-buff jar with a neck that was assigned to the functional group of short-term liquid or dry storage/cooking (see Table 61).

Sand-Tempered Buff Ware

Sand-tempered buff ware sherds have been identified in site collections from the New River drainage and are considered to be products of local manufacture (Doyel and Elson 1985:510–511). The sand-tempered buff ware sherds in the Luke Solar project collection were primarily tempered with rounded and angular quartz particles that were medium sorted and fine-sand sized ($^1/_8$–$^1/_4$ mm). Secondary inclusions of fine-grained volcanic particles, possibly basalt, were also observed. These basalt particles were also medium sorted and fine-sand sized. Several sherds also exhibited some kind of precipitate inclusion similar to the possible carbonate inclusions of the micaceous-schist-tempered buff ware sherds. However, we placed drops of diluted hydrochloric-acid solution on several sherds with these inclusions, and none reacted. Thus, we suspect that these precipitate inclusions may be another mineral, such as gypsum, and may have resulted from postdepositional processes and not intentional inclusion of the material in the ceramic paste of the vessels.

A selection of sand-tempered buff ware sherds from the Luke Solar project collection are shown in Figure 90. The unpainted surfaces of sand-tempered buff ware sherds range from very pale brown (10YR 8/4) to brownish yellow (10YR 6/6) in Munsell color, and sherds range from 4 to 6 mm in thickness. In total, two rim sherds and six body sherds were typed as sand-tempered buff ware. Both rim sherds were from jars with necks, and both were categorized as fragments of vessels used for short-term liquid storage/cooking (see Table 61).

The Recovery Contexts of Ceramics in the Luke Solar Project Area

Though rare, ceramics were recovered from a variety of contexts in the project area (Table 62). The majority of sherds (68 percent) were recovered from Falcon Landing, and the majority of the remainder (31 percent) were recovered from the surface of Site 423 (see Table 62). The Site 423 ceramics consisted entirely of Gila Plain, Salt variety, body sherds (see Table 62) collected from two surface locations, PDs 14 and 16 (see Figure 234, Volume 1). Only one sherd was recovered from a nonsite context: a Gila Plain, Salt variety, body sherd that was grab-sampled from TR 10067, in the northeastern portion of the project area (Area A), between Falcon Landing and Site 437 (see Table 62).

Falcon Landing

The ceramic collection from Falcon Landing was composed of 69 percent plain ware and 31 percent Hohokam Buff Ware (see Table 62). The plain ware from Falcon Landing was dominated by Gila Plain, Salt variety, which made up 78 percent of all plain ware sherds from the site. The micaceous-schist-tempered Gila Plain, Gila variety, sherds constituted only 17 percent.

Figure 89. Selection of micaceous-schist-tempered Hohokam Buff Ware sherds: (*a*) jar-body sherd, Catalog No. 04000C19E; (*b*) body sherd, Catalog No. 04000FBB0; (*c*) body sherd, Catalog No. 04000BF00; (*d*) body sherd with vessel shoulder, Catalog No. 0400122A36; and (*e*) jar-body sherd, Catalog No. 04000C199. Sherd exteriors are shown to the left, and interiors are shown to the right.

Figure 90. Selection of sand-tempered Hohokam Buff Ware sherds: (*a*) body sherd, Catalog No. 04000BD21; (*b*) body sherd, Catalog No. 04000BCD1; (*c*) body sherd, Catalog No. 04000BCD0; (*d*) body sherd, Catalog No. 04000BCA6; (*e*) jar-rim sherd, Catalog No. 04000F395; and (*f*) jar-rim sherd, Catalog No. 04000BCD2. Sherd exteriors are shown to the left, and interiors are shown to the right.

Table 62. Analyzed Ceramics, by Site and Recovery Context

Recovery Context	Date Interval	Analytical Group	Dating Method	Plain Ware			Granite-Tempered Buff Ware	Micaceous-Schist-Tempered Buff Ware			Sand-Tempered Buff Ware			Total
				Gila Plain, Gila Variety	Gila Plain, Salt Variety	Indeterminate Plain Ware	Indeterminate Buff (No Paint)	Indeterminate Buff (No Paint)	Indeterminate Red-on-Buff	Sacaton Red-on-Buff	Indeterminate Buff (No Paint)	Indeterminate Red-on-Buff	Sacaton Red-on-Buff	
Falcon Landing														
Site surface	not dated	not dated		9	36	1	1	8	1	6	3	4	1	70
Feature 3963 (structure fill)	A.D. 130–330	Red Mountain phase	radiocarbon	—	6	—	—	—	—	—	—	—	—	6
Feature 4626 (pit fill)	A.D. 980–1150	pre-Classic period	radiocarbon	—	—	—	1	—	—	—	—	—	—	1
Feature 10514 (pit fill)	A.D. 1050–1220	poorly dated	radiocarbon	—	1	—	—	—	—	—	—	—	—	1
Feature 14959 (pit fill)	2130–1940 B.C.	late Chiricahua phase	radiocarbon	—	1	—	—	—	—	—	—	—	—	1
Feature 15044 (pit fill)	790 B.C.–A.D. 1520	poorly dated	stratigraphy (hiatus between Units IIs and IIsf and Unit V)	—	—	—	—	—	1	—	—	—	—	1
Feature 15482 (pit fill)	1200–1000 B.C.	San Pedro phase	radiocarbon	—	—	1	—	—	—	—	—	—	—	1
Feature 19067 (pit fill)	A.D. 610–670	pre-Classic period	radiocarbon	1	—	—	—	—	—	—	—	—	—	1
TR 2217 grab-sample	not dated	not dated		—	2	—	—	—	—	—	—	—	—	2
TP 8874, Level 3	720–200 B.C.	Cienega phase	stratigraphy (Unit III2)	—	—	1	—	—	—	—	—	—	—	1
Subtotal				10	46	3	1	9	2	6	3	4	1	85
Site 423														
Site surface	not dated	not dated		—	39	—	—	—	—	—	—	—	—	39
Subtotal				—	39	—	—	—	—	—	—	—	—	39
Nonsite Context														
TR 10067 grab-sample	not dated	not dated		—	1	—	—	—	—	—	—	—	—	1
Subtotal				—	1	—	—	—	—	—	—	—	—	1
Total				10	86	3	1	9	2	6	3	4	1	125

All 26 buff ware sherds in the project collection were recovered from Falcon Landing. Only 2 of the 26 were recovered from buried contexts (see Table 62). The majority of buff ware sherds (65 percent) were micaceous-schist tempered. As discussed earlier, only 7 buff ware sherds were attributable to a type—Sacaton Red-on-buff, which dates to the Sedentary period (ca. A.D. 950–1150).

Buried Contexts

Sherds recovered from buried contexts represented 13 percent of the analyzed collection (see Table 62). Three of these sherds were Gila Plain, Salt variety, body sherds that were grab-sampled from the excavation of two trenches: TR 2217 at Falcon Landing and TR 10067 in Area A. A single indeterminate plain ware sherd was recovered from Level 3 of TP 8874 at Falcon Landing (see Table 62), and as discussed above, it was an untempered miniature-bowl fragment with a rim-diameter measurement of 4 cm (see Figure 86). Level 3 of TP 8874 was excavated within Unit III2, which dates to 720–200 B.C. (Cienega phase) (see Chapter 2). Given the age of this allostratigraphic unit, the untempered sherd recovered from the test pit may be a fragment of an incipient plain ware vessel. The size of the original vessel and the lack of temper matched well the descriptions of incipient plain ware remains from Cienega phase (ca. 800 B.C.–A.D. 150) Tucson Basin sites (see Heidke 1999, 2005, 2006), and given the existence of one other untempered sherd recovered from a Late Archaic period buried context (see below), we suspect that the untempered sherd from the test pit is an incipient plain ware sherd.

In total, 12 sherds were recovered from feature fill, all at Falcon Landing (see Table 62). The majority of those 12 corresponded to the radiocarbon or stratigraphic dates associated with the features within which they were recovered. Features 3963, 4626, 10514, 15044, and 19067 all contained sherds the production-date ranges of which overlapped with the radiocarbon- or stratigraphic-date ranges for their respective features (see Table 62).

The fill of pit Feature 14959 contained a single sand-tempered plain ware sherd (see Table 62). This relatively large (17–49-cm^2) sherd was identified as Gila Plain, Salt variety, and was indistinguishable from other sherds attributed to that variety (see Figure 86). Feature 14959 also yielded a Middle Archaic period radiocarbon date of 2130–1940 B.C. (early Chiricahua phase) (see Chapter 2). This date is obviously incompatible with the production-date range of Gila Plain (see above discussion) and with the earliest-known dates of the adoption of ceramic-vessel technology (the Late Cienega phase [ca. 400–1 B.C.]) (see Garraty 2011:220). Thus, we strongly suspect that the sherd was intrusive and postdates the use and abandonment of the feature.

As we discussed above, the fill of pit Feature 15482 contained an untempered plain ware rim sherd (see Figure 87). Given the radiocarbon date from the feature (1200–1000 B.C., or the San Pedro phase) (see Chapter 2), it is possible that the sherd may be a fragment of a vessel of an incipient plain ware described by Heidke (1999, 2005, 2006; see also Garraty 2011) from Archaic period sites in the Tucson Basin. The sherd has a possible incising mark on its exterior and tapers in width at the rim. It may be from a relatively small vessel (approximately 8 cm in diameter) (see above). The possible incising, the lack of temper, and the small original vessel size all correspond to published descriptions of incipient plain ware (see Heidke 1999, 2005, 2006).

Discussion

We end this chapter with a discussion of the major research issues that emerged from our analysis of the ceramic collection from the Luke Solar project. We identify three broad research issues to which the collection can productively contribute: (1) past ceramic use in the project area, (2) ceramic production and exchange in the local area, and (3) incipient plain wares and the invention stage of ceramic technology in the Phoenix Basin.

Ceramic Use in the Project Area

The low frequency of ceramic remains recovered from the project area attests to what undoubtedly was the relative rarity of ceramic use in this location in the past. Overall, the small sample generally reflects what could be seen, in terms of types and wares, in much larger samples of ceramics from this area. With the exception of the likely intrusive Gila Plain, Salt variety, sherd in early Chiricahua phase Feature 14959 (see above), the recovery contexts and wares and types identified among the sherds in the collection suggest that the use of ceramics in the project area largely dates to the interval of A.D. 1–1450. Gila Plain dates to ca. A.D. 300–1450, and the only datable buff ware in the collection was Sacaton Red-on-buff, which dates to ca. A.D. 950–1150. Notable for its absence is red ware pottery, a hallmark of the late prehistoric Classic period (A.D. 1150–1450) (Heckman et al. 2000). Given the total lack of red ware in this collection, we can further refine the dates to A.D. 50–1150. Assuming that the sherds in the collection represented the remains of vessels used in the project area, and given our estimate of 111 vessels represented in the collection, which is likely a high estimate (see above), we estimated that approximately 8 vessels were broken and discarded in the project area every 100 years. This low breakage rate suggests that ceramic vessels were infrequently used in the past.

What little ceramic-function information we could glean from the collection suggested that ceramic vessels fulfilled short-term-liquid- or dry-storage needs and/or cooking functions (see Table 61). The collection did not appear to reflect the use of the project area as a primary habitation, such as a hamlet or village site, and would seem to suggest the limited use of project sites during the Ceramic period. This conclusion is supported by other archaeological evidence from the project that also suggests intermittent, short-term use of the area over time. The varieties of storage, food-preparation, cooking, and food-presentation activities that would be reflected in a village ceramic assemblage were absent from the Luke Solar project collection (see Doyel and Elson [1985] for an example of more-diverse habitation-site assemblages). The collection seems to be dominated by the remains of jar forms (or, at least, a relative lack of identifiable bowl forms) that were relatively small in size (see Table 61). It appears likely that the ceramic collection consists largely of the remains of vessels used to provision individuals or a small group with food or water for short periods of time. We surmise that the people who used and discarded ceramics in the project area were inhabitants of nearby habitation sites who perhaps acquired and processed food resources in the area and/or collected wood from the area on an occasional basis, or who perhaps simply passed through the area.

Ceramic Production and Exchange in the Local Area

The ceramic collection also provided some possible clues regarding ceramic production and exchange in the area. Although there was no evidence of ceramic manufacture within the project area itself (e.g., green vessels, raw materials, or tools), the presence of both micaceous-schist-tempered and sand-tempered varieties of both Gila Plain and Hohokam Buff Ware in the collection suggests that both locally produced and imported ceramics may have been used and discarded in the project area. Doyel and Elson (1985) argued that sand-tempered varieties of Gila Plain and Hohokam Buff Ware were manufactured using locally available tempers in the New River drainage and that micaceous-schist-tempered varieties of Gila Plain and Hohokam Buff Ware were imported into the New River drainage from production locales along the Salt and Gila Rivers. We know of no local sources of micaceous-schist temper materials in the surrounding area, and given the nearly 3.5:1 ratio of sand-tempered varieties of Gila Plain and Hohokam Buff Ware to micaceous-schist-tempered varieties in the project collection, it seems reasonable to assume that sand-tempered sherds were of local manufacture and that micaceous-schist-tempered sherds were produced along the Gila River, to the southeast of the project area.

If this assumption is correct, then it would appear that the majority of plain ware vessels used in the local area may have been locally produced (see Table 62). Conversely, the majority of buff ware vessels may have been imported into the area, because approximately 65 percent of the buff ware in the project collection was micaceous-schist tempered (see Table 62). Interestingly, there were slight but discernible differences in surface and paint colors and in design execution between the two temper varieties of Hohokam Buff Ware that may provide clues to differences in the overall appearance of locally produced and imported wares (see Figures 89 and 90). The paint of sand-tempered buff ware appears more watery, less precise in application, and darker in color than the paint of micaceous-schist-tempered buff ware. Sand-tempered buff ware also lacks the micaceous sheen commonly seen in the surfaces of the micaceous-schist-tempered variety. These distinctions in appearance from one temper variety to another suggest that the vessels themselves were likely distinctive and that one would have been able to easily determine the place of manufacture of a vessel from only a cursory examination. The complete absence of phyllite-tempered pottery, commonly known as Wingfield Plain, from the Luke Solar project collection is somewhat surprising, given that production areas for this pottery are close by, to the north and east (Doyel and Elson 1985).

Incipient Plain Wares and the Invention Stage of Ceramic Technology in the Phoenix Basin

Importantly, we identified two possible incipient plain ware rim sherds, each from a dated Late Archaic period buried context (see Figures 87 and 88 and above discussions). These sherds were the remains of two small, untempered vessels and closely resembled published descriptions of incipient plain ware from Archaic period sites in the Tucson Basin (Heidke 1999, 2005, 2006). Finding two possible incipient plain ware fragments from Late Archaic period buried contexts in the project area (San Pedro phase Feature 15482 and Cienega phase Level 3 of TP 8874) is remarkable and provides the basis for hypothesizing about the earliest stage of the development of ceramic technology in the Phoenix Basin.

We know of no other possible incipient plain ware in the desert Southwest from sites outside the Tucson Basin (but see Garraty 2011). It seems likely that the production and use of such early ceramics were exceedingly rare. Heidke et al. (1998) have suggested that these vessels were only produced about once a generation at the Tucson Basin sites where they have been documented. These very earliest vessels were likely used in ceremonial contexts for ritual drinking or as prayer bowls and were not used for domestic functions, such as cooking or food or liquid storage (Heidke 1999). The small rim diameters and the lack of temper of the two possible incipient plain ware sherds from the Luke Solar project were consistent with the attributes that Heidke (1999) examined to identify possible functions of these earliest vessels. These two sherds may represent fragments of small vessels that were ill equipped to function as cooking or storage vessels.

The possible occurrence of incipient plain ware in the Phoenix Basin contemporaneous with its adoption and use in the Tucson Basin suggests that the very earliest adoption of ceramic technology in the desert Southwest may have been more widespread geographically than previously thought. Models of the earliest development of ceramic technology in the region (e.g., Garraty 2011; Heidke 1999, 2005, 2006) have identified the Santa Cruz River valley in the Tucson Basin as the locus of what Rice (1999) called the "invention" stage of ceramic adoption. It is surmised that in that stage, early potters occasionally experimented with ceramic technology, making small vessels for nonpractical or nonutilitarian uses, and that the social and economic contexts of pottery use shifted to eventually support or encourage the adoption of a widespread, practical container technology for domestic consumption. The invention stage preceded the "innovation" stage, which was the stage in ceramic development when container technology became widespread, and pottery was used for everyday domestic tasks, such as cooking, storage, food preparation, and food presentation (Garraty 2011; Rice 1999).

In the desert Southwest, the invention stage of pottery development has, until now, only been identified in the Tucson Basin. There, incipient plain ware vessel fragments have been identified from sites along the Santa Cruz River, in buried contexts dating back as far as 2100 B.C. The majority of incipient plain wares, however, have been recovered from contexts dating to the Cienega phase (ca. 800 B.C.–A.D. 50) (Garraty 2011:220). Thus, these vessels would have preceded the adoption of a more practical, utilitarian, domestic ceramic technology by 500–1,000 years (Garraty 2011:220). By the first few centuries A.D., Tucson Basin inhabitants produced more utilitarian vessels for a wide range of domestic needs. This shift in ceramic technology has been related to contemporaneous trends toward intensification in agriculture and settlement permanence and density (see Garraty 2011:231–232; Heidke 1999:331–332). Garraty (2011:231–232) argued that along the Queen Creek drainage, in areas from which evidence of the invention stage of ceramic development is absent, the adoption of a domestic ceramic technology was part of an overall trend of increasing privatization and household control over resources that was related to increasing intensification in the exploitation of plant resources and increasing residential stability.

With the discovery of potential incipient plain wares from Falcon Landing, it appears that processes of ceramic adoption similar to those in the Tucson Basin and the Queen Creek drainage were in play in the Phoenix Basin, as well. The production and occasional use of small, untempered vessels, presumably for ritual purposes (sensu Heidke 1999), appear to have set the social stage for the subsequent development of a practical domestic container technology related in some way to increasing intensification of settlement and subsistence pursuits. To understand the adoption of pottery in the desert Southwest, we cannot rely on simple diffusion models that presume the movement of ideas or technologies across space, driven by the logic of technological efficiency. As Garraty (2011:232) has stated, the adoption of pottery "was regionally variable and historically contingent." Ceramic invention and innovation may have occurred in multiple historical and social contexts across the Sonoran Desert, and mapping the relationships among these stages across the region and within local areas can contribute to our overall understanding of the universal adoption of pottery across the Southwest.

Conclusions

A small ceramic collection (125 sherds) was recovered from Falcon Landing, Site 423, and a trench excavated in a nonsite context in Area A. The majority of the sherds in the collection were recovered from the surface of Falcon Landing and Site 423. In total, 12 sherds were recovered from feature-fill contexts, all at Falcon Landing. All but 3 sherds were classified as one of four varieties of plain ware or buff ware, based largely on inclusions: Gila Plain, Gila variety; Gila Plain, Salt variety; micaceous-schist-tempered Hohokam Buff Ware; and sand-tempered Hohokam Buff Ware. Two of the 3 unidentified sherds were rim sherds and probably of an incipient plain ware, based on vessel-size measurements and a lack of inclusions. The 2 sherds were recovered from two buried contexts that yielded radiocarbon dates within the interval of 1200–200 B.C. (San Pedro phase pit Feature 15482 and Level 3 of TP 8874, which dated to the Cienega phase).

Though small, the ceramic collection from the Luke Solar project provided some interesting insights into the use of ceramics at the project sites and in the local area, and possibly the adoption of ceramic technology. The relative lack of variety in the ceramic collection, coupled with the limited ceramic-function-analysis data, suggests infrequent use of ceramics in the project area in the past to fulfill short-term-liquid- or dry-storage needs and/or to cook. We agree with the conclusions made by other Luke Solar project analysts that characterize the past use of the project area as intermittent or short-term and for limited, largely nonhabitation, uses. Ceramics were likely used only occasionally at the site to support or provision activities, such as the acquisition of food resources or wood.

Sherd inclusions also suggested the presence of both decorated and plain ware pottery made within the local area (i.e., somewhere within the vicinity of the Agua Fria River valley) and vessels tempered with crushed micaceous schist and imported from areas to the south and east of the project area (e.g., likely along the Gila River). Finally, the presence of two untempered plain ware rim sherds from two Late Archaic period buried deposits at Falcon Landing indicated the possibility that the earliest stages of the adoption and development of ceramic technology in the desert Southwest were more widespread geographically than has been previously recognized.

CHAPTER 6

Macrobotanical Remains

Karen R. Adams

Research Goals

The Luke Solar project aims to elicit the nature of human use of a Sonoran Desert landscape over a period that spans 5,000 years. It appears that small groups of humans repeatedly visited the area, presumably to gather wild foods and to prepare them using fuel wood from local trees and shrubs. These groups built many small house-in-pit structures, and at least one possible large one, and left evidence of their activities within thermal pits and house fill. They also left evidence within a large number of nonthermal pits. Their groundstone-artifact assemblage included manos and metates, mortars, and many rather large pestles with a variety of very interesting shapes. Together, these artifacts suggest that people ground some resources and pounded others. The archaeological plant record, consisting of tiny fragments of reproductive and nonreproductive plant parts, can reveal some of the resources that drew groups to this area. The plant record can also shed light on the seasons these resources were harvested for food.

Over the 5,000-year period represented in the Luke Solar project area, groups left evidence of their presence during the Early, Middle, and Late Archaic periods. Other well-represented occupations included early and late Chiricahua phase, Early Agricultural period (San Pedro and Cienega phases), and Early Ceramic period (Red Mountain phase) use of the area. Eventually, Pioneer, pre-Classic, Classic, and Protohistoric period groups were also drawn to the area. Stabilization of modern plant communities approximately 4,000 years ago, as revealed in pack-rat-midden studies in the U.S. Southwest (Betancourt et al. 1990), suggests that the same dependable resources may have drawn groups to this area throughout time. The introduction and early use of maize in the Southwest around 4,000 years ago (Merrill et al. 2009) occurred even as groups were repeatedly drawn to this location and eventually led to settled communities and a major commitment to agriculture in the Southwest.

Previous Archaic Period Research in Nonriverine Settings

Previous archaeological projects that have focused on nonriverine foraging adaptations in the region during the Archaic period include those conducted at Last Ditch (AZ U:5:33 [ASM]) and Coffee Camp (AZ AA:6:19 [ASM]). These projects are well summarized by Smith in Chapter 7. Last Ditch is situated on a *bajada* near a wash east of Cave Creek and represents a seasonal camp visited between 2900 and 1500 B.C. (Hackbarth 1998, 2001; Phillips et al. 2001, 2009; Rogge 2009). Features from both the Middle and Late Archaic periods were documented, and excavation focused on thermal pits and hearths, ephemeral structures, and limited ground stone artifacts. Coffee Camp is located north of Tucson and west of Picacho Peak and was repeatedly visited during the Late Archaic/Early Agricultural period from 1500 B.C. to A.D. 1 (Halbirt and Henderson 1993). Features included extramural pits and structures (living and storage) and a large pit structure that possibly served as a communal or ceremonial house. Similar to the Luke Solar project, the Coffee Camp project preserved numerous ground stone tools (manos, metates, and pestles) for grinding and pounding, some of which were found in caches.

Although both locations lacked permanent water sources, groups likely had seasonal access to water. For the Last Ditch location, archaeologists speculated that water from winter rains and summer monsoons might have become perched over a subsurface hardened paleosol, and/or groups could have dug wells or utilized small seeps associated with drainages (Phillips et al. 2001:62). At the Coffee Camp location, standing water likely accumulated on the ground surface during winter rains and summer monsoons and may have remained accessible for weeks to months.

Neither project preserved evidence of cultivated crops within flotation samples. However, both projects came to similar conclusions about the resources that drew groups to the two locations. Middle Archaic period foragers were drawn to Last Ditch to gather small seeds of grasses and annual plants that they parched in baskets, using heated rocks (Phillips et al. 2009:63–64). Lacking ground stone, they may have transported parched seeds to another base-camp location for further processing and consumption. Again, at Coffee Camp, grasses and the seeds of annual plants were of interest, as were mesquite pods and cholla buds. Pollen preserved from both project areas indicated a strong late-winter to spring signal including *Plantago* spp. (often referred to as woolly wheat, Indianwheat, or plantain) and grasses (Poaceae) at Last Ditch (Phillips et al. 2009) and other spring resources at Coffee Camp (Gish 1993:328). Both projects also preserved archaeobotanical evidence of visits during other seasons of the year. Generally, these two projects suggest that Archaic period foragers repeatedly returned to locations during seasons when they could reasonably expect to find both water and an abundance of small seeds of numerous desert annuals and some perennials.

Methods

Two types of archaeobotanical samples are discussed in this chapter: (a) flotation samples, which are sediment samples processed via a flotation process for small plant parts, and (b) larger macrobotanical samples hand-picked from site deposits or screens during excavation. Both sample types are often labeled "macrobotanical" samples, to distinguish them from samples with even-smaller plant parts, such as pollen grains (see Chapter 7), phytoliths, and starch grains. In total, 145 flotation samples and 48 hand-picked macrobotanical samples were analyzed from four archaeological sites and some nonsite contexts; the bulk of the samples were from Falcon Landing (Table 63). A complete list of Luke Solar project samples can be found in Appendix 6.1. Well-sampled contexts represented a number of cultural deposits from all five sites, among them (a) thermal features, such as thermal pits, a hearth, a fire-affected-rock (FAR) concentration, and a charcoal/ash lens; (b) nonthermal pits; and (c) house-in-pit structures (Table 64). Thermal features are inferred to represent short periods of time, and they are features in which focused activities involving plants can be documented. Structures, particularly house-in-pit features, are represented by fill, floor fill, and some posthole contexts. Some of the materials inside structures may represent use within the structure or materials that came in after abandonment. Floor-fill materials may represent cultural materials that were left behind on structure floors.

Table 63. Distribution of Luke Solar Project Flotation and Macrobotanical Samples, by Site

Site No.	No. of Flotation Samples	No. of Macrobotanical Samples	Time Span
Falcon Landing	136	40	Sulphur Spring phase through Protohistoric period
AZ T:7:68	7	1	Middle to Late Archaic through Protohistoric period
AZ T:7:423	1	—	Late Cienega phase through Red Mountain phase
AZ T:7:437	1	1	Sulphur Spring phase
Nonsite	—	6	Sulphur Spring phase through Snaketown phase
Total	145	48	

Note: Contexts and chronological data for the samples are presented in Appendix 6.1.

Table 64. Luke Solar Project Flotation and Macrobotanical Samples, by Context

Feature Type	Flotation Samples		Macrobotanical Samples		Context Group
	No. of Features	No. of Samples	No. of Features	No. of Samples	
Activity area	1	1	1	1	extramural cultural deposits
Cache	1	1	—	—	extramural cultural deposits
Midden	—	—	1	1	extramural cultural deposits
Culture-bearing sediment	—	—	—	11	extramural cultural deposits
House-in-pit	25	39	5	5	structures
Structure (possible)	3	3	—	—	structures
Surface structure	1	1	—	—	structures
Posthole	4	5	1	1	structures
Nonthermal pit	48	52	7	7	nonthermal pits
Nonthermal pit, bell shaped	2	2	—	—	nonthermal pits
Reservoir	1	1	—	—	reservoir
Charcoal/ash lens	1	1	—	—	thermal features
Hearth	1	1	—	—	thermal features
Thermal pit	26	30	3	3	thermal features
Thermal pit, bell shaped	1	1	—	—	thermal features
FAR concentration	1	1	—	—	thermal features
Mixed sediment	—	—	—	8	cultural and noncultural sediment
Noncultural	6	6	—	5	noncultural
Drainage	—	—	1	6	noncultural
Total	122	145	19	48	

A limited number of extramural cultural deposits (an activity area, a cache, a midden, and culture-bearing sediment) and a few noncultural contexts were also sampled. The entire sample set represents a very broad time range of occupation of the region, from the Sulphur Spring phase to the Protohistoric period (Table 65).

Flotation and Macrobotanical Samples

The original flotation-sample volumes ranged from 1 to 9 liters, and their processed light-fraction volumes ranged from 1 to 125 ml. Light fractions were examined in their entirety, except items smaller than 0.5 mm, which are usually broken pieces of larger items that have already been identified on the basis of more-complete specimens. Macrobotanical samples were spread out on a paper plate and examined completely. For all sample types, up to 20 pieces of charred wood were identified, or as many as were available that had broad cross-section surfaces adequate to view anatomical details. All items were identified at magnifications ranging from 8× to 50× under a Zeiss binocular microscope and in comparison to an extensive modern comparative collection of Sonoran Desert charred and uncharred plant materials backed by herbarium specimens deposited in the University of Arizona herbarium.

Because the collection of flotation samples was guided by a systematic sampling strategy, the plant remains contained in the collections are considered reliable for detecting general patterns of plant use. To aid in the interpretation of data, calculations of ubiquity are reported in this chapter. Ubiquity is the percentage of flotation samples from a particular time period or context in which a given taxon/part was identified. This provides a sense of the level of use and discard of each plant and its parts, allowing inferences of past plant access

Table 65. Luke Solar Project Flotation and Macrobotanical Samples, by Temporal Period

Temporal Period	Date Range	No. of Flotation Samples	No. of Macrobotanical Samples	Temporal Group
Sulphur Spring phase	9500–3500 B.C.	1	6	Sulphur Spring phase
Early to Middle Archaic period	9500–1200 B.C.	2	6	Early to Late Archaic period
Early to Late Archaic period	9500 B.C.–A.D. 50	5	—	Early to Late Archaic period
Early Chiricahua phase	3500–2100 B.C.	38	12	early Chiricahua phase
Middle to Late Archaic period	3500 B.C.–A.D. 50	17	6	Middle to Late Archaic period
Middle Archaic to Pioneer period[a]	3500 B.C.–A.D. 750	1	—	
Middle Archaic to Protohistoric period[a]	3500 B.C.–A.D. 1800	6	—	
Late Chiricahua phase	2100–1200 B.C.	9	2	late Chiricahua phase
San Pedro phase	1200–800 B.C.	21	3	Early Agricultural period
Late Archaic to Protohistoric period[a]	1200 B.C.–A.D. 1800	2	—	
Cienega phase	800 B.C.–A.D. 50	3	1	Early Agricultural period
Early Cienega phase	800–400 B.C.	5	1	Early Agricultural period
Late Cienega phase	400 B.C.–A.D. 50	2	2	Early Agricultural period
Late Cienega to Red Mountain phase	400 B.C.–A.D. 450	6	—	Early Agricultural to Early Ceramic period
Red Mountain phase	A.D. 50–400	5	2	Early Ceramic period
Early Ceramic to Protohistoric period[a]	A.D. 50–1800	2	—	
Pioneer to Classic period[a]	A.D. 400–1450	1	—	
Pioneer period	A.D. 400–750	—	1	Pioneer period
Snaketown phase	A.D. 650–750	8	5	Pioneer period
Sacaton phase	A.D. 1000–1150	3	1	pre-Classic period
Sedentary to Classic period[a]	A.D. 1000–1450	1	—	
Soho/Civano phase	A.D. 1150–1450	2	—	Classic period
Classic to Protohistoric period[a]	A.D. 1150–1800	1	—	
Protohistoric period	A.D. 1450–1800	1	—	Protohistoric period
No temporal data		3	—	
Geologic date		—	—	
Total		145	48	

[a] Temporal period(s) covered by sample(s) were too broad to include in chronological discussions.

and preferences. Macrobotanical samples provide a more subjective sample of larger plant materials in use in the past and are considered most useful for recovering plant parts not preserved within flotation samples or for recovering larger plant specimens. Discussion of plant specimens in macrobotanical samples was incorporated into this text when it could provide insights beyond those contributed by the flotation samples.

Results

In total, 11 plant taxa and their parts preserved in the nearly 200 archaeobotanical samples examined (Table 66). Some of these are represented in Figures 91 and 92. All specimens were charred and are assumed to have become burned in some way as a result of the actions of humans in the past. Use of the word "type" following a taxonomic identification indicates that the specimens compare well to the taxon named in anatomical and morphological features but might also represent other plants that have characteristics within the range for the taxon cited. This conservative approach acknowledges the similarity in appearance of various plant taxa in the U.S. Southwest, especially when an ancient specimen has been carbonized and damaged. For ease of use, this chapter indicates "type" only in Table 66, but the word is implied in all text and tables. All analysis data, including a limited number of "unknown" plant parts that will not be discussed further, are provided in Appendixes 6.2 (flotation data) and 6.3 (macrobotanical data). Identification criteria for the taxa and parts recovered can be found in Bohrer (1987) and K. Adams (1997, 2003).

The flotation and macrobotanical samples preserved a relatively limited record of plant use. Both the diversity of taxa/parts and the actual numbers of specimens were low, considering that nearly 200 archaeobotanical samples were analyzed. Various factors likely contributed to this situation. The longer that charred specimens lay in the ground, the more likely they were to degrade and become unrecognizable, and the Luke Solar project uncovered features extending back to the Early, Middle, and Late Archaic periods. Features located relatively close to the ground surface may have lost plant specimens faster than those that were deeply buried. Most Luke Solar project features were within 18 inches of the modern ground surface. Also, bioturbation by insects and rodents can move ancient plant parts closer to the ground surface, exposing them to oxidation and weathering, and evidence of termites, larval casts, and an active root zone were all present. It is suspected that all these factors may have operated to degrade plant remains within Luke Solar project sites. Ten flotation samples that preserved no charred specimens and 3 that preserved tiny charred plant fragments too small to identify have been included in the sample counts in the tables.

Table 66. Charred Plant Taxa and Parts Recovered from Luke Solar Project Flotation and Macrobotanical Samples

Taxon	Identification Level	Common Name	Part(s)
Atriplex spp.	type	saltbush	fruit, utricle core, twigs, and wood
Carnegiea gigantea	type	saguaro	wood
Chenopodium-Amaranthus		cheno-am, goosefoot-pigweed	seeds
Fouquieria splendens	type	ocotillo	wood
Larrea spp.	type	creosote bush	wood
Panicum spp.	type	panicgrass	caryopsis
Plantago spp.	type	woolly wheat	seed
Poaceae	type	grass family	stem fragments
Portulaca spp.	type	purslane	seed
Prosopis spp.	type	mesquite	seed fragments and wood
Trianthema portulacastrum	type	horse purslane	seeds and seed fragments

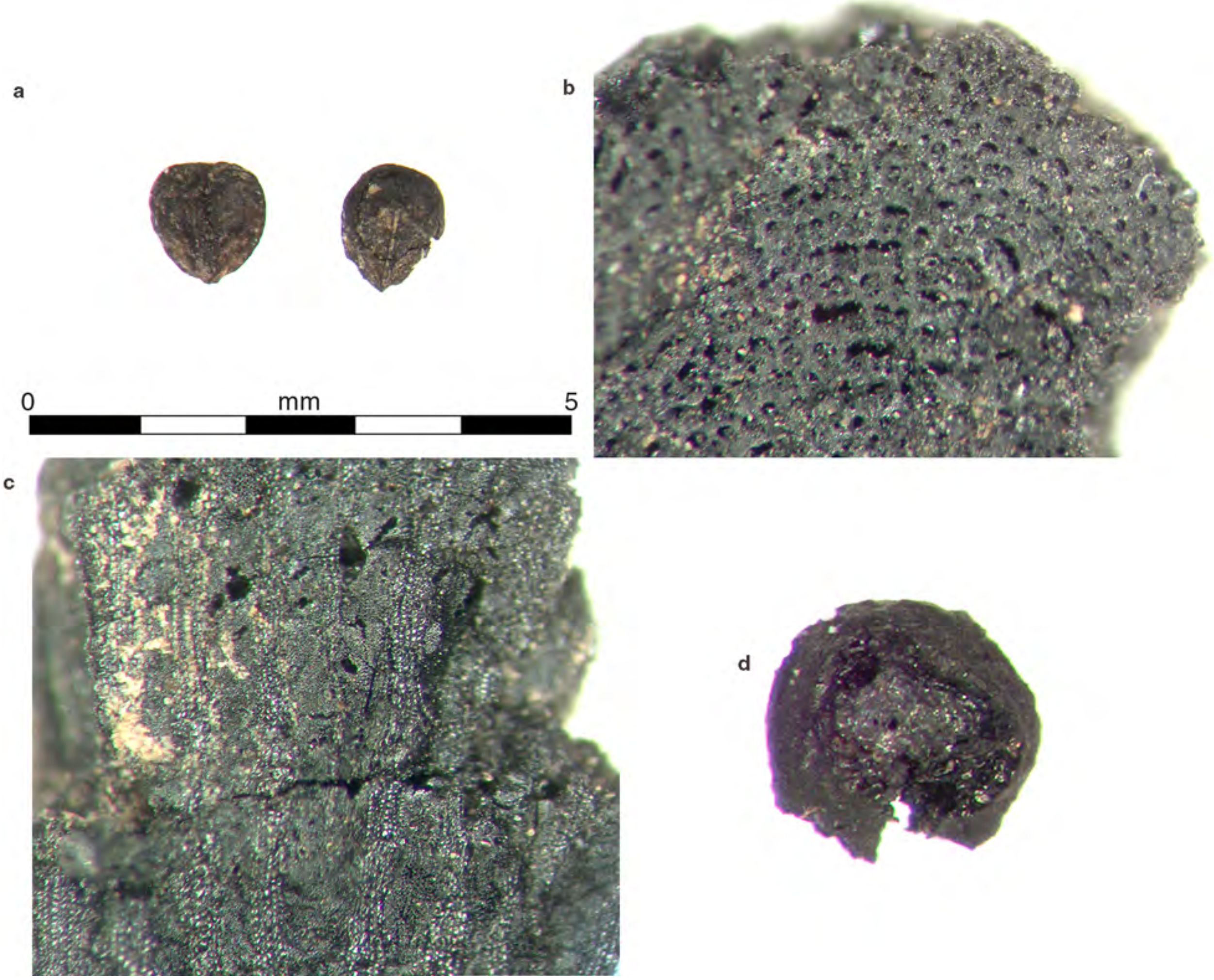


Figure 91. Charred plant parts preserved at project sites: (*a*) saltbush (*Atriplex* sp.) fruit from AZ T:7:68 (ASM), Feature 206; (*b*) transverse view of saltbush wood from Falcon Landing, Feature 2602, Subfeature 7900; (*c*) transverse view of saguaro (*Carnegiea gigantea*) wood from Falcon Landing, Feature 2602, Subfeature 7900; and (*d*) fragment of a cheno-am seed from Falcon Landing, Feature 17908, Subfeature 20285.

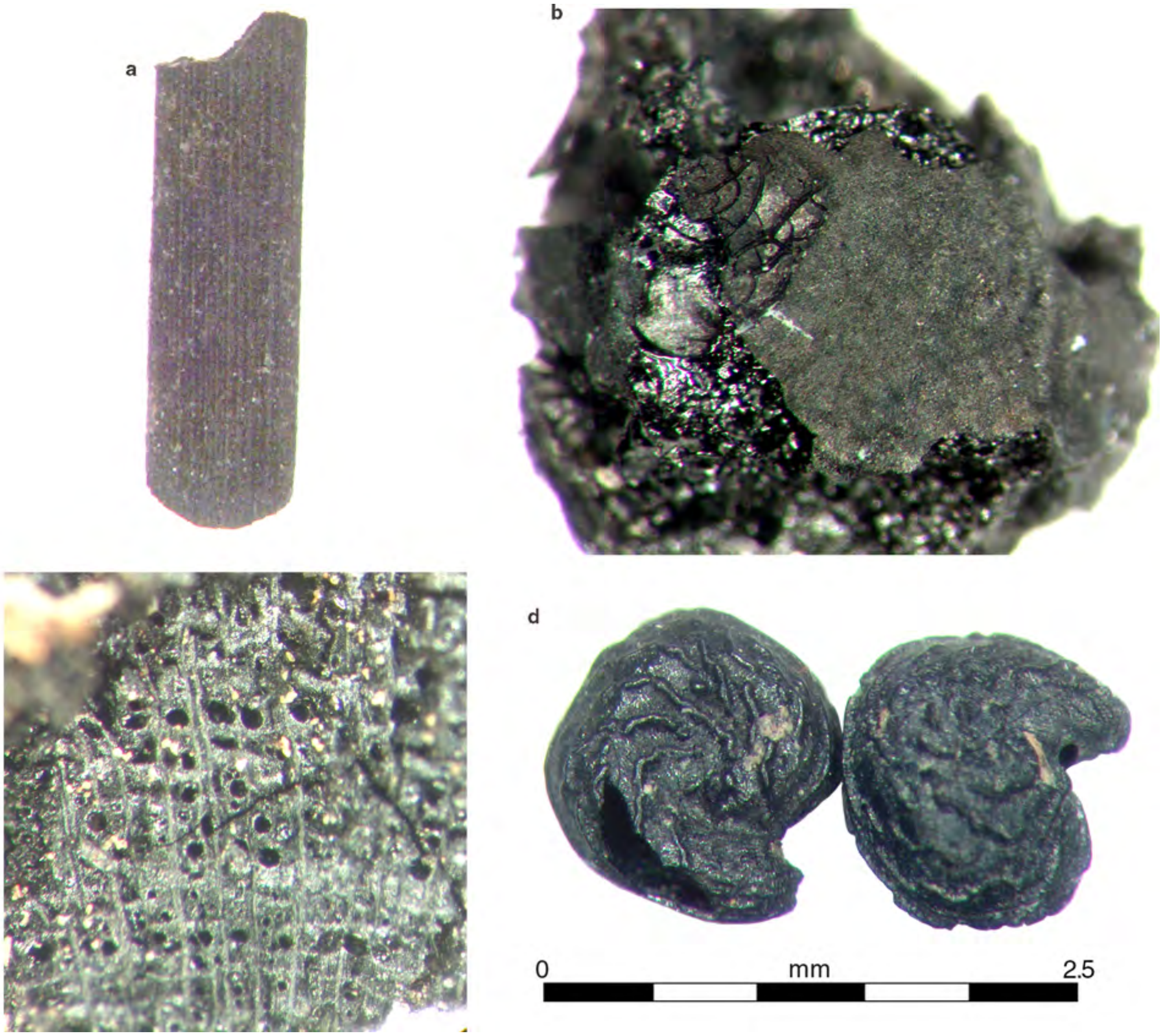


Figure 92. Charred plant parts preserved at project sites, continued: (*a*) grass (Poaceae) stem with evident parallel fibro-vascular bundles from Falcon Landing, Feature 2602, Subfeature 7757; (*b*) fragment of a mesquite (*Prosopis* sp.) seed with surface crazing from Falcon Landing, Feature 18237; (*c*) transverse view of mesquite wood from Falcon Landing, Feature 2602, Subfeature 7757; (*d*) two horse-purslane (*Trianthema portulacastrum*) seeds with the characteristic wavy seed-coat pattern from Falcon Landing, Feature 15317.

Subsistence Resources

The flotation and macrobotanical samples from the Luke Solar project included no evidence of domesticates from Mexico (maize, beans, and squash). A single pollen grain from the floor of a San Pedro phase structure represents the only evidence of agriculture (see Chapter 7). The samples also did not include any evidence of the indigenous domesticates currently known from the Sonoran Desert (little barley and agave) or any other native plants suspected of having been managed in the past (Bohrer 1991). Charred reproductive parts (fruit, seed, utricle, and caryopsis) of seven wild plants indicated food use. Ethnographic literature from the U.S. Southwest (Adams and Fish 2006, 2011) and the Sonoran Desert (Adams 1988; Castetter 1935; Castetter and Bell 1942, 1951; Curtin 1984; Hodgson 2001; Rea 1997; Russell 1908) and previous summaries of archaeobotanical records for the U.S. Southwest (Adams and Fish 2006, 2011; Huckell and Toll 2004) and the Sonoran Desert (Adams 1988; Bohrer 1991; Gasser 1982; Gasser and Kwiatkowski 1991a, 1991b; Gasser and Miksicek 1985; Miksicek 1988) together have provided substantial evidence for use of these plants through time.

Atriplex spp. Fruit and Utricle Core

Fruit of at least two species of saltbush preserved. The unmistakable *Atriplex canescens* (fourwing saltbush) is a shrub with quadrangular fruit (utricles). Four fragile bracts attached to the fruit often erode and leave only the utricle core. Such a charred utricle core preserved within a Soho/Civano phase Classic period thermal pit (Feature 5213). Other species of annual (*A. fasciculata*) and shrubby (*A. lentiformis* and *A. polycarpa*) saltbush known from the Sonoran Desert (Kearney and Peebles 1960:255–260) generally have flat fruit with wings. Such a charred *Atriplex* sp. fruit preserved within a nonthermal pit (Feature 206) dated to the very broad range of the Late Archaic to Protohistoric period. Saltbush plants can begin flowering in the late spring/early summer, and once the fruits are mature, they may cling to the plants for months. This provides convenient “on-the-plant” storage, releasing human groups from the need to gather the fruit as soon as it matures (Bohrer 2007:110–111). Ethnographic references generally report the use of saltbush seeds as food (Rea 1997:127–128; Russell 1908; Stevenson 1915:66; Yanovsky 1936:21–22), and these seeds were often preferred for their salty flavor (Swank 1932:31).

Cheno-Am Seeds

Charred seeds representing either goosefoot (*Chenopodium* spp.), in the Chenopodiaceae family, or pigweed (*Amaranthus* spp.), in the Amaranthaceae family, preserved within three contexts. Seeds of these plants are difficult to separate when charred and broken and are referred to as “cheno-am” seeds. These seeds preserved within a early Chiricahua phase possible structure (Feature 2622), a San Pedro phase house-in-pit (Feature 2627), and a Late Cienega to Red Mountain phase nonthermal pit (Subfeature 20285) within a house-in-pit (Feature 17908). Goosefoot seeds often germinate in the late spring, prior to summer monsoon rains. Pigweed seeds are more likely to germinate following the start of the summer monsoon season. These differences in timing would offer a long period of availability of plants generally utilized in a similar manner as both greens and seeds (see Adams 1988:168–183).

Panicum spp. Caryopsis

A charred panicgrass (*Panicum* spp.) grain (caryopsis) was recovered from a Middle to Late Archaic period thermal pit (Feature 4294). The harvest of different panicgrass species would have probably taken place during the fall season (Kearney and Peebles 1960:134–138). No archaeological evidence to date suggests that Hohokam groups actually domesticated or cultivated this grass. Stronger evidence for a domesticated panicgrass (*Panicum sonorum*) in the U.S. Southwest comes from late pre-Hispanic period and ethnographic accounts (Nabhan and DeWet 1983). A broad range of wild grasses, including five species of *Panicum*, have provided important foods to historical-period groups in the U.S. Southwest (Doebley 1984).

***Plantago* spp. Seed**

A charred *Plantago* spp. seed also preserved in the same Middle to Late Archaic period thermal pit (Feature 4294) as the panicgrass grain. Seeds of annual *Plantago* sp. plants generally germinate with the winter rains (Kearney and Peebles 1960:802–805), and their seeds are mature by mid-spring (Adams 1988). Leaves and seeds have provided many historical-period groups with food and medicinal treatments (see Adams 1988:394–398). Cool-season resources such as this provide critical foods during the late winter through spring seasons (Bohrer 1975), times of the year when foods can be scarce.

***Portulaca* spp. Seed**

A charred purslane (*Portulaca* spp.) seed was identified in a noncultural context (Feature 4409) that dated to the Classic to Protohistoric period. It is possible that this seed represents ancient use of the plant as a resource or that, possibly, a natural fire was responsible for its charred condition. Pre-Hispanic and historical-period records of purslane seeds as food are extensive (see Adams 1988:416–423). These annual plants generally germinate with the summer rains and can be eaten as greens; they mature seeds through the fall months.

***Prosopis* spp. Seed Fragments**

Charred mesquite (*Prosopis* spp.) seed fragments preserved in five contexts from the Middle to Late Archaic period through the San Pedro phase. Mesquite pods were the desired food products, and the hard seeds might have been discarded as inedible, unless food was scarce. Mesquite pods were generally pounded or ground into meal that could be formed into a cake or gruel (Bell and Castetter 1937; Felger 1977). Sometimes the seeds were ground with the pods or were separated and parched in a basket with live coals, to make them easier to eat (Bell and Castetter 1937:22, 24). Dried pods could be stored for long periods of time, provided they were parched to keep beetles from damaging them. Southern Paiute in Death Valley stored them in pits dug into alluvial gravel, uphill from mesquite dunes, where damage from rodents living in the mesquite bosques could be minimized (Bean and Saubel 1972:111). The pits averaged depths of 0.6–0.9 m below the ground surface, measured an average of 1.5 m across at their mouths, and narrowed to 0.6 m in average diameter at their bases. Sometimes the pits were lined with grasses (*Sporobolus airoides*) or a type of saltbush (*Atriplex hymenelytra*). Pods gathered in late May or early June could be stored until the following spring, which was often a food-stressed time of year (Hunt 1960). Amadeo Rea (1997:186) also reported that groups living along the middle Gila River stored foods in aboveground granaries. Mesquite-pod use in the Sonoran Desert is well documented in the archaeological record (Gasser and Kwiatkowski 1991a, 1991b).

***Trianthema portulacastrum* Seeds and Seed Fragments**

Charred horse-purslane (*Trianthema portulacastrum*) seeds and seed fragments preserved within two thermal pits (Feature 2602/Subfeature 7757 and Feature 15317) and two nonthermal pits (Feature 4650 and Feature 2602/Subfeature 7900), all representing the early Chiricahua phase. Annual horse-purslane plants germinate following the summer rains and can cover a landscape (Parker 1958:114). As a fleshy-leafed plant, they can be cooked as greens (Curtin 1984:64) or harvested for seeds that ripen over many months into the middle to late fall (Kearney and Peebles 1960:281). This plant is very similar to purslane (*Portulaca* spp.)

in its seasonality and in the way groups have processed them by heaping them onto a mat under trees and allowing the seeds to naturally mature and drop onto the mat for easy collection (Cushing 1920:44).

Nonsubsistence Resources

The charred nonreproductive parts (stem fragments, twigs, and wood) of six plants likely represent fuel, construction timbers, tools, and other nonsubsistence-material-culture needs. The ample literature cited above contains ethnographic and archaeological evidence of use of these resources for millennia.

Atriplex spp. Twigs and Wood

Although numerous species of saltbush have provided foods for historical-period groups, as discussed above, citations of nonfood uses of saltbush are difficult to find. However, the availability of both perennial and annual saltbush plants in the general region (Rea 1997) would have ensured access to easily acquired tinder and fuel for cooking and heating. Charred saltbush (*Atriplex* spp.) wood and twigs preserved within 21 features, including thermal pits, nonthermal pits, a number of houses-in-pits, and a possible structure. The presence of the twigs and wood in nonthermal pits suggests that charred materials from other features were moved about the ground surface by rains and winds or were discarded during the cleaning out of of thermal pits.

Carnegiea gigantea Wood

Although saguaro fruits have had a long history of use among Sonoran Desert groups, the long and straight saguaro ribs also served as roofing materials for pre-Hispanic period groups in southern Arizona (Huckell and Toll 2004:79). Saguaro ribs were once used to fashion "hooks" by attaching a straight piece of wood to the end of a saguaro rib, and these were used in dislodging saguaro fruit from tall saguaro plants (Russell 1908:108). Charred fragments of saguaro (*Carnegiea gigantea*) wood (ribs) were recovered from four nonthermal pits, six thermal pits, and a single house-in-pit. This wood type was well represented in thermal features in the unusually large structure Feature 2602. Specialized requirements may be responsible for this pattern. The only other thermal pit that contained saguaro wood was Feature 7998. The presence of this wood in nonthermal pits suggests the movement of charred debris across the landscape by water and wind or as a consequence of thermal-pit cleanout.

Fouquieria splendens Wood

Historically, along the middle Gila River, storehouses that sat next to dwellings were constructed of ocotillo stems (Russell 1908:156). Groups also used them for fences (Rea 1997:263–264) that could sprout and become living fencerows. It is likely that on occasion, the dried stems could be used as tinder or fuel or as elements in ramada covers and windbreaks. Charred fragments of ocotillo (*Fouquieria splendens*) wood were identified in two possible structures, a house-in-pit, two nonthermal pits, and a thermal pit. These contexts may represent use of the wood both for construction elements and as tinder or fuel.

Larrea spp. Wood

Creosote bushes are common shrubs in the region (Turner and Brown 1982:190–200). Groups in southern Arizona used various parts of the plants, from leaves to bark, primarily for making medicinal treatments (Curtin 1984:62–63; Rea 1997:139–141; Russell 1908:79). Creosote bush gum (lac) was gathered for mending pottery, coating the outsides of kicking balls, and making round ball handles for awls (Russell 1908:105, 131, 172). Readily available twigs and stems could provide quick tinder or fuel sources. Despite these apparent uses, only a single charred fragment of creosote bush (*Larrea* spp.) was recovered (from a macrobotanical sample within a drainage [Feature 20378]), which indicates minimal interest in this wood by the groups that inhabited the Luke Solar project area.

Poaceae Stem Fragments

Grass stems could serve a wide range of household needs, including atlatl darts, arrow shafts, basketry, and bedding (see Ebeling 1986). The presence of grass stems only in the large Feature 2602 house-in-pit suggests a need for soft materials.

Prosopis spp. Wood

Historically, mesquite wood was utilized by native groups in the U.S. Southwest for fuel, shelter, weapons, cordage, and tools (Felger 1977). In aboriginal times, mesquite wood was preferred for the same reasons, particularly for the construction and fuel needs of groups living in the Sonoran Desert (Huckell and Toll 2004:79). The presence of charred fragments of mesquite (*Prosopis* spp.) wood in a large number of Luke Solar project flotation and macrobotanical samples, both by time and by context (discussed below), suggests that a mesquite bosque was within walking distance of the location.

Discussion

Though limited in both the diversity of taxa/parts and the actual numbers of specimens recovered, the plant parts preserved within flotation and macrobotanical samples provided valuable perspective on patterns of plant use through time, in different contexts, and within structures. The plant record also sheds light on the season(s) of use of the area and whether or not nonlocal resources were sought. For these discussions, analysis results from the well-sampled Falcon Landing have been pooled with findings from the other four sites in order to produce the most-robust sample numbers possible. No insights into past human behavior have been lost by pooling these data.

Overview of Plant Use through Time

The record of subsistence and nonsubsistence plants sought through time is sparse but consistent (Table 67). Based on 128 flotation samples assigned to 10 reasonably bounded time periods from the Early to Late Archaic period through the Protohistoric period, fragments of charred mesquite (*Prosopis* spp.) seeds preserved in four of them. Seeds of weedy goosefoot-pigweed (cheno-am) plants were recovered from three. Reproductive parts of saltbush (*Atriplex* spp.), panicgrass (*Panicum* spp.), *Plantago* spp., and horse purslane (*Trianthema portulacastrum*) preserved in limited samples but indicate knowledge of a number of wild foods. These plants either occupy disturbed habitats in large numbers (cheno-ams, horse purslane, and *Plantago* spp.) or can be relied upon to produce pods (mesquite) or edible fruit (saltbush) in most years. Panicgrass represents one of many wild, edible grasses in the region. Two additional foods preserved in contexts that were less precisely dated: a saltbush fruit was identified in a sample dated broadly to the Late Archaic to Protohistoric period, and a purslane (*Portulaca* spp.) seed was recovered in a sample dated broadly to the Classic to Protohistoric period.

Table 67. Overview of Plant Use through Time

Taxon	Common Name	Part(s)	Temporal Period (No. of Flotation Samples per Period)									
			Early to Late Archaic (8)	Early Chiricahua (38)	Middle to Late Archaic (17)	Late Chiricahua (9)	San Pedro (21)	Early Agricultural (21)	Pioneer (8)	Pre-Classic (3)	Classic (2)	Protohistoric (1)
			Subsistence Resources[a]									
Atriplex spp.	saltbush	utricle core	—	—	—	—	—	—	—	—	1 (50)	—
Chenopodium-Amaranthus	goosefoot-pigweed	seeds	—	1 (2.6)	—	—	1 (4.8)	1 (4.8)	—	—	—	—
Panicum spp.	panic grass	caryopsis	—	—	1 (5.9)	—	—	—	—	—	—	—
Plantago spp.	woolly wheat	seed	—	—	1 (5.9)	—	—	—	—	—	—	—
Prosopis spp.	mesquite	seed fragments	—	1 (2.6)	1 (5.9)	1 (11.1)	2 (9.5)	—	—	—	—	—
Trianthema portulacastrum	horse purslane	seeds and seed fragments	—	4 (10.5)	—	—	—	—	—	—	—	—
			Nonsubsistence Resources[a]									
Atriplex spp.	saltbush	twigs and wood	—	18 (47.4)	3 (17.6)	—	2 (9.5)	2 (9.5)	—	1 (33.3)	—	—
Carnegiea gigantea	saguaro	wood	—	10 (26.3)	—	—	—	—	—	—	—	—
Fouquieria splendens	ocotillo	wood	—	6 (15.8)	—	—	—	—	—	—	—	—
Poaceae	grass family	stem fragments	—	2 (5.3)	—	—	—	—	—	—	—	—
Prosopis spp.	mesquite	wood	5 (62.5)	37 (97.4)	14 (82.4)	6 (66.7)	20 (95.2)	18 (85.7)	8 (100)	3 (100)	2 (100)	1 (100)

Note: Ubiquities and percentages of charred plant taxa/parts are reported for well-dated flotation samples.

[a] Numbers of samples containing the taxa/part(s); percentages are given in parentheses.

The use of mesquite wood for fuel, and likely for other needs, such as construction elements and tools, was strongly indicated by the presence of charred mesquite-wood fragments in all time periods and in 62.5–100 percent of the samples examined (see Table 67). The likelihood is high that mesquite bosques were accessible to all groups that passed through or lived in the area. This is supported by the presence of charred mesquite-seed fragments indicative of food use in samples from the early Chiricahua phase through the San Pedro phase. Evidence preserved within macrobotanical samples reinforces the recovery of charred mesquite-wood fragments in cultural deposits through time and of charred saltbush-wood and -twig evidence from the early Chiricahua phase through the pre-Classic period.

Overview of Plant Use by Cultural Context

The contexts that preserved the most extensive records of subsistence and nonsubsistence resources were thermal pits, nonthermal pits, and structures (Table 68). These feature types were also the best sampled, which could well have influenced patterns of plant-part preservation. Accidents that occurred while food was processed or prepared over fires could have left evidence in the ashes. At least five different foods (saltbush, panicgrass, *Plantago* spp., mesquite, and horse purslane) preserved in that way. Tinder, fuels, and other daily needs were met by the wood/twigs of saltbush, saguaro, ocotillo, and mesquite and by grass stems. Charred evidence of three foods (saltbush, Cheno-am, and horse purslane) and four wood types (saltbush, saguaro, ocotillo, and mesquite) also preserved within nonthermal pits, perhaps because charred materials got scattered across living areas over time. Houses-in-pits and possible structures preserved two foods (cheno-am and mesquite) and five fuels (saltbush, saguaro, ocotillo, mesquite, and grass) that represented plants utilized within the features or possibly moved there through post-use accumulation. An activity area, a cache, an FAR concentration, a charcoal/ash lens, and a reservoir all preserved only charred fragments of mesquite wood, attesting to the very common use of this wood type and its regular distribution across the area in which groups lived. The macrobotanical record confirmed the widespread distribution of charred mesquite-wood fragments and, to a lesser extent, saltbush-twig/-wood fragments in house-in-pit, thermal-pit, nonthermal-pit, midden, and posthole samples. The recovery of charred plant specimens (purslane seeds and mesquite wood) from noncultural deposits could represent cultural sheet-trash movement or occasional natural fires that could have contributed charred plant remains to the local sediments.

Overview of Plant Use within Structures

From one to three flotation samples were examined from each of 23 houses-in-pits, representing fill and floor contexts. The charred plant specimens that preserved primarily consisted of charred wood fragments (Table 69). Mesquite (*Prosopis* spp.) wood preserved in every feature, representing construction materials, fuels, tools, and other daily needs for wood. Flotation samples from 4 postholes in house-in-pit Features 13, 1313, 10735, and 13071 and surface-structure Feature 11105 contained mesquite, reinforcing the use of mesquite for construction elements. Saltbush (*Atriplex* spp.) wood and twigs preserved within four houses-in-pits, perhaps representing tinder, fuel, or layers of branches used in house construction. Saguaro (*Carnegiea gigantea*) ribs, ocotillo (*Fouquieria splendens*) stems, and grass (Poaceae) stems were occasionally carried in, likely for use in ramadas, windbreaks, and internal wall supports and for other reasons. Evidence of food use within structures was generally limited. Among the very few reproductive parts preserved were mesquite-seed fragments (in Features 4388 and 10114) and cheno-am seeds (Feature 2627)—all evidence suggestive of foods.

Macrobotanical samples from 5 houses-in-pits (Features 1244, 1290, 3321, 4302, and 10849) preserved mesquite wood in four samples and saltbush in one, similar to the flotation record. Flotation samples from 3 "possible" structures (Features 2622, 2630, and 2821) preserved mesquite, saltbush, and ocotillo wood, and cheno-am seeds preserved in 1 of them. No charred plant specimens were recovered from a surface structure (Feature 4621), likely because of poor preservation potential.

Table 68. Overview of Plant Use by Context

Taxon	Common Name	Part(s)	Context (No. of Flotation Samples per Context)								
			Activity Area, Cache (2)	House-in-Pit (39)	Possible Structure (3)	Posthole (5)	Nonthermal Pit (54)	Thermal Pit (31)	Hearth, FAR Concentration, Charcoal/Ash Lens (3)	Reservoir (1)	Noncultural (6)
Subsistence Resources[a]											
Atriplex spp.	saltbush	fruit and utricle core	—	—	—	—	1 (1.9)	1 (3.2)	—	—	—
Chenopodium-Amaranthus	goosefoot-pigweed	seed	—	1 (2.6)	1 (33.3)	—	1 (1.9)	—	—	—	—
Panicum spp.	panic grass	caryopsis	—	—	—	—	—	1 (3.2)	—	—	—
Plantago spp.	woolly wheat	seed	—	—	—	—	—	1 (3.2)	—	—	—
Portulaca spp.	purslane	seed	—	—	—	—	—	—	—	—	1 (16.7)
Prosopis spp.	mesquite	seed fragment		2 (5.1)				3 (9.7)	—	—	—
Trianthema portulacastrum	horse purslane	seed and seed fragment	—	—	—	—	2 (3.7)	2 (6.5)	—	—	—
Nonsubsistence Resources[a]											
Atriplex spp.	saltbush	twig and wood	—	5 (12.8)	2 (66.7)	—	11 (20.4)	9 (29.0)	—	—	—
Carnegiea gigantea	saguaro	wood	—	1 (2.6)	—	—	4 (7.4)	6 (19.4)	—	—	—
Fouquieria splendens	ocotillo	wood	—	1 (2.6)	2 (66.7)	—	2 (3.7)	1 (3.2)	—	—	—
Poaceae	grass family	stem fragment	—	1 (2.6)	—	—	—	1 (3.2)	—	—	—
Prosopis spp.	mesquite	wood	2 (100)	32 (82.1)	3 (100)	4 (80)	51 (94.4)	31 (100)	2 (66.6)	1 (100)	5 (83.3)

Note: Ubiquities and percentages of charred plant taxa/parts are reported. Nonthermal pits included two bell-shaped pits, and thermal pits included one bell-shaped pit. Table does not include sample from surface-structure Feature 4621 that contained no charred plant taxa/parts.

[a] Numbers (percentages in parentheses) of samples containing the taxa/parts.

Table 69. Overview of Charred Plant Taxa/Parts Preserved within Flotation Samples from House-in-Pit Features

House-in-Pit Context, by Feature No.	No. of Flotation Samples	Subsistence Resources and Parts[a]		Nonsubsistence Resources and Parts[a]				
		Chenopodium-Amaranthus Seed	*Prosopis* spp. Seed Fragments	*Atriplex* spp. Twigs and Wood	*Carnegiea gigantea* Wood	*Fouquieria splendens* Wood	Poaceae Stem Fragments	*Prosopis* spp. Wood
13								
Fill	1							X
Floor	1							X
88								
Floor	1							X
1413								
Fill	3			X				X
2529								
Floor	1							X
2602								
Fill	1			X	X	X	X	X
2605								
Fill	1				X			X
2627								
Fill	1	X						X
2628								
Fill	1			X				X
2632								
Fill	2							X
2642								
Floor	1							X
2967								
Fill	1[b]							
Floor	1							X
3321								
Fill	1							X[c]
3963								
Fill	3							X

continued on next page

House-in-Pit Context, by Feature No.	No. of Flotation Samples	Subsistence Resources and Parts[a]		Nonsubsistence Resources and Parts[a]				
		Chenopodium-Amaranthus Seed	*Prosopis* spp. Seed Fragments	*Atriplex* spp. Twigs and Wood	*Carnegiea gigantea* Wood	*Fouquieria splendens* Wood	Poaceae Stem Fragments	*Prosopis* spp. Wood
4308								
Fill	1							X
4349								
Fill	2							X
4387								
Fill	3			X				X
4388								
Fill	1		X					X
10114								
Fill	1							X
Floor	1		X					X
11181								
Floor	1							X
11229								
Floor	1							X
14613								
Floor	1							X
14702								
Floor	1							X
18192								
Floor	1							X

Key: X = parts present.

[a] Presence of taxa/parts within flotation samples.

[b] The taxon of the sample from the fill of Feature 2967 is unknown.

[c] A macrobotanical sample from Feature 3321 also preserved charred mesquite wood.

The Feature 2602 house-in-pit bears special mention. It is a substantial structure representing the early Chiricahua phase that was possibly used either more intensively than the other smaller structures or for different reasons. This structure preserved the highest diversity of wood types of all structures sampled, and it was almost the only structure to contain saguaro wood. An associated thermal pit (Subfeature 7757) and a nonthermal pit (Subfeature 7900) both preserved charred horse-purslane seeds, which most likely represented food.

Evidence from a Noncultural Drainage

Eight macrobotanical samples from a noncultural drainage (Feature 20378) dated to the Early to Middle Archaic period (9500–1200 B.C.). Four of these samples preserved charred wood of mesquite, and saltbush and creosote bush wood were preserved in a single sample each. Two possible explanations for this record are that (1) human groups were in the area burning these woody resources, and leftover debris from thermal features or middens was swept into the drainage and that (2) occasional natural fires produced these specimens.

Seasonality of Site Occupation

The seasons that plant parts are available give some indication of when people formerly occupied or visited landscapes, with the exception of wood, which can be gathered in any season throughout the calendar year. However, the fact that groups often stored foods for future use makes it harder to link the season of availability to a season of actual use (Adams and Bohrer 1998). Evidence from the Luke Solar project sites indicated the harvest of cool-season annual *Plantago* spp. seeds in the springtime. Annual goosefoot plants could also have been gathered as greens in the springtime, and their ripe seeds could have been harvested from summer through fall. Fruit from perennial and annual species of saltbush also ripen in the summer, and their availability extends into the following winter and spring, because mature saltbush fruits have the ability to remain attached to plants for many months. Annual pigweed, purslane, and horse-purslane plants all tend to germinate with summer monsoons, producing greens and mature seeds for the remainder of the growing season. Pods of mesquite trees mature during the summer, and ethnographic accounts have revealed that sometimes, groups buried the parched pods in pits in the ground or in aboveground caches in order to extend access into the following winter and spring, potentially food-stressed times of year. Panicgrass grains ripen for harvest in the fall.

Local- vs. Nonlocal-Plant-Resource Use

None of the plants reported in this chapter would be considered resources that required extensive travel to acquire. All are currently part of the Sonoran Desertscrub flora, including the Lower Colorado River Valley subdivision, where the Luke Solar project area is located (Turner and Brown 1982:181–203). Except perhaps for saguaro ribs or ocotillo stems, no travel to higher elevations was indicated, nor was the use of materials transported by rivers or tributaries.

Environmental Interpretations

The current vegetation at the Luke Solar project site has experienced historical-period disturbance. Introduced plants from other continents now occupy the area, as well. It is reasonable to assume that the relative proportions of individual plant species have likely shifted from the precontact, natural distributions. Use of a cultural record to reconstruct past plant communities must take into consideration the cultural bias of human selection of certain plants and possible avoidance of others. Despite these concerns, the archaeological record suggests that many of the same plants found on the landscape today were also present during the pre-Hispanic period. Trees, shrubs, and herbaceous plants reported as part of the modern Sonoran Desertscrub flora (Turner and Brown 1982:181–203) seem to have been available in the Luke Solar project area for a very long time. The area was likely within a short walking distance of mesquite groves, based on the repeated recovery of mesquite wood in flotation and macrobotanical samples. This is supported by two additional lines of evidence: (1) the presence of land-snail shells (*Succinea* sp.) at the large Falcon Landing site, which is suggestive of moist habitats (see Chapter 4), and (2) evidence that surface water was delivered into the area during the Middle Archaic period (see Chapter 2). Mesquite groves form shade for other plants and provide protection for a range of animals, as well. More than one species of saltbush, including fourwing saltbush (*Atriplex canescens*), grew nearby. Open ground that was available naturally and as a result of human disturbance in the area supported populations of annual weedy plants, such as *Plantago* spp., goosefoot (*Chenopodium* spp.), pigweed (*Amaranthus* spp.), purslane (*Portulaca* spp.), and horse purslane (*Trianthema portulacastrum*). Ample winter rains and summer monsoons would have spurred annual plants to produce quantities of edible seeds.

Summary

The small but relatively informative plant record preserved within the flotation and macrobotanical samples documents a long history of plant use in the Luke Solar project area. A number of wild plants with edible parts drew people to the area. These include two species of saltbush (*Atriplex canescens* and *Atriplex* spp.); mesquite (*Prosopis* spp.); annual plants, including *Plantago* spp., goosefoot (*Chenopodium* spp.), pigweed (*Amaranthus* spp.), purslane (*Portulaca* spp.), and horse purslane (*Trianthema portulacastrum*); and at least one type of grass, panicgrass (*Panicum* spp.). Mesquite and saltbush plants also provided wood though time, and less often, other plants did, as well (saguaro, ocotillo, and creosote bush). Grass stems served useful purposes on occasion.

During the early Chiricahua phase and lasting through the Late Archaic period, mesquite pods were important foods. People also gathered goosefoot/pigweed, *Plantago* spp., and horse-purslane seeds and panicgrass grains. They relied heavily on mesquite wood and, less often, on saltbush wood, saguaro ribs, and ocotillo stems. The relatively small record of plant use is similar during the pre-Classic and Classic periods.

The evidence suggests that the area was visited seasonally. Springtime use of the area would have provided groups with *Plantago* spp. seeds, saltbush fruit still clinging to plants months after their maturity, and, potentially, aboveground or belowground caches of mesquite pods from previous harvests. By early summer, goosefoot greens would also have been available. Following the start of summer monsoon rains, greens of pigweed, purslane, and horse purslane would have been added to the list of edible plants, which could then have expanded to include ripening seeds of all these plants. Mesquite pods would also have matured during the summer and been available for consumption or storage for the future. Saltbush fruit would likewise have ripened during the summer, and their fruits would have remained attached to plants for weeks or months to come. Panicgrass grains would have matured in the fall.

Both the flotation and macrobotanical records confirmed that mesquite wood was gathered most often through time and was utilized within structures and thermal pits. It is likely that there was so much burned mesquite wood that it spread across the area into nonthermal pits via rains and winds or was intentionally deposited as trash. Together, the flotation and macrobotanical records revealed that saltbush wood was also burned through time in the same thermal features as mesquite. Considering that there was evidence that mesquite pods and two types of saltbush plants were subsistence resources, these two plants could be considered among the more-important multiuse plants sought regularly by groups in the area.

Insight into Archaic period foraging was preserved in the plant records of the Luke Solar project and projects such as those conducted at Last Ditch and Coffee Camp. Despite the fact that the emphases on sampled contexts diverged among the three projects, the evidence of plant use from the Luke Solar project was complementary and revealed successful foraging strategies that lasted for millennia. All three projects present a strong signature of springtime visitation, when groups harvested small seeds of annual plants, such as *Plantago* spp., grass grains, and other resources, such as cholla buds. Interest was also high in summer-ripening mesquite pods, saltbush fruit, and numerous annuals that provided both greens and ripe fruit during and following the summer rainy season. At Last Ditch, seed harvest and parching were likely followed by preparation and consumption elsewhere, based on the limited ground stone record from that project area. However, in both the Coffee Camp and Luke Solar project areas, all such activities likely occurred in place. The three projects suggest that foragers repeatedly returned to locations in seasons when both ephemeral water sources and seeds of a number of native annual and perennial plants were plentiful. The strongest evidence was of visits in the spring and summer, and evidence suggested that fall visitation also occurred.

CHAPTER 7

Pollen Analysis

Susan J. Smith

Research Goals

The pollen research for the Luke Solar project was based on 117 samples: 11 control samples from natural strata and geologic columns and 106 archaeological samples (Table 70). All but 4 were from Falcon Landing, and those 4 were from Site 68. Sixty-five cultural features were represented in the pollen data, only 2 percent of the 3,065 features documented during SRI's fieldwork.

The Luke Solar project archaeological record indicates a light, intermittent human presence on the landscape, but a presence that spanned more than 5,000 years. Small groups of people apparently returned repeatedly to gather and process local plants. In total, 48 structures were identified and excavated at Falcon Landing, but nonthermal extramural pits (n = 2,398) constituted, overwhelmingly, the most prevalent feature type encountered. Recovered ground stone tools included metates, manos, a few mortars, and an impressive number of pestles (see Chapter 3), which indicates a milling technology involving pounding and perhaps gyratory grinding. Identifying the plants sought and processed by Middle Archaic period people was the primary goal of the pollen research. Defining economic pollen signatures can contribute to inferring the seasons of occupation, which is key to the research themes of land use and subsistence (see Volume 1, Chapter 2).

Examining the pollen data for chronological trends or patterns was a second research goal. Because of the thousands of years encapsulated within site features and sediments, there is potential to reconstruct environmental information in addition to temporal cultural patterns. Through the use of radiocarbon dating and geochronology, the highest number of features (n = 708) in the Luke Solar project were dated to the early Chiricahua phase of the Middle Archaic period (between 3500 and 1200 B.C.). The Late Archaic period was represented by 20 San Pedro phase (1200–800 B.C.) and 75 Cienega phase (800 B.C.–A.D. 50) features. Significantly fewer features were dated to the Early Ceramic, pre-Classic, Classic, and Protohistoric periods. In deserts of the southern Southwest, the Middle Archaic period has been visible in just a handful of documented sites, and most lacked any archaeobotanical information. The desert Late Archaic period is better represented, because people began to blend agriculture into their gathering and hunting societies and to settle in substantial communities.

Previous Archaic Period Research

Southwestern Archaic period research has grown over the past few decades, and much of this work has been integrated in important syntheses (Diehl 2005; Huckell 1995; Mabry and Stevens 2000; Roth and Freeman 2008; Vierra 2005). These studies have focused on the transition to Late Archaic period agriculture in riverine settlements, because the big discoveries have been Late Archaic period farming communities that flourished along southeastern Arizona rivers. In this chapter, the Middle Archaic period nonriverine foraging tradition is emphasized, and two previous projects with Middle Archaic period pollen data, at Last Ditch and Coffee Camp, are summarized below (Table 71). Neither site yielded evidence of Archaic period cultigens through pollen or flotation samples.

Table 70. Distribution of Pollen Samples by Context

Context, by Category	No. of Features	No. of Samples	No. of Sterile Samples
Structures			
Floor or fill sample	23	31	1
Nonthermal pit	14	17	6
Thermal pit	1	5	—
Posthole	1	1	—
Hearth	1	1	—
Extramural pits			
Nonthermal pit	7	8	—
Thermal pit	7	7	1
Ground stone caches			
Cache in a pit	3	7	2
Cache on an activity surface	1	3	—
Activity areas	5	5	—
Pollen washes			
Artifact wash	2	7	1
Control for artifact washes	—	14	1
Natural strata	—	3	—
Geologic column	—	8	4
Total	65	117	16

Table 71. Pollen Research at Middle to Late Archaic Period Sites Last Ditch and Coffee Camp

Project Aspect	Last Ditch (AZ U:5:33 [ASM]) Project			Coffee Camp (AM AA:6:19 [ASM]) Project
	Hackbarth (1998)	Phillips et al. (2001)	Rogge (2009)	Halbirt and Henderson (1993)
Palynologist	Susan J. Smith	Bruce G. Phillips	Bruce G. Phillips	Jannifer Gish
Location	Mayo Boulevard, West Rawhide Locus	State Route 101L, Pima Freeway	State Route 101L/64th Street	Greene Wash, southwest of the Picacho Mountains
Environmental setting	lower *bajada*	lower *bajada*	lower *bajada*	lower *bajada*/desert grassland
No. of Middle Archaic period samples analyzed	—	25	20	26[a]
No. of Late Archaic period samples analyzed	9	3	—	7
Use seasons interpreted from pollen data	visits over multiple seasons: strong early-spring signal, late spring, and summer through fall	visits over multiple seasons: strong early-spring signal, late spring, and summer through fall	visits over multiple seasons: strong early-spring signal, late spring, and summer through fall	early through late spring

[a] From mixed Early and Late Archaic period contexts; excludes sterile samples and samples from poorly dated Archaic to Protohistoric period contexts and contexts of unknown age

Prior to the Luke Solar project, the best Middle Archaic period record was from the northern Phoenix Basin, at Last Ditch (AZ U:5:33 [ASM]), a logistical field camp dated to between 2900 and 1500 cal. B.C. and located along Rawhide Wash, east of Cave Creek, on the middle to lower *bajada* of the McDowell Mountains. Data recovery excavations at Last Ditch were conducted three separate times (see Table 71), and each investigation included pollen and macrobotanical research. The Middle Archaic period component was represented by more than 150 thermal pits or hearths, 2 structures that were probably expedient brush-covered shelters, a midden, and a small ground stone collection consisting primarily of hand stones and a few metates. The Late Archaic period expression at Last Ditch was similar and included 2 structures, 24 thermal pits, a midden, 3 rock clusters, and sparse ground stone artifacts.

There is no water at the site today, but Phillips et al. (2001:62) speculated that during wet seasons, a perched water table could have formed over a subsurface cemented paleosol that was revealed in soil trenches. Hand-dug wells or small seeps along drainage borders might have supplied water for Archaic period foragers. Plant resources are relatively rich because of the many small drainages that cut the *bajada* surface. In the areas between drainages, creosote bush (*Larrea tridentata*) and bursage (*Ambrosia* spp.) shrubs dominate, and there are varieties of cacti, especially cholla (*Cylindropuntia* spp.), barrel cactus (*Ferocactus* spp.), prickly pear (*Platyopuntia* spp.), and the occasional saguaro (*Carnegiea gigantea*). The drainage courses shelter paloverde (*Cercidium* spp.), ironwood (*Olneya tesota*), and mesquite (*Prosopis* spp.).

Phillips et al. (2009:63–64) theorized that Middle Archaic period gatherers targeted small seeds from grasses and annual herbs and parched them in baskets with heated rocks, which would explain the many thermal pits found at Last Ditch. After parching, seeds were apparently transported to a base or field camp to be ground into meal for consumption. Rains come to the Sonoran Desert in two seasons, winter/early spring and the summer monsoons, and different suites of plants flower and fruit in response to the seasons. Because different species set seed at various times, Archaic period people may have made multiple collecting visits to Last Ditch throughout a year, or collecting trips could have been sporadic, initiated in years blessed by a wet spring or a strong monsoon. This model is supported by the composite Last Ditch pollen data, which registered a strong late-winter to early-spring signal (grasses, Indianwheat [*Plantago* spp.], and a trace of hackberry [*Celtis* spp.]) and late-spring-into-fall use (cholla, lily family [probably yucca], and possible wild gourd [*Cucurbita* spp.]).

Coffee Camp (AZ AA:6:19 [ASM]) is a primarily Late Archaic/Early Agricultural period (3120–1920 years B.P.) site characterized by a predominance of San Pedro phase projectile points. Three early Chiricahua phase points and rare features originating in Stratum II, which predated 1500 B.C., indicated that Coffee Camp was known to Middle Archaic period people. Halbirt and Henderson (1993:114) summarized the site as a repeatedly occupied, semipermanent encampment the main occupation of which occurred during the terminal Late Archaic period (ca. 1500 B.C.–A.D. 1), which spans the San Pedro and Cienega phases. The San Pedro to Cienega phase transition was marked by the introduction of ceramics, cremations with offerings, and architectural variety.

Coffee Camp is located north of Tucson, west of Picacho Peak, and north of the West Silver Bell Mountains, in a geomorphic transition between the lower *bajada* and the expansive semidesert grassland of the Santa Cruz Flats northeast of Greene Wash. There is no water at the site, but during prehistoric times, seasonal water-filled depressions, or "pans," may have developed nearby after storms. Halbirt and Henderson (1993:56) reported that before local drainages were dammed to provide watering tanks for cattle, sheetwash would pond in and around Coffee Camp, "sometimes resulting in open bodies of water lasting for a few months." Modern vegetation includes woody species, such as mesquite (*Prosopis* spp.), saltbush (*Atriplex* spp.), crucifixion thorn (*Canotia* spp.), and cholla (*Cylindropuntia* spp.), and ground-cover plants of grasses, Indianwheat (*Plantago* spp.), and other annuals (Halbirt and Henderson 1993:56). Lower-*bajada* communities of paloverde (*Cercidium* spp.), ironwood (*Olneya tesota*), and cacti are accessible to the west, and riparian habitat is within 10 miles to the east, along the Santa Cruz River. The Coffee Camp setting, which is sandwiched between the mountains and the river, is similar to the Luke Solar project location between the White Tank Mountains, approximately 12 km (7.5 miles) to the west, and the Agua Fria River, 5 km (3.3 miles) to the east.

The distribution of surface artifacts at Coffee Camp covered an area of 400 by 250 m (10 ha), but data recovery was limited to an area of 250 by 50 m along the site's eastern edge and outside the main concentration of surface artifacts (Halbirt and Henderson 1993:1). The heart of the site lies on private land and was not surveyed. Hundreds of extramural pits and four structures were excavated within the project corridor. The Archaic period structures consisted of pit-house Feature 289, with an interior hearth; one possible storage structure (Feature 39); and one large (16.1 m^2 in floor area) Cienega phase pit house (Big House Feature 315, dated to B.C. 357–A.D. 59) that may have functioned as a ceremonial or communal house. Within the Big House, two complete deer-antler racks were found that had probably been mounted in the roof above the hearth. Five burials were also documented at Coffee Camp: two inhumations and two cremations that dated to the Archaic period occupation and a fifth inhumation in mixed deposits. Artifacts at the site included a large number of tool caches; 29 caches contained 90 artifacts, and most were milling tools (manos, metates, and pestles).

The archaeobotanical evidence and the amount of ground stone at Coffee Camp indicated that grasses and small-seeded annuals were exploited throughout the site's history, combined with harvests of mesquite (*Prosopis* spp.) and cholla (*Cylindropuntia* spp.). There was a strong spring seasonal signal. Gish (1993:328) stated that "[p]ossibly as many as 13 features at Coffee Camp have a spring seasonality index, three have more of a summer index, with six suggesting [a] spring-summer index." Four pollen washes from metates found in Archaic period contexts yielded mesquite pollen, which is unusual. Mesquite pollen is generally rare in archaeological samples and is unlikely to persist on mature seed pods. The Coffee Camp pollen washes could reflect the grinding of flowers, perhaps along with grains or other foods, or young green mesquite pods, which could co-occur on trees with the last flowers.

Methods

Two types of samples were processed for the Luke Solar project: bulk sediment samples and pollen washes. The majority of samples (n = 110) were from sediments collected from feature fill or specific contexts, such as sediment beneath or adhering to an artifact. Seven samples were pollen washes from six metates. The specific methods for the two classes of samples are described below.

Bulk Sediment Samples

The sediment samples were processed at the Northern Arizona University Laboratory of Paleoecology, using a procedure recommended by Smith (1998), with the modification of a series of timed decants. Subsamples (10–20 cc in volume) were taken from the sample bags, and a known concentration of tracer spores (*Lycopodium* sp.) was added to each. Spiking samples with tracers enables calculation of pollen concentrations and also serves to monitor pollen recovery during chemical extraction. Warm hydrochloric acid (10 percent solution) was added to the sediment to dissolve caliche, and the mixture was sieved through 180-μm mesh to remove coarse materials (rocks, roots, seeds, and charcoal). The remaining fine fractions were mixed with warm sodium hexametaphosphate (less than 2 percent solution) and allowed to settle for 8 hours in 1-liter beakers. The clay-rich, cloudy water above the settled sediment was then decanted, and the process was repeated using only distilled water until decanted liquids were clear. This procedure was adopted especially for this project, because the fine silts and clays that characterize the sediments are difficult to remove with chemicals. The decants are also effective at reducing microscopic charcoal, which is another particle class that plagues archaeological samples. Following the decanting, samples were treated for 24 hours with hydrofluoric acid to reduce silicates, rinsed in distilled water, and "floated" in lithium polytungstate. The heavy liquid separates pollen grains and particles lighter than about 1.9 specific gravity from the heavier fractions. The recovered light fraction was finished by acetolysis, an oxidation step that digests organics and lignin, and the residues were rinsed, mixed with glycerol, and stored in vials.

At the microscope, two levels of magnification were employed: 400×-magnification counts of all pollen types up to 100–200 grains, if possible, and 100×-magnification scans for larger pollen types. If preservation is moderate, pollen greater than 30 µm in size is easily identified at 100× magnification, including corn, squash, cotton, agave, cacti, and some herb types. Pollen identifications were made to the lowest taxonomic level possible based on published keys (Fægri and Iversen 1989; Kapp et al. 2000; Moore et al. 1991) and the Northern Arizona University Laboratory of Paleoecology modern-pollen reference collection. Aggregates (clumps of the same pollen type) were counted as 1 grain per occurrence, and taxon and size were recorded separately. As an example of the aggregate shorthand used in the database, "3 (100+)" noted in the cheno-am category translates to 3 aggregates observed, the largest of which contained more than 100 cheno-am grains.

Three parameters were calculated from the pollen counts: taxon richness, sample concentration, and pollen percentages. Taxon richness is the number of different pollen types identified in a sample, and pollen concentration is a measure of the density of pollen grains per unit of sediment. Concentration was calculated by taking the ratio of the pollen count to the tracer count and multiplying by the initial tracer concentration. Dividing this result by the sample volume yielded the number of pollen grains per cubic centimeter of sample sediment, abbreviated "gr/cc." Pollen percentages are proportions of taxa in a sample relative to the pollen sums and were calculated by taking the ratio of the taxon count to the pollen sum and multiplying by 100.

Pollen Washes

Six metates were selected for pollen washes. SRI field crews bagged artifact-wash candidates with as much encasing field dirt as possible to protect stone surfaces from modern ambient-pollen contamination. In the SRI Tucson laboratory, the artifacts were first cleaned of dirt, down to the rock surface, and control samples were taken from the sediment in contact with the use or exterior surfaces. Field control samples were also routinely collected from sediments surrounding or directly beneath artifacts. The exterior nonuse surfaces of the artifacts were further cleaned by simple brushing or a combination of brushing and rinsing. Cleaning the nonuse surfaces is a precaution to protect the targeted wash surface from extraneous materials. At that point, the artifacts were ready for washing by brush-scrubbing the use surfaces with hot distilled water and diluted hydrochloric acid (less than 10 percent solution). The wash waters were collected and allowed to settle overnight, surface liquids were decanted, and the settled sediments were transferred to appropriate containers for mailing. At the Northern Arizona University pollen laboratory, the wash samples were sieved through 180-µm-mesh screen to remove coarse sand and organic particles, and the filtered material was centrifuged and given an overnight hydrofluoric-acid treatment to reduce silts and clay. Samples were finished by rinsing, and residues were suspended in glycerol. Pollen identification and data transformation were the same as described above for bulk sediment, except no concentration data were calculated. Pollen concentrations are meaningless when working with pollen washes, because there is no consistent sample size or volume to calculate the density of recovered grains (Geib and Smith 2008).

Results

The project samples were challenging in many respects. They were difficult to process because of the amounts of fine silts and clays and because the recovered assemblages were degraded, as demonstrated by examples of typically resilient cheno-am grains thinned to ghost outlines. In the majority of samples, there were examples across all taxa of grains with smoothed or melded surfaces, which made identifications difficult, and it is likely that some unknown fraction of pollen was lost over time through physical grain deterioration. Despite these problems, samples were countable, and only 16 were evaluated as sterile or containing inadequate pollen for a statistically significant estimate of the pollen population. The least-productive contexts were intramural nonthermal pits, with 6 sterile samples out of 17, and the geologic column, with 4 sterile samples out of 8 (see Table 70). The raw counts from the project pollen samples are reported in Appendix 7.1.

Pollen concentrations were moderately high. Excluding sterile samples and pollen washes, the average concentration of the countable samples was 11,026 gr/cc (n = 95), and the range was from 959 to 44,615 gr/cc. The richness or variety of pollen taxa per sample was generally low, with an average richness of 8 and a range of 3–15. Forty-three pollen types were identified, but 20 were rare, occurring in three or fewer samples; 12 taxa registered in single samples only. The project pollen types are listed in Table 72 by their common and scientific names, organized by ethnobotanical and ecological categories, and ranked by ubiquity.

Among the rarest types were maize; prickly pear; hackberry; cattail; cottonwood; nonlocal plants, such as lily family (probably yucca), ocotillo, and silktassel; the possible introduced species cranesbill; and an unknown that was tentatively assigned to the pea family (Figure 93). The unknown pea-family type was described as follows: the grain is tricolporate with transverse widening at the pores, the longest grain dimension is 30–35 μm, and the shape is approximately round (polar to equator axis ratio of 0.9), with a tectate exine with a coarse to supra-reticulate surface. The unknown pea type was found at high values (13–24 percent) in two samples taken from the only bell-shaped pit analyzed, Feature 3551, which also contained a metate. A large grass grain was identified in eight samples and is believed to represent a contaminant introduced during laboratory processing. The large grass grains were distinctive and well preserved and were identified in pollen samples from other projects located far from LAFB that were processed at the Northern Arizona University laboratory.

There was one maize-pollen grain recorded in a floor sample from a San Pedro phase structure, Feature 13071, dated to 970–830 cal. B.C. The maize occurrence was not unusual in terms of age, because maize is known from Late Archaic period San Pedro phase farming sites (Diehl 2005; Gregory 1999), but the grain was odd because no other pollen samples yielded maize, and no flotation or macrobotanical maize remains were identified (see Chapter 6). Maize pollen could have hitchhiked into the San Pedro phase house on tools, trade items, or clothing, or its preservation in Feature 13071 could reflect some ritual or ceremonial use of maize pollen. The single pollen grain is inadequate evidence to infer any level of agriculture at the sites.

The most abundant pollen type was cheno-am, with an average pollen percentage of 71 (n = 101 samples with significant counts) and a range of 26 to 93. Cheno-ams are the most common plant remains recovered from southwestern archaeological sites (Huckell and Toll 2004) and are typically attributed to annual cheno-am weeds, like amaranth, that thrive in disturbed soils, especially at farming sites. However, in this analysis, "cheno-am" is interpreted to represent primarily saltbush (*Atriplex* spp.) because of the saline and fine-textured soils at the Luke Solar project sites. Saltbush is one of the few plants that are obvious in the modern vegetation, and *Atriplex* spp. twigs, wood, and fruit were prominent in Middle Archaic period flotation and macrobotanical samples (see Chapter 6). The Middle Archaic period local environment may have fostered different *Atriplex* species through time, and there might have existed a changing mix of understory cheno-am weeds and other salt-tolerant species.

Plant species subsumed by the broad cheno-am category are wind pollinated and produce large amounts of pollen. The strong cheno-am signal in project samples is interpreted to represent a swamping effect from local saltbush that diluted both natural and potentially culturally influenced pollen from other plants. Mesquite and paloverde, for example, are insect pollinated and are evaluated to have been underrepresented in project samples, partly because of the overrepresentation of cheno-ams. It is also likely that part of the cheno-am signature reflects harvest and processing of cheno-am food products. Common plants subsumed by the cheno-am pollen type are listed in Table 73 with their flowering seasons and ethnobotanical uses.

Woodland pollen types occurred in the project samples (see Table 72), but in minimal percentages. The pine, juniper, and other extralocal to regional taxa are interpreted to have drifted in from higher-elevation woodlands and forests.

Economic Pollen Types

One of the interpretive foundations of archaeobotany is the ethnographic record. There are several published ethnobotany sources and summaries in which subsistence uses can be found for plants represented by all of the identified project pollen taxa (e.g., Hodgson 2001; Moerman 1998). But pollen assemblages

Table 72. Pollen Types found in Project Samples

Common Name, by Ecological and Economic Category	Taxon/Taxa	Ubiquity among 117 Samples (%)
Interpreted economic pollen taxa		
Cheno-ams	cheno-ams (see Table 7.4 for common species)	97
Grass family	Poaceae	66
Indianwheat, plantain	*Plantago* spp.	21
Paloverde	*Cercidium* spp.	15
Cactus family	Cactaceae, including saguaro (*Carnegiea* spp.), hedgehog cactus (*Echinocactus* spp.), barrel cactus (*Ferocactus* spp.), and others	13
Cholla	*Cylindropuntia* spp.	9
Mustard family	Brassicaceae	8
Wolfberry type (nightshade family)	Solanaceae, attributed to wolfberry (*Lycium* spp.)	7
Mesquite	*Prosopis* spp.	6
Lily family	Liliaceae, including *Yucca* spp., onion (*Allium* spp.), and others	4
Unknown, possible pea family	unknown Fabaceae	3
Hackberry	*Celtis* spp.	1
Cultigen		
Maize	*Zea mays*	1
Other desert food and subsistence resources		
Sunflower family	Asteraceae, including brittlebush (*Encelia* spp.), desertbroom (*Baccharis* spp.), and others	92
Spiderling	*Boerhaavia* spp.	74
Globemallow	*Sphaeralcea* spp.	49
Ragweed/bursage	*Ambrosia* spp.	36
Spurge family	Euphorbiaceae	34
Summer poppy	*Kallstroemia* spp.	24
Evening primrose	Onagraceae	21
Buckwheat	*Eriogonum* spp.	20
Cottonwood	*Populus* spp.	3
Unknown, possible grass	unknown grass	3
Pea family	Fabaceae	2
Ocotillo	*Fouquieria* spp.	2
Four o'clock family	Nyctaginaceae	2
Mint family	Lamiaceae, including chia (*Salvia* spp.)	1
Prickly pear	*Platyopuntia* spp.	1
Possible cattail	*Typha* spp.	1
Mallow family	Malvaceae	1
Greasewood	*Sarcobatus* spp.	1
Cheeseweed type	*Sidalcea* spp.	1
Extralocal to regional woodland trees and shrubs		
Large pine	*Pinus ponderosa* type	44
Small pine	*Pinus edulis* type	28
Juniper	*Juniperus* spp.	14
Mormon tea	*Ephedra* spp.	10
Alder	*Alnus* spp.	1
Silktassel	*Garrya* spp.	1

continued on next page

Common Name, by Ecological and Economic Category	Taxon/Taxa	Ubiquity among 117 Samples (%)
Douglas fir	*Pseudotsuga* spp.	1
Oak	*Quercus* spp.	1
Rose family	Rosaceae	2
Exotic		
Cranesbill	*Erodium* spp.	2
Laboratory contaminant		
Large grass	large Poaceae	7

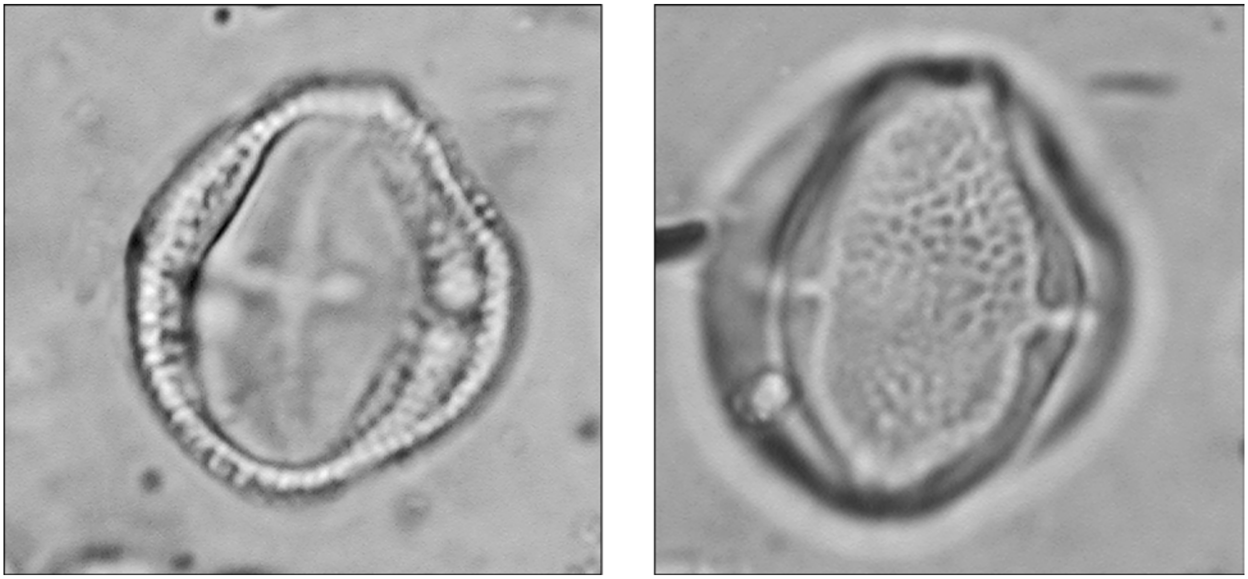


Figure 93. Microphotograph of an unknown (possible pea-family) pollen type identified from bell-shaped-pit Feature 3551. The longest grain dimension is 30–35 µm.

Table 73. Cheno-Am Pollen: Common Plants

Species Name	Common Name(s)	Type	Flowering Season	Uses and Seasons	References
				Herbs	
Amaranthus palmeri	amaranth, carelessweed	annual	summer	young leaves (boiled for greens) gathered in summer; seeds gathered in late summer/early fall, parched, and ground to meal	Rea 1997:201
Chenopodium berlandieri	pit-seed goosefoot	annual	fall	young leaves (boiled for greens) collected in fall	Rea 1997:202
Monolepis nuttalliana	patota	annual	early spring	young leaves picked January–February; prolific seed producer; gathered seeds were boiled or parched and ground to meal	Rea 1997:204
				Shrubs	
Allenrolfea occidentalis	pickleweed	perennial	summer	seeds gathered in summer, winnowed, roasted, and ground	Rea 1997:122
Atriplex canescens	fourwing saltbush	perennial	summer	leaves saponin rich; used to wash baskets	Moerman 1998; Rea 1997:125
Atriplex lentiformis	quailbush, lens-scale, big saltbush	perennial	summer	leaves saponin rich; used to wash baskets; seeds harvested in summer, pit-baked/steamed, roasted, dried, or parched and stored or ground to meal; two references to pounding seeds to meal	Moerman 1998:116; Rea 1997:126
Atriplex polycarpa	desert saltbush, cattle spinach	perennial	summer	summer seeds may have been gathered and ground	Hodgson 2001:151
Atriplex wrightii	Wright's saltbush	annual	summer	young leaves gathered in early spring (March–April) and after monsoons (September) and boiled for greens or dried and stored; seeds gathered in late summer/early fall, parched, and ground to meal	Hodgson 2001:151; Rea 1997:201

are created by a mix of natural processes that affect pollen abundance and preservation that becomes further muddled by the overlay of human activities (Adams and Smith 2011; Fægri and Iversen 1989; Geib and Smith 2008). Therefore, not every pollen type signifies past human activities. A core suite of 11 taxa plus the unknown pea family are interpreted here as the important economic resources visible through the pollen lens (see Table 72). This does not mean these were the most important food resources utilized at the project sites, only that they are the ones that left pollen evidence. Ethnographic summaries are presented below for 5 resources, in order to emphasize the seasonal implications of pollen in addition to the range and timing of food products available from a single resource.

Mesquite

Mesquite pollen was relatively rare, occurring in only seven project samples (6 percent), but four of the seven samples were from structures, implying a strong cultural link. There are two dominant mesquite species in the Sonoran Desert, honey mesquite (*Prosopis glandulosa*) and velvet mesquite (*P. velutina*), and in the past, screwbean (*P. pubescens*) was probably more widespread. Screwbean mesquite grows at better-watered sites than where the other two species grow, and as water in the Sonoran Desert has been diverted by modern farming and development, the screwbean range has contracted (Turner et al. 1995). Mesquite is one of the most dependable desert resources, because deep root systems tap groundwater, thereby buffering trees from droughts, although late frosts or high winds during the flowering season can destroy a season's seed crop (Hodgson 2001).

All three trees were used by southwestern Native American tribes, and in regions where mesquite was abundant, the seed pods were a staple. Rea (1997:184) described velvet mesquite as the tree of life for the Gila River Pima, the Gileño, who based 2 months of their calendar on the tree—the mesquite leafing out moon (around April) and mesquite flowers moon (around May). The Seri Indians recognized eight usable products in fruit development, ranging from pods less than 1 inch long to mature pods that had fallen to the ground (Felger and Moser 1985). Another reference to the use of new pods is from Mexico, where green pods were harvested in April and dried for later use (Hodgson 2001:186). The Gileño considered mesquite flowers a snack food and were known to eat flowers mixed with a certain mud (Rea 1997:184). The staple food was the seed pods, which were harvested after the pods dried and fell to the ground, usually in late June through July. In wet summers, a second harvest was available in September through October. The Gileño stored great quantities of seeds in granaries made from arrowweed (*Pluchea* spp.) sticks that were sealed with a layer of arrowweed and mud (Rea 1997:186). If Archaic period people at the Luke Solar project sites used a similar storage system constructed from local plants, no evidence would have survived.

Mesquite seed pods are not hollow containers encasing several seeds. Instead, a soft mesocarp tissue composed of sweet carbohydrates fills the pods and surrounds and insulates the seeds. The pods were gathered, usually after dropping to the ground; dried in various ways; and then pounded in a mortar (Hodgson 2001; Felger and Moser 1985; Rea 1997). The pounding freed the hard seeds and shredded the mesocarp into a fine meal or flour, which was separated by winnowing or screening. The meal was mixed with water to make a gruel or a doughy mass that was dried, baked, or boiled. Dried mesquite cakes apparently have an indefinite shelf life, making them a perfect traveling food (Rea 1997:187). Beverages were made from the meal mixed with water, which could also be fermented to make a sort of beer (Rea 1997:187). The Seri and other Native American groups separated and pounded the stone-hard seeds to meal in crushers, using gyratory grinders (see Felger and Moser 1985:340). Other valuable mesquite products included medicines made from saps, the pounded roots, and inner bark; all manner of wooden tools and gadgets; a black hair dye and a pottery paint made from sap; and even a superior binding or strapping material from the inner bark of certain species.

The technology of milling mesquite pods is of interest, in light of the number of stone pestles and the token number of mortars recovered during the Luke Solar project excavations. Historically, seed pods were pounded with a wooden or stone pestle in a wooden mortar that was made from a mesquite or cottonwood log by burning a cavity into the wood with coals. Rea (1997:187) wrote this description of mesquite-seed grinding from Julian D. Hayden, who worked with the River Pima in the 1930s: “The Pima avoided cracking the mesquite seeds by always pounding the pods in a wooden mortar with a stone pestle or a stone mortar with a wooden pestle because stone on stone would produce sharp-edged seed fragments.” If mesquite seed pods were processed in wooden mortars at the project sites, the wooden artifacts would have disappeared long ago.

Paloverde

From the White Tank Mountains west of the Luke Solar project area, Keil (1973) reported two paloverde species growing along washes: foothill or littleleaf paloverde (*Parkinsonia* [*Cercidium*] *microphyllum*) and blue paloverde (*P. floridum*). Both trees flower from March through April and, at higher elevations, into May, although blue paloverde will flower a few weeks before littleleaf paloverde (Turner et al. 1995), and seeds are mature from May into July, before summer monsoons (Hodgson 2001:164; Turner et al. 1995). Paloverde-seed production may be linked to wet winters, as shown by early-summer fruiting in years when winter rains have been bountiful (Hodgson 2001:167).

Paloverde pollen was identified in 15 percent of the project samples. Most desert cultures in the Southwest ate the sweet, young seed pods of littleleaf paloverde and ground the mature seeds to meal, often mixed with mesquite or ironwood flours (Hodgson 2001:164–167). Hodgson (2001:165) reported that blue-paloverde seeds are bitter tasting and harder than those of littleleaf paloverde, but blue-paloverde seeds were also ground into edible meals. Paloverde seeds could be parched or toasted before grinding, and parched seeds could be stored whole. In Baja California, the Seri Indians relied on paloverde seeds as a staple (Felger and Moser 1985:324) and shelled, toasted, and ground them to flour that could be stored in vessels. They even ate the flowers, made necklaces by stringing dried seed pods, and used the flowers as a component of a red face paint (Felger and Moser 1985:324).

Indianwheat

Indianwheat or plantain (*Plantago* spp.) was identified in 21 percent of the project samples. Indianwheat is an annual represented by several species that grow throughout Arizona in almost every ecosystem, from higher-elevation forests to the driest deserts. The small, ground-hugging plants pop up during the wet seasons and are noticeable as fluffs of grey-green leaves and tiny white flowers. In the southern deserts, Indianwheat is one of the first spring plants, appearing as early as February, with mature seeds by March into April, and flowering a second time after wet monsoons. For such a small plant, the seeds are relatively large, at 2–3 mm, and look like small flax seeds. The seeds become mucilaginous when wet, and Kearney and Peebles (1960:803) reported that during wet seasons in locations where seeds are abundant, thin crusts of wetted seeds can form around the plants. Seeds of two species (*Plantago insularis* and *P. purshii*) have been substituted for psyllium, a popular herbal remedy obtained from the Old World species, *P. psyllium* (Kearney and Peebles 1960:803).

Native tribes throughout North America used Indianwheat, particularly the leaves, which were made into a drawing poultice for wounds and bites and were also used as a gastrointestinal laxative (Moerman 1998:416–418). According to Moerman (1998:417), southwestern Hopi Indians applied *P. patagonica* to individuals to make them “more agreeable.” Food use of Indianwheat is well known, and in the Southwest, following a wet spring, abundant seeds could be threshed and winnowed from carpets of Indianwheat-seed heads. Water added to a handful of seeds made a mucilaginous drink, and toasted seeds were ground into gruel. Felger and Moser (1985:354) reported that the Seri Indians of Baja California harvested Indianwheat by pulling up and stockpiling whole plants. Seri women rolled the plants between their fingers to free the seeds, and then handfuls of seeds and chaff were wind-winnowed. It is easy to envision Indianwheat and a little water being ground with different spring seeds and grass grains to bind the mix into sheets or cakes.

Hackberry

Hackberry pollen was identified in 1 percent of the project samples. There are two species of hackberry in Arizona. Netleaf hackberry (*Celtis reticulata*) is usually a small tree found along water courses throughout the state, and desert hackberry (*C. pallida*) is a spiny shrub to small tree that is common along washes and in drier sites in the Sonoran Desertscrub and desert grassland (Kearney and Peebles 1960; Turner et al. 1995). Desert hackberry grows at the bases of cliffs and along washes in the White Tank Mountains, west of LAFB (Keil 1973).

Desert hackberry flowers in early spring (March and April) and will often flower a second time after summer monsoons. The summer-into-fall fruits are small and pulpy, and each fruit contains a relatively large stone. The fleshy fruits were pounded to pulp or ground to meal, dried, and caked for storage, or they were simply dried to be reconstituted later. In the Southwest, use of hackberry fruits has been reported from most native cultures, including Navajo, Apache, Yavapai, Tohono O'odham, Seri, and the Rio Grande Pueblos (Moerman 1998:147).

Wolfberry

Wolfberry (*Lycium* spp.) is relatively abundant today at the project sites, and these spiny shrubs were probably also present during the Archaic period. Wolfberry pollen was identified in 7 percent of project samples. Several species grow throughout the Southwest and can flower in any warm month when there is a good soil wetting. The most edible desert wolfberries flower from March to May, although desert-thorn (*Lycium exsertum*) can flower as early as January (Hodgson 2001:236). The sweet, red to orange berries quickly follow the flowers and were an important, widely exploited spring food resource. The berries were eaten raw; sun-dried; cooked in water to make soups, sauces, syrups, and beverages; or dried and ground (Hodgson 2001:236–237; Rea 1997:144). Sun-dried berries store well and have been reported to taste sweeter after drying (Hodgson 2001:236; Rea 1997:144).

Environmental Patterns

Three samples from natural strata and eight samples from a geologic column described in TR 9067 were collected as controls to define the natural local pollen rain, in addition to capturing some sense of the paleoenvironments through the Archaic and Ceramic period occupations. Unfortunately, only four samples from the geologic column yielded significant counts, and the ages of the natural strata did not adequately represent older periods.

The four productive geologic samples included two samples from Stratum IIA, which dated to the early Chiricahua phase; a sample from the broadly dated Stratum IV (Pioneer to Classic period); and a sample from Protohistoric period Stratum V. The pollen assemblages were dominated by cheno-ams and did not show any clear trends indicative of climatic or environmental shifts (Table 74). Within the geology column, Stratum IIA (Provenience Designation [PD] 9182) recorded the lowest cheno-am percentage and the highest sunflower-family percentage, which could reflect a decrease in saltbush that was perhaps related to wetter springs and drier monsoons. However, PD 9182 may have been compromised, based on a minimal pollen concentration and a high percentage of degraded pollen, and the pattern was not replicated by two other Stratum IIA samples, one from the geologic column (PD 9180) and one from the natural strata (PD 20382).

One interesting result from the natural strata was the presence of cholla and cactus family pollen, but in a sample of unknown age and in the early-historical-period sample (Stratum V). Cacti are conspicuously absent from the modern environment, although during SRI's fieldwork, a single barrel cactus was spotted in one of the small washes (Jesse Ballenger, personal communication 2013). There was evidence of increased water delivery and sedimentation in the project area during the Middle Archaic period, between 2970 and 2420 cal. B.C. (see Chapter 2), which might have resulted in the downslope expansion of desert vegetation zones, which may have brought cactus resources closer to the project sites. Alternatively, increased moisture during the Middle Archaic period might have fostered a greater variety of resources as plants found

Table 74. Summary Pollen Data from the Geologic Column and Natural Strata

Context	Geologic Column, Trench 9067, PD No.				Natural-Strata PD No.		
	9182	9180	9178	9176	20382	7513	8984
Stratum	IIA	IIA	IV	V	IIA	V	unknown
Approximate depth (cm below ground surface)	60–70	40–50	20–30	0–10			
Age	2810–2420 cal. B.C.	2810–2420 cal. B.C.	cal. A.D. 610–1220	cal. A.D. 1520–1800			
Temporal affiliation	early Chiricahua phase	early Chiricahua phase	Pioneer to Classic period	Protohistoric period	early Chiricahua phase	post–early historical period	unknown
Pollen concentration (gr/cc)	1,635	8,567	41,349	8,127	3,899	19,131	16,083
Taxon richness	10	12	14	8	4	11	11
Pollen percentages							
Cheno-ams	55	74	68	85	70	67	51
Sunflower family	23	10	13	6	16	11	8
Grass		1	5		1	3	4
Pine	2		1	1			1
Degraded	12	10	6	5	9	14	6
Others present		paloverde, lily family				cholla, cactus family	cactus family, silktassel

favorable topographic niches. Low representations of cholla and cacti in the archaeological samples suggest that isolated patches of cholla, barrel, and/or other cacti might have grown at or near the project area.

Excavated structures were the best-dated project features, and structure-floor or -fill samples made up almost one-third of the database. Primary archaeological features are not ideal for environmental reconstructions because of confounding human factors. For example, construction materials and any interior plant processing could strongly skew house pollen assemblages. Another negative aspect of using houses as environmental proxies is the large area covered by the project sites. Small microsite differences in vegetation could register as significant shifts in pollen spectra. However, because structures appear to have been, for the most part, ephemeral and lightly used and because the project landscape is relatively homogeneous, floor surfaces and floor fill may hold environmental information from pollen rain that drifted in through entries and thatch. Respecting the above caveats, it is worth exploring the structure samples from an environmental perspective.

In Table 75, average percentages for cheno-am, sunflower-family, and grass pollens are listed for only the best-dated structures. Excluded were structures with broad-range dates (for example, Early to Late Archaic period) as well as two substantial structures (early Chiricahua phase Feature 2602 and Cienega phase Feature 4621) that may have been used more intensively than other structures or for different functions and therefore are more likely to have been influenced by human activities. The temporal comparison highlights two periods during which cheno-ams may have been suppressed, the early Chiricahua and Cienega phases, and one interval during which cheno-ams may have been enhanced, the Red Mountain phase. The lower cheno-am values were offset by higher input from sunflower family and slightly higher input from grasses. The outlier of 27 percent grass pollen in one Cienega phase floor sample (Feature 1413) was discounted, because it suggested a cultural signal, perhaps from grass thatch. If there was a climate signal in the pollen flux from structure samples, the averages in Table 75 suggest wetter winters and springs during the early Chiricahua and Cienega phases that favored sunflower family and grasses and perhaps drier summers that restricted saltbush. Cheno-ams, with a few species exceptions, are in a summer-flowering category, and the high cheno-am percentage in Red Mountain phase structures could reflect stronger summer monsoons.

Contextual Patterns

It is important to consider the pollen results from the perspective of context, because how features were used can affect the deposition, composition, and preservation of pollen assemblages (Adams and Smith 2011; Geib and Smith 2008). Almost half of the project samples came from structures (n = 55), and 40 percent came from extramural features or surfaces (n = 44, including controls for pollen washes). There were differences in the presence of economic pollen types by context that highlighted certain resources and perhaps reflected food-processing technology (Table 76).

Considering first the results from structures, the record of economic taxa was low compared to other contexts. Within structures, floor or floor-fill samples were more likely to preserve evidence of subsistence

Table 75. Average Pollen Percentages from Structure-Floor and -Fill Samples, by Age

Temporal Affiliation	No. of Structures	No. of Samples	Average Pollen Percentage		
			Cheno-Ams	Sunflower Family	Grass
Early Chiricahua phase	2	4	70	15	3
Late Chiricahua phase	3	4	76	4	1
San Pedro phase	3	4	74	10	3
Cienega phase	2	3	62	13	27[a]
Red Mountain phase	2	2	80	3	1
Snaketown phase	2	2	76	10	—

Note: Early Chiricahua phase Feature 2602 and Cienega phase Feature 4621 were excluded from this table.

[a] An outlier in one sample.

Table 76. Sample Ubiquities of Economic Pollen Types, by Context

Context	No. of Features	No. of Samples	Indianwheat (%)	Paloverde (%)	Mesquite (%)	Cholla (%)	Cactus Family (%)	Others
Structures								
Floor or fill	23	31	23	16	7	10	19	Maize in 1 sample (San Pedro phase Feature 13071), ocotillo in 1 sample (Feature 14702), and wolfberry type in 4 samples.
Nonthermal pit	14	17		6		6		Unknown, possible pea family in 1 sample (Feature 4302).
Thermal pit	1	5	20	20		20	20	Lily family.
Posthole	1	1						
Hearth	1	1	X		X			
Extramural Pits								
Thermal pit	7	7		14	14			Prickly pear in 1 sample.
Nonthermal pit	7	8	38	13		38	25	Lily family in 2 samples, ocotillo in 1 sample, high counts of unknown possible pea family and high counts of mustard in 2 samples (Feature 3551), and hackberry in 1 sample.
Ground Stone Caches								
Ground stone cache in a pit	2	7	43	14		14	14	Wolfberry type in 1 sample.
Cache on an activity surface	1	3	67		33		33	
Activity Surfaces								
Activity surface	5	5	20			20	20	
Pollen Washes								
Artifact wash	—	7	14	29			14	Cottonwood type in 3 wash samples, possible cattail in 1 wash sample (metate [PD 15189]), and lily family in 1 wash.
Control for artifact wash	—	14	43	21	7		7	Wolfberry type in 2 samples.
Natural Strata								
Natural strata	—	3				33	67	Silktassel in 1 sample (PD 8984).
Geologic Column								
Geologic column	—	8		25				Lily family in 1 sample.

Note: Ubiquity is the percent of samples per context, including sterile samples.
Key: X = scan-identified data.

plants than any intramural features. The presence of economic taxa in five intramural thermal pits is misleading, because only one structure was represented, the large early Chiricahua phase structure Feature 2602. Intramural features may have been rarely used, and perhaps for purposes not involving plants, whereas foot traffic into and out of structures would have created more opportunities for pollen deposition. One notable pollen type from structure samples was the wolfberry type (nightshade family), which was documented in four structure-floor or -fill samples but only one extramural context, a ground stone cache.

The most productive project contexts were extramural nonthermal pits, which is surprising, because pollen samples from these types of features are usually disappointing. Nonthermal pits were the most abundant features at the project sites. At Falcon Landing, 2,738 of the greater-than-3,000 features documented were extramural pits, of which 1,396 were excavated; 1,098 of the excavated pits were nonthermal basin-shaped features (see Volume 1, Chapter 4). The basin-shaped pits were typically small, shallow, nondescript depressions recognized from surrounding sediment by the contrasting fill color and texture. Notable pollen types in the pits were Indianwheat, cholla, cactus family, and rare types, such as hackberry and lily family. Feature 3551 at Falcon Landing was the only analyzed nonthermal bell-shaped pit that contained a metate. Two productive pollen samples from Feature 3551 produced assemblages distinct from those from any other contexts, with high values of mustard family (7–8 percent) and the unknown possible pea family (13–24 percent) (see Figure 93). A third pollen sample from beneath the metate in Feature 3551 was sterile.

The highest ubiquity of Indianwheat was from nonthermal pits, one extramural ground stone cache (Feature 3074), and pollen-wash control samples collected from the sediments around metates. High values (pollen percentages) of Indianwheat (2–7 percent) were calculated from three of four samples collected from ground-stone-cache Feature 3074 and from one Middle to Late Archaic period nonthermal pit (Feature 4650). The correspondence between Indianwheat and ground stone tools and caches suggests that this early-spring annual was an important resource that was probably gathered for its seeds. The pattern further suggests that shallow, basin-shaped nonthermal pits were metate or mortar supports in which harvests of Indianwheat and other plants were piled and possibly ground.

Pollen Washes

Pollen washes and the suite of collected control samples make up a special subset within the project samples. Geib and Smith (2008) conducted controlled grinding experiments with metates and manos to test the assumption that evidence of plant processing is preserved in pollen washes. Their results emphasized the difficulty of recovering and recognizing cultural-pollen signals, especially from tools found in open-air situations in which natural pollen rain quickly swamped grinding signatures. One of the insights from their experiments was that locations where harvests were cleaned and stripped of chaff are more likely to have preserved pollen from the processed resources than the actual artifact washes, because in general, pollen does not persist on cleaned seed or fruit.

The seven project pollen washes were from six metates found upside down. Carefully matched control samples were collected from the artifacts in the field and in the laboratory before washing. The assumption explored in the pollen washes and controls was that the project artifacts would be linked to locations where plant materials became concentrated for processing and that pollen from those food resources would imprint on washes and/or controls. This theory appears to have borne fruit, because the pollen washes and controls were ranked second behind nonthermal pits for diversity of economic taxa.

Two taxa were emphasized in the washes: paloverde in wash and control samples and Indianwheat in controls. The relatively high ubiquity of paloverde pollen suggests the use of early-spring flowers, young green pods, or perhaps mature seeds. Paloverde seeds were a widely exploited food throughout the southern deserts (Hodgson 2001), but there are no experimental data available to help understand whether grinding seeds would have left a pollen signature. The contrast in Indianwheat between washes and controls is interesting. If Indianwheat were stockpiled near grinding stations to be stripped of seeds, pollen might have remained with the chaff and become concentrated in sediment around the grinding tools. If seeds were then ground, little or zero pollen is predicted to have stuck to seeds, and thus no Indianwheat pollen would have registered in artifact washes. One other spring resource was visible in two of the metate control samples: the probable wolfberry type (nightshade family). Wolfberry berries were collected as early as March and April, and there are ethnographic accounts of grinding of the berries.

The pollen washes produced the only project evidence of riparian conditions. Cottonwood pollen was recovered from two metates (PDs 15189 and 15403), and one possible cattail grain was recovered from PD 15189. Two wash samples were generated from one metate (PD 15189), one sample from the flat surface and one from the concave use surface. The use surface yielded the possible cattail grain and the maximum 13 percent cottonwood value, and only 1 percent cottonwood was calculated from the flat nonuse surface. This evidence for riparian habitat is difficult to reconcile with the absence of water indicated in the other 114 pollen samples analyzed, and unfortunately, the two metates were from culture-bearing sediments that were difficult to date. PD 15403 was assigned to the Middle to Late Archaic period, and PD 15189 was dated to the Late Archaic to Pioneer period.

Water may have been carried to the sites and used specifically with the metates (PDs 15189 and 15403), or the tools may have been transported from a riparian location where cottonwood pollen became embedded within stone textures. The Agua Fria River is accessible within 5 km (3.3 miles) to the east, and it is also possible that in the past, seeps or ponded water might have supported riparian habitat closer to the sites. The cottonwood pollen might also signify the use of new leaf buds, flowering catkin strands, and/or the round green balls of young seeds, called "berries" by the Pima (Rea 1997:178). New cottonwood buds and reproductive parts are early-spring resources available from February through April.

Temporal Patterns

In order to examine the project pollen data for temporal patterns, features were sorted first by context and then by age. Using this organization, the concentration and percentage of grass pollen and the presence of important economic types were compiled by context and listed by feature. Cheno-ams were not included because of the swamping effect of the predominantly wind-pollinated members within this broad category, although the project cheno-ams are acknowledged as probable important food resources. Average cheno-am values for structures by temporal affiliation were calculated in a previous section (see Table 75), and a discussion of the project cheno-am signature can be found in the Results section (see Table 73).

Structures are listed in Table 77, along with feature volume, when available, as an index to house size. Structure intramural features were excluded because of too few samples, unequal representation between temporal components, and sparse evidence of economic taxa (see Table 76; Appendix 7.1). There were no clear patterns between house size and economic pollen types. Two small Archaic period structures of less than 1 m^3 in volume, Features 1313 (Early to Late Archaic period) and 4349 (Middle to Late Archaic period) stood out, with the greatest diversities of economic taxa, from any house but Cienega phase Feature 1413. The pollen-concentration measures also did not reveal any temporal patterns, and as discussed previously, abundant pulses of natural cheno-am pollen, the main driver of concentrations, likely obscured some portion of the ethnobotanical evidence.

The results from Cienega phase Feature 1413 were anomalous in many respects, compared to those from other structures represented by pollen samples. Feature 1413 was of medium size, with a volume of 1.7 m^3, and in two fill samples, pollen concentrations were low, almost minimal (5,100 and 1,200 gr/cc). Yet five economic taxa were identified, and in one sample, the project maximum grass (27 percent) was calculated. The Feature 1413 high grass sample also produced one of two project instances of cranesbill pollen, which may represent the introduced, exotic species (*Erodium cicutarium*) and, if so, would indicate a minor degree of mixed sediments.

Strong temporal patterns are visible in structure-floor or -fill samples. The better-represented Middle Archaic period structures produced more evidence of economic taxa than those of later periods. High percentages of grass pollen with grass aggregates characterized Middle Archaic period (early Chiricahua phase) and Late Archaic period (San Pedro and Cienega phase) features and contrasted with lower grass in later house samples. Single samples from two Snaketown phase features did not preserve any grass pollen. Structure frames were probably thatched with local materials, and perhaps grass was the choice of Middle and Late

Table 77. Economic Pollen Record from Structure Floors or Fill, by Temporal Affiliation

Feature No.	Feature Volume (m³)	No. of Floor or Fill Samples	Pollen Concentration (gr/cc)	Grass Family (%)	No. of Samples with Taxon Present, per Feature						
					Grass Aggregates	Indianwheat	Wolfberry Type	Paloverde	Cholla	Cactus Family	Others
Early Chiricahua Phase											
2602	23.4	2	7,171	1	1	—	—	—	—	—	
4387	2.5	3	18,196	3	2	—	—	1	—	2	cactus-family aggregate
14613	1.9	1	15,011	2	—	1	—	—	—	—	
Late Chiricahua Phase											
2642		2	8,819	2	—	1	—	—	—	—	
10114		1	3,059	2	1	—	—	—	—	—	mesquite aggregate
11229	0.7	1	7,297		—	—	—	1	—	—	mesquite
San Pedro Phase											
2628		1	8,300	3	1	—	—	—	—	1	
2967		2	7,171	2	—	—	—	—	—	—	
13071	1.4	1	8,992	5	1	—	—	—	—	—	maize
Cienega Phase											
1413	1.7	2	3,150	13	1	2	—	1	1	1	mustard family in 1 sample, cranesbill (possible exotic) in 1 sample
Late Cienega Phase											
4621		1	42,530	2	—	—	—	—	1	—	
14702	0.9	1	9,315	<1	—	—	—	—	—	—	ocotillo
Early to Late Archaic Period											
1313	0.8	2	3,490	4	1	—	1	1	—	1	
Middle to Late Archaic Period											
88	2.4	1	6,582	<1	—	—	—	—	—	—	
3521	1.6	1	2,060	1	—	—	—	—	—	—	
4349	0.6	1	15,362		—	1	—	1	1	1	

Feature No.	Feature Volume (m^3)	No. of Floor or Fill Samples	Pollen Concentration (gr/cc)	Grass Family (%)	No. of Samples with Taxon Present, per Feature						
					Grass Aggregates	Indianwheat	Wolfberry Type	Paloverde	Cholla	Cactus Family	Others
					Red Mountain Phase						
3963	3.1	1	9,961	1	—	—	1	—	—	—	
10849	1.0	1	3,276	1	—	—	1	—	—	—	
					Snaketown Phase						
13		1	32,662		—	1	—	—	—	—	
3321	6.3	1	6,814		—	1	—	—	—	—	pea family
					Middle Archaic to Protohistoric Period						
2632		1	6,726	<1	—	—	—	—	—	—	mesquite
					Early Ceramic to Protohistoric Period						
10735	1.0	2	26,563	<1	—	—	1	—	—	—	

Note: Features 13 and 88 are at Site 68; all other structures are at Falcon Landing.

Archaic period builders, but during later occupations, other materials were favored. Harvest and the possible milling or storage of grass grains for food constitute another explanation for high grass values in early houses.

Getting at the season in which grass might have been harvested for thatch or food is difficult, because there are several native grass species, and each is keyed to winter/spring and/or summer/fall flowering and seed production (Doebley 1984). Paloverde is a strong spring indicator, and this resource, like grass, was associated with earlier structures. Paloverde was present in two of the Middle Archaic period structures (early Chiricahua and late Chiricahua phase), two poorly dated structures (Middle to Late Archaic and Early to Late Archaic period), and one Cienega phase house (Feature 1413) but was absent from all six Late Cienega, Red Mountain, or Snaketown phase structures. Also, paloverde was absent from the two poorly dated Middle Archaic to Protohistoric and Early Ceramic to Protohistoric period features. Another spring indicator is Indianwheat, but there was no temporal pattern for Indianwheat among structures. Mesquite, which flowers in late spring (April to May), was present in two late Chiricahua phase structures and the poorly dated Middle Archaic to Protohistoric period Feature 2632.

Late-spring-flowering resources are weakly associated with later structures. Cholla, which flowers in May, was rare in project samples, but three samples recording cholla pollen were from Late Archaic period structures. Cactus-family pollen, another May- or later-flowering category, was present in early Chiricahua phase Feature 4387; San Pedro phase Feature 2628; two broadly dated Archaic period structures, Features 1313 and 4349; and Cienega phase Feature 1413 but was absent from Red Mountain phase to Protohistoric period structures. The nightshade-family type, attributed to wolfberry in this analysis, flowers as early as March. The wolfberry type was documented in four structure samples, one from Early to Late Archaic period Feature 1313 and the other three from Red Mountain phase and Early Ceramic to Protohistoric period structures.

Extramural features (Table 78) are less informative than structures because of the less-precise, primarily stratigraphic, dating. One faint pattern that may be real is the temporal distribution of cholla and cactus-family pollen in Late Archaic period and later features, with the exception of cholla in one early Chiricahua phase nonthermal pit (Feature 7620). Three pit features of broad age ranges, Middle to Late Archaic and Late Archaic to Protohistoric period, and one Pioneer to Classic period activity area (PD 17912) recorded cholla pollen. Cactus-family pollen occurred in one Middle to Late Archaic period nonthermal pit, one Late Archaic to Protohistoric period nonthermal pit, one Late Archaic to Protohistoric period ground stone cache, and the Cienega phase surface ground stone cache (Feature 3775).

Pollen concentrations were high, at greater than 10,000 gr/cc in several of the nonthermal pits and two activity areas. In the majority of these high-concentration samples, the driver was cheno-ams, as demonstrated by values of greater than 80 percent. A correspondence between Indianwheat and samples from ground stone caches is evident and is inferred to relate to food processing, as discussed in the Contextual Patterns section, above.

The strong pattern for high grass in early structure-floor and -fill samples was not replicated in extramural features, which may support the interpretation that grass from structures reflects thatch. However, high percentages of grass pollen were recorded from a metate (PD 15427) found during the excavation of a early Chiricahua phase pit. This was the strongest temporal pattern in the suite of metate washes and related control samples (Table 79). Other economic pollen types recovered from the pollen washes and controls were interpreted to reflect food-processing activities around grinding stations. Indianwheat and paloverde were particularly notable in the pollen-wash controls and were discussed previously in the Contextual Patterns section.

Discussion

SRI's excavation and data recovery efforts at LAFB have resulted in an archaeological record that provides a rare view of Middle to Late Archaic period human activities at a lower-*bajada* location in the Phoenix Basin. The project pollen record of subsistence was faint, characterized by low representation of a suite of 11 economic taxa and 1 unknown possible pea family. But considering the antiquity of the project sites; the evidence

Table 78. Economic Pollen Types from Extramural Features

Feature No., by Temporal Affiliation	No. of Samples	Pollen Concentration (gr/cc)	Grass Family (%)	No. of Samples with Taxon Present, per Feature					
				Grass Aggregates	Indianwheat	Paloverde	Cholla	Cactus Family	Others
				Nonthermal Pits					
Early Chiricahua phase									
7620	1	2,080	2	1	—	—	1	—	
8422	1	1,573	3	—	—	—	—	—	
Early to Late Archaic period									
3551[a]	2	3,456	1	—	1	—	—	—	lily family in 1 sample, unknown pea family (13–24%) and mustard (7–8%) high in both samples
Middle to Late Archaic period									
4370	1	6,500	<1	—	1	—	1	—	
4650	1	10,121	8	—	1	1	1	1	lily family, ocotillo, mint family
Late Archaic to Protohistoric period									
206	1	35,888	7	—	—	—	—	1	
68	1	33,357	—	—	—	—	—	—	hackberry
				Ground Stone Caches in Pits					
Late Archaic to Protohistoric period									
3074	4	10,916	4	1	3	1	1	1	wolfberry and cranesbill (possible exotic) in 1 sample
3792	1	19,405	—	—	—	—	—	—	
				Surface Ground Stone Cache					
Cienega phase									
3775	3	31,351	<1	—	2	—	—	1	mesquite
				Thermal Pits					
Early Chiricahua phase									
7998	1	2,636	4	—	—	—	—	—	mesquite, greasewood
8497	1	1,685	1	1	—	1	—	—	prickly pear
1523	1	2,829	—	—	—	—	—	—	
Middle to Late Archaic period									
7813	1	1,069	1	—	—	—	—	—	juniper (2%)

continued on next page

Feature No., by Temporal Affiliation	No. of Samples	Pollen Concentration (gr/cc)	Grass Family (%)	No. of Samples with Taxon Present, per Feature					
				Grass Aggregates	Indianwheat	Paloverde	Cholla	Cactus Family	Others
Middle Archaic to Pioneer period									
4660	1	3,587	4	—	—	—	—	—	
Sacaton phase									
11072	1	3,969	4	—	—	—	—	—	
				Activity Areas					
Early Chiricahua phase									
10180	1	2,660	1	—	—	—	—	—	
Middle to Late Archaic period									
15082	1	8,301	<1	—	1	—	—	—	
10599	1	14,164	<1	—	—	—	—	—	
Late Archaic to Pioneer period									
3954	1	20,527	1	—	—	—	—	—	
Pioneer to Classic period									
PD No. 17912	1	7,668	1	—	—	—	1	1	

Note: Features 68 and 206 are at Site 68; all other features are at Falcon Landing.

[a] Bell-shaped pit.

Table 79. Economic Pollen Types from Pollen Washes and Controls

Temporal Affiliation, by Context	Artifact PD No.	Description	Pollen Concentration (gr/cc)	Grass Family (%)	No. of Samples with Taxon present, per Feature		
					Indianwheat	Paloverde	Others
Pit Feature 15317							
Early Chiricahua phase	15427	pollen wash, metate		3	—	—	
Early Chiricahua phase	15427	laboratory control	10,437	3[a]	1[a]	1[a]	
Early Chiricahua phase	15427	field control beneath metate	5403	4	1	—	mesquite
Early Chiricahua phase	15427	field control around metate	1906		—	—	
Early Chiricahua phase	15427	field control beneath another metate (PD 17847) in pit Feature 15317	5730	4	1	1	paloverde (high, 4%)
Culture-bearing sediment							
Middle to Late Archaic period	14711	pollen wash, metate			—	—	
Middle to Late Archaic period	14711	field control beneath metate	16,545	1	—	—	
Middle to Late Archaic period	15403	pollen wash, metate			—	1	cottonwood type, cactus family
Middle to Late Archaic period	15403	laboratory control	16,410		1	—	
Middle to Late Archaic period	15403	field control around metate	19,518	2	—	—	wolfberry type
Middle to Late Archaic period	15403	field control beneath metate	4020	1	—	1	
Pit Feature 10955							
Middle Archaic to Pioneer period	16542	pollen wash, metate			—	—	
Middle Archaic to Pioneer period	16542	field control beneath metate	29,702	1	—	—	wolfberry type
Middle Archaic to Pioneer period	16542	field control, base of pit Feature 10955	995		1	—	
Culture-bearing sediment							
Late Archaic to Pioneer period	15189	pollen wash, metate, flat side		—[a]	—	—	lily family, cottonwood type
Late Archaic to Pioneer period	15189	pollen wash, metate, concave side		2	1	1	cottonwood type, possible cattail
Late Archaic to Pioneer period	15189	laboratory control	10,723	1	1	—	
Late Archaic to Pioneer period	15189	field control beneath metate	28,581	—[a]	1	—	cactus family

[a] Indicates the presence of pollen aggregates.

for light, intermittent use; the preservation challenges in recovered pollen assemblages; and the small fraction (2 percent) of project features represented by the pollen samples, the fact that any economic pollen was recognized points to a cultural imprint vibrant enough to persist through the past 5,000 years. The pollen results contribute information to some of the project research questions and themes, although there were exceptions across contextual and temporal categories to all of the patterns identified in the following sections.

Environmental Patterns

The modern vegetation at the project sites is not diverse, and it is difficult to imagine what drew prehistoric people to the area. Shrubs of saltbush (*Atriplex* spp.) and wolfberry (*Lycium* spp.) grow on the flats between drainages, and within drainages, trees of paloverde (*Cercidium* spp.), mesquite (*Prosopis* spp.), and nonnative tamarisk (*Tamarix* spp.) are found with desertbroom (*Baccharis* spp.) and crucifixion-thorn (*Canotia* spp.) shrubs. A few hardy perennial grasses and herbaceous plants survive in the shade beneath trees. Today, this environment appears a stark landscape, but before historical-period development and modern farming impacts, wet seasons, especially in late winter to early spring, would have painted a green flush of annuals and grasses across the lower *bajada* for a short few weeks.

Control samples from a column of geologic samples and natural strata were examined for possible inflections through time that could relate to climatic shifts, but the results from the productive control samples were inconclusive. Structure-floor and -fill samples were investigated for environmental information, although cultural features are not ideal proxies because of human influences. Most of the project structures were apparently lightly used constructions predicted to have captured some sense of the surrounding environment. The main advantage to considering structures is the precise dating that completes a network of points spanning several-thousand years. The structure temporal comparison did not reveal any dramatic or definitive climatic shifts, but there were hints that the early Chiricahua and Cienega phases may have been characterized by wetter springs than the late Chiricahua, Red Mountain, and later phases. The evidence for these interpretations is in the suppressed cheno-am percentages (in a summer-flowering category) and higher sunflower-family and grass percentages during the early Chiricahua and Cienega phases (see Table 75).

Overall, the archaeological pollen spectra showed that during the Archaic period, vegetation was similar to modern vegetation, with saltbush (cheno-am pollen) and what is probably wolfberry (nightshade family), mesquite, and paloverde. Other elements that may have been growing in the neighborhood or at least within a few kilometers included hackberry, cholla, other cacti, ocotillo, and perhaps yucca. What is clear in the pollen data is that there was never any riparian habitat at the project sites and, therefore, no permanent surface water. The only evidence of riparian conditions from pollen samples or from macrobotanical remains (see Chapter 6) was cottonwood pollen recovered from two metates.

Chronological Patterns

Chronological patterns were teased out of the changing pollen spectra across contexts and temporal affiliations. Structures produced the best temporal records because of the radiocarbon chronology. Pollen assemblages from structures should also be closely linked to the times of use, because pollen is more likely to remain protected under collapsed roofs and walls than in the uncertain natural and cultural histories of extramural contexts.

The strongest temporal patterns in structure-floor and -fill samples were a greater diversity of economic taxa; a higher grass representation, including grass-pollen aggregates; and a greater frequency of paloverde from early Chiricahua and San Pedro phase contexts and two broadly dated Early to Late Archaic period structures (Features 1313 and 4349) than from other structures (see Table 77). The variety of economic taxa during the Middle Archaic period makes sense; that was the period of greatest use and would be expected to have left the richest archaeobotanical record. One Cienega phase structure (Feature 1413) broke the pattern, with the maximum grass percentage and number of economic types out of all 34 structures represented in the sample set, which suggests that Feature 1413 was particularly well used or for some other reason preserved a strong pollen record. Weaker trends in structures were that cactus-family pollen (hedgehog cactus, barrel cactus, and saguaro) occurred more frequently in Late Archaic period structures, including those from the San Pedro phase, and cholla occurred more frequently in the Cienega and Late Cienega phase structures.

The bias for high grass, especially aggregates of grass, in Middle Archaic period and San Pedro phase structures could be an architectural trait, if grass thatch were used to cover house frames, but there was also evidence for food use of grasses from a metate recovered in a early Chiricahua phase pit. One implication of the early grass signature is that it could relate to resource availability, which, in turn, might reflect a use season and/or climatic conditions that favored grasses. Vorsila Bohrer (1975) has written about the prehistoric importance of grains from cool-season grasses to fill the gap between winter famine and the late-spring bounty of desert cacti. The environmental patterns discussed above are subtle but suggest wetter springs during the early Chiricahua and Cienega phases that might have favored grasses. The co-occurrence of early-spring-flowering paloverde and high grass in the Middle Archaic period and San Pedro phase structures supports the idea that people used the project sites in the early spring, perhaps by February and March through April. The strong signature of Indianwheat in extramural nonthermal pits also reinforces an interpretation of spring use. Indianwheat desert species can flower as early as February. The tenuous pattern for cacti and cholla to show up in later structures could be interpreted as a slight seasonal shift by Late Archaic period people to gather late-spring cacti resources and to transport a few cacti products to project sites for processing with other late-spring resources, like paloverde seed pods.

Subsistence and Land-Use Patterns

One grain of maize pollen identified in the floor sample from a San Pedro phase structure (Feature 13071) was the only evidence of a cultigen, and although it is interesting as a possible ritual or ceremonial artifact, the other 116 cultigen-negative pollen samples and the absence of any cultigen macro remains (see Chapter 6) prove that people at the project sites were not farming. Except for the problematic late-summer cheno-am indicator that overwhelmed pollen assemblages, the suite of interpreted economic resources were weighted to early-spring, perhaps even late-winter, occupations; another use season between April and June; and a possible third season in the early fall, after summer monsoons (Table 80).

One important aspect of these economic plants is that a single resource produced more than one food product over the course of a few weeks and overlapped with other resources that were also developing different food products. By March into April, greens from spring annuals; Indianwheat and mustard-family seeds; paloverde flowers and young seed pods; certain products from the lily family, such as yucca flowers; and possibly grain from spring grasses or winter grasses retaining seed heads would have been available at or near the project sites. Plant flowering and fruiting are staged across elevations, and the distal-fan location of the project sites would have produced the earliest foods, but within a month, people could have followed the same resources upslope. The location of the project sites between the White Tank Mountains and the Agua Fria River, a scale of only about 20 km (9 miles), would have been ideally situated for repeated visits from foragers who ranged back and forth across an ever-changing landscape of food resources. Middle Archaic period and San Pedro phase foragers would have understood intimately where and when plant resources were available.

Contextual patterns in the pollen results suggest that food resources were linked to nonthermal basin-shaped pits and not to structures, except for possible grass processing in structures. The numerous shallow, basin-shaped pits might have supported baskets or grinding stations where food resources were stockpiled to be processed. The majority of the smaller structures may have been expedient shelters for shade and weather protection, or perhaps they served specialized functions, such as storage. Ethnographic accounts from the Gila River Pima have documented the storage of mesquite seed pods in granaries constructed from brush and other perishable materials (Rea 1997:186). It is possible that some type of ephemeral mesquite-storage bins were used by Archaic period people at the project sites, inside or outside structures.

One nonthermal-pit sample recorded hackberry, and wolfberry type (nightshade family) was identified in eight project samples, four of which were from structures. Both plants flower early and produce edible berries or fruits. Wolfberry is interpreted to have been common at the project sites, yielding berries by April or May,

Table 80. Interpreted Economic Pollen Taxa and Seasonal Implications

Pollen Type, by Seasonal Signal	Flowering Season	Part(s) Harvested and Season(s)
Early spring		
Indianwheat	February to March	leaves, February to March; seeds, March to April
Mustard family	February to April	seeds, early spring
Paloverde	March to April	flowers and young green seed pods, March to April; mature seeds, May into July
Wolfberry type (nightshade family)	March to May	wolfberry fruits, April through May into June
Grass family	early spring through fall, depending on the species	grains and leaves, early spring through late fall, depending on the species
Lily family	February to May, depending on the species	yucca flowers, April to May; yucca fruits, June
Hackberry	March	June through September
Late spring to summer		
Cholla	April to May	flower buds, May; fruits, June through late summer into fall
Cactus family, including saguaro, hedgehog cactus, barrel cactus, and others	April to June	fruits, June through July
Mesquite	April to May	flowers, April to May; young green pods, after May; seed pods, June through July into Fall
Late summer to early fall		
Cheno-ams, including saltbush, seepweed, herbaceous weeds, and others	July to August	greens, July; seeds, August into October/November

depending on the year. Hackberry probably did not grow at the sites but may have been nearby. Hackberry fruits become available throughout the summer and were probably more of a snack food for traveling foragers.

Based on the pollen data, cacti were never abundant at the project sites but would have been accessible within a few kilometers upslope, on the middle *bajada*, and during the Middle Archaic period, they might have grown closer to the project sites. Resources like cholla-flower buds would have fit into the seasonal round in May before mesquite seed pods were mature and dry enough to grind (June to July).

Mesquite may have been one of the main resources utilized at the project sites, but pollen is not the best source to discern use. Mesquite is insect pollinated, and the pollen does not travel far and is not predicted to persist on mature pods. In the pollen-sample set, two late Chiricahua phase structures (Features 11229 and 10114) produced mesquite pollen, and Feature 10114 yielded a mesquite-pollen aggregate. The signature suggests an April to May use for these structures and might also be a glimpse of the consumption of mesquite flowers or possibly young green seed pods. In wet monsoon years, mesquite produces a second seed crop that is ripe by September into October, which would have helped carry prehistoric people into the winter season.

The overwhelming Luke Solar project cheno-am signature could represent several different species, but the most logical candidate is saltbush (*Atriplex* spp.), which is a dominant shrub in the modern vegetation. In the past, a greater variety of saltbush shrubs and herbs might have grown at the project sites, in addition to other cheno-am taxa, such as seepweed (*Suaeda* spp.), picklebush (*Allenrolfea* spp.), and weeds (*Amaranthus* spp. and *Chenopodium* spp.). Quailbush (*Atriplex lentiformis*), a halophytic phreatophyte, might also have thrived in the project area. Quailbush seeds were milled by several native desert tribes, and one interesting thing to note is that seeds could be ground on metates or pounded (Moerman 1998:116). Pestles were remarkable in the Luke Solar project ground stone collection (see Chapter 3), and hard saltbush seeds might have been some of the resources processed with pestles. Stone-hard mesquite seeds are another food product processed by pounding or gyratory grinding, and paloverde seeds might have been similarly treated.

Regional Considerations

The project pollen results are not directly comparable to other regional records because of the disparity in the types of contexts represented. In southern Arizona, the two Middle Archaic period sites with any good pollen data are Last Ditch and Coffee Camp. Both are characterized by few structures and more than 100 extramural features, but those features are thermal pits and hearths (see the Previous Research section, above). In contrast, the Luke Solar project sites contained only a few thermal features, several structures, and more than 2,000 nonthermal pits.

Last Ditch, Coffee Camp, and the Luke Solar project sites all registered strong spring pollen signatures characterized by grasses, Indianwheat, and mustard family, and all three projects found preserved evidence of mesquite. The major differences among the three records are the emphasis on cholla and lily family (yucca) at Last Ditch, the emphasis on cholla at Coffee Camp, and the minimal emphasis on cholla and other cacti at the Luke Solar project sites. All three projects found evidence of multiple annual visits through two to three seasons. Alternatively, occupations could represent different seasons in different years and could have been triggered by wet springs or wet summers. The speculative pattern in this comparison is the correlation between cacti processing and thermal pits at Last Ditch and Coffee Camp and between saltbush, paloverde, and mesquite-seed processing and nonthermal pits at the Luke Solar project sites.

CHAPTER 8

Bioarchaeology

Mitchell A. Keur

Introduction

Two burial features were encountered during the Luke Solar project. One was a secondary cremation (Feature 106) at Site 68, and the other was a secondary inhumation (Feature 3139) at Falcon Landing. Feature summaries for the burials appeared in Chapters 4 (Feature 3139) and 5 (Feature 106) of Volume 1 of this report. In accordance with the project NAGPRA Plan of Action, all human remains and associated mortuary items recovered from the Luke Solar project area were repatriated to the Salt River Pima-Maricopa Indian Community on June 28, 2013.

This chapter serves to address bioarchaeological attributes of the area of potential effects (APE). As will be seen, the paucity of human remains frustrates attempts to infer demographic and mortuary behavioral characteristics of the population. Few conclusions may be drawn from two burials, fewer still when bone preservation is poor and feature characteristics are ephemeral. Nevertheless, the absence of bioarchaeological data and observations is instructive when examining site structure and formation. These considerations will be introduced here by way of comparison to bioarchaeological findings at similar sites. The discussion will then be continued in Chapter 11.

Research Goals

The Luke Solar project adds to our understanding of Phoenix Basin prehistory, particularly in regard to, among other things, subsistence, mobility, and inferred social structure. Mortuary behavior contributes to the overall picture of human interaction with a location, occurring during periods of time that are unique in the expression of both the utilitarian and the ceremonial. The manner in which a group explores the postlife of its members can provide insight into group needs and values.

Considerable numbers of bioarchaeological investigations have focused on the Archaic period in the U.S. Southwest. Mortuary behavior, like technological transmission and subsistence innovations, is best examined as a set of attributes within a temporal and spatial context. Sites that are similar in time and space offer a powerful lens through which to view the bioarchaeology of a particular site under consideration. This is especially important when the bioarchaeological record is minimal and the available observations are few. Comparisons to similarly situated sites help to place in context the bioarchaeological attributes that we can see and allow for some reasoned inferences about what we cannot see.

In the following sections, the bioarchaeology associated with Site 68 and the Falcon Landing site is described, including both osteological attributes and observable mortuary behavior, followed by summary descriptions of the bioarchaeological components of 10 other sites in the Phoenix and Tucson Basins and in southeastern Arizona that span time periods that include those of the burials at Site 68 and Falcon Landing. These 10 sites serve to provide context and comparison for the bioarchaeology of the Luke Solar project. The goal of these comparisons is to identify trends across time and space, as well as illuminate differences between what is known of these 10 sites and what is understood of Site 68 and Falcon Landing.

Bioarchaeology of the Luke Solar Project

Analytical Methods

As noted above, two features in the APE contained human remains: Feature 3139 at Falcon Landing and Feature 106 at Site 68. Chapters 4 and 5 of Volume 1 of this report detail the excavation methods associated with these features. The following sections will (1) summarize the burial context; (2) describe the osteology of the recovered human remains, including demographic characteristics, evidence of injury or disease, and taphonomy; and (3) discuss the mortuary behavior inferred from the contextual, biological, and artifactual evidence.

Feature 106, Site 68

Burial Context

Feature 106 at Site 68 was a secondary cremation that consisted of fragmented and thermally altered human remains across an area of 6.53 by 3.35 m (Figure 94). A burial pit was not identifiable, and the feature boundary was determined by the presence of human skeletal remains. Bone fragments were either point-provenienced or recovered from 1/8-inch mesh and then transported to a secured-access on-base facility for laboratory examination and recording.

In total, 59 fragments of human bone were recovered from Feature 106 (Table 81). These included 2 fragments of unsided parietal, 2 fragments of occipital, and 4 unidentifiable cranial fragments. The postcranial skeletal elements included 2 unsided long-bone-diaphysis fragments (1 of which was possibly a tibia) and a distal tarsal phalanx, possibly from the second or third digit. The remaining 48 fragments were not identifiable to element; however, all of the fragments were consistent with having originated from a single individual.

In total, 231 artifacts were recovered from Feature 106, including ground stone and flaked stone fragments and fragments from 6 projectile points (Table 82). Two of the projectile point fragments were diagnostic as Elko Corner-notched and San Pedro points (Figure 95). Additionally, 1 piece of FAR was recovered as well as several hundred fragments of nonhuman faunal bone. It is unlikely that the faunal remains are associated with the burial, however, as is discussed further below.

Skeletal Biology

The lack of identifiable and diagnostic skeletal elements severely limited the demographic interpretations of Feature 106. As noted above, all of the human-bone fragments recovered from Feature 106 were consistent with a single individual, and the interpretation of the skeletal biology was based on that assumption. The overall density of the bone fragments suggested an age of at least complete development, generally accepted as around 18 years (Buikstra and Ubelaker 1994). One of the fragments of parietal bone included a small section of the lambdoidal suture. The margins of the suture appeared well defined and showed no evidence of synostosis (suture closure). This observation was inconsistent with extremely advanced age, but because the section of the suture represented by the fragment was not precisely locatable, the Meindl and Lovejoy method of age estimation by cranial-suture closure was not available (White and Folkens 2005). An age range of 18+ years could not be sensibly narrowed. The distal tarsal phalanx showed complete development and no observable wear on the articular surface. These observations are also indicative of an individual at an unknowable stage of adulthood.

The sex of the individual could not be determined, because of an absence of diagnostic elements. The recovered cranial fragments, including those from the parietal and occipital bones, displayed a density consistent with an adult individual but did not display any dimorphic characteristics. In other words, none of the fragments exhibited a robustness or gracility that would suggest male or female sex. No evidence of injury or disease was noted on any of the fragments.

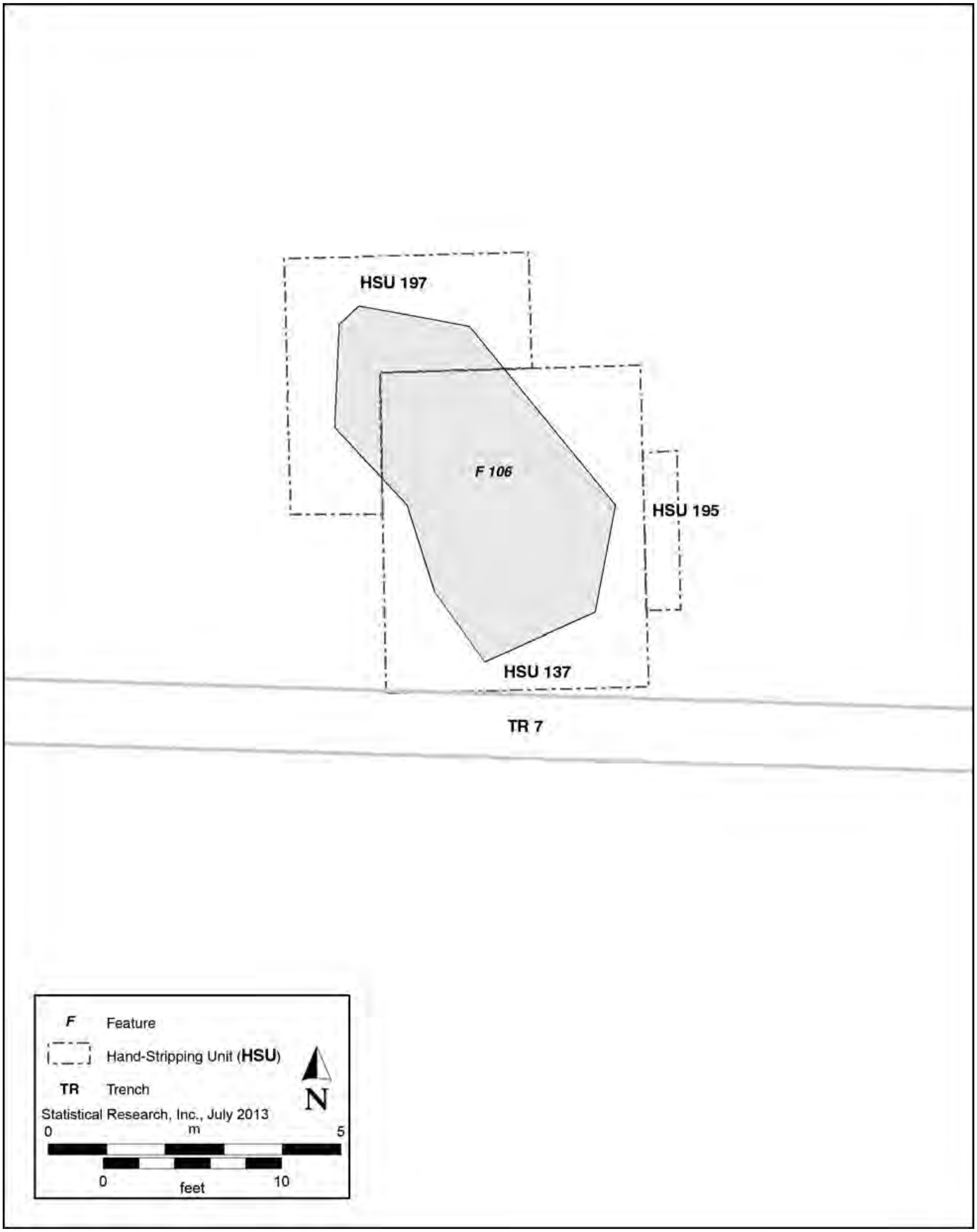


Figure 94. Feature 106 at Site 68, a secondary cremation.

Table 81. Inventory of Skeletal Elements Recovered from Feature 106 at Site 68

Element, by Skeletal Region	n	Remarks
Cranial		
Parietal	2	Unsided.
Occipital	2	
Unidentifiable	4	
Appendicular		
Tibia	1	Possible tibia, unsided.
Unidentifiable	1	
Extremities		
Distal tarsal phalanx	1	Possibly the second or third digit, unsided.
Unidentifiable	48	
Total	59	

Table 82. Artifacts Associated with Feature 106 at Site 68

Artifact Type	Count
Biface fragment	2
Flaked stone debitage	221
Mano fragment	1
Projectile point fragment	6
Scraper fragment	1
Total	231

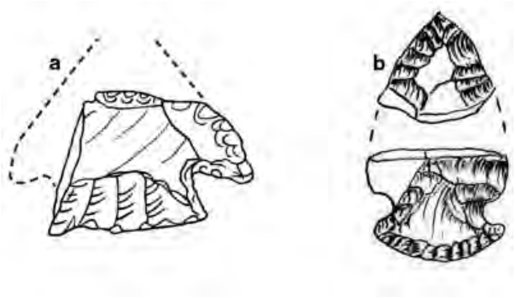


Figure 95. Projectile points associated with Feature 106 at Site 68: (*a*) Elko Corner-notched and (*b*) San Pedro.

Mortuary Behavior

The recovery context associated with Feature 106 represented the confluence of mortuary behavior and anthropogenic and natural taphonomic processes. As noted above, no formalized burial pit was encountered, and no evidence of a burial or cremation vessel was located. In short, any evidence of the human activity that led to the deposition of the remains, if existent, was not observable.

Many recovered elements showed evidence of thermal alteration, along a range of severity. Some fragments were wholly unburned, and other fragments were blackened or even calcined. The majority of burned elements showed thermal alteration in cross section, indicating that exposure to heat occurred after the remains had been fragmented. Additionally, of the eight fragments identified as cranial, only three showed evidence of burning. One unsided parietal fragment (PD 120) was charred and calcined in cross section, and two occipital fragments (PD 125) were grey and nearly calcined in cross section. The remaining cranial fragments showed no evidence of burning. This disparity suggests either very localized exposure to heat or, more likely, separation of contiguous elements prior to exposure to heat.

Feature 3139, Site 419

Burial Context

Feature 3139 at Site 419 was a secondary inhumation that consisted of a small pit containing fragmentary human remains and FAR (Figure 96). The pit measured 1.9 m long and 0.75 m wide and was divided into two sections to define its horizontal boundaries. Section (SEC) 7226 was situated in the northern portion of the pit and was excavated in two levels. Five fragments or clusters of fragments of human remains were point-located, and an additional 9 fragments were recovered from the fill of Level 1. Five pieces of FAR were also recovered from SEC 7226. The southern section of the pit (SEC 7228) contained 27 pieces of FAR. In addition to the FAR, 1 chert biface flake was found in the burial pit. It is unlikely, however, that this flake represented a mortuary artifact. No human remains were recovered from that section.

In total, 114 human-bone fragments were recovered from Feature 3139. Sixty-one of these fragments were identifiable as portions of cranial elements (Table 83). These included 3 fragments of frontal bone, 4 fragments of left parietal, 1 fragment of right parietal, 11 fragments of occipital, and 42 fragments of unspecified cranial bone. Although few fragments could be reconstructed, all were consistent with a single individual. The 42 unidentifiable bone fragments were similarly not inconsistent with having originated from a single individual.

Skeletal Biology

Some of the human-bone fragments associated with Feature 3139 exhibited characteristics that suggest certain demographic attributes of the individual. As was the case with Feature 106 at Site 68, the prevailing presumption was that all of the human remains recovered from Feature 3139 belonged to a single individual, and each line of evidence contributed to the biological profile of that individual. The bone density of all observed remains was consistent with an individual at or past the age of adulthood, and there were no indications of incomplete development. Several fragments included portions of cranial sutures; however, as was noted for Feature 106, the Meindl and Lovejoy method was unavailable, because the portions of the sutures associated with the fragments could not be precisely identified (White and Folkens 2005). The age category of adult, corresponding to an age of 18+ years, could not be narrowed further. No evidence of synostosis was observed; it is therefore unlikely that the individual was of extremely advanced age.

Most of the fragments observed were inconclusive for determining the sex of the individual. The cranial fragments were generally robust, but not to an extent that permitted reliable evaluation of sex. One fragment, however, did exhibit dimorphic characteristics. A point-provenienced fragment of frontal bone (PD 7233) included a portion of the supraorbital margin of the left eye orbit. The margin was blunt and rounded, an observation generally suggestive of males (Buikstra and Ubelaker 1994:19–20). Although this single observation was insufficient to determine sex with certainty, it would be appropriate to conclude that the chance that the individual in Feature 3139 was male is greater than 50 percent.

No evidence of injury or disease was observed on any remains from Feature 3139.

Mortuary Behavior

As noted above, the burial pit associated with Feature 3139 measured 1.9 m long and 0.75 m wide. The pit followed a generally north–south orientation and was basin shaped in cross section. All of the human remains were found in the northern half of the pit, and the southern half of the pit was dominated by fragments of FAR; 27 of the 32 recovered pieces of FAR were clustered in a roughly 20-cm-diameter area in the southwestern area of the pit. The purpose of the FAR, if intentional, was not immediately clear. It is possible that the rock served as a grave cap or marker, but that interpretation is speculative. The placement of the remains within the pit was similarly unclear. Although all of the remains were cranial elements, the locations of the

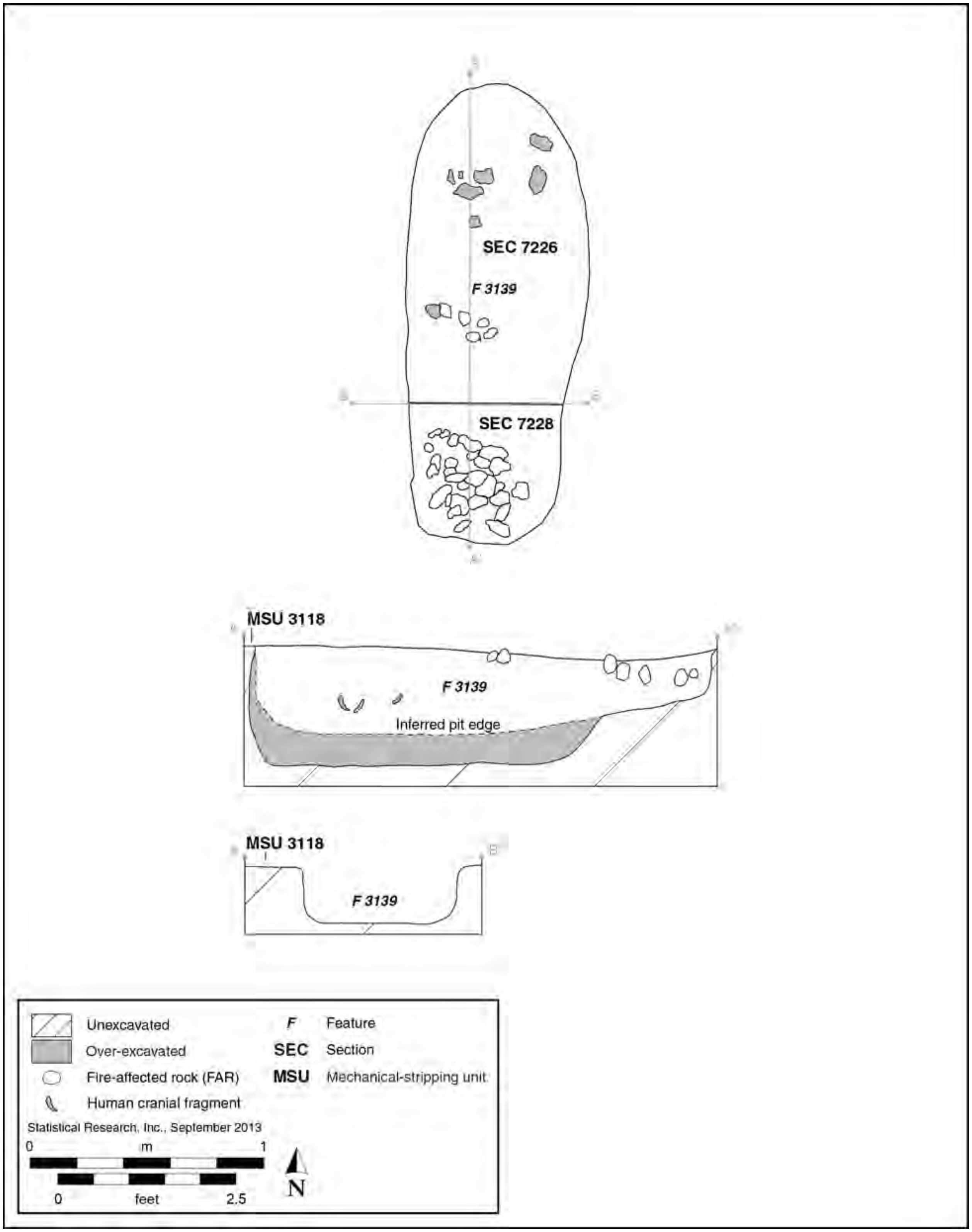


Figure 96. Feature 3139 at Falcon Landing.

Table 83. Inventory of Skeletal Elements Recovered from Feature 3139 at Falcon Landing

Element, by Skeletal Region	n	Remarks
Cranial		
Frontal	3	Includes one fragment of the left orbit with a blunt supraorbital margin.
Occipital	11	
Parietal, left	4	
Parietal, right	1	
Unidentifiable	42	
Total	61	

fragments or clusters of fragments were not consistent with anatomical positions or relationships. No elements were in articulation, and the distribution of fragments provided no indication of the original placement or orientation of the cranium.

Apart from sharing a single pit, the FAR and the human remains appeared to have had only a casual relationship to each other. Nevertheless, several of the cranial fragments showed charring and blackening in cross section. This indicates a mild, if not coincidental, exposure to heat. The amount and extent of burning was not consistent with intentional cremation. Additionally, the distribution of the burning suggested that the elements were fragmentary prior to exposure to heat. Blackening was observed in cross section, but little thermal alteration was seen on the external surfaces of the bones. These observations indicate that the burial was a secondary inhumation.

The Bioarchaeology of Comparative Sites

This section provides a brief description of 10 sites in and around the Phoenix and Tucson Basins and in southeastern Arizona. The periods represented by these sites include the San Pedro phase, the Cienega phase, and the Red Mountain phase, from approximately 1200 B.C. to A.D. 400. The 10 sites provided a comparative population of 111 burials, with 16 from the San Pedro phase, 47 from the San Pedro/Cienega phases, 20 from the Cienega phase, 26 from the Cienega/Red Mountain phases, and 2 from the Red Mountain phase. The 10 sites are presented below chronologically, by archaeological phase.

San Pedro Phase

Las Capas

Excavations at Las Capas (AZ AA:12:111 [ASM]) in the Tucson Basin have resulted in the recovery and reporting of 16 San Pedro phase burial features (McClelland et al. 2007; Ruble et al. 2008). Of these, 14 were primary inhumations, 1 was a secondary inhumation, and 1 was a primary cremation. All of the inhumations were flexed or tightly flexed. The age distribution of the skeletal sample was 4 infants, 3 adolescents, and 9 adults. Sex could be determined for 8 of the adults and 1 of the adolescents: 5 were male, and 4 were female. Mortuary artifacts included red ochre, clay-figurine fragments, and shell beads. Few ground stone or flaked stone artifacts were recovered from the burial contexts.

San Pedro and Cienega Phases

Cienega Creek

Haury's (1957) reporting of excavations at the San Pedro/Cienega phase site along Cienega Creek on the San Carlos Indian Reservation (here referred to as the "Cienega Creek site") included 47 cremations, 40 of which were from a single, large pit with pockets of cremated bone. Each pocket represented a discrete secondary cremation covered with earth or slabs of tuff. The remaining 7 cremations were west of the large pit, in two small clusters. All of the cremations were secondary depositions, and it is unclear where the cremations took place. One of the 7 cremations away from the large pit produced a small amount of intact basketry suggestive of the presence of cremation vessels. No inhumations were recovered from the site.

The 47 cremations did provide a substantial number of artifacts, including 35 projectile points, 20 assorted flaked stone tools, 4 stone pipes, 1 pestle, and 1 stone tray, as well as red paint and the basketry fragment. Radiocarbon dates associated with the cremations produced an age between 1146 cal B.C. and cal A.D. 33, a time frame that roughly spans the San Pedro and Cienega phases.

Cienega Phase

Donaldson

The Donaldson site (AZ EE:2:30 [ASM]), a Cienega phase site located along lower Matty Wash in the Tucson Basin, included five burials (Huckell 1995; Minturn and Lincoln-Babb 1995). All five burials were primary inhumations of adult individuals. Three of the individuals were male, and two were female. All three of the male individuals were interred in flexed positions, as was one of the females. The other female individual was interred in an extended position. Apart from a basin metate apparently placed on top of one of the male individuals, no mortuary artifacts were associated with any of the burials. A sixth burial was excavated during the work at the Donaldson site, but it was determined to be from a later Hohokam occupation and did not receive similar analysis to that of the other five burials.

Another site (AZ EE:2:577 [ASM]), located immediately north of the Donaldson site, was recently identified and contained three burials (Hall, Windingstad, et al. 2010). Erosion along the cutbank of Matty Wash partially exposed human remains, and investigators were contacted to assess and remove them. Practical limitations prevented investigators from fully excavating the burials, but field observations supported the conclusion that five individuals were present. One burial was the cranium of a young-adult male, lying supine. The second burial consisted of the lower legs and feet of two adults of indeterminate sex, lying in a basin-shaped pit capped by rocks. The third burial consisted of the lower legs and feet of two young-adult individuals of indeterminate sex, lying in a rock-lined, bell-shaped pit.

These three burials were contemporaneous with the Donaldson site: the multiple inhumations were consistent with the Cienega phase inhumations, and the male cranium was consistent with the Hohokam occupation. Given their locations and temporal characteristics, it is sensible to regard these three burials as part of the Donaldson site. Nevertheless, the lack of observable context for these burials prevents any specific conclusions about their associated mortuary behavior. Indeed, apart from excluding cremation as part of the burial program, the contribution of these burials to the bioarchaeology of the Donaldson site was limited.

Los Ojitos

The Los Ojitos site (AZ EE:2:37 [ASM]) is a Cienega phase site that is complementary to the Donaldson site (Huckell 1995; Minturn and Lincoln-Babb 1995). Seven burial features were excavated from Los Ojitos during the 1982–1983 field efforts. Six of the burials were flexed primary inhumations. Of these, five exhibited skeletal characteristics consistent with or suggestive of adult females. The sixth individual was represented by the incomplete remains of an adolescent for whom sex could not be determined. A complete projectile point was encountered in association with one of the individuals, but it was unclear whether it was a burial offering. Otherwise, none of the burials included any mortuary artifacts.

In addition to the six primary inhumations, a secondary inhumation containing the remains of at least four individuals was excavated. The remains appeared to have been arranged with three skulls atop "an impressive mass of long bones" (Huckell 1995:49). A fourth skull was encountered during subsequent laboratory examination of the feature. It was unclear to investigators whether the secondary inhumation was part of a specified burial program or the remains had been disturbed by the construction of other pit features and subsequently reinterred. No mortuary artifacts were recovered with this secondary inhumation.

Los Pozos

Los Pozos (AZ AA:12:91 [ASM]) is a multicomponent (Chiricahua and Cienega phase) site in the Tucson Basin that included three inhumations from the Cienega phase (Gregory 2001). Two inhumations were of adult females, both tightly flexed. Indeed, the positions were so tightly flexed that investigators suggested the possibility that the inhumations represented secondary interments. Disturbance to the burial features prevented a clear determination. A third burial, that of an adult male, displayed a semiflexed position with articulation that clearly indicated a primary inhumation. Apart from some metate fragments beneath one of the tightly flexed female inhumations, no mortuary artifacts were encountered.

Human remains were also recovered from five "nonburial contexts" at Los Pozos (Minturn and Lincoln-Babb 2001:303). These included three teeth and elements of the extremities. The remains were all consistent with a single individual; however, one completely calcined carpal phalanx was encountered among the remains from nonburial contexts. This element was the only one at Los Pozos that showed evidence of thermal alteration.

Kearny

The Kearny site (AZ V:13:201 [ASM]), located along the Gila River east of the Phoenix Basin, included three burials, all inhumations (Hurlbut 2000:12-1). Although the site includes a Hohokam component, the burials were from the Early Agricultural period/Cienega phase component of the site. Two of the burials were primary inhumations, one of an adult female and one of a child of indeterminate sex. Both burials were in the floors of pit structures, although it is not known whether the child inhumation was intrusive to the structure or the structure was constructed over the burial. The third burial was a secondary inhumation of an adult of indeterminate sex. "The long bones were laid in rows oriented roughly east–west on the bottom of the burial [pit], covered by ribs and the skull" (Hurlbut 2000:12-2).

None of the burials showed evidence of thermal alteration. Among the three burials, only the child inhumation included a mortuary artifact. A small, rectangular shell pendant was encountered under the skull of the child.

Cienega and Red Mountain Phases

Coffee Camp

The Coffee Camp site (AZ AA:6:19 [ASM]) is a Cienega to Red Mountain phase site located in the Santa Cruz Flats of southeastern Arizona (Dongoske 1993; Halbirt and Henderson 1993). In total, five burials were encountered: three primary inhumations and two secondary cremations. The inhumations included (1) a semiflexed adult of indeterminate sex; (2) a flexed adolescent/young adult, possibly female; and (3) a seated middle to mature adult, possibly male. No mortuary artifacts were associated with any of the inhumations.

The two secondary cremations consisted of completely calcined bone fragments in two small pits. The pits showed no evidence of thermal alteration, indicating that the cremation had taken place elsewhere, and the bone was transported to the pits. Both individuals were adults of indeterminate sex. One of the cremations included 885 unburned shell beads. The beads were arranged contiguously, suggestive of a strung necklace. As Dongoske (1993:178) noted, "the fact that the shell beads exhibited no signs of exposure to heat indicates that they were added to the already cremated remains, which were secondarily interred."

Finch Camp

Finch Camp (AZ U:11:7 [ASM]) was excavated as part of a series of sites associated with the ongoing development of U.S. 60 between Florence Junction and Superior in the eastern Phoenix Basin. Finch Camp was one of four sites from which human remains were encountered, but it represented the most complete picture of the mortuary behavior associated with the project area (Lincoln-Babb et al. 2011). In total, 18 burials were recovered: 16 primary inhumations and 2 secondary inhumations. What was notable about the burials at Finch Camp was the relationship of the inhumations to the structures. Indeed, 15 of the burials were intramural, in subfloor pits (Lincoln-Babb et al. 2011:555). The two secondary inhumations were included among these 15 intramural burials. The postabandonment processes affecting the structures included burning of the structures in some cases, which led to thermal alteration of some of the remains. One cremation was encountered at Finch Camp, but that feature dated to the pre-Classic period site component and was not associated with the rest of the mortuary behavior evident at Finch Camp. Indeed, the only thermal alteration to human remains was incidental, resulting from postabandonment structure burning. No other formalized cremations were encountered.

The demographic elements of the Finch Camp burials were varied. Of the 18 individuals, 7 were neonates or infants, 1 was a child, and 10 were adults. The 10 adults included 6 males and 4 females. Burial positions, when observable, spanned from fully extended supine to tightly flexed on the side, to seated positions. The mortuary artifacts were also varied. Among the burial artifacts recovered from the inhumations were a Cienega projectile point, three stone pipes or fragments of pipes, flaked stone tools, ground stone tools and beads, worked-bone artifacts, shell beads, and a painted fragment of leather.

Pueblo Patricio

The Pueblo Patricio site (AZ T:12:70 [ASM]) is a Red Mountain phase site in downtown Phoenix (Vaughn 2009). In total, three burials were recovered: one primary inhumation, one primary cremation, and one secondary cremation. The inhumation was in a pit that intruded into a pit-house floor, and the individual was slightly flexed on the left side. Poor preservation prevented investigators from determining the age, sex, or other biological attributes of the remains. The primary cremation was that of a subadult aged 9–15 years and of indeterminate sex. The remains were contained in a pit exhibiting oxidation and dark charcoal staining, leading investigators to conclude that the remains had been cremated in situ. The remains were described as "[96 percent] completely incinerated" (Vaughn 2009:169). The secondary cremation consisted of 3.5 g of fragmented, completely incinerated remains encountered in a pit with no evidence of in situ burning. The condition of the remains prevented the establishment of the age or sex of the individual.

Mortuary artifacts were largely absent from the burials. All three individuals were recovered with ceramic sherds. Two burials included flaked stone debitage, and the primary cremation included two fragments of unworked shell. It is unlikely, however, that these artifacts were included as mortuary items. A handstone was recovered with the secondary cremation, but its relationship to the burial was unclear.

Red Mountain Phase

Red Mountain

The Red Mountain site (ASU U:10:2) in the Phoenix Basin was described by Morris in 1969, and serves as the type site for the Red Mountain phase. Two primary inhumations were excavated at the site. The first was a semiflexed, supine individual encountered beneath a cairn. The age and sex of the individual was not described. It was noted that apart from the cairn itself, no mortuary items were found associated with this individual. No burial pit was identified. The second inhumation was a tightly flexed individual on the left side. No cairn or burial pit was identified, and no mortuary items were recovered in association with the remains. The bone was described as being in poor preservation, and no biological attributes such as age or sex were described for this individual.

Results

Ten sites from southern Arizona dating to the San Pedro to Red Mountain phases were compared to the burial features at the Luke Solar project sites (Figure 97). On cursory examination, the bioarchaeology of Site 68 and Falcon Landing was not substantially different from that of the 10 comparative sites. The comparative sites produced a total of 111 burial features that included primary inhumations, secondary inhumations, primary cremations, and secondary cremations (Table 84). Although none of the sites perfectly matched the burial program seen at the Luke Solar project sites, some elements of the 2 burials from the Luke Solar project sites appeared consistent with elements observed at other sites in Arizona between the late Chiricahua and Red Mountain phases.

Closer examination, however, revealed stark differences between the Luke Solar project bioarchaeology and that of the comparative sites as a whole. In regard to inhumations, none of the comparative sites included secondary inhumations in the absence of primary inhumations. The secondary inhumation at Las Capas as well as the two secondary inhumations at Finch Camp were acknowledged to possibly have been disturbed primary inhumations (Lincoln-Babb et al. 2011; McClelland et al. 2007). The secondary inhumation at Los Ojitos consisted of the stacked remains of at least four individuals (Huckell 1995), and the secondary inhumation at Kearny consisted of a very compact, likely bundled, set of remains in the floor of a structure (Hurlbut 2000). None of these were consistent with the secondary inhumation at Falcon Landing, the fragmentary elements of a single cranium.

The secondary cremation at Site 68 was distinguishable from those at the comparative sites in one important way: Feature 106 was not contained in a pit. Indeed, the 47 secondary cremations from Cienega Creek, the 2 from Coffee Camp, and the 1 from Pueblo Patricio all included discrete pits, each of which was no larger than 70 cm in diameter (Dongoske 1993; Haury 1957; Vaughn 2009). Feature 106 at Site 68 consisted of fragmented, incompletely cremated remains spread over an area of 6.53 by 3.35 m, with no identifiable pit. This was larger than the 3-m-diameter pit Haury (1957:11) described as containing 40 of the 47 discrete pockets of secondary cremations at the Cienega Creek site.

The differences between the burial features at the Luke Solar project sites and those of similar types at the comparative sites were striking, and they call into question the reliability of inferring mortuary behavior from the burials at Site 68 and Falcon Landing. To be sure, the difficulty of deciphering the mortuary behavior was aggravated by the relative lack of human remains. Nevertheless, the contexts of the two Luke Solar project features were illuminating. With the exception of the Cienega Creek site, the preferred method of burial treatment in southern Arizona during the Late Archaic period through the Red Mountain phase was primary inhumation. Secondary inhumations, when not closely mimicking primary inhumations, exhibited clear intent by way of stacking (Los Ojitos) or bundling (Kearny). These characteristics were not consistent with Feature 3139 at Falcon Landing.

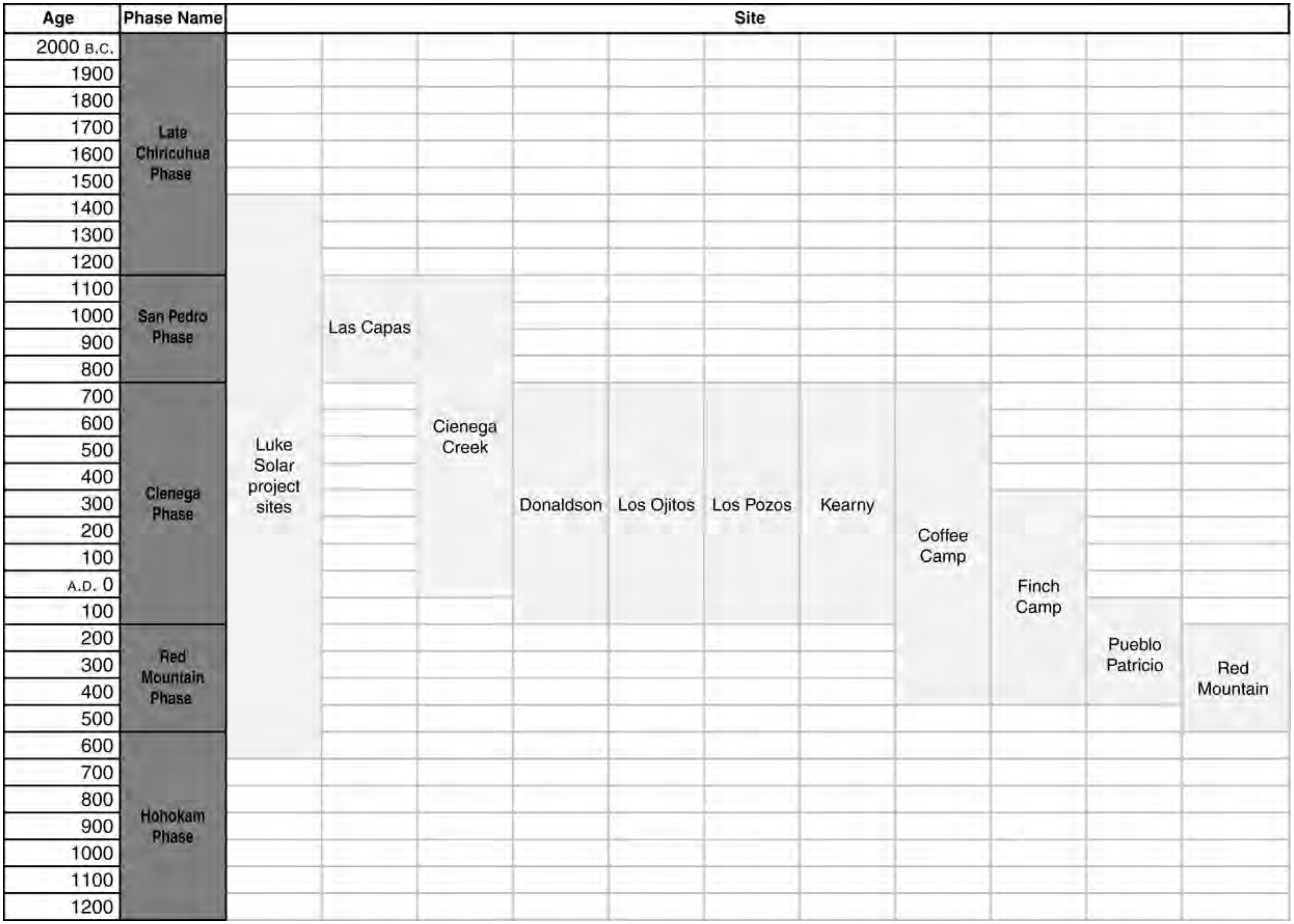


Figure 97. Time depths represented by burials at the Luke Solar project sites and 10 comparative sites.

Table 84. Summary of Burial Programs from the Luke Solar Project and Comparative Sites

Site	Primary Inhumations	Secondary Inhumations	Primary Cremations	Secondary Cremations	Total No. of Burials
Luke Solar project sites	—	1	—	1	2
Subtotal	—	1	—	1	2
Comparative sites					
Las Capas	14	1	1	—	16
Cienega Creek	—	—	—	47	47
Donaldson	7	—	—	—	7
Los Ojitos	6	1	—	—	7
Los Pozos	3	—	—	—	3
Kearny	2	1	—	—	3
Coffee Camp	3	—	—	2	5
Finch Camp	16	2	—	—	18
Pueblo Patricio	1	—	1	1	3
Red Mountain	2	—	—	—	2
Subtotal	54	5	2	50	111
Total	54	6	2	51	113

The secondary cremations at the Cienega Creek site were conspicuously numerous, indeed. Nevertheless, the 47 secondary cremations Haury (1957) described were more similar in context to the secondary cremations at Coffee Camp and Pueblo Patricio than to the secondary cremation Luke Solar project Site 68. Feature 106 at Site 68 did include six projectile point fragments, and the Cienega Creek secondary cremations produced 35 projectile points. This similarity was potentially mitigated, however, by the presence of several dozen pieces of flaked stone debitage and several hundred fragments of nonhuman faunal bone in Feature 106. The large area over which the cremated bone was found, the absence of any identifiable pit, and the presence of many likely unrelated artifacts severely undermined the discoverable mortuary behavior represented by Feature 106.

Chapters 10 and 11 of this volume examine the structure and land-use patterns for the Luke Solar project sites. The bioarchaeological investigations of Site 68 and Falcon Landing will contribute to those discussions insofar as they suggest the absence of regularly constituted burial programs and mortuary behavior. In other words, the composition and structure of the Luke Solar project sites did not anticipate or include substantial emphasis on postlife needs and values. The time depth and spatial breadth of the APE doubtlessly intersected with the mortality of the individuals and groups creating the sites. As will be examined in Chapters 10 and 11 of this volume, the role the Luke Solar project sites played in the regional seasonality and mobility of aboriginal groups did not extend in broad and meaningful ways to their mortuary practices.

CHAPTER 9

Subsistence on the Lower *Bajada*: Ethnographic Examples and Archaeological Signatures

Rein Vanderpot

This chapter consists of three main parts: (1) a discussion—based on a review of the ethnographic and ethnobotanical literature—of the methods used to process the various foods suspected to have been available to the people who used the project area; (2) an overview of the different archaeological signatures expected to have been left behind as a result of those activities, including a preliminary assessment of how or whether these expected signatures match the project evidence (pursued further in Chapters 10 and 11); and (3) in the conclusions, a recap of the findings and how they reflect on site function, seasonality, and mobility (all pursued further in Chapters 10 and 11). To set the stage for these discussions, we first look at the greater project environment as it pertains to economic plants and animals and also excerpt the results of the project's paleobotanical and faunal analyses. Results of the lithic analysis, with a particular focus on ground stone, are then integrated into an overview of the expected archaeological signatures of plant-processing features. An important goal of this chapter is to look at how various food-processing activities (primarily plants) may have resulted in the numerous extramural features excavated during the project. For each step in the processing of different plant species, expected associated features are identified and described. Different processing methods are also linked to the possible functions of the recovered artifacts (ground stone, in particular).

This chapter is primarily about archaeological signatures, and no chronological considerations are provided. From previous chapters, it is already clear that subsistence strategies in the project area persisted virtually unchanged for five millennia, primarily during the Archaic period. As to the expected signatures, the reader should note that these pertain only to preserved features and materials; perishable items, such as wooden grinding implements and basketry—although discussed in the ethnographic overview because they are critical components of the subsistence activities—do not qualify. To provide an idea of some of the materials missing from the archaeological record, Appendix 9.1 presents a detailed study of the kinds of basketry that may have been used as part of the subsistence activities in the project area. The ultimate goals of this chapter are to provide baseline information for the interpretation of the project's excavated pit features, presented in Chapter 10, and to answer questions on site function, subsistence patterns, and social organization, among others, in Chapter 11. In doing so, this chapter sets the stage for addressing the series of research questions concerning land-use practices outlined in Chapter 2, Volume 1.

Environment and Subsistence

The Luke Solar project area environment has already been discussed in Chapter 2, Volume 1, and also in Chapter 2 of this volume. Here, the project setting is briefly reviewed insofar as it concerns the economic plant and faunal resources. LAFB is located on the lower *bajada*, at an elevation ranging from 326 to 330 m (1,070–1,083 feet) AMSL, between the White Tank Mountains (whose 1,244-m [4,083-foot] AMSL summit, Barry Goldwater Peak, is less than 15 km [9.3 miles] to the west) and the Agua Fria River (about 5 km [3.1 miles] to the east). The lower *bajada* is part of a varied series of five environmental zones identified between the river and the mountains (Keil 1973). LAFB falls within the Saltbush series of the Lower Colorado River

Valley subdivision of the Sonoran Desert, with saltbush (*Atriplex* spp.) thriving particularly well in this saline environment. Only slightly higher (at about 350–1,000 m [1,148–3,281 feet] AMSL) and only several kilometers away, the Paloverde-Cacti-Mixed Scrub series of the Arizona Upland biotic community is found, with much greater densities and varieties of edible plants, particularly cacti, weedy annuals, and legumes.

The lower *bajada* is the most xeric of all five zones, with moisture only fleetingly retained in the wash channels. But in certain places on the lower *bajada*, water may be more permanently contained. Uplifting of extensive salt deposits along the western side of the Agua Fria River caused elevated water tables and funneled surface runoff into the project area during discrete periods of the Holocene (see Chapter 2, this volume). This possible surface or near-surface water would have been particularly conducive to mesquite (*Prosopis* spp.) growth, especially because these trees, like saltbush, do well in saline soils. The main attraction of the project area for Archaic period people likely was the mesquite bosque that developed through these special hydrological conditions. A bosquelike setting exists today and would have been much more pronounced in the past. It is unknown how many other of these mesquite bosques exist elsewhere in the vicinity; possibly, this is a unique situation. The lush bosque would have provided people not only with edible mesquite pods and seeds but also with the meat of rabbits, rodents, and birds that found food and shelter amongst the trees. The ancient environment of the lower bajada is not completely understood; in particular, the mix of mesquite, native grasses, and weedy annuals may have been different. In the U.S. Southwest, past heavy grazing and protection from fire, coupled with drought and flooding, have resulted in widespread soil erosion, diminished grasses and annuals cover, and shrub invasions, in particular of mesquite (Bahre 1991; Betancourt 1990; Hastings and Turner 1965). Prehistorically, mesquite was likely less abundant in the general bajada zone, found primarily concentrated in well-watered areas along the river and in places with elevated water tables such as at the project area.

In the present day, the lower reach of the Agua Fria River is an intermittent stream, largely dry year-round as a result of modern development, retaining water during the summer monsoon rains and occasionally also for short periods during the winter. But prehistorically, it was an important source of water for irrigation; Hohokam farmers ran several canals off the lower stretch during the Classic period. Its channel banks host riparian trees typical of the Lower Colorado River Valley subdivision of the Sonoran Desert. These include cottonwood (*Populus fremontii*) along the channels and, before development, varying densities of mesquite and palo verde (*Parkinsonia* [*Cercidium*] spp.) on the floodplain. As discussed in Chapter 2, Volume 1, terraces above the modern Agua Fria River channel range in age from about 10,000 to 1,000,000 years old and are primarily gravel deposits. These boulder-strewn terraces provided excellent materials for flaked stone and ground stone manufacture (see Chapter 3, this volume) but—along the stretch of the river adjacent to the project area—provided little that would have facilitated any kind of agriculture. The absence of a significant floodplain would also have limited the growth of economic plant species along the river.

The White Tank Mountains are a small, isolated mountain range oriented northwest–southeast and rise above a broad alluvial plain drained by the Hassayampa, Agua Fria, and Gila Rivers (see Figure 4, Volume 1). Erosional processes have deposited coarse alluvium along the mountain bases, creating deep but poorly developed soils on the upper *bajada* and finer-grained alluvium on the lower *bajada*, where soils are better developed but are underlain by a calcareous hardpan layer (see Chapter 2, this volume). Both *bajadas* are crossed by numerous washes flowing east toward the Agua Fria River. Several major, east-oriented canyons dissect the eastern part of the mountains, and in some of these canyons, flash floods have dug plunge pools and scour holes into the white granitic bedrock. These rock tanks (the “White Tanks” for which the range was named) hold water much of the year (Keil 1973:85).

As part of a plant inventory of the 11.3-ha (28,554-acre) White Tank Mountains Regional Park (WT-MRP), which extends to about 10 km (6.2 miles) west of the project area, Keil (1973:37–38) delineated five environmental zones covering the mountains and the eastern *bajada*: (I) Upland Sonoran Desertscrub (upper *bajada*), (II) Alluvial Plain Desertscrub (lower *bajada*), (III) Desert Grassland, (IV) Sheltered Sites Vegetation, and (V) Wash Channel Vegetation. For indigenous people, these zones formed a diverse subsistence catchment in a relatively small and circumscribed area.

Zone I, which also includes the mountain zone, is mostly upper *bajada*, with abundant saguaro (*Carnegiea gigantea*) and other cacti, blue palo verde (*Parkinsonia florida* [*Cercidium floridum*]) and littleleaf palo verde (*P. mycrophylla* [*C. microphyllum*]), acacia (*Acacia* spp.), ironwood (*Olneya tesota*), wolfberry (*Lycium* spp.), desert hackberry (*Celtis pallida*), and other food plants. Although the mountains are a relatively small range, and certainly no sky island, the higher elevations with a northern exposure host edible mountainous plants, such as desert agave (*Agave deserti*) and shrub live oak (*Quercus turbinella* Greene).

Zone II (350–1,000 m [1,148–3,281 feet] AMSL), encompasses the lower *bajada* (the area under 610 m [2,000 feet]); the Saltbush series is found at the lower elevations (including the project area) and the Paloverde-Cacti-Mixed Scrub series at higher elevations. This zone is cut through by Zone V (the wash channels). Locally common on the lower *bajada* are grasses. A total of 45 different grass species has been identified in the WTMRP, and edible species include panicgrass, or Arizona signalgrass (*Urochloa arizonica* [formerly *Panicum arizonicum*]), Mexican panicgrass (*Panicum hirticaule*), alkali sacaton (*Sporobolus airoides*), and spike dropseed (*S. contractus*). Other edible plants include members of Amaranthaceae and Chenopodiaceae, such as slimleaf goosefoot (*Chenopodium leptophyllum*), nettleleaf goosefoot (*C. murale*), wheelscale saltbush (*Atriplex elegans*), carelessweed (*Amaranthus palmeri*), and fringed pigweed (*A. fimbriatus*); wild buckwheat (specifically Native American pipeweed, or desert trumpet [*Eriogonum inflatum*]); members of the purslane family (*Calandrinia ciliata* and *Portulaca oleracea*); Indianwheat (*Plantago* spp.); and various other annuals and perennials.

Zone III, grassland, is found on upland slopes, particularly those with a northern exposure. The many grasses and shrubs make this area highly attractive to deer and other game. Zone IV, sheltered locations, is found on the mountain slopes at the bases of cliffs, rock outcrops, and large boulders. Common in this zone are food plants such as desert hackberry, wolfberry, various acacias, and shrub live oak. Zone V, the wash channels, has the most variable vegetation of all the zones, ranging from semiaquatic along the mountains to xeric at lower elevations, such as near the project area. People residing at the project area sites could easily have followed these vegetation ribbons upslope to gather the various legumes and other edible plants growing in them.

Paleobotanical and Faunal Evidence

The macrobotanical analysis yielded no evidence of exotic (e.g., maize [*Zea mays*], beans [*Phaseolus*], and squash [Cucurbitaceae]) or indigenous domesticates (e.g., agave and little barley [*Hordeum pusillum*]); a single maize pollen grain was the only evidence of agriculture. This is not surprising, given the adverse conditions for agriculture in the area. The flow of the nearby Agua Fria River is volatile and the adjacent part of the river lacks a true floodplain. Even if water was available in or near the project area, the salinity of the local soils would have prevented farming. The project's flotation samples included charred reproductive parts of seven native plants commonly used for food. In order of ubiquity, these were mesquite, horse purslane (*Trianthema portulacastrum* L.), cheno-ams (goosefoot or pigweed), saltbush, woolly Indianwheat, panicgrass, and purslane (Portulacaceae) (see Chapter 7, this volume). Of these, purslane was found in a noncultural context and may not indicate food use. Macrobotanical nonfood plant parts consisted of wood of mesquite, saltbush, creosote bush (*Larrea tridentata*), saguaro, and ocotillo (*Fouquieria splendens* Engelm.) All of these were likely used for fuel; the first three were available in the project area, and the others were farther away, on the upper *bajada*, although they could have washed down in one of the nearby drainages.

Pollen analysis identified a core suit of 11 taxa interpreted as potential important economic resources, although not all of them were necessarily used at the project sites. Of the 11 taxa, at least 8 were likely used in the project area; in order of ubiquity, these were cheno-ams (likely saltbush), grass family, woolly Indianwheat, palo verde, cholla (*Opuntia* spp.) and other cacti, wolfberry, mesquite, and hackberry. Ubiquity should not be relied on to attribute importance. Mesquite and palo verde, for instance, are insect pollinated and were probably underrepresented.

Faunal-bone specimens at the project sites were relatively rare, and most were from leporids, including black-tailed jackrabbit (*Lepus californicus*), antelope jackrabbits (*L. alleni*), and cottontails (*Sylvilagus*), followed in number by rodents and only a few artiodactyl (or artiodactyl-sized) specimens. It appears that people did some occasional hunting for jackrabbits and cottontails and opportunistically caught a few rodents and other animals, but hunting never played an important role at the sites in the project area. There was no evidence that hunters came to the sites from the mountains with game such as deer (*Odocoileus* spp.), pronghorn (*Antilocapra americana*), or bighorn sheep (*Ovis canadensis*). On the other hand, there was good evidence that men residing in the project area manufactured and refurbished bifacial tools (for animal procurement and processing); however, the actual tools were not found at the sites, indicating that they were carried away for use elsewhere. Overall, hunting was not an important economic focus for people living in the project area, and it was certainly not the reason they were there. Therefore, the following discussions on food processing and expected archaeological signatures primarily deal with plant foods.

Food-Processing Technologies: Ethnographic Examples

Historically, indigenous residents of the Sonoran Desert used a wide range of plants for food, medicine, crafts, construction, and ritual purposes. Different groups used plant resources in distinctive ways but in ways that were often quite similar. Two groups of plants were particularly vital and were used widely by most groups: desert succulents and seed-producing plants, and of these, saguaro and mesquite, in particular, were by far the most dependable staples. Small seeds of grasses and various weedy annuals were also important. Based on results of the environmental and paleobotanical studies summarized above, the availability of mesquite likely was the primary reason people kept coming back to this location for 5,000 or more years. Other plants likely collected from the project area and the vicinity were grasses, cheno-ams (such as saltbush), various annuals, berries (hackberry and wolfberry), and cholla. Most native-plant processing included the use of ground stone, basketry (and later on, pottery), fire, and rocks. Critical to our present study are the numerous thermal features and ground stone artifacts identified in the project area. Although we may never completely understand how individual features functioned, it is only by comparing them to data from ethnographic and ethnobotanical narratives and, of course, the results from the paleobotanical studies, that we can obtain some idea of what went on at the sites and what processes resulted in the particular makeup of the features.

In the following sections, the plant species most likely processed at the sites—mesquite and other legumes, small seeds, berries, cacti and other succulents, and leafy vegetables—are discussed, followed by a brief review of animal use. Casting a wide ethnographic net (i.e., the greater U.S. Southwest, Texas, and northwestern Mexico), different processing methods will be correlated to specific archaeological signatures (features and artifacts). Of course, the time leap backward from the ethnographic period to the Middle Archaic period (3500–1200 B.C.) is huge, which might argue against using such recent data. Yet there are only a limited number of ways to process these plants, and given the great similarity in processing methods and tools or technology between different people in different regions, we can surmise that, in general, the processing options were the same through time. Most relevant for our comparisons are ethnographic groups who lived (or still live) in an environment near or similar to the project area, such as the Akimel O'odham and the Maricopa (although the latter originally lived in the lower Colorado River region). Other relevant groups include the Tohono O'odham; Western and Northwestern Yavapai; Western and Chiricahua Apache; Paiute; Shoshone; the Mohave, Quechan, and Cocopah of the lower Colorado River region; and groups in California, such as the Cahuilla. Given the primarily Middle and Late Archaic period occupation of the project sites, hunter-gatherers (such as the Seri) or people doing only limited farming (such as the Hia C'ed O'odham or some Apache) make for the best regional comparisons, as opposed to completely sedentary or "two-village" agriculturalists, who may have stayed closer to their villages and fields or put less emphasis on native plants. More-committed agriculturalists, for example, replaced mesquite with maize and wheat, or only used the more easily processed parts of the mesquite, abandoning the practice of processing the seeds (Felger 1977).

There is a considerable body of ethnographic and ethnobotanical literature describing plant use by hunter-gatherers and groups that practice limited agriculture, and some of the most-used sources for the present study included Hodgson (2001) for the Sonoran Desert; Felger (2007) for the Dry Borders area (i.e., the lower Sonoran Desert along the United States–Mexico border); Bell and Castetter (1937) for mesquite; Castetter and Bell (1937) for saguaro; Castetter et al. (1938) for agave; Castetter and Bell (1942) for general O'odham; Castetter and Underhill (1935) and Austin (2000) for the Tohono O'odham; Rea (1997) and Russell (1908) for the Akimel O'odham; Nabhan et al. (1989) for the Hia C'ed O'odham; Gifford (1936) for the Yavapai; Gifford (1933), Kelly (1977), and Alvarez de Williams (1983) for the Cocopah; Castetter and Bell (1951) and Stewart (1983) for the Mohave; Forde (1931) and Spier (1933) for the Maricopa; Bean and Saubel (1972) for the Cahuilla; and Felger and Moser (1985) for the Seri.

Mesquite

Mesquite was the most widespread and important wild-food source for the indigenous people of the U.S. Southwest. Mesquite pods combined several factors to make them an important staple: excellent nutritional qualities, high yield in a relatively short amount of time, and dependability, because its deep root systems tap groundwater. Mesquite was predictably available at the height of the pre-monsoon summer dry season, roughly at the same time as (though usually before) saguaro fruits, making it a time of plenty. Only saguaro came close in being such a dependable wild-plant food. All three mesquite species of the Sonoran Desert (velvet mesquite [*Prosopis velutina*], honey mesquite [*P. glandulosa*], and screwbean mesquite [*P. pubescens*], or *tornillo*) were used extensively for food, and in regions where mesquite was abundant, the seedpods were a staple. An added advantage of mesquite was that the flour could be made into rock-hard cakes that preserved a long time and were highly transportable. So important is the tree that native groups have named months or times of the year after its various stages of ripening. For instance, the Akimel O'odham based 2 months of their calendar on the tree, the "mesquite leafing out moon" (around April) and "mesquite flowers moon" (around May) (Rea 1977). There also is extensive nomenclature for the various stages of pod ripening. The Seri Indians recognize eight usable products in fruit development, ranging from pods less than 2.5 cm (1 inch) long to mature pods that had fallen to the ground (Felger 1977; Felger and Moser 1985). The Cahuilla had three: blossoms, green pods, and mature dried pods (Bean and Saubel 1972:108).

Different Mesquite Uses

Historical and ethnographic records have indicated that almost every part of the mesquite tree has a use. The Akimel O'odham referred to velvet mesquite as the "tree of life" (Rea 1997:184). Mesquite flowers, pods, seeds, leaves, wood, bark, gum, roots, and sap all have been used by humans for thousands of years. Most importantly, mesquite was a vital source of food, which is the focus of the following discussion. But before discussing mesquite as food, it is useful to review its other uses. Mesquite was also important for fuel, medicine, ritual, and cordage. For instance, its hard wood was used for making tools and musical instruments. Several groups used mesquite wood for the construction of implements, dishes, and structures. War clubs and atlatls, digging sticks, and mortars and pestles were made from mesquite (Cosgrove 1947; Russell 1908). Vertical structures of pit houses, pueblos, and shade ramadas were built of mesquite, including posts, beams, and lintels (Felger and Moser 1985). Mesquite is a very fibrous wood, and the pliable softwood roots retain sufficient elasticity to be pounded into cordage. Cocopah women made basketry from mesquite roots, pounding the fibers and then twisting them into cordage (Gifford 1933; Kelly 1977). Cordage from mesquite root was durable and well suited for making storage baskets, burden baskets, and carrying nets. The Seri used mesquite cordage not only for carrying nets but also as ropes attached to harpoons for spearing large marine animals, especially turtles and large fish (Felger and Moser 1985:335–337). Reeds were lashed together with mesquite rope to build boats (Felger and Moser 1985). Mesquite gum, herbage, roots, and bark were also used in medicinal applications. Leaves were often used in topical applications. Mescalero Apache ground or mashed leaves and mixed them with water and then applied the mix to an afflicted area, especially the eyes. Both mesquite gum and powdered mesquite bark have antiseptic qualities (Gifford 1933). Mesquite gum, an exudate that collects in cracks in the bark, was dissolved in water and applied to the eyes (Hrdlička 1908). The Cocopah boiled the inner bark, and the water was given to newborns

(Gifford (1933). The Akimel O'odham treated diarrhea with an infusion of mesquite roots or gum and also used the astringent qualities of mesquite bark (Curtin 1949).

Mesquite as Food

Not all species of mesquite provide edible pods, but all three species found in the Sonoran Desert do. The two most widespread species in the Sonoran Desert are honey mesquite and velvet mesquite; screwbean mesquite, which grows in better-watered areas, is less common. Honey mesquite and velvet mesquite are very similar to each other in terms of growth habit. Their geographic distribution is different, however. Honey mesquite is most common along the lower Colorado River and also extends south to the Gulf of California and Baja California and east to the south Texas plains, where it is the signature plant. Along the Seri coast (the Gulf of California littoral between Puerto Lobos and Guaymas, Mexico), honey mesquite is the only species found (Felger and Moser 1971). Velvet mesquite is mostly restricted to the Arizona Upland, and it is the species growing in the project area; it also is the sole species identified nearby in the WTMRP (Keil 1973). No doubt, the mesquite species used by the prehistoric occupants of the project area was velvet mesquite. The following discussions of ethnographic use of the tree focus on both velvet mesquite and honey mesquite, whose uses for food and other purposes were very similar. The use of screwbean mesquite differs, however, and the discussions include this species only to supplement or clarify processing details not available for the other two species.

Mesquite was highly prized as a food source among indigenous people of the U.S. Southwest; its nutritious pods and seeds are rich in sugar and protein (Bell and Castetter 1937:21–22; Palmer 1871). Russell (1908:74) stated that in former times "mesquite beans formed nearly if not quite the most important article of diet of the Pimas." The great importance of mesquite pods as a food source is related to several factors: the ease of preparation, its abundance and dependability as a crop, its capacity for preservation and storage, and its rich food content. Mesquite pods are rich in carbohydrates and low in moisture content, both important qualities for efficient harvesting, processing, and storage. Data compiled by Foster (1916:4–5) and Garcia (1917:71–82) indicate that mesquite pods/seeds per 45 kg (100 pounds) contain 3.8 kg (8.34 pounds) of crude protein, 23.6 kg (52.02 pounds) of carbohydrates, and 1.1 kg (2.4 pounds) of fats. Hodgson (2001:188) reports that mesquite mesocarps contain about 32 percent sugars and 7 percent protein. The seeds are much higher in plant protein (29–39 percent), but they are not easy to process. Their hard outer coating (endocarp) is indigestible, so this must be broken first, which is an arduous process. Seeds still within their endocarp have been recovered from a few coprolites (e.g., Williams-Dean 1978), but swallowing the very hard seed would have been accidental. When processing the pods, care needs to be taken to separate the woody endocarps containing the seeds from the pods, which is best done by parching, crushing, and mashing.

Importantly, like saguaro, mesquite is a reliable crop, meaning that—with rare exceptions—each year one can always depend on a large crop, independent of droughts or freezes (Felger 1977:153–154). Furthermore, mesquite can produce a second crop during early fall in years with adequate to superior summer rain. Mesquite is one of the most dependable desert resources because deep root systems tap groundwater and thereby buffer trees from droughts, although late frosts or high winds during the flowering season can destroy a season's seed crop (Hodgson 2001). Crops are also highly lucrative, with vast amounts of pods collected in a relatively short amount of time. For example, two Seri women, working with a man who keeps them supplied with pods, were able to prepare about 40 kg (88 pounds) of mesquite-pod flour in a day (Felger 1977:158). As noted by Walton (1923:2), "during a favorable season each tree will average one-half to one bushel of beans, the quantities available in an area being 'limited' only by the facilities available for gathering the fruit." Walton estimated that a single worker could gather about 79 kg (175 pounds) of dried pods in a day, weighing approximately 9.5 kg (21 pounds) to the bushel, or 8$^1/_2$ bushels per day. He further estimated that 0.4 ha (1 acre) of land well covered with trees could produce 100 bushels per year. Such estimates must be treated with some caution, however, because not every tree (or even whole areas of trees) produces good-tasting pods. Some trees have bitter, unpalatable pods while others provide sweet, edible pods. Also, not every tree produces significant seed crops in all years, although normally a given area will have some production each year.

Depending on area and elevation, mesquite pods were gathered in the summer and early fall, and whole pods or processed products such as cakes were stored for consumption in the winter. In the Sonoran Desert, mesquite food products were available for harvest roughly from April through August. People used mesquite in three different forms (i.e., three phases in the maturation of its reproductive parts): blossoms, green pods, and dried pods. The blossoms were gathered in spring, the green pods in early summer, and the mature, naturally dried pods in early autumn. As noted, the Seri recognize eight stages of growth of the pod, ranging from the youngest, incipient stage (less than 2.5 cm [1 inch] long) to the mature fallen pods (still edible but easily spoiled when wet). As described below, pods can be eaten raw, soaked, boiled, roasted, pulverized, ground, and eaten as cakes or used to make beverages (including alcoholic drinks) and gruels. The soft inner seed, although less easy to access, can be ground into a protein-rich flour and similarly made into cakes, drinks, or gruels.

The mesquite pod is slightly curved, with those of some species measuring up to 15–25 cm (6–10 inches). Because mesquite pods have the shape and size of a green bean, they are often called mesquite "beans," which has caused some misunderstanding of how the fruit is used. The term "bean," for either the seed or the whole pod, is often loosely and uncritically applied. The pod ripens into a light tan or brown pod consisting of a thin exocarp and a thick, spongy mesocarp surrounding woody endocarps that encase the seed (Kingsolver et al. 1977). Unlike most legumes, mesquite seedpods contain not just seeds in an otherwise hollow container but are also filled with soft mesocarp tissue of sweet carbohydrates that surrounds and insulates the seeds. Not the entire mesquite pod is edible—its exocarp or husk is made of indigestible fiber and so is the hard seed coat or endocarp. The most-accessible edible portion of the pod is the pulp or pith between the brittle outside and the hard seeds. Ordinary bean pods do not have this pith, but in mesquite, this portion has a very sweet, brown-sugary flavor and can be ground into meal for use in baking. The pith surrounds a number of stone-hard seeds, inside of which are found the protein-rich embryos or true seeds. The actual seed has a thin, shiny smooth seed coat enclosing an embryo with large, soft, dark green cotyledons. Cotyledons of mesquite seeds have high protein content, and research has shown that this biological quality improves even further with thermal processing like toasting, microwaving, or using moist heat under pressure (Zolfaghari et al. 1985). Endosperm is the tissue produced in the seeds of most flowering plants around the time of fertilization. It surrounds the embryo and provides nutrition in the form of starch, although it can also contain oils and protein. Simply said, in terms of processing for food, a mesquite pod consists of four main parts: the husk (exocarp), pulp (mesocarp), the tough leathery wooden pith surrounding the seed (endocarp), and the seed itself. The pulp, which is rich in calories and carbohydrates, is the most easily accessible edible part of the pod. The pod husk (outer shell) is not digestible, but if ground it adds dietary fiber to the flour. The seed coats similarly are not only indigestible, but also add no dietary fiber and are toxic. The inner seeds are edible and highly nutritious, but the fact that the mesquite seed is enclosed in a hard, stony outer seed coat (the endocarp) forms a challenge for those wanting to access and process this seed. For this reason, many people have focused on the pulp only. Pods were also consumed without any preparation by breaking them into small pieces and chewing them (Russell 1908), although the hard seeds would have had to been spit out, preventing consuming large quantities.

The first European to note details on the use of mesquite by Native Americans was Cabeza de Vaca, traveling through either southern Texas or northern Mexico in the 1520s. While living among the Cuchendados, he observed the use of mesquite pods for food (Bandelier and Bandelier 1905; Campbell and Campbell 1981; Krieger 2002). A pit was filled with pods, which were pounded with a large wooden pestle with "the thickness of a man's thigh" (Campbell and Campbell 1981:39). The pod meal was then consumed raw, along with handfuls of earth that had been mixed with the meal. The seeds were discarded along with their woody casings. But in general, and throughout the U.S. Southwest, harvested pods were first fire-parched or, less often, sun dried; both of these methods separated the beans and pods and greatly facilitated grinding. The pods were then crushed and mashed to a pulp, typically in a bedrock, stone, wooden, or even earthen mortar, with the use of a large pestle made of stone or wood, and then finally ground into flour with a metate and mano (Felger and Moser 1985; Hodgson 2001; Rea 1997). The pounding freed the hard seeds and shredded the mesocarp into a fine meal or flour, which was separated by winnowing or screening. The meal was mixed with water to make various beverages and gruels or a doughy mass that was dried, baked, or boiled. Several ethnographic groups also pounded and cracked the stone-hard endocarps to free the seeds, which were then similarly ground into flour with uses similar to the mesocarp meal. But most people abandoned this second stage of mesquite processing, likely because of the great effort needed to do this, combined with the fact that the productivity return was much less than for the pod mesocarp.

In the following sections, the various stages of collecting and processing mesquite flowers, pods, and seeds are described, based on ethnographic examples among the O'odham, Cahuilla, Seri, and others.

Blossoms and Green Pods

Given their small biomass and the time-intensive nature of gathering them, mesquite blossoms would not have been a very important crop. The Akimel O'odham considered mesquite flowers a snack food, eating them mixed with a certain kind of mud (Rea 1997:184). The cylindrical, cream-colored flower spikes are composed of dozens of tiny flowers. Blossoms were also collected by the Cahuilla and either boiled in ceramic containers or roasted on heated stones in a pit, squeezed into balls, and then consumed (Curtis 1926:24). Prepared blossoms were stored in pottery vessels and cooked as needed in boiling water. They were also used in making tea. Cahuilla women either prepared green pods at the time of picking or let them ripen more by drying them in the sun (Bean and Saubel 1974:109). Preparation consisted of pounding them into a juice using a wooden mortar and pestle. The resulting beverage was kept in an olla and drunk during the hot summer months. A light fermentation process appears to have enhanced the taste of the beverage. There also are records of direct consumption of portions of freshly-harvested green pods by O'odham people prior to drying them (Nentvig 1980). The Maricopa prepared the green pods by pounding them in a wooden (mesquite or cottonwood) mortar, and without removing the hard seeds, mixing the meal in water to make a drink (Bell and Castetter 1937:29). The Timbisha Shoshone of the Mojave Desert pit-roasted immature green pods on a layer of hot stones (Fowler 1995). The Seri first mashed the green pods in a bedrock or hard earthen mortar, using a mesquite or ironwood pestle, and then cooked the mashed pods in clay pots (Felger 1977). The Opata of northwestern Mexico gathered the young pods in April and boiled and dried them for later use in stews (Hodgson 2001:186). Overall, however, the use of green pods was far less common than that of the mature pods.

Collecting the Mature Pods

For all groups, most of the harvest focused on the mature, dried pods, which were collected in great quantities and were an important staple food. The mature pods were harvested after the pods dried and were either still on the tree or had fallen to the ground, usually from late June through July, but as late as September in dryer regions or at higher elevations. After wet summers, a smaller, second harvest might have been possible in the fall. Mature pods were also collected in considerable quantities later in the year from pack-rat nests. The mesquite groves or bosques with the better-tasting pods were preferred. On average, in a given grove, 3 weeks or more lapsed between the time that green pods were ripe enough to be harvested and the time that dried, fully mature pods could be picked. In general, and this is true for most groups described in the ethnographic literature, none of the trees were owned but were instead shared by different families. Castetter and Bell (1937:23) noted that Tohono O'odham gathered the pods in August (after the saguaro harvest) near the summer villages. But for many other groups, harvesting mesquite pods often meant resettling close to the resource. People would remain at the gathering site for the duration of the harvest and would do all processing there also. Processing was generally done immediately after or during the harvest to avoid spoilage of the pods, in particular through the summer monsoon humidity. There was also the danger of severe thundershowers, which could destroy an entire crop. Processing would also cut down considerably on storage space. Because mesquite produces a large quantity of fruit in a short period of time, the crop needed to be harvested quickly and all available labor was recruited. Although most wild-plant collecting was women's work, entire families, including men, assisted in the mesquite harvest (Felger 1977). For many hunter-gatherer societies, and for certain agricultural people as well, this was a time of coming together. For the Akimel O'odham, mesquite gathering was a major tribal event, with large parties of women and men coming together (Russell 1908:74). Before processing, the collected pods were stored in large cylindrical baskets placed on house roofs or on platforms to protect them from rodents.

Mesquite pods are large and easy to pick, either from the tree when ripe or from the ground after they fall. The Cocopah used a pole with a short cross-piece, lashed with mesquite bark, which was set at an acute angle and served as a hook to bend down the tree branches and pick the pods (Gifford 1933:267). Collected pods were put in burden baskets, carrying nets, or blankets and brought to the processing camp. Sometimes the men helped the women carry the pods to the camp. Mohave women carried the pods home in carrying nets on their backs, supported by tumplines across their foreheads (Hodgson 2001:178). Seri women gathered the pods in shallow baskets carried on their heads; upright sticks around the edge of the baskets allowed them to carry a bigger load (Felger and Moser 1985:196, Figure 15.24; Moser 1963). The Walapai harvested the ripe pods in August, moving their camp close to the scene of gathering and collected four or five large baskets of pods for each family (Bell and Castetter 1937:25).

Parching the Pods

There were many different variations in the preparation of the pods and grinding them to flour. In general, the first step in processing was to parch the pods to facilitate grinding and separating out the seeds. Parching was also necessary because otherwise the sugar-rich flour would get sticky by absorbing moisture from the air. Parching also promoted the overall nutrition of the flour and had the added advantage of ridding the pods of the larvae of seed-eating beetles (Bruchinea). Indeed, when stored in the form of whole or pulverized pods, "they soon became a living mass, since an insect, a species of Brachus, was present in almost every seed" (Bell and Castetter 1937:23). O'odham women parched the pods "by tossing them up in a basket of live coals" (Bell and Castetter 1937:22). For the O'odham, "parching was done at the time of gathering as part of the storing technique to prevent mildew, although the inner seeds were not ground into a flour until just before they were used" (Castetter and Underhill 1935:45). Pfefferkorn (1949:72) described two ways in which O'odham handled mesquite pods. The first involved roasting the pods and then grinding them between two stones. The result was then mixed with water and drunk as *atole*. The second involved pulverizing the pods in a wooden mortar, adding water, and cooking the mixture as *pinole*. The Akimel O'odham parched the pods in a tray with hot coals or placed them in an olla with at least one broken side, which was then placed on a fire. The pods could then be stirred manually while they were heated. As reported by Curtis (1926:24), the Cahuilla "parched (the pods) by stirring them about in a flat dish containing embers," although none of Bean and Saubel's (1972:110) informants could conceive of the reason for this practice. As reported by Felger (1977), the Seri parch the pods by toasting them in hot earth. To do this, they first clear the ground, light a fire, and then remove the coals. The pods are then placed on the hot earth, and at the same time additional fires are burned on top of small piles of earth surrounding this area. The surrounding hot earth is then sprinkled on top of the pods. Named after this method, the moon or month of the year when the mesquite harvest takes place is known as the "to-sprinkle moon."

Pounding the Pods

After parching, the pods were crushed into pulp by pounding them with pestles in mortars, the tools of choice for mesquite processing; for other species of legumes (such as palo verde and ironwood), metates and manos sufficed (Goodyear 1975:168–170). Mortars were needed because the crushed pods were too sticky for the use of a metate (Castetter and Underhill 1935). Experimental efforts confirm the fact that a combination of mortar and pestle is the only effective means of reducing mesquite pods to meal. Furthermore, to separate the beans from the pod, a crushing motion is more effective than a grinding one. In the U.S. Southwest, bedrock mortars found along lower-elevation drainages typically indicate mesquite-processing camps; those at higher elevations were likely used to process acorns. For large quantities of pods, wooden mortars were used. Mortars were often made of mesquite trunks, and mesquite wood was considered superior to other woods for this purpose. The typical mesquite-wood mortar was about 76 cm (30 inches) tall, had a hole about 38 cm (15 inches) deep, and the lower 38 cm (15 inches) of the mortar was buried in the ground. A pestle, ca. 1 m (3 feet) long, was used, sometimes made from a mesquite limb, and grinding was carried out in a standing position. Although any type of mortar or pestle combination probably was used to process mesquite, large wooden mortars with matching wooden pestles or stone pestles were the preferred tools at specialized mesquite-processing camps.

The Tohono O'odham used a stone pestle against a bedrock mortar or a stone pestle in a cottonwood mortar (Felger 1977; Rea 1979). The Cocopah used wooden mortars (Gifford 1933:267) and so did the Maricopa (Castetter and Bell 1951:184; Spier 1933:128) and Quechan (Forde 1931:116). Mortars were embedded in the ground about 15 cm (6 inches) to prevent them from tipping over; they measured up to 41 cm (16 inches) in diameter and 51 cm (20 inches) in length (Spier 1933:128). The pestle used with these wooden mortars "was a more or less cylindrical water-worn boulder, ten to sixteen inches in length . . . if the lower end was too flat, it was pecked into a proper rounded form" (Spier 1933:128). Yavapai women usually pulverized the pods in a bedrock mortar with a stone pestle (Gifford 1932:211, 1936:257). Wooden mortars from cottonwood or mesquite were also used, but the bedrock mortars were preferred, especially because these were usually available near the mesquite sources. No wooden pestles were used. The wooden mortars were deeper than the stone ones and were hollowed out using burning coals (Gifford 1936:280).

Seri women mashed the pods in bedrock mortars or hard earthen pits, using cylindrical pestles, about 1 m (3 feet) long, made of mesquite or ironwood (Felger 1977:158). A large pile of pods was placed in the mortar and more were spread around it. Several women might pound at the same time, working at adjacent mortars. After the pods were mashed, they were placed between deerskins to prevent spoiling in the often hot and humid summer wind.

The Cocopah made extensive use of the mortar and pestle for crushing mesquite pods. Dimensions and materials are reported by Kelly (1977:51):

> Mortars were made of short pieces of mesquite logs and were from 10 to 14 inches in diameter. . . . The log or stump was shaped by alternate burning and chipping of the wood. A pestle to be used while sitting was made from a hard stone about 15 inches long and 3 or 4 inches in diameter at the base. A pestle to be used while standing was made from a mesquite branch about 4 feet long and 6 inches in diameter at the base.

For crushing mesquite pods, the Cahuilla used a deep wooden mortar sunk deep into the ground (Kroeber 1953:697). A pestle of great length (often ca. 60 cm [2 feet] and slender to prevent undue weight) was used, and this pestle was quite different from the more roughly shaped one used for stone mortars. The wooden mortar was not only deep but often also had a pointed bottom for use with a conical pestle. These wooden mortars were not connected with acorn processing, only with that of mesquite. Bean and Saubel (1972:109) similarly describe the Cahuilla use of wooden mortars made from either cottonwood or mesquite stumps. The stump was hollowed out with hot coals and the carbonized interior scraped clean using flaked stone tools. It was made from a section of tree, ca. 60 cm (2 feet) in length or more. The greater part of this log was sunk in the ground. The projecting portion looked like a stump cut from a tree in situ. The mortar hole was quite deep, in some cases as much as 30 cm (1 foot) or more. A correspondingly long pestle was needed. This pestle was about 60 cm (2 feet) in length, fairly well shaped, and quite slender. A similar wooden mesquite mortar was used by the Mohave, although block, cavity, and pestle were shorter than among the Cahuilla. In southeastern California, very large and deep cone-shaped mortars of wood were used, worked with long and sharp but thick pestles of extraordinary weight. The Mohave crushed mesquite beans with a stone pestle in a wooden mortar, the hard seeds remaining whole (Kroeber 1953:736–737). The Mono of California (Great Basin and High Sierra) pounded mesquite beans in wooden mortars (Kroeber 1953:592). California Indians also used a coiled basket hopper (see Appendix 9.1) set on a stone, likely to save labor in stonework.

Winnowing the Pulp

The mesquite pulp was basket-winnowed or sifted to separate out the endocarps (with the seeds still inside), which were discarded by most people because they were difficult to grind and represented only about 10 percent of each pod (Felker 2005). The most detailed descriptions of winnowing mesquite meal, after crushing in a mortar, are for the Seri, who did (and still do) process the seeds. As reported by Felger and Moser (1985:339),

> the women then placed the pestle across the mortar hole. Mashed pods or pulp were put in a basket and gently winnowed by tapping the basket against the pestle. Flour from the mesocarp, or pulp, of the pod fell into the mortar hole: the "seeds" (seeds and endocarp) and pieces of fiber and shell or pod (exocarp) remained in the basket and were set aside on a skin. The flour, *haas copxöt* (mesquite loose) was winnowed again until pure. It was then placed in a pottery vessel to keep it dry and could be stored for a "long time" (probably weeks or months), retaining its smell and taste.

Preparing Cakes

As is common with flour obtained from seeds and other plant parts, mesquite-pod and mesquite-seed flour was often made into cakes for better preservation and storage. Dried mesquite cakes have an indefinite shelf life, making them a perfect traveling food (Rea 1997:187). Akimel O'odham women would line a group of baskets with clean cloths on which they placed successive layers of flour, each layer sprinkled with a little water (Bell and Castetter 1937:22). When filled, a piece of cloth was tied over each basket and the moistened meal was allowed to stand overnight. The mass caked together and could be kept for an indefinite period without spoiling or becoming wormy. Maricopa women used a similar method for making cakes, with the ground meal sifted in an Akimel O'odham tray basket by shaking it over the edge onto a cloth (Spier 1933:51). The sifted flour was poured into an elliptical hole, which had been dug in the ground, 46 cm (18 inches) long by 30 cm (12 inches) wide by 25 cm (10 inches) deep. Before adding the flour, the hole was sprinkled with water until its surface was firm. The flour was sifted in the hole, layer after layer, and each layer sprinkled with a little more water. When the hole was full, it was sprinkled one more time and then covered with dirt. The following morning, the hard cake of flour was uncovered and stored for use on humid days when stored pods could not be ground because they were damp. (Mesquite pods and flour absorb the slightest moisture in the atmosphere.) A woman would prepare 20 or more of these cakes, which kept the same shape and dimensions as the pit in which they were formed. For use, a bit of the cake would be broken off, soaked in water to make a drink or gruel, or boiled and mixed with the meal of other seeds.

Mescalero and Chiricahua Apache women first winnowed the seeds out of the mix of mashed pods and then put the pulp in a container, kneading it by hand until it had a thick consistency (Castetter and Opler 1936:41). The dough was then made into bread or pancakes, which were considered a great delicacy. In general, the Apache made cakes similar to those of the Akimel O'odham (Bell and Castetter 1937:25). The Walapai made the pulp into loaves, which were wrapped in rabbit skins to facilitate transportation (Kroeber 1935:53). These cakes were broken, soaked in water, and the mixture drunk.

Yavapai people hydrated the pulverized pods in a watertight basket, poured the resulting juice in another basket, and drank it (Gifford 1932:211, 1936:257). Another method was to simply put the wet meal in one's mouth and spit out the residue. The Timbisha Shoshone sifted the crushed pods to remove the fiber and seeds, with the latter crushed further to remove the endocarps (Fowler 1995). The seeds were then ground into a meal, which was made into cakes. To make their cakes, they lined a winnowing tray with the fiber, and then formed the flour into a cake on the tray, sprinkling water between the layers to pack it more tightly. The cake could be more than 30 cm (1 foot) high. It was covered with an additional layer of fiber and made wet to form a crust. The cake was then sun-dried and cached in a grass-lined pit. Moapa Southern Paiutes made their cakes in either conical burden baskets or in a small hole dug to a desired shape and lined with the pulp of mesquite pods (Fowler 1995). These cakes could be as much as 60 cm (2 feet) thick. They were dried thoroughly and stored in grass- or bark-lined underground pits.

The Cahuilla made cakes that were not as thick, based on the description provided by Bean and Saubel (1972:110):

> The ground mesquite meal was placed in a basket or vessel, dampened with water, and left for a day or so to harden. . . . The hardened meal was sometimes formed into round balls, but more frequently it was molded into cakes ranging in size from two to ten inches in diameter and from one to three inches thick. The larger size was most common. Pieces were broken from these cakes (kakhat) and eaten dry, made into mush, or mixed with water to form a beverage. The dried-cake meal was particularly useful to hunters and travelers, since a small amount with the addition of water could provide a substantial meal.

The cakes could also be stored in this dried form, but often bruchid beetle eggs would hatch and the cakes would become infested with larvae (Bean and Saubel 1972). Many people did not mind these larvae because they added some zest to the meal. Of course, thorough parching of the pods prior to grinding would eliminate the larvae.

The Seri similarly made cakes from the flour, which was put in a large basket, mixed with water, and kneaded into dough from which rolls (about 20 cm [8 inches] long and 5 cm [2 inches] thick) or round cakes were made (Felger and Moser 1985:339). The rolls and cakes were dried immediately so they would not spoil and when dry they could be stored for a long time.

Cakes generally hardened naturally and did not need to be fire-baked or sun-dried. There are some reports, however, of baking. For the Akimel O'odham, for instance, Grossman (1873) mentioned that sometimes after pounding the dry pods in a mortar (no mention was made of the seeds), they were boiled in water until soft. After the water was squeezed out, the pulpy substance was molded into cakes, which were baked in hot ashes. The resulting "bread" had a sweet taste and was very nourishing. Similarly, Russell (1908:68) stated that the Akimel O'odham baked mesquite flour (and also that of corn and later wheat) "as tortillas, as loaves in the ashes, frying in a suet, or mush, or with other foods in the shape of dumplings." The Mohave made mesquite-flour dough into huge jar-shaped cakes, covered these with wet sand, and baked them on hot mesquite coals (Kroeber 1925:736–737). After baking, the cake was so hard that it had to be cracked with a stone. In eating, the seeds were spat out or swallowed whole. As described by Stewart (1965:48) for the Mohave,

> they pounded the mesquite beans to a powder, then added a little water to make a ball. A fire was built, and when it burned to ashes they scraped off the sand. They put the ball of mesquite powder there and left it out in the sun until it got hard. They'd put mesquite bean seed over it to cover it. When it gets hard, it binds in and holds it together. Then they would break off little chunks and eat it when they wanted to. They would also put it in water and drink it.

Atole and *Pinole*

There are numerous accounts of making a drink, gruel, mush, or even a pudding from the mesquite pods, seeds, flour, or the cakes. Most of these are variations of *atole* (a beverage made by mixing a toasted meal to water) and *pinole* (similar to *atole*, but thicker like a gruel or porridge). Beverages were made from the meal mixed with water, which could also be fermented to make a beer-like beverage (Rea 1997:187). The Mescalero and Chiricahua Apache made *pinole* out of the mesquite flour. They also boiled the whole pods (seeds included) in water until the mixture turned red, took out the pods, mashed them by hand, and returned them to the liquid, which was then boiled down into a kind of pudding (Castetter and Opler 1936:41). The San Carlos Apache had a different method of mesquite consumption. After pounding the pods in a bedrock mortar, they soaked the pulp in cold water, squeezed it out by hand through a straining basket, threw the remainder away, and drank the sweet liquid (Bell and Castetter 1937:24). Another of their methods was to pick the seeds from the broken pods and discard them, pound the crushed pods thoroughly to a pulp, and then mix them with warm or cold water, eating the dish as a mush without boiling (Bell and Castetter 1937:24). The White Mountain Apache crushed the pods in a bedrock mortar, mixed the pulp with water, and cooked it or ate it raw (Reagan 1929:145). The Walapai mixed the pulp with water and a little salt and then drank or ate the mixture (Kroeber 1935:53). The Havasupai gathered the dry pods in September and pounded them on a grinding slab, winnowed the hard seeds from the mashed pod, discarded the seeds, and soaked the pod meal in water for several hours to make a beverage (Bell and Castetter 1937:25). The Seri commonly mixed the mesquite flour with water to make a *pinole* or *atole*, sometimes adding flour from palo verde seeds to the mix (Felger and Moser 1985:339). They also placed the dry pods (or alternatively, the endocarps with the seeds in them) in a vessel of water, weighted them down with a stone, and left it until the water became sweet and formed a refreshing juice or a fermented beverage (Felger 1977:160; Felger and Moser 1985:340).

Processing the Seeds

As described above, during the first pounding in the large mortar, the endocarp containing the seed was separated from the pods, which were processed separately. For the Seri and several other groups such as the Hia C'ed O'odham (Felger 2007:163), Shoshone (Fowler 1995), Walapai (Bell and Castetter 1937), and Warihio (Gentry 1963), a second round of pounding focused on breaking open the hard outer shell to free the soft seed. Most Historical period tribes, however, appear not to have used the mesquite seeds, although the pods (mesocarp) were widely used (Castetter and Bell 1937). The Cocopah, for instance, generally did not eat the hard seeds, although occasionally they would grind them into coarse meal (Alvarez de Williams 1983). Although breaking the endocarps does not have the associated issue of stickiness that the pods do, mortars were also the chosen tools. A metate would not work because the hard endocarps would immediately escape, and a crushing motion would be more effective than a grinding one. Gyratory crushers found in the Pinacate region and other places probably were used to process mesquite seeds (Hayden 1969) (see below). Overall, mesquite seeds are hard and require extra effort to break. J. Adams (1997:27) has noted that "once the pods were broken apart with mortars and pestles, they could be reduced further with a mano and metate."

As discussed above, the ethnographic literature is not always consistent in its use of "seed" versus "bean" (the two terms are often confused) and caution is needed when interpreting the various sources on the use of mesquite seeds. Some of the most reliable reports on the use of mesquite seeds are Bell and Castetter (1937), Bohrer (1970), and Felger and Moser (1971, 1985). However, Bell and Castetter (1937:22–30) noted few instances of mesquite-seed use, and when they did, not much information was provided on how the hard endocarp was cracked. Much of this knowledge seems to have been lost. Case in point are the Akimel O'odham, for whom Russell (1908:75) reported that, after separation, the seeds were parched by tossing them up in a basket of live coals, then reduced to flour by grinding, after which they were prepared and eaten as *pinole*. Yet Rea (1997:187) noted that the "use of parched mesquite seeds must have been abandoned long ago; not one of the (Akimel) consultants with whom I worked knew about (or remembered?) a mesquite-seed *pinole*." As commented by Julian D. Hayden, who worked with the Akimel O'odham in the 1930s: "The Pima avoided cracking the mesquite seeds by always pounding the pods in a wooden mortar with a stone pestle or a stone mortar with a wooden pestle because stone on stone would produce sharp-edged seed fragments" (Rea 1997:187). For the Tohono O'odham, Castetter and Underhill (1935:24) noted that the "pods were flailed to beat out the seeds, the whole then winnowed in a basket and the seeds parched and stored" but they did not tell how the seeds were actually processed. We can only guess whether or not, prior to storage, the seeds were parched, endocarp and all, or the endocarp was removed first. The same is true for the information on seed processing in Bell and Castetter's (1937) survey of mesquite use. The only information is for the Walapai, and it is minimal at best: "Occasionally, the seeds were crushed and eaten as mush, or the flour made into loaves and wrapped into rabbit skins to facilitate transportation" (Bell and Castetter (1937:25). The Warihio of northern Mexico (the upper reaches of the Mayo and Chínipas Rivers in Sonora and Chihuahua) similarly prepared both pods and seeds (Gentry 1963:93). The meat of the pods was cooked by boiling in water; the seeds were roasted and ground.

The best—although still rather sparse—information about mesquite-seed processing comes from the Seri (Felger 1977; Felger and Moser 1971, 1985). The Seri usually accomplished this second stage of pounding in a stone mortar, which has better abrasion than one made of wood. For the same reason, stone pestles were preferred. Although no good ethnographic information exists, one would surmise that a vesicular material would work best. A vesicular rock would be constantly rough: new pores would be opened as old ones wore away. The pounding breaks open the hard endocarp, frees the inner seed, and winnowing then separates the two. Following this separation, the soft seeds are turned into flour using a metate and mano. Whereas the O'odham and Warihio parched the seeds before pounding, the Seri appeared to have prepared them raw.

Storage

Whole pods and cakes were stored, but the flour was not because it is hygroscopic and soon becomes hard. Dried mesquite pods could be stored for long periods of time, up to a year or possibly longer, provided they were kept airtight and watertight and were parched first to keep beetles from damaging them. Pods gathered in early summer could easily be stored until the following spring, which was often a food-stressed time of year (Hunt 1960). For mesquite pods and their products, there were two basic kinds of storage: (1) short-term storage of freshly picked pods prior to processing and (2) long-term storage of pods and cakes to last through the winter. One can surmise that there also were differences between storage by mobile hunter-gatherers and sedentary, agriculture-based people. The first would either not store at all, instead taking their product along on the next leg of their seasonal round, or they would cache the food in deep, watertight and airtight pits, or in the case of the Seri, in large ollas. Unfortunately, little information exists on storage by semi-hunter-gatherers such as the Hia C'ed O'odham or the Apache. Sedentary groups stored mesquite products in pits or wicker-type storage bins on house roofs or other elevated places, such as specially constructed platforms of stone or wood.

The Akimel O'odham stored great quantities of pods in granaries made from arrowweed (*Pluchea sericea*) sticks, sealed with a layer of arrowweed and mud (Rea 1997:186). Tohono O'odham stored the collected pods in cylindrical granary baskets, which were placed on their roofs or on platforms (Bell and Castetter 1937:22). The Southern Paiute in Death Valley stored mesquite pods in pits dug into alluvial gravel, uphill from mesquite dunes where damage from rodents living in the mesquite bosques could be minimized (Bean and Saubel 1972:111). The pits averaged 0.6–0.9 m (24–35 inches) below the ground surface, were 1.5 m (59 inches) across at the mouth, and narrowed to 0.6 m (24 inches) in diameter at the base. Sometimes they would line the pits with grasses (*Sporobolus airoides*) or species of saltbush (*Atriplex hymenelytra*). Early settlers in Nevada's Moapa Valley mentioned seeing enormous conical mesquite cakes, weighing from 23 to 27 kg (50 to 60 pounds) each. These dried cakes were stored in grass-lined pits in rockshelters and along the rear walls of Southern Paiute wickiups (Fowler 1995). The Timbisha cached the pods in pots lined with arrowweed and covered them with earth (Fowler 1995). In the fall, the beans were uncovered and processed before the pea weevil (*Brachus pisorum*) emerged, and the larvae were eaten with the flour.

Cahuilla storage facilities were large wicker baskets perched on platforms of poles to keep them out of reach of rodents; the largest of these baskets held up to 15 bushels of pods, enough to feed a family of 6 to 10 people for a year (Bean and Saubel 1972:111). As described by Bowers (1888:5),

> these bins or storehouses are made by twisting willow twigs or arrowweeds into long ropes and sealing one layer over another in a similar manner to the straw-rope beehives we see pictured in old books. This is cemented or plastered on the inside and made airtight. They look like huge bulging jars covered with wicker work, and which hold 10 to 15 bushels each. When filled with pods they are carefully covered to exclude insects or they will soon be perforated and breed worms.

The Cocopah similarly stored the dried pods in "bird's net weave circular granaries" placed on pole-supported platforms (Gifford 1933:267, Plate 33).

Other Legumes: Palo Verde, Ironwood, and Acacia

Although less desirable, other legumes such as palo verde, ironwood, and acacia were also exploited, although processed in different ways. Unlike mesquite, however, mature pods of palo verde and ironwood have no nutritious mesocarp and the seeds were the primary food source. Other big differences are that their pods are not as sticky and the seed coats not as hard, and they could thus be ground more easily on a metate (Castetter and Underhill 1935:45). For the Tohono O'odham, ironwood and littleleaf palo verde immediately followed mesquite in importance as wild protein sources (Nabhan et al. 1979). But unlike the dependable mesquite, yearly variability in palo verde and ironwood crops was expected because of the plants' dependence on rainfall for pod production (Nabhan et al. 1989).

Both species of palo verde found in the Arizona portion of the Sonoran Desert—foothill or littleleaf and blue palo verde—grow along washes on the *bajada* below the White Tank Mountains, west of the project area (Keil 1973). Ribbon-like stands of these trees, in particular foothill palo verde, would previously have been found within a short distance from the project sites. Both trees have mature seeds from May into August, usually a little earlier than mesquite, before the summer rains start (Hodgson 2001:164; Turner et al. 1995). Mature seeds are available at about the same time that saguaro fruits ripen. The fruiting of the palo verde is earlier in years when winter rains have been bountiful (Hodgson 2001:167). Indigenous people in the Southwest ate the sweet young seedpods of littleleaf palo verde as snacks, and ground the mature seeds to meal, often mixed with mesquite or ironwood flours (Hodgson 2001:164–167). The seeds of blue palo verde are bitter tasting and harder than those from littleleaf palo verde, and they were used less commonly (Hodgson 2001:165).

Because palo verde ripens earlier at lower elevations, gatherers would start on the lower elevations, following the ribbons of trees and moving upward on the *bajada* as the season progressed. After collecting them in a basket, palo verde pods were laid on the ground, beaten or stirred with sticks to release the seeds, which were then parched or toasted and then ground, or the parched seeds were stored whole. The meal was dampened with some water and then eaten as a gruel or *atole*, sometimes mixed with some ground saguaro seeds or mesquite flour. In Baja California, the Seri Indians relied on palo verde seeds for a staple (Felger and Moser 1985:324). The Seri ate the flowers, and shelled, toasted, and ground the seeds to a flour that could be stored in vessels (Felger and Moser 1985:324). Hia C'ed O'odham gathered large quantities of palo verde pods, shelled and ground them, mixed them with deer fat or water, and then baked them in pit ovens to form a breadlike mass (Bell et al. 1980). The Cahuilla similarly ground the seeds into flour, mixed it with water and ate it as *atole* or used it in mush or cakes (Bean and Saubel 1972).

Ironwood seeds are a good protein source, and parched seeds have a protein efficiency ratio three times higher than that of uncooked seeds (Hodgson 2001:170). The fruits begin to ripen in May or June, and fall on the ground 4–8 weeks later, from July to August (Shreve 1964). After gathering, the pods were first laid on the hard smooth ground and the seeds beaten out with a stick. Ironwood seeds are bitter and were generally leached before preparation, making them one of the few Sonoran Desert plant foods that were cooked in multiple changes of water (to rinse them) or water leached (similar to what was done for acorns). One method was to soak them in water for several days, often followed by boiling (Gifford 1932:211 [for the Southeastern Yavapai); Gifford 1936:258 [for the Western Yavapai, who stone-boiled the seeds in a basket or pot]; Hrdlička 1908 [for the Akimel O'odham, who put the seeds in deep baskets hung overnight in the swift current of the river]; Felger and Moser 1985 [for the Seri]). Another method was first to grind the seeds coarsely and put them in a dampened pit, which was then covered and allowed to sit overnight (Rea 1997). After leaching, Yavapai women dried the seeds and then parched them with coals in a basket (Gifford 1932:211). Next, the seed hulls were cracked on a metate, winnowed in a basket to remove the hulls, and sometimes soaked again to remove any lingering bitterness. Finally, they were ground on a metate and the meal, which was "very greasy," was eaten dry or made into cakes, which similarly were greasy. Some Akimel O'odham just parched the seeds without leaching and then ate them like that (Russell 1908) or ground and mixed the flour with water to make *pinole* (Curtin 1949). Overall, though, it appears that substantial amounts of water were needed to make the seeds more palatable. Felger (1977) noted that indigenous people in central and southern Baja assumed ironwood seeds to be inedible, likely because, lacking abundant water, they never attempted to leach them.

Various acacia species were prepared in similar ways; they matured at roughly the same time as ironwood and palo verde. For instance, the seeds of catclaw acacia (*Senegalia [Acacia] greggii*), which grows near the project area today, were parched, pounded, and ground into a coarse, nutritious meal that was made into *atole* or cakes by various indigenous people of the Sonora Desert (Barrows 1900; Bean and Saubel 1972; Castetter 1935).

Small Seeds: Grasses and Weedy Annuals

Small seeds of grasses and various weedy annuals were a much-favored food of desert dwellers. Since early prehistory, wild grasses have played a major role in many subsistence systems around the world. Accumulating archaeological evidence indicates that this is also true for the U.S. Southwest. Grass grains are often abundant in macrobotanical samples from habitation sites, although few of the various grain types can be identified to species. Paleoethnobotanists in the U.S. Southwest often do not distinguish between "economic and noneconomic" (economically important and unimportant) grasses in macro- or microfossil collections, although doing so is theoretically possible. Separating grasses has not been viewed as a critical research objective, although this perspective is now changing. Certainly, the ethnobotanical literature reveals that wild grasses were an essential food source for Native Americans of the U.S. Southwest (Doebley 1984; Ebeling 1986). For instance, the important role that grasses played in the native economy of the Yumans is highlighted by the fact that of the 29 identified wild or weedy species that yielded seeds important as food, 7 are grasses (Castetter and Bell 1951:187). In contrast to mesquite, however, these grasses and other small-seed–bearing plants are facultative wild crops, meaning they are dependent on short-term conditions such as rainfall to bloom and fruit. In the Sonoran Desert, unlike what we know for mesquite or saguaro, no special species of grasses were targeted to the degree that special expeditions were made or people set up camps near the resource. This is different along the lower Colorado River or in grassland environments, where wild cereals formed a much bigger part of the subsistence economy.

The seeds of these plants were prepared as food in various ways. Among the O'odham and Yumans, various methods were used to separate grass seeds from the spikelets (Castetter and Bell 1951:188; Castetter and Underhill 1935:24). One approach was to beat seeds off the plant into large baskets or to strip them by hand into smaller baskets. Another method was to place whole plants on a fiber mat and beat out the seeds with a stick. Yet another method was to burn a large bundle of plants and sweep the seeds off the ground. To prepare grass seeds for storage, they were first basket-winnowed and then parched and sun-dried in wide-mouthed bowls or baskets (Castetter and Underhill 1935:24–25; Russell 1908:68–69). Winnowing was accomplished by shaking the seeds horizontally in a flat basket, jogging the basket occasionally to bring the chaff to the upper edge and allowing the wind to remove it. After this initial processing, grass seeds were parched before grinding. A few embers were placed in a container along with the seeds, and the container was shaken constantly to prevent burning. An olla with at least one broken side sometimes was used for this purpose (Russell 1908). Russell (1908:68) described the parching process of the Akimel O'odham:

> The coals are raked into a parching pan and after the grain has been thrown upon them it is given a series of tosses with a quarter-turn to each which redistributes the light but bulky coals and the heavier grain. A frequent puff of breath carries away the quickly gathering flakes of ashes. The contents of the pan are separated by a few short jerks that carry the coals in a mass to the edge of the dish, whence the larger particles are scraped off and the smaller blown out.

The parched grass seeds were ground into flour that was used to make a beverage, a cooked cereal, and baked foods.

Panicgrass (*Panicum* spp.) seeds contain about 15 percent protein (Earle and Jones 1962:136), and Saunders (1919:136) concluded that its nutritional value was similar to that of millet. The Cahuilla first singed the seeds to remove hair and then boiled them for several hours (Bean and Saubel 1971:98). For the Cocopah, panicgrass was so important that they planted it in the sandy mudflats along the Colorado River channel (Kelly 1977:37–38). After harvesting, the seeds were winnowed and stored for winter use. When used, "it was ground, mixed with water, and the mass kneaded into hard cakes which, when dried in the sun, were ready to eat. Gruel and mush were also made of the flour" (Castetter and Bell 1951:170–171).

At least five species of saltbush (*Atriplex* spp.) growing in the Sonoran Desert were used for food, supplying edible seeds and also leaf matter (Hodgson 2001:150). Saltbush seeds contain about 12.5 percent protein (Earle and Jones 1962:227). The Cahuilla harvested the seeds from July to September, using a seed beater and gathering basket (Bean and Saubel 1971:45). The seeds were pounded to separate the seeds from the bracts, and then parched, ground into flour, and mixed with water to make gruel (mush) or small cakes. The cakes could be stored for long times. The Akimel O'odham dried, parched, and stored the seeds. To remove their salty taste, the seeds were first steam-baked by placing them on the inner papery bark of cottonwood with iodinebush (*Allenrolfea occidentalis*) in a heated hole in the ground. They covered the hole with additional vegetation and then baked the mass for 1 or 2 days (Hodgson 2001:150). As reported by Kelly (1977:39), the Cocopah had a similar, although simpler method:

> The seeds were beaten off the plant into a basket with a stick and were then winnowed. To prepare the seeds for eating, a small hole was dug and lined with hot coals. The seeds were poured on top of the coals and covered with another bed of coals, and then everything was covered with dirt and allowed to cook for about three hours. When removed, the seeds were parched, ground on a metate, and eaten dry, or boiled in water to make mush.

Indianwheat (*Plantago* spp.) is a winter/spring annual (February–April) that can form dense carpets of low ground cover after adequate winter rain, and it may flower a second time after wet monsoon season. Seeds are usually available from late spring to early summer. The Akimel O'odham threshed and winnowed the seeds and then added water to make a beverage, or they toasted and ground the seeds to make gruel or cakes (Rea 1997; Russell 1908). O'odham people ate the seeds uncooked or toasted and ground them to make a *pinole* (Castetter and Underhill 1935). The Seri considered Indianwheat an important food, mixing the seeds with water, using the glutinous mass as is, or soaking it in water to make a cooling drink (Felger and Moser 1985).

Purslane seeds were commonly used for food, available summer though the fall (Adams 1988:416–423). Because the plants often form dense ground cover, large amounts of seeds could be quickly collected, winnowed, sifted, and ground. Immature plants could also be gathered because they matured even after having been picked. The Zuni gathered the plants when still in flower, placing them in large piles on mats to dry, after which they beat the pile of plants to release the mature seeds (Cushing 1920).

Horse purslane is a succulent-like, herbaceous perennial, which has small edible seeds and was also used as greens. The Cochimí of Baja California collected the seeds by pulling up the plant and releasing the seeds on their tray baskets (Hodgson 2001:76), but overall there is little information on the use of the seeds as food.

Goosefoot and pigweed (*Amaranthus* spp. and *Chenopodium* spp.) were used in similar manners as both seeds and greens. The seeds of various goosefoots were eaten after being parched and ground into flour. In a good year, mass quantities could be harvested and stored (Barrows 1900). The Northeastern and Western Yavapai gathered the seeds of goosefoot in the fall (Gifford 1936). They collected the inflorescences with mature seeds in conical burden baskets, spread them on a flat surface, and beat them with a stick. The winnowed seeds were parched with coals in a basket, then ground, boiled, and eaten.

Pigweed seeds were collected in summer through fall. Kelly (1977:36) provides detailed descriptions of collecting and processing methods used by the Cocopah. Collecting the seeds involved breaking off the inflorescences into a basket that was carried to a collecting/trashing area. Women might also simply pull the plant over the basket and rub the seeds off between their hands. At camp, the inflorescences were put in piles, which were then beaten with a stick to remove the seeds. The seeds were then pounded in a mortar with a pestle and winnowed to separate the chaff. The seeds were then ground into a meal with a metate and mano, and this meal was eaten uncooked or added to boiling water to make a mush. The Cocopah also made cakes by mixing the flour with water. The cakes were about 2.5–5.0 cm (1–2 inches) thick and 17–25 cm (7–10 inches) in diameter.

Berries

Wolfberry and hackberry pollen types were identified in the analyzed project samples, indicating that these species grew nearby (wolfberry was actually found growing in the project area) and may have been used by people living at the project sites. Most edible desert wolfberries (*Lycium macrodon*) flower from March to May, with the berries collected from June through August (Hodgson 2001:236). People collected wolfberries in a basket and then generally washed, dried, boiled, and ground them. They mixed the meal with water to make a beverage or stored the fruits in gourds, ollas, or watertight baskets. The mass was later eaten as is, or pulverized, mixed with water and drunk. The berries were also eaten raw as a snack, sun-dried, and cooked in water to make soups, sauces, syrups, and beverages (Hodgson 2001:236–237; Rea 1997:144). Sun-dried berries store well and were reported to taste sweeter after drying (Hodgson 2001:236; Rea 1997:144). Tohono O'odham collected the berries and sold them in 10-pound bags, indicating that considerable quantities could be collected.

Desert hackberry fruits mature in the summer and fall; they are small and pulpy and contain a relatively large stone. The fruits have a relatively high percentage of crude protein, phosphorous, and calcium (Everitt and Alaniz 1981). In the Southwest, use of hackberry fruits is reported for most indigenous cultures. Northeastern and Western Yavapai gathered the red fruits in June, then pot-boiled and ground them into a meal on a metate (Gifford 1936). The meal was mixed with some water and kneaded into cakes, which were dried for storage. Another method was simply to dry the fruits, which could be reconstituted when needed.

Greens

Various greens were used, usually gathered from spring through summer in washes or disturbed areas such as fields or residential sites. The O'odham diet included stalks or leaves of lacy ragweed (*Ambrosia tenuifolia*), lambsquarter (*Chenopodium album*), nettleleaf goosefoot, fringed pigweed, carelessweed, canaigre (*Rumex hymenosepalus*), dandelion (*Taraxacum officinale*), and saltbush (Castetter and Underhill 1935:14). Some of the greens were first cooked (e.g., in soups), others were eaten fresh immediately, and none were stored. Amaranths and various *Chenopodium* plants are commonly called "desert spinach" or *quelite* and were prepared like spinach. Amaranth was (and still is) widely used as greens by the Akimel and Tohono O'odham, who boil the tender leaves and tips of stems in water (Nabhan et al. 1982; Rea 1997). Some of the lower Colorado River tribes did not just boil the greens but also rolled the cooked greens into balls that they baked on hot coals (Castetter and Bell 1951). The Cocopah laid a thick layer of amaranth leaves on a bed of hot coals, mashed the leaves down, and packed the mass with their feet (Kelly 1977). Other dry and green plant matter was put on top and set on fire. The mashed amaranth leaves were allowed to bake for about 3 hours, after which time the baked "cakes" were cut up and eaten. Like most *quelites*, the young *Chenopodium* herbage was gathered and boiled alone or with other foods. Saltbush branches were used for seasoning, either in cooking or in pit-baking. The leaves and young shoots were harvested from April through September and used as greens, imparting a salty taste when added to other foods (Hodgson 2001:151). Purslane, a plant found in many parts of the world, is cooked and eaten as greens and is high in vitamin C (Hodgson 2001:221). This plant is one of the best-known and most commonly used edible greens in the Southwest, where it germinates after the summer rains. The greens are sometimes available in grocery stores in Tucson. Horse purslane was also (although less commonly) cooked as greens by O'odham people (Nabhan et al. 1982; Pennington 1980). The young stems and leaves of wild buckwheat were collected in spring and eaten raw, boiled, or pickled (Bean and Saubel 1972; Hodgson 2001:219).

Cacti and other Succulents

Among the succulent plants favored by the O'odham were saguaro, cholla, prickly pear, agave, and yucca. The plants were boiled or roasted (Castetter and Bell 1942:59; Rea 1997; Russell 1908; see Gifford [1936] for the Yavapai). Cholla and prickly pear would have grown close to the project area, with saguaro dense on the upper *bajada*, about 10–15 km (6–9 miles) to the west. Agave grows along the mountain flanks, but yucca does not grow in the area at all today, although it may have at the time the sites were occupied, given its possible presence in a pollen sample from the project. The most important of the cacti was the saguaro, whose fruit yielded nutritious beverages and jams (Crosswhite 1981). The saguaro fruit pulp also was eaten fresh, and the seeds were parched, ground, and eaten as cakes (Castetter and Bell 1937:13; Castetter and Underhill 1935:20). Each O'odham family had an established camp for the collection and processing of saguaro fruit to which they returned year after year. Saguaro fruit was picked in July in a season that lasted approximately 2 weeks. The fruit was collected from a region roughly 260 ha (1 square mile) in size.

Cholla collecting and processing followed a pattern different from the one established for saguaro. The buds of the cholla were gathered in May and the fruits in late summer. Cholla buds have high calcium content, can be gathered in large quantities, and were baked and preserved for year-round use. The fruit and young stems of cholla could be eaten in times of greater need (Castetter and Bell 1942:59–60; Castetter and Underhill 1935:14–15, 23). Small parties of Tohono O'odham women collected cholla buds in coiled baskets using only wooden tongs, and they then brought the collected buds back to a central location close to the source. When all the gathering parties arrived, a pit was excavated and filled with rocks, and a fire of mesquite wood was burned over the rocks (Castetter and Underhill 1935:15). The usual pit size was 1 m (ca. 3 feet) in diameter with a depth of 0.5 m (20 inches). It was common to line the pit with rocks to avoid contamination with sand. Once the rocks were hot, the pit was emptied. It was then refilled in a series of layers: a lining of grasses or bush seepweed (*Suaeda nigra*), the cholla buds or fruits, and the hot rocks. This grass-cholla-rock layering was repeated until the pit was filled, and it was then covered with dirt and left to bake overnight. After baking, the cholla was spread out and dried. The dried buds were then boiled or ground into a meal, which was often used with other greens in a sort of vegetable stew (Castetter and Underhill 1935:16). Doelle (1980) has presented estimates of the amount of calories used to gather and process cholla in relation to the amount gained by eating them. Although much less nutritious than saguaro, cholla buds were nevertheless an important food source in late spring when, after a long winter, people would have benefited from the nutritional bounty of cholla buds.

In summer, O'odham women collected prickly pear fruit with tongs, piled the fruits on the ground, and removed the spines by brushing them with creosote bush branches (Castetter and Underhill 1935:23). The fruit was then taken back to the village and eaten fresh or processed into syrup. The latter activity required a hearth and ceramic containers (Fontana et al. 1962).

According to ethnographic accounts, agave was a dietary staple of many indigenous peoples in arid portions of North America (e.g., Castetter et al. 1938; Dobyns 1988; Doyel and Eiler 2003; Nabhan 1985; Parsons and Parsons 1990). Although it never would have grown naturally at low elevations such as in the project area, agave grows in the White Tank Mountains, less than 15 km (9.3 miles) to the west. By the Classic period, however, the Hohokam were cultivating domesticated varieties in low-lying areas of the Phoenix Basin. Agave food products are heavy and take considerable effort to carry over long distances. Therefore, it was usually processed close to the source in places with ample fuelwood for the roasting process. Bean and Saubel (1972:31–36) provided a good description of agave collection and processing among the Cahuilla of southern California. The Cahuilla ate three parts of the plant—the flower, leaves, and stalks (primarily the lower part of the stem, also termed the agave "heart")—which were available in different seasons. Agave-gathering areas were generally 8–16 km (5–10 miles) from villages and were owned by Cahuilla sibs and lineages. When the plants were ready to harvest, male representatives from each family who owned the particular territory traveled to the gathering areas and selected the best locations for that year.

Agave flowers are available from April through August. The flowers were parboiled (i.e., partial boiling of food to remove poisonous or foul-tasting substances from foodstuffs) to release bitterness, after which they were eaten or preserved by drying. The leaves could be collected throughout the year, although they were best from November through May. The leaves were generally collected with the stalks, which were the Cahuilla's favorite part of the agave, from April through the summer months. The stalks were carefully selected for harvesting. Only those that had reached a height of 1.2–1.5 m (4–5 feet) and had not yet blossomed were collected. Furthermore, not all suitable plants were harvested in one gathering. Instead, some plants were left for processing later that year. A group of men could collect several hundred kilograms of stalks in a day, with a dozen or more stalks gathered per hour. The tools used in gathering were relatively simple. Leaves were removed with a mescal cutter—a shovel-shaped, hardwood tool with a sharp, fire-hardened edge. Stalks were detached from the plant by means of a sharp, pointed pole made of oak or ironwood. Like cholla fruit, agave was baked in a pit, which was much larger (1 m [39 inches] or more in diameter), and is commonly termed an *horno* (oven) or mescal pit. Bean and Saubel (1972:34) described the process:

> A pit about three feet deep and five feet long was dug by hand or with an agave shovel in sandy soil. A large rock was placed in the center of the pit and smaller rocks were placed around it. Logs were next placed in the pit and permitted to burn into a bed of long-lasting coals. The coals were covered with a layer of rocks, and agave stalks and leaves were laid across these rocks. The pit was then covered with grass and leaves to facilitate steaming and enhance the flavor of the roasted stalks. Several bushels of stalks and leaves could be roasted in one pit. The cooking process lasted three nights.

Fauna

A variety of large- and small-game animals found between the mountains and river would have been potential prey for the hunters residing in the project area, including mule deer (*Odocoileus hemionus*), desert bighorn sheep (*Ovis canadensis mexicana*), pronghorn, and javelina (*Pecari tajacu*) in the mountains and upper *bajada*, with leporids and a host of rodents, birds, reptiles, and perhaps amphibians on the lower *bajada* and along the river nearer to the project area (see above and also Chapter 4, this volume, for the actual animals exploited in the project area). Hunting camps would not be expected on the lower *bajada*, but in the grassland areas on the upper *bajada* and in the canyon mouths where the larger game was found and water sources were available. Hunting on the lower *bajada* would largely have been opportunistic. There is ethnographic evidence, however, of hunting drives in open, flat areas of the *bajada* focused on cottontails and jackrabbits (Rea 1998:48–53). Such communal drives (O'odham *shaada*) were usually festive, especially occasioned when different families converged in one place. Drives were done by encircling a large horseshoe-shaped area (up to 3 km [2 miles] in diameter), with drivers chasing animals into the circle, which was then narrowed, after which animals were killed with rocks, clubs, and arrows. The small animals were baked whole in pits or grilled on the hot coals of surface fires. Pits for communal roasting would have been large, but cooking of opportunistically caught small animals was done in small pits. The Hia C'ed O'odham baked desert tortoises by placing them on fire-heated rocks in a pit, which was then covered (Doyel and Eiler 2003).

Food-Processing Technologies and Expected Archaeological Signatures

The diet of the indigenous groups of the Sonoran Desert included many native succulents, notably saguaro, agave, yucca, cholla, and prickly pear. All of these plants were boiled, roasted, or baked to render their parts edible (Felger 2007; Felger et al. 1992; Gifford 1936; Hodgson 2001; Lumholtz 1912; Nabhan et al. 1989; Rea 1997; Russell 1908; Underhill 1938:31; Zepeda 1985). Other plants processed with heat from a fire included legumes, grasses, and other, small-seed–bearing plants. In general, mesquite pods and the various seeds were parched using hot coals or fire and then ground into flour. Flour might be mixed with water to produce cakes by baking them on hot rocks (or unbaked in the case of mesquite). For the O'odham (Castetter and Bell 1942; Castetter and Underhill 1935; Thackery and Leding 1929) and the Hohokam (Doelle 1976, 1980; Gasser and Kwiatkowski 1991b; McGuire and Schiffer 1982), pit-cooking was one of the most common methods of succulent preparation, although not for saguaro and prickly pear. A wide range of other cooking methods using rocks has been recorded throughout the greater U.S. Southwest. Although hot rocks are frequently associated with pit ovens or roasting pits, they were also an important component of other cooking techniques, such as boiling, grilling, broiling, searing/charring, parching, and contact frying (Ellis 1997; Wandsnider 1997). Ethnographic accounts of traditional hot-rock cooking suggest that the various processes took from just a few to more than 50 hours for different plant materials (Wandsnider 1997:Figure 6).

Using ethnographic data, the first part of this chapter presented methods to process the various food resources suspected to have been used by—or available to—people that occupied the project sites. Importantly, each of the desert plants described above was collected and processed using a distinct set of tools and behaviors. From the ethnographic descriptions, it is possible to identify behavioral sets for each plant that would leave a distinct impression in the archaeological record. It is then therefore possible to predict the types of archaeological features and associated artifacts and other materials that would serve as a "signature" for a given plant-collecting or plant-processing activity. Finding out what these signatures may be is the purpose of the present section, which looks at what may have been preserved in the project's archaeological record as part of the processing of mesquite, palo verde, small seeds, berries, cholla, greens, and faunal resources. This list is shorter than the food suite discussed above because several of these foods can be eliminated as they are not relevant. In particular, saguaro, agave, and ironwood grew too far away and were also absent in the project's analyzed paleobotanical samples.

Based on previous research, archaeological signatures of plant procurement and plant processing consist of thermal features (e.g., features with oxidized surfaces and containing FAR, ash, and/or charcoal), unburned rock features (e.g., threshing areas), middens and other trash deposits, flaked stone debris, specific types of flaked stone tools, ground stone tools, ceramics, and diagnostic paleobotanical materials (including residue on lithic tools and pottery). Other possible signatures—perishables such as wooden grinding implements, seed beaters, and basketry, to name the most likely ones—would only be preserved in protected environments such as caves and rockshelters, and are not part of this discussion (but see Appendix 9.1 for an overview of the various basket types that might have been used at the project sites). Ceramics play only a minor part in this discussion because most Luke Solar project features date to the Archaic period. Furthermore, any processing methods needing much water will be deemphasized. Given the presumed relative dearth of water in the project area, stone-boiling and other water-intensive processing methods were likely not an option and are not discussed here, although small amounts of water were probably used for making gruels and cakes. Animal resources will only be touched upon briefly because the faunal bone collection was too small to suggest that hunting activities were important in the project area. Ethnobotanical data and expected archaeological signatures for selected plant species processed for food purposes with the aid of fire are summarized in Table 85. The reader should note that the expected signatures in the following discussions are for idealized scenarios, in which features still contain their original fill, or at least enough remnants thereof to provide evidence of the primary activities. In reality, of course, the original fill of most pit features will have been cleaned out, with features subsequently refilled with secondary geologic and/or trash deposits.

Mesquite

Mesquite harvesting and processing were likely the primary subsistence activities in the project area. In fact, the project sites are best characterized as specialized mesquite-processing camps. Of the other legumes growing on the *bajada*, palo verde and acacia may also have been harvested but only in small amounts and opportunistically. Ironwood grew much higher up on the *bajada* and needed water for leaching, so it is highly unlikely that its seeds were processed in the project area. Before discussing the mesquite-processing steps and associated archeological signatures, it is useful to recap what we know about the mesquite-harvesting season, what kinds of labor groups were involved, and what the desired end product may have been. In the Sonoran Desert, mesquite was primarily gathered in the summer, usually from mid-June through July, with

Table 85. Processing Methods for Selected Plants of the White Tank Mountains/Aqua Fria River *Bajada*

Family/Species	Common Name	Most Common Habitat	Annual (A)/ Perennial (P)	Harvest Season	Plant Parts Used	Processing Method	Archaeological Correlates			End Product
							Features[a]	Artifacts	Paleobotany	
Asparagaceae (Agavaceae)	agave family									
Agave deserti	desert agave	upper *bajada*; mountain flanks	P	April–August (flowers); November–May (hearths/ stalks)	hearts; stalks; flowers	pit baking; parboiling (of flowers)	large (over 1 m [39 inches] diameter) roasting pit (*horno*)	tabular knives; large flakes with cutting edge; steep-edged scrapers	charred agave parts (monocots)	sliced baked hearts; cakes
Aizoaceae	mesem (iceplants, fig-marigold) family									
Trianthema portulacastrum	horse purslane	lower *bajada*	P	June–September	seeds; greens	parching; grinding; boiling	thermal pit or surface with FAR	metates and manos; ceramics	charred horse-purslane seeds, pollen	cooked greens; cakes, beverages, and gruel (from seeds)
Amaranthaceae (Chenopodiaceae)	goosefoot family									
Allenrolfea occidentalis	iodinebush	lower *bajada*	P	September–December	seeds	parching; grinding; baking (cakes); boiling	thermal pit or surface with FAR	metates and manos; ceramics	charred cheno-am seeds, cheno-am pollen	cakes, beverages, gruel
Amaranthus palmeri	carelessweed	lower *bajada*	A	May–August	seeds; greens	threshing; parching; grinding; boiling and baking (greens)	thermal pit or surface with FAR	metates and manos; ceramics	charred cheno-am seeds, cheno-am pollen	cooked greens; cakes, beverages, and gruel (from seeds)
Atriplex spp.	saltbush	lower *bajada*	A/P	June–August	seeds; greens	parching; grinding; baking (seeds and cakes); boiling	thermal pit or surface with FAR	metates and manos; ceramics	charred saltbush seeds; cheno-am pollen	cooked greens; cakes, beverages, and gruel (from seeds)
Chenopodium berlandieri	pit-seed goosefoot (pigweed)	lower *bajada*	A	June–August	seeds; greens	winnowing; parching; grinding; boiling	thermal pit or surface with FAR	metates and manos; ceramics	charred cheno-am seeds, cheno-am pollen	cooked greens; cakes, beverages, and gruel (from seeds)
Chenopodium murale	nettleleaf goosefoot (pigweed)	lower *bajada*	A	June–August	seeds; greens	winnowing; parching; grinding; baking; boiling	thermal pit or surface with FAR	metates and manos; ceramics	charred cheno-am seeds, cheno-am pollen	cooked greens; cakes, beverages, and gruel (from seeds)
Cactaceae	cactus family									
Carnegiea gigantea	saguaro	upper *bajada*	P	June–August	fruits; seeds	boiling (fruits); parching and grinding (seeds)	thermal pit with FAR	ceramics dominated by jar forms; metates and manos	charred saguaro seeds	syrup (from fruit pulp); cakes (from seeds)
Cylindropuntia spp.	cholla	upper/lower *bajada*	P	April–May	Buds; fruits	pit baking; boiling; grinding	medium-sized (0.5–1 m [20–39 inches] diameter) roasting pit, often rock-lined	ceramics; metates and manos	charred cholla buds/fruits	dried buds; gruel
Opuntia spp.	prickly pear	upper/lower *bajada*	P	May–July	fruits; stems; pads	drying; boiling	thermal pit with FAR	ceramics	charred fruits	cooked stems/pads; dried fruits; juice, syrup, jam (fruits)
Fabaceae	legume family									
Olneya tesota	ironwood	upper *bajada*	P	July–August	seeds	trashing, winnowing, leaching (soaking or boiling), parching, grinding, baking	thermal pit with FAR	metates and manos, ceramics	charred ironwood seeds	cakes, gruel
Parkinsonia florida	blue palo verde	upper and lower *bajada*; drainages	P	May–August	seeds	trashing, winnowing, parching, grinding, boiling, baking	thermal pit with FAR	metates and manos, ceramics	charred palo verde seeds	cakes, beverages, gruel
Parkinsonia microphylla	yellow or littleleaf (foothill) palo verde	upper and lower *bajada*; drainages	P	May–August	seeds	trashing, winnowing, parching, grinding, boiling, baking	thermal pit with FAR	metates and manos, ceramics	charred palo verde seeds	cakes, beverages, gruel
Prosopis velutina	velvet mesquite	drainages	P	June-august	pods, seeds	parching, pounding, winnowing, grinding, boiling, baking	thermal pit or surface with FAR (for parching); non-thermal pits (as basket supports, earthen mortars, cake moulds)	mortars and pestles; metates and manos; pieces of ollas (parching)	charred mesquite pods, endocarp parts, and seeds	cakes; beverage, gruel
Senegalia greggii	catclaw acacia	upper and lower *bajada*; drainages	P	July	seeds	threshing, winnowing, parching, grinding, boiling, baking	thermal pit or surface with FAR	metates and manos, ceramics	charred acacia seeds	cakes, beverages, gruel
Lamiaceae	mint family									
Salvia columbariae	desert chia	upper *bajada*	A	June–July	seeds	parching, grinding, boiling, baking	thermal pit or surface with FAR	metates and manos, ceramics	charred chia seeds	cakes, beverages, gruel
Plantaginaceae	plantain family									
Plantago spp.	woolly plantain, Indianwheat	upper/lower *bajada*	A	May–June	seeds	parching, grinding, boiling, baking	thermal pit or surface with FAR	metates and manos; ceramics	charred wooly wheat seeds	cakes, beverages, gruel
Poaceae	grass family									

Family/Species	Common Name	Most Common Habitat	Annual (A)/ Perennial (P)	Harvest Season	Plant Parts Used	Processing Method	Archaeological Correlates			End Product
							Features[a]	Artifacts	Paleobotany	
Panicum spp.	panicgrasses	lower *bajada*	P	June–July	seeds	parching, grinding, boiling, baking	thermal pit or surface with FAR	metates and manos; ceramics	charred grass seeds, grass pollen	cakes, beverages, gruel
Sporobolus spp.	dropseed	lower *bajada*	P	June–July	seeds	parching, grinding, boiling, baking	thermal pit or surface with FAR	metates and manos; ceramics	charred seeds, grass pollen	cakes, beverages, gruel
Polygonaceae	buckwheat family									
Eriogonum inflatum	desert trumpet	lower *bajada*	P	May–July	greens; achenes	boiling	thermal pit with FAR	ceramics	charred achenes, *Eriogonum* pollen	cooked parts
Portulacaceae	purslane family									
Portulaca spp.	common purslane	lower *bajada*	A	June-August	seeds; greens	parching; grinding; boiling	thermal pit or surface with FAR	metates and manos; ceramics	charred purslane seeds	cooked greens; cakes, beverages, and gruel (from seeds)
Solanaceae	nightshade or potato family									
Lycium spp.	wolfberry	upper/lower *bajada*	P	June-August	fruits	sun-drying and grinding; fresh-boiling	thermal pit	metates and manos, ceramics	wolfberry pollen	soups, sauces, syrups, and beverages; dried fruits for storage
Cannabaceae	hemp family									
Celtis spp.	hackberry	upper/lower *bajada*	P	June-August	fruits	pounding; grinding; boiling, drying	thermal pit	mortars and pestles; metates and manos; ceramics	hackberry pollen	pulp; meal/cakes (for storage)

[a] Not listed are ephemeral features, such as basket, pot, or millingstone rests; only large basket supports (i.e., for mesquite pods) are listed.

harvest completed by the time that the monsoon storms started. The Tohono O'odham gathered the mature pods in late August after the saguaro harvest, but at low elevations—such as in the project area—pods begin to fall by mid-June. Thus, we can state with good certainty that mesquite harvest in the project area occurred before the saguaro harvest, which would have occurred in late July though early August on the upper *bajada*. As discussed above, harvest and processing together may have taken 4–6 weeks. Importantly, this places the mesquite harvest at the height of the summer drought when no water would have been available other than what people brought with them, unless water could be obtained (perhaps by digging) from the elevated water tables at the mesquite bosque.

Mesquite harvest often meant relocation close to the resource. Because mesquite produces a massive quantity of fruit in a short period of time, the crop needed to be harvested quickly and all available labor was recruited. One other reason that the harvest needed to be done so quickly was that neither the pods nor the flour preserve well in the summer humidity. In fact, high humidity is the greatest constraint to a successful crop. In ethnographic accounts, the mesquite harvest was a major communal event, with gatherings involving entire families, including men. Because mesquite was harvested in such large volumes, the baskets, parching features, grinding equipment (pestles "big as a man's leg," often 1 m (ca. 3 feet) long), and storage structures (even if temporary) all were similarly large. If the harvest and processing were accomplished in 4–6 weeks, and if entire and multiple families were present (perhaps groups of 20 or more men, women, and children), archaeologists would expect to find remains of temporary structures.

Another point to consider is whether people were only targeting the pulp (mesocarp) of the mesquite pod, or also the less easily processed seeds contained within the hard endocarp. As discussed above, the pulp is rich in calories and carbohydrates, and it is the most easily accessible edible part of the pod. The hard endocarp containing the seed is indigestible, which of course is how mesquite reproduces, and cracking it to obtain the soft inner seed takes much more effort than obtaining the pod's pulp. Yet, the seed has high protein content and is very edible. It was processed by hunter-gatherers such as the Seri and perhaps the Hia C'ed O'odham, but—at least by the beginning of the twentieth century—not by agriculturalists such as the Tohono and Akimel O'odham and tribes along the lower Colorado River, or by any other people with easy access to mass quantities of pods. Archaic period people, however, very likely consumed both pulp and seeds, and the signatures reflecting this are expected in the Luke Solar project.

Mesquite-pod flour was typically made into storable cakes (little or no water needed) or consumed immediately as *pinole* (more water needed) and *atole* (most water needed). An important question is what end product people desired: were they making storable and transportable cakes for later use or were they consuming mesquite flour mixed with water on the spot as beverages or gruels? For two reasons, making beverages or gruels likely was not an important activity in the project area. First, if the mesquite harvest in the project area occurred during the dry summer season, water availability may have been limited. Second, because mesquite flour spoils quickly in the monsoon humidity (which probably began to increase as the harvest progressed), making cakes would have been the preferred option. Furthermore, cakes did not just store well, they also were highly transportable.

At its most completely accomplished (with not just the pods but also the seeds processed), mesquite production had 15 basic steps from collection to long-term storage (Table 86). For simplicity, the features are grouped into three basic sizes in this table and the following discussions: small (diameter of less than 0.5 m [20 inches]), medium-sized (0.5–1.0 m [20–39 inches] in diameter), and large (diameter of over 1 m [39 inches]). Also, in the table and in the following discussions, "thermal" as a feature descriptor means that the feature exhibited in-place oxidation on its base or walls, but this definition does not necessarily mean that the feature had a thermal (i.e., heat-providing) function. Perishables such as wooden mortars or pestles and basketry are not listed in Table 86 because they would not have preserved at the project sites. Also, although mesquite flowers and green pods were used for food, the first were just a snack food, and the second were never as important as the mature pods. Therefore, the present discussion only focuses on the mature pods.

The first step was to collect the ripe pods from the trees or the ground beneath them and bring the pods to the processing camp in large burden baskets, carrying nets, or blankets. The second step was to temporarily store them on-site, likely in large baskets placed on the ground if it was only for a short duration of time. For longer storage, the pods themselves, or large coiled baskets containing the pods, could be put out

Table 86. Mesquite-Food-Processing Steps and Expected Archaeological Signatures

Step	Basic Activity	Specific Activity	Resulting Feature Type[a]	Diagnostic Materials
1	collect dried pods	in carrying baskets or nets	none	none
2	store dried pods	temporarily in baskets	medium-sized, shallow nonthermal pit as basket rest	none
3a	parch pods	toss in basket with live coals	small thermal pit	FAR, charred pods
3b	parch pods	stir in ceramic vessel on coals	small thermal pit	FAR, ceramics, charred pods
3c	parch pods	toast in hot earth	medium-sized to large thermal pit	charred pods
3d	parch pods	on hot rocks	broad (1 m [39 inches] or more in diameter) thermal surface or large but shallow pit	FAR, charred pods
4	store parched pods	short-term or long-term storage, in large baskets (on ground, roof, or platform) or in pits	medium-sized, shallow nonthermal pit as basket rest; large and deep thermal or nonthermal storage pit, bell shaped or basin shaped	none
5	pound pods	crush or mesh pods in large stone, wooden, or earthen mortars with stone or wooden pestles	small but relatively deep nonthermal pits as mortar supports or earthen mortars (earthen mortars are expected to have well-defined pit walls)	large mortars and pestles
6	winnow	to separate husks, flour, and endocarp-coated seeds	none	none
7	grind pod pulp	into finer flour (optional)	small and shallow nonthermal pit as metate support	basin metates and manos
8a	make cakes	unbaked, in elliptical hole in ground	small but deep nonthermal pit	none
8b	make cakes	baked in hot ashes or on coals	small to medium-sized, deep thermal pit	none
9	store cakes	in storage pit	medium-sized to large, deep thermal or nonthermal storage pit, bell shaped or basin shaped	none
10	pound endocarp-coated seeds	crack endocarps in mortar with pestle to obtain seed	small but relatively deep nonthermal pit as mortar support	smaller mortars and pestles
11	winnow	to separate cracked endocarps and seeds	none	none
12	parch seeds	toss in basket with live coals	small thermal pit	FAR, charred seeds
13	grind seeds	into flour	small and shallow nonthermal pit as metate support	basin metates and manos
14a	make cakes	unbaked, in hole in ground	small but deep nonthermal pit	none
14b	make cakes	baked in hot ashes or on coals	small to medium-sized thermal pit	none
15	store cakes	in storage pit	deep, medium-sized to large, thermal and nonthermal pits, basin shaped or bell shaped	none

[a] Small (less than 0.5 m [20 inches] in diameter), medium-sized (0.5–1 m [20–39 inches] in diameter), large (1 m [39 inches] or more in diameter), broad (1 m [39 inches] or more in diameter).

of reach of animals on storage platforms or on house roofs. Archaeologically, short-term storage in baskets might appear as shallow but medium-sized nonthermal pits in an area that also contained thermal features; longer-term storage on platforms would be indicated by postholes.

The third step was to parch the pods, which was done in at least four ways: (1) toss the pods around in a large basket with live coals, (2) stir them in a piece of an olla placed on hot coals, (3) toast them in hot earth, or (4) toast them on hot rocks. The first method was to place several embers along with the pods in a basket (of a larger size than used to parch small seeds), and toss the contents around by gently shaking the basket. Short-term hearths produced the embers, and the resulting archaeological feature would have been a small, oxidized pit with a fill of FAR. Rocks were put on the fire to choke it, thereby maintaining a steady supply of coals. The second method of parching would have resulted in a very similar feature, but with the possible addition of broken pottery to the fill. The same goes for the third method (toasting in hot earth), except there would be no FAR and the pit would be larger. The fourth method (toasting on hot stones) would have resulted in a broad oxidized surface or large shallow pit with an FAR concentration. All four methods would also result in charcoal, ashes, and perhaps some charred mesquite-pod fragments. A good archaeological example of this method has been provided by the Arroyo de la Presa site in Presidio County, Texas (Cloud 2004). There, a 2-by-4-m (78-by-157-inch) rock cluster (dating to A.D. 1040–1290) contained significant quantities of charred mesquite seeds and pods. It appears that a fire of mesquite and saltbush wood was covered with several layers of stones, after which the plant material was placed on the rock surface for parching. The fourth method, as well as the third (toasting pods in hot earth), would have been especially well suited for processing large quantities of pods, and these are the features one would expect to find at large, specialized mesquite-processing camps, such as in the project area. To summarize, there are at least four different expected types of mesquite-parching features, all possibly including charred pod fragments in their fill: Methods 1 and 2 would result in a small thermal pit with associated FAR and for Method 2 perhaps ceramics; Method 3 would result in a medium-sized to large thermal pit without associated FAR; and Method 4 would result in a broad thermal surface or large shallow pit overlain by a broad cluster of FAR. A fifth type of parching feature is not for the pods, but for parching the seeds (see below). This feature would be similar to the ones described for Methods 1 and 2, but instead of charred pod fragments, its fill would contain charred seeds and seed fragments.

With parching done, the next task (Step 4) was to store the pods in baskets, either temporarily or long term, before further processing. At specialized mesquite-processing sites, this temporary storage was likely more a matter of days than weeks. In the archaeological record, this step might be detected as shallow and wide nonthermal pits serving as basket rests for short-term storage, or as large and deep thermal or nonthermal pits (bell shaped or basin shaped) for long-term storage. None of these features would provide evidence (such as plant materials) of their actual function.

Step 5, pounding the pods, initiated the series of mesquite-processing stages involving ground stone, that concluded in Steps 7, 10, and 13 (see Table 86). Pounding involved mashing the pods to separate the husk (exocarp), pulp (mesocarp), and the hard stony coat (endocarp) surrounding the seed. Step 7 consisted of grinding the pulp to finer flour and was optional. Step 10 was a second round of pounding, now to crush the hard endocarp to free the soft seed inside. Step 13 was to grind the seeds into flour. Thus, great variability in forms and sizes of ground stone are expected: large mortars and pestles used while in a standing position (Step 5), smaller mortars and pestles used while sitting down (Step 10), and basin metates and manos to grind pulp and seeds into flour (Steps 7 and 13). In particular, there would be differences depending on whether it was the pods or the hard seed coats that were crushed. Compared to Step 5, Step 10 needed a smaller mortar and pestle, and this pestle would have been more versatile, serving to crush, pound, and grind. Archaeological features resulting from these four steps would be small nonthermal pits serving as mortar and metate supports. These pits would be shallow for the metates (5–10 cm [2–4 inches] at the most), deeper for the mortars (to 15 cm [6 inches] in depth), and deepest for earthen mortars (30 cm [12 inches] or more). The earthen mortars might be recognized by "polish" or other grinding evidence on their walls. It is unlikely, however, that sediments at the site would have a sufficiently high clay content to permit the creation and use of earthen mortars; the predominance of silt may have made it impossible, or at least not easy, to achieve the degree of compaction necessary to make a usable earthen mortar. After the seeds were released (with mortar and pestle) from the endocarp (Step 10), they were ground into flour with a mano and metate (Step 13). For both Steps 7 and 13, basin metates and manos would be expected, and these would be similar to those used for other seed grinding.

Given that ground stone forms the project's largest artifact collection, it is useful to look at the expected grinding signatures in more detail. For Step 5, deep mortars made of stone, wood, or earth were documented in the ethnographic record; some groups also used a basket-lined pit or a basket hopper. Larger mortars were particularly favored when great quantities of pods needed to be processed. In the scenario where groups of people temporarily relocated to a mesquite source for its harvest, and time and timing were important concerns, one would expect that the faster option—processing while standing up, using larger wooden mortars—would have been preferred. Based on ethnographic data, wooden mortars were preferred for this scenario, especially those of mesquite wood. Wooden mortars were large, about 76 cm (30 inches) tall, 38–51 cm (15–20 inches) in diameter, with a hole about 38 cm (15 inches) deep, and were buried some 38 cm (15 inches) deep in the ground. Women pounded in a standing position, using 0.9–1.2-m (3–4-foot) long cylindrical pestles made of stone or of mesquite or ironwood; that some of these pestles were as big as a "man's leg" indicates that considerable weight was needed to enable heavy pounding. Step 5 pounding could also have been done sitting down, with the preferred pestle made of stone (to maximize weight) and about 38 cm (15 inches) long and 8–10 cm (3–4 inches) in diameter at the working end. Pounding while sitting down was more likely done when smaller quantities of pods were processed. Given that at most archaeological sites (including those of the current project) wooden implements have not preserved, the only remaining artifacts associated with Step 5 would be stone mortars and pestles. One would expect to find the long cylindrical pestles that were used with wooden or earthen mortars, but probably no or only a few large stone mortars of the type used for pounding while standing up (such huge blocks of stone would have been too heavy to carry from the river to the project area). One would expect much higher numbers of smaller stone mortars and pestles of the type used while sitting down. These pestles would not only be smaller, but also be more roughly shaped. Furthermore, they would likely differ from the more formally shaped Step 10 pestles used to crush the endocarps. The ethnographic literature makes little mention of vesicular basalt, but where available, this material was one of the favorite grinding surfaces employed by prehistoric people for processing mesquite. Igneous, basaltic rocks, because of their rough surface, vesicular nature, and hardness, were the rocks of choice, just as they were for manos and metates used in grinding corn. As discussed in Chapter 3 (this volume), the Luke Solar project collection included several different subtypes of cylindrical pestles, but generally they were either very big cylinders—including conical shapes—or smaller squat-shaped examples. The conical pestles were mostly made from vesicular basalt, but the smaller ones were not. The correspondence (or lack thereof) between the ground stone collection from this project and the expected signatures of the four grinding stages is explored and discussed in Chapter 11.

Of the four steps involving ground stone, Step 10 was the most challenging because the endocarps are hard and unyielding and require much extra effort to break open. Furthermore, compared to the quickly produced massive quantities of pulp (20 kg [44 pounds] per person per day, see above), this huge extra effort resulted in only relatively small amounts of seed flour (1 kg [2.2 pounds] per person day at the most). Cracking the endocarps was done sitting down and using stone mortars and pestles, which were smaller than those used for pounding the pods. Wooden mortars or pestles were not used because they were not abrasive enough. Vesicular basalt would have been the preferred material, consistent with the mortars collected from the project sites, most of which were vesicular. Rather than the downward-pounding motion of the Step 5 cylindrical pestle (which would result in the hard and smooth endocarp-coated seeds flying out of the mortar), a simultaneously twisting and crushing motion with a somewhat flattened pestle might have been an efficient way to crack the endocarps. Interestingly, Kroeber (1953:Plate 45) depicts a series of flattened pestles alongside a group of bedrock mortars, and also an oak mortar, all likely used for acorn processing. The analogy with acorn processing is not so strange because acorns are similarly hard, round, and smooth, and may similarly escape from the mortar if an up-and-down pounding motion is used. These pestles look much like the distinctive Lukeoliths defined in Chapter 3, this volume. Lukeoliths are multipurpose, flat pestles, manufactured from fine-grained materials (usually quartzite) and vesicular basalt. (The project's cylindrical pestles were only rarely made from vesicular basalt.) What makes the Lukeoliths so important is not just that they are unique in the archaeological record, but that they may hold the key to aspects of the specific plant-processing activities that occurred at the sites in the project area. Like the cylindrical pestles, Lukeoliths often exhibited polish extending up the tool, which may mean that they were used with wooden mortars (see Chapter 3, this volume). The sheen may also have been caused by the actual plant material being processed, however, which we may be able to substantiate through future plant-residue analysis. Be that as it may, if we can identify tools used to crack endocarps, major progress will have been made in unraveling the mechanics of Archaic period mesquite processing.

Another method to accomplish Step 10 is by using a "gyratory crusher," a stone implement named by archaeologist Julian Hayden (1967, 1969), who first documented these tools in the archaeological record of the Sierra Pinacate of northwestern Mexico. A gyratory crusher is a very distinctive kind of mortar, either in slab or block form, with a hole in its bottom (see Hayden 1969:Figures 1–3). For years, investigators thought these artifacts—which are also found elsewhere in the low desert regions of the U.S. Southwest—were just worn-out or exhausted mortars. But Hayden surmised the hole had a purpose. As it turns out, when a heavy wooden pestle is projected through the perforation in the mortar base and gyrated, the projection provides leverage against the under rim of the hole in such a way that not just the pod husks but also the hard seeds can be cracked. In the Sierra Pinacate, the tool was developed very early in Phase I of the Amargosan-Pinacateno (about 11,000 to 17,000 B.P.), and its use probably spanned three to four millennia; the technology was abandoned after the disappearance of the region's mesquite forests at about A.D. 1100–1200 (Hayden 1967). Similar tools were used later in time in the western Sierra Madre (Hayden 1969:160), Mexico, and also during early horizons in Iran (Hole et al. 1969) and Israel (Stekelis and Yizraely 1963). Two gyratory crushers were also found during SRI's excavations of the Mescal Wash site in southeastern Arizona (Greenwald and Vierra 2011:Figure 99). A modern-day equivalent of the gyratory crusher is a piece of farm and milling equipment called a hammer mill. This tool can crush and grind both the pith and the seeds of mesquite pods and sift out most of the debris automatically, providing great quantities of high-protein mesquite meal with little effort.

For both pods and seeds, the end products likely were the cakes made from the flour. These cakes were usually made in pits, unbaked (Step 14a) or baked (Step 14b), and could be stored (Step 15) or transported for future use (see Table 86). Unbaked cakes could be made by putting flour in a basket or a hole in the ground, and then sprinkling some water on top, after which the cakes hardened by themselves. These cakes were quite large. As described for the Maricopa, the "hole in the ground" was elliptical, 46 cm (18 inches) long by 30 cm (12 inches) wide by 25 cm (10 inches) deep; Southern Paiute made cakes that could be as thick as 60 cm (2 feet). In the archaeological record, making cakes in pits would show up as small but deep nonthermal pits. Cakes could also be baked, but this method required more water. Baking was done by making dough, either by boiling the flour in water or by just adding water and forming the dough into cakes (with shapes including balls and bars), which were then baked in hot ashes. This process would result in small to medium-sized (perhaps about 50 cm [20 inches] in diameter) oxidized pits without FAR and would not contain any paleobotanical evidence as to what was being processed.

Storage of the cakes (Step 15) was the final step. (Temporary storage of the parched pods in baskets [Step 2] and short-term or long-term storage in baskets [on the ground, roof, or platform] or in pits [Step 4] have already been discussed.) The most common scenario for a specialized mesquite-processing camp would be to temporarily store the cakes until all processing was complete, after which they were packed for transport. Cakes would be stored in storage pits or large baskets, and the resulting archaeological features would be deep, thermal or nonthermal storage pits or shallow nonthermal pits serving as basket rests.

In sum, the various stages of mesquite processing required a varied tool kit, primarily wooden and stone mortars and pestles, stone manos and metates, baskets, and after ca. A.D. 1, ceramic vessels (such as pieces of ollas or wide-mouthed bowls [Goodyear 1975:171–174]). Flaked stone artifacts are not expected to have been directly associated with mesquite processing. Baskets and ceramics were the primary storage utensils. Baskets and wooden mortars and pestles would not have survived in the archaeological record at most open-air sites.

Mesquite processing would have resulted in an equally wide range of archaeological features, primarily nonthermal pits and thermal pits and surfaces. Expected nonthermal pits include: (1) small shallow pits (5–10 cm [2–4 inches] deep at the most) serving as basket or metate supports; small, deeper pits serving as (2) earthen mortars (30 cm [12 inches] or deeper), (3) mortar supports (to 30 cm [12 inches] in depth), or (4) cake molds (50 cm [20 inches] or more deep); and (5) larger pits serving to store the cakes (50 cm [20 inches] or more deep). Polish or other pounding or grinding evidence on pit walls might point to their use as earthen mortars. Storage pits could be bell shaped or basin shaped and would also include a thermal variant (see below). None of the nonthermal features would include any paleobotanical evidence pointing to the specific taxa (mesquite) processed or stored in or with them.

Seven different types of thermal features are expected: five types corresponding to different types of parching, one type corresponding to baking cakes, and one type corresponding to storage. The fill of the first four types of parching features might include charred pod fragments and that of the fifth might include charred seeds. Continuing the numbering of feature types from the previous paragraph, these are (6) thermal pit with associated FAR, (7) thermal pit with associated FAR and perhaps ceramics, (8) larger thermal pit without associated FAR, (9) broad thermal surface overlain by an FAR cluster, (10) thermal pit with associated FAR (similar to [6] and [7], except possibly associated with charred seeds instead of charred pods); (11) oxidized pit without FAR and no charred plant materials (cake baking); and finally, for storage, (12) deep bell-shaped or basin-shape pit with oxidized walls and no FAR from its original use. With regards to the parching and storage features, it is important to keep in mind that presence or absence of oxidization on a feature is not always an indication of a thermal function (i.e., heat used to process plants). Thermal and nonthermal features are not always what they seem. On the one hand, low-heat fires used for seed parching may have left little or no thermal evidence on pit walls or a surface; on the other hand, storage pits may have been given oxidized walls to make them more moisture resistant and seal them off.

Diagnostic macrobotanical remains can be expected in all thermal feature types (except those used for baking cakes [11] and storage [12]), but in none of the nonthermal features. No cultural pollen is expected to have remained from any of the 15 steps outlined in Table 86 because the mesquite trees had flowered a month or more before the harvest. The only chance of finding associated pollen would be if the blossoms were prepared, or if pollen still clung to the green pods if these were prepared.

Small Seeds

Results of the paleobotanical analyses suggest that various small-seed–producing grasses and weedy annuals were prepared at the sites (see Chapter 6, this volume). The project's macrobotanical study identified charred grains, seeds, or fruits of horse purslane, cheno-am (goosefoot or pigweed), saltbush (two different species), woolly wheat or Indianwheat, panicgrass, and purslane. Purslane was found in noncultural context and may not indicate food use. Cheno-am (likely saltbush) was also common in the pollen samples, which also included woolly wheat and members of the grass family. With sufficient rain in winter, all these plants could be harvested during the summer. Seed processing had eight basic steps, three of which had more than one scenario, and only one for saltbush seeds, which were baked in pits to remove their salty taste (Table 87).

Based on species, there were several ways to collect seeds: beat them off the plant into a large basket with a stick, strip off the seeds by hand into a smaller basket, carry whole plants or inflorescences onto a fiber mat and beat out the seeds with a stick, or burn a bundle of plants on the ground and sweep off the seeds (as discussed below, only this method would result in a feature). The next step was to temporarily store the freshly collected seed-bearing plants, inflorescences, or already cleaned-out seeds in baskets or ceramic vessels near the processing area. Archaeologically, this second step might show up as small shallow nonthermal pits in an area also containing thermal features.

Of special relevance to the current project is the pit-baking of saltbush seeds prior to parching to remove their salty taste. Akimel O'odham steam-baked the seeds in a "heated hole" in the ground, placing them on pieces of the papery inner bark of cottonwood, together with iodinebush. The hole was then covered with additional plant materials and left to bake for 1 or 2 days. Saltbush, iodinebush, and cottonwood are all available in or near the project area. The "heated hole" likely was a pit in which a fire had been burned, after which rocks were added to retain the heat. Cocopah had a similar but simpler method, pouring the seeds directly on top of a bed of hot coals in a pit, adding more coals on top of the seeds, and then covering the pit

Table 87. Small-Seed–Processing Steps and Expected Archaeological Signatures

Step	Basic Activity	Specific Activity	Resulting Feature Type[a]	Diagnostic Materials
1a	collect seeds	in basket	none	none
1b	collect whole plants	on a fiber mat and beat out the seeds with a stick	none	none
2	store plants/seeds	temporally store the seed-bearing plants or seeds in basket/ceramic vessel	small and shallow nonthermal pits as basket or pot rests	none
3	pit-bake seeds (saltbush only)	in pits	small, relatively deep thermal pit	FAR, charred saltbush seeds
4a	parch seeds	burn bundles of seed-bearing plants on cleared surface	broad thermal surface	charred seeds
4b	parch seeds	toast seed-bearing plant parts on hot rocks	thermal surface with FAR	charred seeds, FAR
4c	parch seeds	toss pods in basket with live coals	small and shallow oxidized pit with FAR	FAR, charred seeds
4d	parch seeds	stir seeds in ceramic vessel on fire/coals	small and shallow oxidized pit with FAR	FAR, ceramics, charred seeds
5	winnow	in baskets	none	none
6	grind	into flour	small shallow nonthermal pits as metate or mortar rests	metates and manos, mortars and pestles
7a	bake flour into cake	on hot ashes, coal, or rocks	medium-sized thermal pits	ash/charcoal, FAR
7b	make flour into gruel or beverage	by boiling with hot stones in basket or ceramic vessel	small thermal pits	FAR
8	store (seeds, cakes)	long-term storage in basket, jar, or pit	shallow nonthermal pits as basket or jar supports; deep, medium-sized storage pits (preferably bell shaped and/or oxidized)	ceramics

[a] Small (less than 0.5 m [20 inches] in diameter), medium-sized (0.5–1 m [20–39 inches] in diameter), large (1 m [39 inches] or more in diameter), broad (1 m [39 inches] or more in diameter).

with dirt. In both scenarios, the resulting archaeological feature would be a small, relatively deep, oxidized pit. After being cleaned out, it would still contain FAR and/or charcoal and a few charred saltbush seeds.

The fourth step was parching, which—like for mesquite pods—was the first and foremost thermal activity, and will therefore be discussed in most detail. Small seeds were parched in four basic ways. Entire seed-bearing plants (such as sacaton grass and amaranths) or their parts were (1) burned on a cleared surface or (2) toasted on hot rocks, and seeds could be parched by (3) tossing them in a basket that also contained hot coals or (4) by stirring them in a basket or on large piece of a broken olla set on hot rocks or coals. The first method would result in an oxidized surface without FAR, and the other three methods would all result in a thermal (i.e., oxidized) surface or pit with FAR. Thus, after building a fire, parching could follow three basic methods resulting in an FAR feature. One method would involve putting stones on top of the fire to create a hot pavement on which plant materials would be placed to parch them through "toasting," much like described for mesquite pods above. After having cooled off, the materials could then be cleaned and winnowed in baskets. A similar surface of hot rocks could have served as a parching platform on which to place one or more ceramic containers (such as a broken piece of an olla) or baskets in which seeds were stirred. The final method is the most common seed-parching technique mentioned in the ethnographic literature. Several embers along with the seeds would be placed in a basket, which was gently shaken until the material was sufficiently parched. With this method, the rock feature would result from putting rocks on top of the fire to choke it and thereby maintain a steady supply of coals.

For all four different methods, parching features are expected to be shallow oxidized pits or surfaces, with or without FAR, and containing a few charred seeds and other plant material as well as fuelwood. The fourth method might also contain ceramics. Ideally, such as at limited-use sites in a stable environment, these types of features should be distinctly visible, with FAR still spatially associated. But at intensively used sites like those of this project, features may have been reused many times, with rocks cleaned out and used elsewhere, preventing us from linking FAR to individual features, although increased FAR densities may indicate where most thermal activities occurred (see Chapter 10, this volume). The first parching method, burning plants on a cleared surface, would appear as an area of oxidized soil upon which—under ideal circumstances—charred seeds and other plant parts would be preserved. But such surfaces do not preserve well, making them rare in the archaeological record. Archaeological evidence does exist for the second method (parching on a hot rock surface) for mesquite pods (Cloud 2004) (see above) and small seeds (Rankin 1989). A rare example of a parching surface in Arizona was excavated at AZ T:3:20 (ASM) along the Agua Fria River in the Northern Periphery of the Hohokam (Rankin 1989:340–341, Figure 13.8). The surface (Feature 113) consisted of a 2.5-m^2 (27-square-foot) pavement of fire-cracked cobbles and boulders without an underlying pit. A flotation sample from beneath the rocks yielded charred cheno-ams, and a pollen sample from the same area contained high-spine composites, suggesting that the feature served to parch small seeds. Likely, as known from the ethnographic record for sacaton grass, masses of entire spikelets or seedpods were spread on the pavement and toasted.

The third method (tossing seeds in a basket with coals) and fourth method (placing seed-filled containers on hot rocks) would both have resulted in a similar type of archaeological feature: a small and shallow pit with oxidized base and walls, FAR in it or nearby, and charred seeds in the fill. Because high heat would have been counterproductive to the parching process, rocks are expected to be only minimally altered by fire, and oxidization might be minimal. In ethnographic accounts, these two parching methods (in particular, the first which used a basket instead of pottery) were the most common. Yet, unless intact features are found, they are difficult to identify archaeologically. At intensively used sites where multiple activities occurred over a long period of time and blurred individual processing episodes, it is often difficult to determine with certainty whether a specific excavated thermal feature was used for this purpose. Unless a thermal feature was sealed off immediately after use, there is no way to tell what was processed in it, or with it, and how processing was done. If such an ideal, sealed feature had been used for parching, excavators might find FAR sitting on top of charcoal, and an ashy matrix containing charred seeds and other parts of economic plants. Clearly, an intensively occupied site is not the best place to study seed-parching processes.

The best places for such a study are less intensively used sites where features and their associated materials are spatially distinct. Because features in these areas are found isolated or in small groups, there is no background noise, and it is much easier to identify associated activities than in the busy matrix of the project sites. For instance, there are large areas in southern Arizona where the most common type of indigenous feature is a shallow thermal pit that perfectly matches the expected signature for parching seeds. As a rule, these features are found in lower-*bajada* settings where grasses and various weedy annuals are common after favorable winter and spring rains. One such area is an extremely arid part of the Sonoran Desert encompassed by the Barry M. Goldwater Range (BMGR) East in southwestern Arizona (60 km [37 miles] south from the project area). Here, large block surveys have identified several thousand thermal features, visible on the surface as concentrations of rocks, which include varying quantities of FAR (Heilen and Vanderpot 2013b). The features are found isolated as well as in small or large groups, often with associated metates and manos. About 100 of these features were considered imperiled and have been excavated. The excavations frequently revealed small, shallow ash-filled pits under or near the rocks. Subsurface pits were not identified at the other features, either because there were no pits associated with the features (i.e., they functioned as surface fires) or the rocks represented cleanouts, with the pits located outside the areas of excavation. On average, the subsurface pits were less than 50 cm (20 inches) in diameter and 5–10 cm (2–4 inches) deep. In most cases, pit walls and bottoms were not oxidized, suggesting that heat had been relatively low, or that oxidization had been lost. The small size of these features, the relatively low heat they were exposed to, and the associated manos and metates argue for a primary function related to parching seeds. This interpretation is supported by the fact that these features typically are found in an environment where grasses and weedy annuals would be the only edible plants. Macrobotanical analyses demonstrated the use of mesquite, acacia, and creosote bush as firewood, and the few identified charred food-plant parts included cheno-am seeds and grass grains. Cheno-ams and Asteraceae found in the pollen assemblage were other indicators of what might have been processed. Most of the few pits that did show oxidization were larger and, based on macrobotanical analyses, largely resulted from baking cholla.

Based on surveys in the Chihuahuan grasslands, Vanderpot (1997:39–41) defined a series of rock-pile feature types associated with grass procurement and processing along the San Pedro River on the lower *bajada* of the Huachuca Mountains. He suggested that the ubiquitous rock clusters represented short-term hearths used to provide embers to parch seeds; circular stone features were inferred to be basket rests; and stone pavements were linked to short-term seed storage in containers, parching, or thrashing. Ground stone artifacts were found in abundance near all types of seed-collection and seed-processing features. The overall land-use pattern consisted of large central base camps surrounded by numerous seed-collecting and parching locales. Rock rings, paved areas, and thermal features at the base camps suggested other plant-processing activities, including baking and storage. The base camps, in turn, were tethered to larger habitation sites located nearby along the San Pedro River. This subsistence economy, based on wild cereals, endured from the Late Archaic period into the Ceramic period. Storage facilities at the lower *bajada* base camps were interpreted as logistical collection centers for wild-grain procurement, presumably in the late summer. The concentric arrangement, extending from outlying seed-parching locales to logistical work camps to central collection areas, functioned as a giant funnel that channeled *bajada* resources to the riverine habitation.

Seed-parching or seed-toasting features are common in Old World archaeology. Typical and ubiquitous components of Egyptian and Near Eastern sites associated with wild-grain collection are thermal features consisting of FAR located in pits or simply resting on the surface. The small roasting pits or hearths have been interpreted as features where wild grain was roasted or parched over heated cobbles (Braidwood and Howe 1960) or where cereal glumes were placed on hot rocks to render them brittle for threshing (Van Loon 1966). An alternative processing method from northern Anatolia mirrors the Native American technique of burning bundles of sacaton grass on a rock surface. Sheaves of wheat were spread over a stone threshing floor and ignited, after which the ash was removed by fanning, followed by winnowing and sieving to separate the grains (Hillman 1984). Clearly, processing methods and archaeological features associated with wild-grain consumption in the Near East (and elsewhere in the world) are not very different from those of the U.S. Southwest.

Whatever the parching scenario, the parched seeds were then basket-winnowed (Step 5) and ground into flour using manos and metates, or perhaps for some species, ground with pestles and mortars (Step 6) (see Table 87). Winnowing would not leave any features or artifacts, but some charred seeds might be accidentally lost and preserved in nearby trash-filled features. The flour could be mixed with a bit of water to make dough from which storable and transportable cakes could be formed (Step 7a) or gruel and beverages could be made (Step 7b). In contrast to cakes made from mesquite pods or mesquite seeds, which needed no fire to harden, the cakes would then be roasted on top of a hot rock surface or in ashes or coal. Cakes could be quite large—Cocopah women made cakes from pigweed flour that were 2.5–5 cm (1–2 inches) thick and 17–25 cm (7–10 inches) in diameter—so these baking pits were likely 50 cm (20 inches) or more in diameter. If preserved, they would be medium-sized pits (50–75 cm [20–30 inches] in diameter by 30–50 cm [12–20 inches] deep), with oxidized walls and a fill containing FAR, ashes, and/or coals. Charred plant parts would include the fuelwood but no evidence of what kinds of materials (cakes) or taxa had been prepared. Making gruel or a beverage (Step 7b) involved adding much water and it may not have been an option for people using the project area. In each case, flour was added to boiling water (in a basket or ceramic vessel), and a thermal pit was used to provide hot stones for boiling.

The last step involved storing the seeds (fresh or parched) or the cakes. Seeds would be stored in airtight baskets set on the ground or in seed jars placed in storage pits, and cakes might be wrapped in fiber material and also placed in storage pits. Thus, expected features are shallow and small nonthermal pits that would have served as supports for baskets and ceramic vessels, and deep medium-sized storage pits, which may be bell shaped or basin shaped, and thermal or nonthermal.

This review shows that a varied set of thermal and nonthermal features would result from the different small-seed–processing activities. Most subtle would be small, shallow nonthermal pits that served as rests for baskets or pots used in short-term storage (Step 2) or as supports for metates and mortars (Step 6); none of these features would retain evidence of their specific function. Larger pits used for long-term storage of cakes and perhaps seeds (Step 8) might be well-defined, bell-shaped or basin-shaped pits, with or without oxidized walls. Most abundant would be the various features associated with parching (Steps 4a–d). All of these would be thermal features, including oxidized surfaces without FAR (Step 4a), oxidized surfaces with FAR (Step 4b), and oxidized pits with FAR (Steps 4c and 4d). The thermal surfaces are expected to be quite large (2–3 m^2 [7–10 square feet]), but the pits would be small and informal. Different types of thermal pits would result from Steps 3 (pit-baking saltbush seeds) and 7a (baking flour into cake). Pit-baking saltbush seeds would result in a small, relatively deep pit with remnant FAR, charcoal, and charred saltbush seeds. Pits used to bake cakes, done on hot ashes, coal, or rocks, might be 50 cm (20 inches) or more in diameter and 30–50 cm (12–20 inches) deep, with oxidized walls and a fill containing FAR, ashes, and/or coals. Charred plant parts would include the fuelwood but no evidence of what kinds of materials (cakes) or taxa had been prepared. Artifacts associated with the various steps would be primarily the basin metates and manos (and perhaps mortars and pestles for some species) needed for Step 6. Ceramics can be expected from parching (Step 4d) and storage (Steps 2 and 8). Diagnostic macrobotanical materials would be the charred seeds and other plant parts resulting from Steps 3 (baking saltbush seeds) and 4a–d (parching). Charred grass seeds are often fragmented, however, hindering identification. In most cases, no pollen would be expected, except from Steps 1b (thrashing), 2 (storage), and 4a and 4b (parching). Most pollen is likely to preserve in areas where harvests were cleaned and stripped of chaff or where entire inflorescences were parched. Grass pollen grains are rarely distinguishable below the family level, with maize being a notable exception. Pollen of other seeds is easily recognized, however, such as that of Indianwheat (plantain), which was identified in 21 percent of the project samples (see Chapter 7, this volume).

Cholla

Cacti, in particular saguaro and cholla, and succulents such as agave and yucca, were an important part of the indigenous diet. Cacti provided edible buds, stems, fruits, and seeds. Ethnographic accounts suggest that thermal processing of certain succulents, such as cholla buds, saguaro fruit, and agave, took place near the source. Harvested cholla, in particular, is heavy and bulky—not a resource that people would have wanted to carry over long distances. Saguaro grows and would have been processed on the upper *bajada*, a considerable distance from the project area. No reproductive parts of saguaro were found in the project's macrobotanical samples, and it is unlikely that saguaro was processed at the project sites. As discussed above, the main aboriginal focus within the Luke Solar project area was the mesquite harvest, which came before—not after—the saguaro harvest closer to the mountains. If people came to the project area after the saguaro harvest, it would be strange not to find charred saguaro seeds in the project samples. They would undoubtedly have carried their fresh saguaro products with them to their next stop. Agave is one of the most important desert succulents used for food in the U.S. Southwest. Agave grows in the White Tank Mountains, some 15 km (9 miles) from the project area, a distance too far to carry these heavy plants back to the project sites for processing. There is no evidence of agave in the project macrobotanical samples. Of all these desert succulents, only cholla would have grown near the project area in numbers significant enough to procure them for processing at the project sites. Cholla pollen was encountered in the project's pollen samples.

Cholla buds were collected in May and June before the monsoon rains, and the fruits were collected in late summer. The buds were favored over the fruits. Basketfuls of buds were carried to the roasting location, and the only material culture used in collecting and processing cholla, in addition to the rocks in the baking pit, were wooden tongs and coiled baskets. Archaeologically, the presence of cholla-processing camps can be inferred from isolated, medium-sized roasting pits, frequently rock lined, and on the surface, visible as piles of FAR (Goodyear 1975:65–76). In favorable circumstances, the pits might contain cactus spines, seeds of inkweed or seepweed (plants used for steaming), low frequencies of cholla pollen, and, of course, FAR, ashes, and charcoal (Greenhouse et al. 1981). Experimental reconstruction of a cholla-roasting pit, followed by excavation 1 year later, revealed the deficiencies of relying on pollen analysis to determine pit function (Greenhouse et al. 1981). Contamination was caused by pollen from plants such as creosote bush and Mormon tea (*Ephreda* spp.) that were attached to the collected buds before processing. Furthermore, the spines were usually removed from cholla buds before roasting (Curtin 1949:58; Thackery and Leding 1929:414). Roasting pits for cholla buds are expected to be sufficiently large (about 1 m [39 inches] wide by 0.5 m [20 inches] deep) to have allowed roasting of a worthwhile quantity of food. Whether artifacts would be associated with such features is questionable because of issues of preservation. The wooden tongs and baskets noted in ethnographic accounts would not have survived in the archaeological record. Also, because cholla is usually transported as plant parts, as opposed to liquid syrup, no ceramic vessels are expected, except in the cases where buds were boiled in a stew. Flaked stone tools are not needed to process cholla, but one would expect metates and manos to have been used in the rare cases where the dried buds were prepared to produce meal.

Greens and Berries

The project's paleobotanical studies suggest that leafy wild vegetables, greens, or desert spinaches, such as amaranths, chenopodium, purslane, horse purslane, saltbush, and wild buckwheat were prepared at the sites. These plants were available from April though September. Preparation methods varied, but most were eaten fresh, eaten like spinach, added to stews, or cooked in soups; none were stored in any fashion. Some of the plants were baked on hot coals, with the greens rolled into balls or made into thick layers, and then eaten. In the archaeological record, this baking activity would appear as an oxidized surface or shallow and relatively wide oxidized pit, containing the charred remains of the plants that were processed amongst the charcoal.

Wolfberry and hackberry fruits may also have been prepared at the project sites. Berries were collected (using baskets) from June through August and eaten fresh, sun-dried, boiled, and ground into flour on a metate. This flour could be mixed with water and baked into cakes. Another way was to just dry the berries and hydrate them later, perhaps the preferred method in the water-poor project area, along with eating them fresh. Archaeological signatures would be manos and metates with diagnostic plant residue and charred remains of the berries in trash deposits in features.

Animals

Archaeological signatures of animal-procurement and animal-processing sites include faunal bone; diagnostic flaked stone tools, such as scrapers, bifaces, and projectile points; and thermal features. Apart from projectile points and debris related to the making and refurbishing of lithic tools, material culture used in game procurement tends to be perishable and difficult to recognize. Faunal bone of small animals is often underrepresented because bone could be ground down on metates and eaten. Larger animal bones may be fragmented because of the custom of breaking bones down to extract the marrow. The project's faunal remains indicate that the site occupants focused primarily on cottontails and jackrabbits consistently over time. In the project area, game procurement appears to have been opportunistic, although it is possible that social drives were held, such as those well documented for groups staying on the *bajada* in late spring and summer (Rea 1998:49–53). Drives resulted in catching dozens of cottontails, rabbits, and rodents, all baked in a celebratory, communal pit. Leporids were cooked by (1) broiling or roasting on top of hot coals in a surface fire or in a shallow pit, or skewered on a stick above; (2) baking in underground pits; or (3) boiling or stewing (Rea 1998:87–91). Boiling and stewing may have been too water-intensive for the project sites, which would leave broiling/roasting and baking as the most likely meat-cooking scenarios. All of these activities would have required some kind of thermal feature, which might still contain burned faunal bone. Communal roasting pits for meat would have been large enough (1 m [39 inches] diameter or more) to cook dozens of animals at once; other roasting pits, used by individual families, would have been small to medium sized.

Summary and Conclusions

Processing Steps and Signatures

A review of the ethnographic literature has helped identify different series of food-processing steps likely practiced in the Luke Solar project area, as well as possible associated archaeological signatures. This examination started with a wide set of ethnographically important plants, and then by process of elimination, this set was narrowed to only a few key plant taxa. Of the various plants reviewed above, only mesquite, small-seed–bearing plants, and cholla are fully considered. Other succulents, berries, and greens are not, either because they are not found near the project area, or because they were not important in the overall subsistence economy at the project sites. Animal processing was also touched upon, but not at great length because it was only of minor importance in the project area. Each of the plants described above was collected and processed using a distinct set of tools and behaviors, and different behavioral sets for each plant would have left a distinct impression in the archaeological record. Thus, it is possible to infer the types of archaeological features and associated artifacts that together form a signature for a given plant-collecting or plant-processing activity. Now, in conclusion, summaries are presented concerning the four most relevant signatures expected at the project sites: features, FAR, ground stone, and paleobotanical materials. For reasons explained more fully above, flaked stone and ceramics are not considered. Also not considered are processing methods that would have required large amounts of water.

Features

As discussed above, for this signature we considered only ideal preservation circumstances in which features were perhaps cleaned out to obtain the processed food but were only minimally disturbed after that time. Thus, these ideal features would retain all their diagnostic traits such as FAR and charred plant materials. Although this is rarely an archaeological reality, certainly not at habitation sites or intensively used processing camps, it is the only way to construct a behavioral baseline. In classifying features, presence or absence of oxidization (thermal or nonthermal) and FAR are considered, and so are associated ground stone and diagnostic paleobotanical materials. Table 88 lists the feature types that would have preserved at the project sites under ideal conditions. Eight of the feature types used for plants are thermal (oxidized) and seven are nonthermal (not oxidized). Nonthermal features are all pits used for storage (n = 3), ground stone supports (n = 2), as mortars (n = 1), and as cake molds (n = 1). Thermal feature types include surfaces and pits that

Table 88. Expected Processing Signatures in the Luke Solar Project Area

Feature Type	Feature Description[a]	Feature Function	Activity	Associated Ground Stone	FAR (Yes/No)	Paleobotanical Evidence
	Nonthermal Features (Not Oxidized)					
1	small, shallow basin-shaped pit	basket or pot rest	short-term storage of seeds	none	no	none
2	medium-sized, shallow basin-shaped pit	basket rest	short-term storage of mesquite pods	none	no	none
3	deep medium-sized bell-shaped or basin-shaped pit	storage pit	long-term storage of parched mesquite pods or mesquite/small seed flour cakes	none	no	charred mesquite pods
4	small, moderately deep pit	mortar support	pounding (mesquite pods and endocarp-coated seeds, small seeds)	large mortars and long pestles (pods); smaller mortars and shorted pestles (seeds)	no	plant residue on ground stone
5	small, deep pit (conical)	earthen mortar	pounding (mesquite pods)	long pestles	no	plant residue on ground stone
6	small shallow pit	metate support	grinding (mesquite flour and seeds, small seeds)	basin metates and manos	no	plant residue on ground stone
7	small, deep pit (elliptical)	cake mold	mesquite-flour cake making	none	no	none
	Thermal Features (Oxidized)					
8	deep medium-sized, bell-shaped or basin-shaped pit	storage pit	long-term storage of parched mesquite pods or mesquite/small seed flour cakes	none	no	charred mesquite pods
9	small pit	provide coals for parching	parching in basket or ceramic vessel (mesquite pods and seeds, small seeds)	none	yes	charred mesquite pods/seeds and small seeds
10	medium-sized to large pit	provide heat for parching	parching on hot earth (mesquite pods)	none	no	charred mesquite pods
11	broad surface	provide hot parching surface	parching (mesquite pods and seed-bearing plants)	none	yes	charred mesquite pods; pollen from small-seed–bearing inflorescences

Feature Type	Feature Description[a]	Feature Function	Activity	Associated Ground Stone	FAR (Yes/No)	Paleobotanical Evidence
12	broad surface	provide heat for parching	parching (small seeds) (whole seed-bearing plants or inflorescences)	none	no	charred seeds and other plant materials; pollen from small-seed–bearing inflorescences
13	small to medium-sized pit	provide heat for baking	baking cakes from the flour of mesquite pods/seeds or small seeds	none	yes/no	none
14	small, relatively deep pit	provide heat for baking	pit-baking of saltbush seeds	none	yes	charred saltbush seeds
15	medium-sized pit, possibly rock lined	provide heat for baking	pit-baking of cholla buds	none	yes	charred cholla buds; cholla pollen
16	small to medium-sized pit with faunal bone	provide heat for baking, roasting, or grilling	pit-baking, roasting, or grilling of meat	none	yes/no	none

[a] Small (less than 0.5 m [20 inches] in diameter), medium-sized (0.5–1 m [20–39 inches] in diameter), large (1 m [39 inches] or more in diameter), broad (1 m [39 inches] or more in diameter).

served for storage (n = 1), parching (n = 4), and baking (n = 3). FAR is associated with six of the thermal feature types, but with none of the nonthermal types. Ground stone is associated with three of the nonthermal feature types, and with none of the thermal types. Charred remains of edible plants are associated with one of the nonthermal types (storage of parched mesquite pods) and with all but one (cake baking) of the thermal feature types. Fuelwood for the thermal features is not considered because these woods (mesquite, saltbush, creosote bush, ocotillo, and/or saguaro) provide no evidence concerning the plant processed. Diagnostic pollen is only expected in two of the thermal feature types: the two surfaces (with or without FAR) on which whole seed-bearing plants or their inflorescences were parched. Diagnostic plant residue may remain on all of the ground stone artifacts.

Thus, there were possibly five basic functions of plant-processing features: parching, baking, grinding support, cake forming, and storage. Most of the nonthermal features likely served as basket rests (small to medium-sized shallow pits) (Feature Types 1 and 2), mortar or metate rests (small shallow pits) (Feature Types 4 and 6), mortars (small deep pits) (Feature Type 5), storage pits (deep medium-sized, bell-shaped, or basin-shaped pits) (Feature Type 3), and perhaps cake molds (small but deep elliptical pits) (Feature Type 7) (see Table 88). Based on the project research, the parching of mesquite pods or seeds and all small seeds was likely the most common thermal activity in the project area. Being so common, it is not surprising that pod and seed parching each used four different methods, in turn corresponding to four feature variants. For mesquite pods, these parching methods are (1) toss in a basket with hot coals, (2) stir in large ceramic vessel on hot coals or rocks, (3) toast on hot earth, and (4) toast on hot stones. For seeds, they are (5) toss in basket with live coals, (6) stir in ceramic vessel on hot coals or rocks, (7) burn bundles of seed-bearing plants on cleared surface, and (8) toast seed-bearing plants on hot rocks. Expected feature types would be different for each of these methods, thus resulting in eight types. But the two sets of methods (for parching pods and seeds) can easily be collapsed into a single set of four types—each possibly containing charred pods or seeds—by combining Steps 1 and 5 (thermal pit with FAR), Steps 2 and 6 (thermal pit with ceramics and FAR), Steps 3 and 7 (thermal surface or pit without FAR), and Steps 4 and 8 (thermal surface with FAR). If Steps 2 and 6 are eliminated, because they involve ceramics, three basic types of parching features are expected in the project area: small thermal pits with FAR (Feature Type 9), large thermal surface or pit without FAR (Feature Types 10 and 12), and broad thermal surface with FAR (Feature Type 11) (see Table 88). Each of these might contain charred pods or seeds, and the last two might also contain pollen evidence of the kinds of seeds that were processed.

Baking was likely the second-most-common thermal activity at the project sites, done to make cakes, remove the salty taste of saltbush seeds, prepare cholla buds, and cook meat. Baking cakes was primarily from the flour of seeds. Although it was sometimes done for mesquite-pod flour, it was not necessary to do this because these cakes hardened by themselves. Thus, four types of baking pits are expected, resulting from (1) baking cakes (Feature Type 13), (2) baking saltbush seeds (Feature Type 14), (3) baking cholla (Feature Type 15), and (4) cooking meat (Feature Type 16) (see Table 88). Cake-baking features would be small to medium-sized thermal pits, containing FAR, charcoal, and/or ashes. No paleobotanical evidence would remain to identify the plant species that were prepared. Baking pits for saltbush seeds would also be small, relatively deep thermal pits, with or without FAR, and contain saltbush seeds among the charred materials. Cholla-baking pits would be medium-sized thermal pits, possibly rock lined, and contain FAR, charred cholla buds, and cholla pollen. Finally, meat-baking pits would be small to medium-sized thermal pits, with or without FAR, and containing burned faunal bone.

These are all ideal feature types, of course, and the reality of the project sites paints a different picture. The excavated pits had nothing in their fill to indicate what plants or animals had actually been processed in them, only redeposited trash. All that can be demonstrated is that certain plants and animals were processed in certain site areas at certain times. Feature size can say something about specific activities. Thus, the project's small thermal pits likely were used for parching (by providing embers), baking saltbush seeds, baking cakes, or cooking meat. Medium-sized thermal pits might have been used for parching (on hot earth or hot rocks), baking cholla buds (with rock lining a good hint), or cooking meat. Some medium-sized and large thermal pits, in particular those with a formal basin or bell shape, likely were used for storage. Thermal surfaces would have been used for parching mesquite pods or small seeds (still on whole plants). The great majority of these thermal pits and surfaces would have been used for parching, either by providing embers or by forming a toasting context.

With regards to the functional difference between thermal and nonthermal features, it is good to reiterate that some thermal features had no thermal function. In fact, some thermal pits, such as basin-shaped and bell-shaped storage pits, may have oxidized walls and bases because they were purposely made harder by oxidizing them with fire. On the other hand, some of the features classified as nonthermal may have been thermal features used with low heat and therefore had no evidence of fire. As an aside, the mechanical stripping used to expose the features undoubtedly truncated the features making them shallower than they were originally. How well thermal features preserve is an important question. If they did not necessarily have to be very deep pits—many may have been shallow or even surficial—a cluster of FAR in or near the feature may be all that remains. Oxidization may have been so light that it could have easily eroded away or been destroyed by burrowing insects and rootlets. Rocks used in the feature may not even have been affected much because the heat needed for parching may have been short-lived and/or relatively low. Of course, on sites like those of the project area, where every rock would be recycled, most rocks are expected to be fire altered. A problem (or just a fact) in the project area is that parching activities took place in the same area for thousands of years, thereby clouding our ability to identify individual activities. In particular, it was often impossible to determine what FAR originally belonged to what feature.

Fire-Affected Rock

Besides oxidized surfaces, thermal activities at the project sites were indicated by the presence of FAR, charcoal, and other charred plant materials, ashes, and burned faunal bone. As a rule, these materials were found outside of their original context as secondary deposits in extramural pits, structure fill, and middens. Most of these materials are lightweight and travel easily across a site, and their place in space is no longer very meaningful. But FAR would not have moved over long distances as easily, and thus its spatial distribution should be more meaningful. As will be shown in Chapter 10, looking at the distribution patterns of FAR can address various questions about thermal activities. For instance, it was suggested above that most parching required only low heat, such as a fire in a small pit, choked with rocks to maintain a small but steady set of embers. Based on excavated examples in the BMGR East (Heilen and Vanderpot 2013b), such features often do not retain evidence of oxidation. Could this also be the case with features in the Luke Solar project area? Did some of the small pits identified as nonthermal actually have a parching—and thus thermal—function, with oxidization either never present or not preserved? Because parching was such an important activity at the sites, it would be good to know whether features classified as nonthermal may have resulted from parching. There are two ways to address this issue, although neither provides a conclusive answer. The first is to argue that the silt-dominated texture of the sediments in the project area causes even the smallest fire to leave an area of oxidized soil. This hypothesis was inadvertently tested during fieldwork by using a small metal barbecue, elevated approximately 30 cm (1 foot) above the ground, which created a red oxidized surface after only 30 minutes. What we do not know, however, is if this stain will remain if exposed on the ground.

Another way to address this issue is by looking at the distribution of FAR across the project area. Because FAR would not have moved far from its location of last use, we can assume that the greatest densities of FAR would be in areas that experienced the most intensive thermal activities (e.g., parching and baking). After identifying these “hot spots” of intense parching or baking, we can look at the co-occurrence of FAR and different kinds of extramural features. Can the FAR distributions help determine whether some, or many, or most of the small nonthermal pits were parching features? One would expect that areas with large numbers of small nonthermal pits would have low densities of FAR, whereas most thermal features (except for storage pits) would be found in areas with high densities of FAR. In this scenario, the small nonthermal pits are assumed to represent basket rests (storage) and mortar or metate supports (grinding), and most of the thermal features (oxidized pits and surfaces) represent parching features. But what if small nonthermal pits are also associated with high densities of FAR? It could mean two things. First, it might mean that most of these features were ground stone or basket supports and these grinding or storing activities went hand in hand with the parching or baking activities. This scenario makes sense, because why would temporary storage (before and after parching), parching, and grinding not happen in the same place? On the other hand, it could also mean that parching resulted in large quantities of FAR but not in much oxidization of the feature surfaces because only low heat was used. Given the low heat, rocks would not have been thermally altered much if used only once or twice (such as on the BMGR East, where many of these features contain little or no FAR [Heilen and Vanderpot 2013b]). In this case, thermal features hide under a nonthermal mask. But in the project area, rocks would have been reused time and again, and ultimately all would be FAR. Be that as it may, at this juncture, if high densities of FAR are found near small nonthermal pits, it only indicates that these features were associated with parching, not that they were actual parching features. This and other FAR-related issues are explored further in Chapters 10 and 11. Some of the questions asked about the FAR distributions and pursued in those chapters are:

1. Where were the highest densities of FAR? This should show where most of the thermal activities (e.g., parching and baking) took place.

2. Did the greatest concentrations of FAR also correspond to the greatest concentrations of thermal features?

3. What was the distributional relationship between FAR and nonthermal features?

4. How did the volume of collected FAR compare to the volume of thermal pits?

5. What was the co-occurrence of FAR and the various ground stone types?

Ground Stone

Expected ground stone tools for mesquite processing are mortars, pestles, metates, and manos, many of which had been cached prehistorically and then collected during data-recovery excavations at the project sites (see Chapter 3, this volume). Mortars were of at least two kinds: large and small. Large mortars were used for pounding mesquite pods while in a standing position, and these would have been used when processing large quantities of pods. These large mortars and accompanying large and long pestles were often made of wood, or a combination of wood and stone. Because wood has not preserved, the project sites only retained a partial signature of this activity—the stone tools. Thus, the large stone mortars and pestles were the only artifacts representing this signature in the project collection. The second round of pounding in mesquite processing—cracking the seed endocarp—was done with smaller mortars and pestles, and these were always made of stone, never of wood. If mesquite seeds were processed at the sites, as argued above, the bulk of this signature should be contained in the project's mortar and pestle collection. In particular, mortars made of an abrasive stone, such as vesicular basalt, would be good candidates for this signature. Of course, smaller mortars and pestles would not only have been used for cracking endocarps, they could also have been used for pounding mesquite (smaller quantities), in which case there likely would have been a combination of stone and wood (stone pestle in a wooden mortar or a stone pestle in a wooden mortar). Smaller mortars and pestles could also have been used for grinding small seeds (for certain species or special uses, where a metate and mano would not work so well), in which case they would likely be made of a finer-grained stone. The best way to crack the mesquite endocarps is not the simple downward-pounding motion used when crushing mesquite pods (which would result in the hard and smooth endocarp-coated seeds flying out of the mortar), but a simultaneously twisting and crushing motion. Above, it is argued that a somewhat flattened pestle—like the Lukeoliths and certain ethnographic examples— might have been the best tool for the job. Chapter 11 will explore how Lukeoliths may have been used in this process.

There are still questions on the use and functions of the various types of mortars and pestles. What were the functional differences between the large and small and the vesicular and fine-grained mortars? What purposes were served by the different pestles—long cylindrical; conical, small, and squat; and flattened Lukeoliths? Use wear on these grinding implements might hint at grinding patterns, but only plant-residue analysis can tell us what kinds of plants were processed; pollen washes have not been much help (see Chapter 7, this volume). As shown by Schneider and Bruce (2009 [http://www.scahome.org/publications/proceedings/Proceedings.23Schneider.pdf]), mesquite protein residue can be identified even on compromised surfaces such as exposed bedrock mortars. The types of metates and manos expected would be simple shallow or deep basin metates and their associated manos, used to grind mesquite pulp, mesquite seeds, and various small seeds, as well as a variety of other foods, including small animals.

Paleobotanical Materials

Macrobotanical materials that are diagnostic for plant processing at the project sites would be charred mesquite pods and seeds, seeds and other parts of small-seed–bearing plants, and cholla buds. Macrobotanical remains can be expected in all types of thermal features (except those used for baking cakes and storage), but in none of the nonthermal features. Charred grass seeds are often fragmented, hindering identification. No cultural pollen is expected to have remained from processing mesquite because the trees had already flowered weeks prior to the harvest. The only chance of finding associated pollen would be if it were the blossoms that had been prepared, or if pollen still had clung to the green pods in instances when these were prepared. Most pollen of small-seed–bearing plants is likely to preserve in areas where harvests were cleaned and stripped of chaff or where entire inflorescences were parched. Grass pollen grains are rarely distinguishable below the family level, but pollen signatures of most other small-seed–producing plants are easily recognized.

Plant Use and Seasonality

If the present study has shown one thing, it is the unique potential of the project sites to contribute to the often-mysterious workings of mesquite processing. The project area contains not just a huge and highly specialized mesquite-processing camp, but this camp was at times residential in nature and it primarily dates to the Middle and Late Archaic periods. The same subsistence strategy persisted throughout this time period, and mesquite was likely the primary food source being targeted. This means that we can view a specific-plant economy not just—as is so often the case with residential sites—through a kaleidoscope of myriad activities, but with a single focus, and this over a time span of five millennia. The Luke Solar project has provided a unique archaeological opportunity; it is the first time in the U.S. Southwest that mesquite processing can be isolated and studied over such a long period of time, unclouded by background noise. The fact that most of the activities occurred during the pre-ceramic Chiricahua phase (3500–1200 B.C.) is also helpful (except for ceramic analysts, of course), because by eliminating this artifact class a better focus is obtained on the activity (grinding) as opposed to containment (storage). In mesquite-processing terms, it is the ground stone that holds the key to the actual activity. What makes studying mesquite so interesting is the option that not just the pods were being processed, but also that a second processing stage occurred—the little-studied scenario when the hard endocarps were cracked to obtain the seeds inside. In ethnographic accounts, hunter-gatherers have been shown to be more likely to process the seeds than agricultural people, and it is important to find out if the same was true for Archaic period groups. The difference between the two processing stages should show up in the ground stone assemblage. In particular, the mortars and pestles used should be different for the two stages. Mesquite storage options are a similarly important study. The end product of mesquite processing was the cake made from the flour, baked or unbaked, which could be transported easily and stored well (a year or more). More than other flours (such as from small seeds), mesquite-pod flour needed to be made into cakes, and fast, because it spoils quickly in the high humidity of summer (monsoon rains immediately followed the mesquite harvest). Importantly, cakes could be consumed any time as gruel by breaking off a piece and mixing it with water. An important question is whether mesquite products (parched pods and cakes) were stored long term at the project sites (throughout the winter) or only short term during processing. The data suggest that the latter was the case, with all product transported away when all processing was done.

An important task of the study was to determine what seasons or months of the year the project area was used. It is argued that the mesquite bosque just south of the project area was the primary prehistoric attraction of the project area and also that the mature pods of this tree were harvested in June, in the dry summer season several weeks before the saguaro harvest. Together, harvesting and processing might take 4–6 weeks, and these tasks were largely completed before the start of the summer rains by the middle of July. Possibly, groups arrived in the project area some time prior to the mature-pod harvest to collect mesquite flowers and green pods, or to process cholla or small seeds. It is clear that the use of the riverine zone was limited. The adjacent lower stretch of the Agua Fria River is a volatile, braided river system with no true floodplain that is flanked by cobble-strewn terraces. There would be few edible plants other than some mesquite, and farming potential would have been minimal, although much further south (ca. 10 km) the Hohokam built several canals off the lower Agua Fria near its confluence with the Gila River (Ciolek-Torrello 2004:Figures 31–34). Instead, the use of the adjacent riverine zone was primarily focused on obtaining stone to manufacture flaked stone tools and grinding equipment. Through the lens of our project data, the river was primarily visited when people using the project area in June and July needed stone materials. It is easy to imagine that as soon as the mesquite harvest was done, and cakes and refurbished tools were packed for transport, these groups would head to the upper *bajada* and mountain flanks where the saguaro fruits had now ripened. Possibly, people followed the drainages and collected palo verde pods as they went along. Saguaro-processing camps would then be set up in specific areas, likely within easy walking distance from the rock tanks in the canyons, which provided the water needed for drinking, making *pinole* and *atole*, and processing saguaro. Following the saguaro harvest, which would take a few weeks at the most, the groups might set up base camps closer to the mountains and water sources from where they could procure mountain floral resources, including acorn and artiodactyls in the fall and agave in late winter/early spring. Stored grass-seed and mesquite cakes would form a sufficient food supply for the winter. From these camps, men would undertake hunting trips to procure the large game attracted to the water and grasses and other forbs. Rockshelters and other protected places served as overnight camps.

It is this scenario, of course, which explains not just why the project sites contained no saguaro products (they would have if people harvested mesquite after the saguaro harvest), but also why they contained so much evidence of bifacial-tool manufacture and refurbishing but not the actual refurbished tools. Projectile points and animal-processing tools would be carefully curated for later use in the mountain zone. The attraction of the mountain and upper *bajada* zone from fall to spring becomes clear when comparing it to the other two zones of the catchment area: the lower *bajada* and the river. The lower *bajada* would be at its most attractive in early summer when grasses and various weedy annuals could be collected, as well as mesquite in places with special hydraulic conditions such as in the project area. But at other times of the year, this area had virtually nothing to offer. Although the river hosts riparian vegetation such as cottonwoods and semi-riparian trees such as mesquite, the first had little use, except perhaps to use the trunks for mortars and the bark for steam-baking. Mesquite would have been found only sporadically along the boulder-strewn bank; there were no concentrated stands such as found in the project area. The absence of a nearby floodplain conducive to a dense growth of plants also limited farming, thereby explaining why not one charred maize fragment was found in the project's flotation samples (the only evidence for agriculture from the project area was a single maize pollen grain in a San Pedro phase structure). In sum, based on just the floral and faunal resources in the mountains, and on the presence of at least one mesquite bosque (and likely more), people using the White Tank Mountains and adjacent *bajada* and river possessed a rich and varied subsistence base. Their procurement areas were largely on the upper *bajada* and in mountain zones, held in balance by mesquite-gathering areas on the lower *bajada* and perhaps also in concentrated places along the river. This discussion concerns the seasonal availability of resources on different parts of the *bajada* and mountains and only provides insight into mobility along vertical dimensions (i.e., across elevationally zoned biotic communities). This is only part of the seasonal movement of these groups, of course. Hunter-gatherer territory sizes were much larger, although the scale of mobility is difficult to assess. Horizontal movement, even within the same biotic community, was important also. Such lateral mobility is typically structured by the productivity of one or more resources that may be widely distributed but not densely concentrated (such as grasses or seed-bearing annuals) or by resources that are clumped (such as mesquite at Falcon Landing). Use of the site appears to have been episodic, implying that there may well have been other resource locales on the lower *bajada* that, in particular years, were more attractive for foraging. More research is needed to determine how far small-seed collection on the lower *bajada* was subsidiary to the mesquite harvest and conducted only in the immediate area, or whether it was an economic focus in its own right. This notion, as well as other subsistence issues, are explored further in Chapter 11, including how the project data compare to other indigenous mesquite-processing sites in the nearby region, and further away in Arizona, Texas, Mexico, and even in the Old World.

CHAPTER 10

Site Structure and Land Use

Michael P. Heilen, Robert M. Wegener, Mitchell A. Keur, Eric E. Klucas, and John D. Hall

The contiguous 44-acre areal exposure achieved at Falcon Landing, and the additional mechanical stripping at surrounding Sites 68, 421, and 437, afford an unprecedented opportunity to examine questions pertaining to site-level use of space over a five millennium span of human occupation. This opportunity did not come without its share of challenges, both in terms of how the data were collected and the selection of appropriate analytical techniques. Key among these challenges were establishing stratigraphic control and assigning each of the 3,006 features identified at Falcon Landing, of which 1,638 (55 percent) underwent controlled sampling, to a specific stratigraphic context (see Chapter 2, and Appendix 1.1).

This chapter begins with a discussion of the various methods that were used over the course of the analyses. It begins with a general discussion of the data that were selected, including feature and artifact typologies, and how these data were grouped into the various analytical units. This is followed by a discussion of how the temporal groupings used in the chapter were defined and how these processes impacted sample selection. The next two sections present the specific analytical methods used in the spatial and aspatial analyses, respectively. After the various methods have been established, investigation and identification of human behaviors inferred from these two data sets are presented, beginning with an examination of site-level patterns for each of the defined temporal groups and occupational episodes. This is followed by an examination of the spatial distribution of these data, providing a more fine-grained study of the use of space over time. We close the chapter with a synthetic discussion of the results of these analyses with an eye to what was learned as well as what additional questions were raised.

The Data

The analyses presented in this chapter employ the full range of feature and artifact data collected during the project excavations with a focus on the Falcon Landing site. To facilitate the analyses, several project-specific typologies, both morphological and functional, were developed. The individual typologies used in this chapter are discussed below.

Pit Types

By far, the single largest class of features investigated at the Luke Solar sites was the extramural pit of various forms. Although treated in detail in Volume 1, a summary of the classification of pit morphology used for the Luke Solar project is presented here. All excavated extramural pits that provided a controlled sample were placed into one of 16 mutually exclusive pit classifications based on four attributes: in situ burning, profile shape, volume, and shallowness. In situ burning and profile shape were observed and recorded in the field and verified by the crew chiefs and project directors. Volume and shallowness were calculated post-field from metrics recorded during excavation. Definitions for the individual attributes are listed below. The four attributes and their corresponding values were used to create a matrix of 16 pit classifications, named and described in Table 89.

Table 89. Morphological and Functional Typology of Extramural Pits

Pit Classification	Pit Function	Pit Attributes
TB1	cooking	thermal, bell shaped, typical volume, shallow
TB2	cooking	thermal, bell shaped, typical volume, deep
TB3	cooking	thermal, bell shaped, atypical volume, shallow
TB4	cooking	thermal, bell shaped, atypical volume, deep
TN1	cooking	thermal, basin shaped, typical volume, shallow
TN2	cooking	thermal, basin shaped, typical volume, deep
TN3	cooking	thermal, basin shaped, atypical volume, shallow
TN4	cooking	thermal, basin shaped, atypical volume, deep
NB1	storage	nonthermal, bell shaped, typical volume, shallow
NB2	storage	nonthermal, bell shaped, typical volume, deep
NB3	storage	nonthermal, bell shaped, atypical volume, shallow
NB4	storage	nonthermal, bell shaped, atypical volume, deep
NN1	processing/storage	nonthermal, basin shaped, typical volume, shallow
NN2	storage	nonthermal, basin shaped, typical volume, deep
NN3	processing/storage	nonthermal, basin shaped, atypical volume, shallow
NN4	processing/storage	nonthermal, basin shaped, atypical volume, deep

In-Situ Burning

In-situ burning was identified by oxidized sediments in the floor and/or walls of the pit, indicating high temperatures in direct contact with the pit. It has been assumed across the project sites that pit fill has only a casual relationship to the pit, most likely reflecting natural infilling. Thus, burned, or thermally altered, pit fill was not considered evidence of a thermal pit—only oxidation to the pit margins was sufficient to define a pit as “thermal.” The absence of oxidized margins defaulted this attribute to “nonthermal.”

Cross-Sectional Shape

Pit cross-sectional shape was determined at the time of excavation. Bell-shaped pits proved exceptionally rare; of the 2,791 extramural pits encountered in the APE, only 36 were bell shaped (1.3 percent). Additionally, the bell-shaped pits all shared a similar morphology in that they lacked “necks.” In other words, the pits began belling horizontally directly below the pit orifice, rather than maintaining a relatively narrow section for some depth before expanding. The remaining 2,755 pits were generally basin shaped in cross section. Basin-shaped pits exhibited their widest horizontal extent at the pit orifice, and then smoothly narrowed to the pit floor. There was some slight variation in cross section, with irregular, conical, and cylindrical cross sections represented. These irregular, conical, and cylindrical shapes accounted for only 7.7 percent (n = 213) of the identified cross sections.

Basin-shaped pits were assumed to express their widest horizontal area at the pit orifice. The walls of basin-shaped pits sloped or curved inward toward the pit floor. Bell-shaped pits were distinguished as having walls that expanded horizontally from the pit orifice, before sloping inward toward the pit floor. Because certain functions are suggested by the morphology of bell-shaped pits, each bell-shaped pit was scrutinized by crew chiefs and project directors to verify the field observation. For the purposes of this attribute, all other pit cross-sectional shapes defaulted to “basin.” In reality, nearly every non-bell-shaped pit at Luke Solar was basin shaped in cross section.

Pit Volume

Pits were separated into four categories—thermal basin shaped, thermal bell shaped, nonthermal basin shaped, and nonthermal bell shaped—and feature volumes for each of these categories were examined for mean and standard deviation. Volumes that fell within one standard deviation above or below the mean were considered "typical" for that group; volume outside the first standard deviation (i.e., smaller than one standard deviation below the mean, or larger than one standard deviation above the mean) were considered atypical. The details of how volume was calculated are in Chapter 4, Volume 1. Pits missing the data required to calculate volume (such as "examined pits," which had no recorded depth) were excluded from the sample on this attribute.

The consistency in pit cross-sectional shape (either generally basin shaped or "neckless" bell shaped) allowed us to apply uniform shape analyses to determine pit volume. Previous investigations (Graves 2011) combined linear measures of pit length, width, and depth to calculate cuboidal or cylindrical volumes. As discussed in Chapter 4, Volume 1, the basin-shaped and bell-shaped pits encountered at the Luke Solar sites resembled portions of a three-dimensional ellipsoid. A basin-shaped pit represents only the bottom half of an ellipsoid. The "neckless" bell-shaped pit represents a greater fraction of a complete ellipsoid, a proportion somewhere between 50 and 99 percent of the calculation:

$$V = \frac{4}{3}\pi abc$$

where *a, b,* and *c* represent radius measures in each of the three dimensions. Thus, *a* is equal to one-half the diametric measure of maximum pit length, and *b* is equal to one-half the diametric measure of maximum pit width. Alternatively, surface areas of pit orifices were generated from feature polygons recorded by total station. This surface area may replace part of the expression as follows:

$$\textit{pit orifice surface} = (\pi ab)$$

The surface area of a pit orifice was produced by a fill method within the closed polygon of the pit and therefore accommodates the linear dimensions and the constant π inherent in all circular or subcircular shapes.

In the above volume formula, pit depth is represented by *c*. This value requires no additional modification because, unlike maximum length and maximum width, pit depth is more closely analogous to a radius than a diameter.

The above formula for ellipsoid volume contemplates a subspherical ball shape. A basin pit, however, is analogous to the bottom half of that shape. Thus, the formula for determining the volume of a basin pit is:

$$V = \frac{\frac{4}{3}(\textit{pit orifice surface area})(\textit{pit depth})}{2}$$

Unlike basin pits, the greatest length and width measures for a bell-shaped pit are below the orifice; the pit "bells" out from the orifice before sloping back in at the pit floor. The maximum length and maximum width of bell-shaped pits were recorded during excavation. Additionally, as noted above, bell-shaped pits represent a greater portion of the full ellipsoid shape than do basin-shaped pits. The ellipsoid volume formula was further modified to accommodate the ellipsoid proportion, a factor between 0.5 and 0.99 to represent the percentage of the full ellipsoid shape represented by the bell-shaped pit. The ellipsoid proportion was determined by inspection of each bell-shaped pit's cross section and applied on a case-by-case basis. The ellipsoid proportion not only affects the amount of a full ellipsoid represented, but also the extent to which the depth measure reflects *c* in the original formula. The resulting volume formula for bell-shaped pits is:

$$V = \frac{4}{3}\pi\left(\frac{\textit{max. length}}{2}\right)\left(\frac{\textit{max. width}}{2}\right)\left(\frac{\left(\frac{\textit{depth}}{\textit{ellipsoid proportion}}\right)}{2}\right)(\textit{ellipsoid proportion})$$

Pit Depth Index and Shallowness

Pits were also evaluated for the relationship between their horizontal area and depth, an attribute called "shallowness." This was determined by way of an index that compared the horizontal surface area (as calculated by mapping polygons or length and width measures) to an analogous vertical surface area, calculated from depth measures. For basin pits, the depth index was calculated as:

$$Depth\ Index = \frac{\pi(depth)^2}{(maximum\ horizontal\ area)}$$

The maximum horizontal area was typically a round or subround polygon generated when the pit boundary was mapped by total station. To calculate the corresponding vertical area, the depth measurement serves as a radius in the circle area formula $A = \pi r^2$. Thus, if the horizontal area is larger than the vertical area, the depth index is less than 1.0, and the pit is "shallow." Conversely, if the vertical area is larger than the horizontal area, then the depth index is greater than 1.0, and the pit is "deep."

Bell-shaped pits required different consideration in calculating their depth index. The horizontal area was calculated from measurements of maximum length and maximum width. As noted above, these measurements are analogous to diameter measurements. To comport with calculations based on radius, each measurement was divided by 2. The depth measurement for bell-shaped pits is greater than that of a vertical radius, by an amount expressed in the ellipsoid proportion. Thus, the ellipsoid proportion can act on the depth measurement for a bell-shaped pit to produce a vertical measurement analogous to the length and width diametric measures, which is then halved to reflect a vertical radius. The depth index calculation for bell-shaped pits is: The result is the same as that for basin-shaped pits for determining whether the pit is shallow or deep.

$$Depth\ Index = \frac{\pi\left(\frac{\frac{depth}{ellipsoid\ proportion}}{2}\right)^2}{\pi\left(\frac{length}{2}\right)\left(\frac{width}{2}\right)}$$

It should be noted that shallowness is the relationship of the pit's maximum horizontal dimensions to its maximum vertical dimensions. This attribute is self-referential and independent of other similar pits—a pit is shallow or deep based only on its own dimensions and morphology. This distinction is important in applying pit function, as what is "deep" varies according to the horizontal dimensions of the pit. Thus, there is no universal depth measurement, below which is "shallow" and above which is "deep."

Pit Function

A second, functional typology of extramural pits was also developed based on the morphological attributes described above. Following Graves's (2011:642) examination of extramural pits in the Queen Creek area, a simplified functional typology was employed here based on the directly observable attributes of the features themselves. This approach worked well for the features at the project sites because many of the attributes used to tease out more-specialized uses were not preserved or observable to result in reliable distinctions. In his typology, Graves (2011:651–654) identified four functions for nonthermal pits: storage, processing and/or storage, caches, and borrow pits. Caches were separated from pits in the Luke Solar data set and were identified in the field based on the presence of multiple pieces of usable flaked stone or ground stone tools. Less than 20 features were identified and excavated as caches, and they did not receive the geometric analyses applied to extramural pits. Thus, their size and shape attributes did not contribute to the sample from which statistical distributions were generated.

Applying this typology, all of the extramural pits identified at the project sites were assigned to one of three categories—cooking, storage, or processing/storage. Following the criteria outlined by Graves, all thermal pits, regardless of diameter, cross-sectional shape or content, were classified as cooking pits, hereafter referred to as firepits in this chapter. All bell-shaped nonthermal pits and those pits that were deep, as determined by their depth index, were classified as storage pits. Finally, all nonthermal, shallow pits, regardless of diameter, were classified as processing/storage. Based on these criteria, each of the 16 pit types described above were assigned one of the three functions (see Table 89).

Artifact Types

As with the features, we chose a simplified typology for our examination of the collected artifacts and faunal remains for aspatial analysis, and the following aspatial analyses concern only artifacts and faunal remains collected from features that underwent controlled sampling. In this aspatial analysis, and based on the classification employed in Chapter 3, the stone artifacts were divided into the categories of flaked stone, ground stone, and FAR when examining the number and relative proportions of these artifact classes over time and between time periods. When examining the abundance and relative proportions of artifact types per cubic meter sampled and dated to a specific time period, flaked stone was divided into the categories of debitage and tools to assess the relative amounts of debitage vs. tools over time. Artifact density per cubic meter sampled was considered the best method to examine the relative abundance and proportions of the artifact classes over time in this analysis because calculating the density per cubic meter applies a common denominator that, in turn, standardizes the often disproportionate number of individual artifacts recovered from the sampled feature fill. The prehistoric component of the project faunal collection, as presented and discussed in Chapter 4, consisted almost entirely of minimally identifiable and intensively fragmented leporid remains. Substantial carbonate coating on these leporid remains made it exceedingly difficult to accurately quantify the number of burned or calcined bone fragments. As such, the faunal remains in the following analyses are presented as a single category, and no attempt was made to assess the relative amount of burned faunal remains per time period.

Project Chronology

The establishment of temporal control at Falcon Landing, in particular, including the chronological placement of individual features, was perhaps the greatest analytical challenge of the Luke Solar project (Figure 98). This challenge was the result of several factors, including the massive 44-contiguous-acre areal exposure and the compressed, laterally complex site stratigraphy of the project's lower-*bajada* setting, where features representing several millennia of occupation were contained within only approximately a half meter of deposition, along with budgetary constraints that significantly limited the number of radiocarbon dates that could be obtained. These difficulties were addressed through the development of a detailed project geochronology that, in addition to identifying the geomorphological history of the project area, provided a mechanism for the relative dating of features that could not be directly dated either radiometrically or cross-dated by their direct association with temporally diagnostic artifacts. The geochronology methods and results are presented in Chapter 2.

The age assigned to an individual feature depended in part on which of five dating methods, or cases, that could be applied. The selection of these methods was based on the relative position of a feature within the natural strata identified at the project area. This process is graphically presented in Chapter 1. The most precise of these cases, Case 1, refers to those features that were directly dated via radiocarbon. Because of the combination of a large number of features and limited resources, the percentage of features that were dated in this way was quite small. The following four methods were developed to assign a temporal range to those features that were not directly dated.

Figure 98. Temporal components, episodes, and phases.

The second case, referred to as the coeval method, was applied if the feature was contained entirely within a single dated natural stratum. In such cases, the date assigned to the feature was identical to that of the associated stratum. Case 3, referred to as the overlying stratum method, was applied to those features that were located at the surface of a natural stratum. In these cases, the assigned date range reflected the latest date of the stratum the feature intruded into and the earliest date of the overlying stratum. Case 4, referred as the unconfined method, was applied to those features found on the surface of a natural stratum but without an overlying stratum. In these cases, the feature could only be said to postdate the stratum into which it intruded. Case 5 was used for those cases where the overlying stratum was unfortunately not identifiable. As with Case 4, Case 5 features could only be said to postdate the stratum into which they intruded.

Because of the variability in the precision of the methods described above, the assigned date ranges for many individual features could be quite large, sometimes encompassing several archaeological periods or phases. As a result, the utility of these features for the examination of temporal trends was limited. For the analyses presented in this chapter, an effort was made to create analytical groups whose temporal range was as precise as possible. In the first analysis, features were assigned to one of the established regional chronological phases, if possible. In the second, features were assigned to more-precise temporal groups reflecting nine radiometrically defined occupational episodes derived from the available radiocarbon dates. The selection processes for these two groupings are discussed individually below.

Chronologic Components: Periods, Phases, and Transitional Intervals

As indicated above, the foundation of all temporal assignments of individual features at the project sites was the dating of the individual geomorphological strata discussed in detail in Chapter 2. As a means of maximizing the temporal precision of our analytical units for the aspatial analyses, individual features were included in the following analyses if their determined ages fell completely within the boundaries of a single period or phase in the regional chronology (see Figure 98 and Chapter 2, Volume 1). Exceptions were made in the case of features whose age exceeded the temporal boundary of a phase by less than a single generation, which we defined here as 30 years. An additional exception was made for four “transitional” intervals between the Chiricahua and San Pedro phases, San Pedro and Cienega phases, Cienega and Red Mountain phases, and the Classic and Protohistoric periods. Features were included in these transitional periods if their assigned ages straddled the temporal range of the two periods or phases but did not extend beyond their cumulative temporal ranges. The temporal groupings defined in this manner are referred to as dated transitional intervals.

Occupational Episodes

Based on terminology of the applied regional chronology (see Chapter 2, Volume 1), the use of the temporal components as described above did pose a number of limitations for the analyses that we hoped would describe and analyze contemporary phenomena. This was further compounded by the fact that the duration of the individual components was quite variable, limiting the kinds of direct comparisons that could be made. As a means of addressing these problems, an alternate method was employed. Although resulting in significantly smaller samples than used in defining Occupational Episodes 0–9 in Chapter 2, the temporal groupings created by this method, also referred to here as occupational episodes, represent the most temporally precise groupings of the project data.

Based on an OxCal analysis of 97 radiocarbon-dated features, nine radiometrically discrete occupational episodes, labeled A–I, were defined for use in this chapter (see Figure 98). We did not include the earliest occupational episode defined in Chapter 2 because it was represented by a single feature. Because the date ranges used to define the occupational episodes were derived solely from the radiocarbon dates, the components expectedly did not map directly to the preestablished regional cultural chronology, nor did they represent an unbroken period of time. The assignment of individual features to the occupational episodes followed the same general procedure as was used to assign features to the temporal components. If the geologically determined date range for an individual feature was fully contained within the date range of a single occupational episode, that feature was selected for analysis. In cases where the stratigraphic position of an individual feature resulted in a geologic age that exceeded the range of a radiocarbon occupational episode or encompassed more than one radiocarbon episode, the feature was excluded from the analysis. This process resulted in 73 features, out of a total of 3,006 features at Falcon Landing, being assigned to one of the nine temporally discrete occupational episodes.

Aspatial Analysis Methods

For the aspatial segment of this study, the features and artifacts assigned to each period, phase, transitional interval, or occupational episode served as the units of analysis. Because of variability in the length of the temporal units, this was not without its challenges. For example, the Chiricahua phase represents approximately 2,300 years of intermittent occupation across the vast excavated area of the project sites. Treated as an analytical whole, temporal variability within the phase cannot be adequately examined. Where possible, assumptions made based on data from the temporal components were compared against data from the more temporally precise occupational episodes.

In the aspatial analysis, the number and relative proportions of features and feature types per temporal component and occupational episode were compared. Feature types used in the aspatial analysis included structures, FAR concentrations, and pits, classified under the functional pit typology established in Chapter 4, Volume 1, and as presented above. The functional pit types used in this analysis included storage pits, processing/storage pits, and firepits. The number and relative proportions of features and feature types per temporal component and occupational episode were then used as proxies to examine potential changes in occupational intensity and site function over time to the extent practical.

Artifact frequency and artifact density were also examined. Artifact counts and relative proportions were also calculated at the level of artifact class: all flaked stone, all ground stone, all faunal remains, all ceramics, and all FAR. These artifact classes were chosen as the units of analyses in order to have sufficiently large numbers of specimens to compare over time. Artifact densities were also calculated as a means of standardizing the unevenness in the amount of artifacts recovered and assigned to temporal component and occupational episode. In this analysis, the total cubic meters of feature fill assigned to each temporal component and occupational episode was used to calculate densities per m^3 for all flaked stone tools, debitage, grinding implements (manos and metates), FAR, faunal remains, and ceramic artifacts recovered from feature contexts assigned to a temporal component or occupational episode. Variation in the presence, absence, or abundance of different artifact types was then used as a mechanism to infer the relative frequency of specific on-site activities such as plant-food processing, biface reduction and maintenance, and faunal processing, and the frequency of activities involving thermal features and FAR. Taken together, the variance in the number and relative proportions of features and artifacts of different kinds provided a somewhat robust vehicle to assess the relative frequency of specific on-site activities and, in turn, site function, and how these may have changed over time.

Spatial Analysis Methods

The spatial analysis methods applied in this chapter were used to document and interpret the spatial distribution of features and extramural artifacts at the Luke Solar sites according to temporal component and occupational episode. We also evaluated spatial distributions of features and artifacts that could not be assigned to a temporal component to determine if there were major differences between the distributions of features and extramural artifacts assigned to a temporal component or occupational episode vs. those that could not be assigned to a temporal component or occupational episode. Finally, we evaluated the spatial distribution of features according to stratigraphic context.

To develop the data needed for analysis, queries were developed in the project database to compile attribute data on features and extramural artifacts that could be joined with spatial data for features and extramural artifacts. For each aboriginal feature at Luke Solar, data were compiled in queries on the following attributes:

- feature code
- feature type
- feature morphology
- artifact frequency according to artifact class (ceramics, FAR, ground stone, flaked stone, and faunal specimens)
- excavated feature volume
- estimated feature volume (based on feature type and level of effort)
- level of excavation effort (examined, sampled, partially excavated, or completely excavated)
- temporal component
- occupational episode
- stratigraphic context

These aspatial attribute data were then linked to spatial data for feature polygons using the feature code. When linked, feature polygon area (in square meters) and Universal Transverse Mercator coordinates of feature centroids were calculated in ArcGIS to develop basic spatial data needed for analysis.

For extramural artifacts, we created a separate query in the project database that compiled, for each extramural provenience with one or more extramural artifacts, the following data:

- provenience code
- artifact type
- material type
- artifact count
- temporal component
- occupational episode
- stratigraphic context

Because some extramural proveniences contained multiple artifacts, there was not a one-to-one relationship between each provenience and extramural artifact. Because ArcGIS can only handle one-to-many relationships in joining attribute tables, we cross-tabulated the extramural artifact data per provenience and artifact type to produce a data set that provided information on the number of artifacts at each extramural artifact location, according to artifact type. These aspatial attribute data were then linked to spatial data for feature polygons using the provenience code.

One of the basic questions we addressed was, were features and artifacts clustered or dispersed and at what scales did clustering occur? From a subjective visual perspective, feature or artifact distributions may often appear to be spatially clustered, but it can be difficult to unambiguously identify clusters using subjective methods. Often, features or artifacts will cluster at multiple scales and the intensity of clustering will vary according to scale. For instance, individual clusters may be composed of multiple smaller clusters, while they themselves are part of larger and more-inclusive clusters. The intensity of clustering at different scales may also vary. This makes it important to apply spatial statistics, where possible, to evaluate and describe clustering or dispersal in an archaeological data set.

To evaluate whether clustering occurred and to identify the spatial scale(s) at which clustering occurred, we calculated Ripley's *L* for features using the Multi-Distance Spatial Clustering (Ripley's *K*) tool in ArcGIS 10. Designed to identify patterns of clustering or dispersion at different spatial scales, Ripley's *K* calculates the expected average number of neighbors (*K*) for any given point within a point pattern—in this case, the distribution of feature or artifact locations—at successively larger regular intervals of a particular radius. Confidence intervals for significance can be generated using multiple Monte Carlo simulations of a random point pattern with the same number of values as the data set (Conolly and Lake 2006:166). Finally, these expected values of *K* are compared against observed values to identify both the intensity of the clusters present in the data set and the distances at which these clusters exist. The *K* functions for a particular data set can then be illustrated using Ripley's *L,* a common transformation of *K* that plots spatially random patterns ($L = 0$) as a horizontal line. Values above this line indicate clustering at a particular distance (d), whereas values below the line indicate dispersion. Statistical significance is indicated if values fall above or below the confidence interval bracketing the line at a given distance.

The Multi-Distance Spatial Clustering (Ripley's *K*) tool requires that features be represented as points in order to make calculations. Thus, we used feature centroids to represent feature locations when running the tool. In general, Ripley's *K* estimates were calculated using 50 intervals from 5 to 250 m, using 5-m increments. This resulted in calculations being made every 5 m at scales between 5 and 250 m. Confidence envelopes were calculated using 99 iterations. We then examined Ripley's *L* to identify the range of scales over which clustering occurred and to evaluate the intensity of clustering at different scales. Interestingly, Ripley's *L* showed that features for many temporal components clustered across a broad range of scales but were often most intensively clustered at scales of approximately 50 m. Some temporal units also had feature distributions that appeared to be distinctively clustered at multiple additional scales, such as at scales of 15 m, 30 m, or 80 m. Information on the scales and intensity of clustering was subsequently used to guide other analyses that relied on the specification of fixed distances for calculating other metrics, such as kernel density calculations (see below).

In comparison to features, extramural artifacts assigned to temporal components were typically few in number, resulting in low sample sizes for calculating Ripley's *L*. However, in order to get a sense of whether these artifacts were clustered or dispersed in space and the degree to which they were clustered or dispersed, we used the Average Nearest Neighbor tool in ArcGIS to calculate the Nearest Neighbor Index (NNI) for extramural artifacts. The Average Nearest Neighbor tool calculates the observed and expected distance between nearest neighbors in a point distribution. The NNI is then calculated by dividing the observed distance by the expected distance. Values below 1 indicate that point distribution is clustered (i.e., points are located closer to one another than expected), and values above 1 indicate that a point distribution is dispersed (i.e., points are located farther from one another than expected).

Another question was, how did the intensity of feature construction vary across the project sites, according to temporal period, as well as overall? Such information could aid in identifying locations where activities that involved features had been focused during particular periods. To do this, we needed to calculate the total volume of each feature as a proxy measure for the effort placed in feature construction. The total volume of features that had been partially or completely excavated had already been estimated during prior analysis, but the volume of features that had only been examined, but not completely excavated, had not been estimated. Thus, in order to estimate the intensity of feature construction across the project sites, we needed to estimate the volume of examined features so that all features for a given temporal component could be assigned an estimated feature volume. This was achieved by examining, for each temporal component, the relationship between feature polygon area and feature volume for completely excavated features. Analysis revealed that the volumes of excavated features could be estimated well using a power law relationship where feature volume (m^3) was treated as the dependent variable and feature polygon area (m^2) was treated as the independent variable (Table 90).

Power law relationships, also referred to as allometric relationships, are common in biological, hydrological, and social systems and are commonly used to describe relationships in which the independent and dependent variables change at different rates (Heilen 2005; West et al. 1997). Power law relationshpis take the form of the equation $y = kx^{\alpha}$, where y is the dependent variable, k is a coefficient, x is the independent variable, and α is a scaling exponent. Such relationships appear as curved lines when plotted on graphs but approximate a straight line on log-log plots. When $\alpha = 1$, both x and y change at the same rate and hence describe an isometric relationship. Relationships are allometric when $\alpha \neq 1$. When $\alpha > 1$, x components grow at a faster rate than y components. Such relationships are referred to as hyperallometric relationships. When $\alpha < 1$, y components grow at a greater rate than x components. Such relationships are referred to as hypoallometric relationships. Power laws are more effective in describing the relationships between excavated feature area and feature volume for the current study because the relationships between the two variables approximate a power law distribution rather than a linear, exponential, or other relationship.

Power law equations describing the relationships between excavated feature volume and excavated feature area were calculated for each temporal component for which a sufficiently large sample of excavated features was available. Small sample sizes or a lack of examined features prevented such calculations from being made for San Pedro/Cienega, Red Mountain, and Classic period temporal components. Power law relationships between feature volume and feature polygon area could be estimated, however, for the remainder of temporal components as well as for undated features. The resulting relationships were, in general, moderate to strong, with r^2 values ranging from 0.74 to 0.94 (see Table 90). Exponents in these relationships tended to be slightly above or below 1, but varied among components.

These relationships were used to calculate, in ArcGIS, per temporal component, the estimated volume of examined features based on feature polygon area and the equations presented in Table 90. In other words, the power law equation calculated for a given temporal component based on feature volumes and areas of excavated features was used to predict the volume of features that had only been examined (and not partially or completed excavated), allowing us to estimate the volume of all features assigned to a particular temporal component. In one case, for the Cienega/Red Mountain phase transitional interval, the calculated relationship appeared to overestimate feature volume. We thus chose, in this case, to use the relationship calculated for features assigned to the Cienega phase to estimate feature volume because the equation appeared to provide more-reliable results than the equation for Cienega/Red Mountain phase features.

Once estimates of feature volume had been compiled for all features, the intensity of feature construction across the project sites was then calculated per temporal component by calculating kernel density estimates. Kernel density estimates were calculated in ArcGIS using the Kernel Density function. This nonparametric technique places a two-dimensional probability distance function, or "kernel," around each data point (Conolly and Lake 2006:175–177). The shape and radius of the kernel is manipulated by the algorithm to create a smooth, readily interpretable approximation of the distribution of a data set. While a default density estimate is based only on the distribution of points in relationship to each other, weights can be assigned to particular types of points to increase the intensity at which they are factored into the analysis. Artifact count or feature volume, for instance, can be used to weight an analysis to ensure that points with more artifacts or the largest feature volume represent higher estimated densities than locations with only a single associated artifact. The scale or distance at which to estimate kernel density also needs to be provided so that this tool estimates density based on calculations made within a specified distance of each feature to be analyzed.

To calculate kernel density estimates representing the intensity of feature construction for each temporal component, we weighted each feature using estimated feature volume and specified a fixed distance of 50 m for making kernel density calculations. We used a fixed distance of 50 m because many features clustered in the sample at a scale of 50 m. Calculating kernel density estimates using a uniform distance also allowed for

Table 90. Equations Used to Estimate Volume for Examined Features, based on Feature Polygon Area

Feature Category	Equation	r^2	n
Chiricahua	$y = 0.1507x^{1.2444}$	0.7468	277
Chiricahua/San Pedro	$y = 0.1375x^{0.9868}$	0.9021	62
San Pedro	$y = 0.1366x^{0.929}$	0.9347	95
Cienega	$y = 0.1369x^{1.0523}$	0.8782	57
Cienega/Red Mountain	$y = 0.1783x^{1.1268}$	0.913	29
Pre-Classic	$y = 0.1782x^{1.0798}$	0.8809	25
Classic/Protohistoric	$y = 0.1708x^{1.2724}$	0.8298	14
No assignment	$y = 0.1299x^{1.1722}$	0.7737	216
All features	$y = 0.1338x^{1.2008}$	0.7384	756
All FAR features	$y = 0.1005x^{0.9872}$	0.8808	125

systematic comparison of kernel density estimates among temporal components. For temporal components where Ripley's *L* estimates suggested additional clustering at scales other than 50 m, kernel density estimates were calculated according to additional scales of analysis to search for further patterning in feature distributions.

For temporal components where large numbers of features were located in multiple clusters, such as the distribution of Chiricahua phase features, we applied Zonal Nearest Neighbor Hierarchical Clustering (ZNNHC) analysis in Crimestat 4.0 to identify specific clusters of features and to evaluate their content and distribution with respect to each other and to the distribution of extramural artifacts. ZNNHC analysis assigns features to clusters based on nearest neighbor statistics and a weight or intensity variable. To perform ZNNHC analysis, we used estimated feature volume as the weight variable and specified a fixed distance of 50 m as well as other distances suggested as potentially important by Ripley's *L* analysis.

Another basic question we were interested in was, how were artifacts of different classes distributed across the project sites, per temporal component, and how did these distributions relate to the distribution of features? To pursue this question, we calculated an estimate of the number of artifacts, per feature class, found in each completely or partially excavated feature. Examined features could not be used because they provided no information about the presence or absence of artifacts within a feature. To derive an estimate of the total number of artifacts in each sampled or excavated feature, per artifact class, we applied the following procedure. For features that had been completely excavated, we simply used the total number of artifacts discovered in the feature as the estimated artifact count. For features that had only been sampled or partially excavated, we first calculated artifact density for each sampled or partially excavated feature by dividing the total number of artifacts (of a given artifact class) discovered in the feature by the excavated volume of the feature. We then multiplied this density by the estimated feature volume to arrive at an estimate of the total number of artifacts, per class, that were likely to have been contained within the feature. The estimated artifact counts allowed us to examine artifact abundance across the project sites, according to artifact class and temporal component, using kernel density estimates. Like kernel density estimates calculated using feature volume, kernel density estimates were calculated using estimated artifact count using a fixed distance of 50 m, as well as other distances, when warranted. These estimates allowed us to evaluate variation across the project sites in artifact density, according to temporal component and artifact class. Given the significant time constraints of the project, we confined these analyses to general artifact classes. It would be worthwhile in the future, however, to perform a similar analysis using finer categories of artifacts, such as evaluating differences among flaked stone tools, cores, and debitage or differences between pounding vs. grinding implements, as well as to examine patterns in artifact size or completeness. For some temporal components, clusters of features consisted mostly or entirely of examined features, making it impossible to derive a reliable estimate of artifact distributions for these particular clusters of features. In most cases, however, examined features were interspersed among many similar features that had been sampled or excavated, allowing for more-reliable estimates of artifact kernel densities in different areas of the site.

An important consideration in examining artifact distributions across the project sites, and especially Falcon Landing, was how particular artifact classes were distributed according to feature type. For instance, were FAR artifacts preferentially found in thermal features or in features of other types? In what kinds of features were flaked stone, ground stone, or faunal specimens most commonly found? To address these questions, we calculated the overall percentage and density of artifacts for each temporal component and artifact class, according to feature type. To do this, we calculated the total combined estimated volume of features, per feature type, for features that were sampled, partially excavated, or completely excavated. We did not include estimated volumes for examined features, as this would have had the effect of underestimating calculated densities because artifacts were not recorded within examined features. We then calculated the combined total sum of artifacts, per feature type, artifact class, and temporal component. These data were then used to calculate the percentage of artifacts of a given artifact class and the density of artifacts of a given artifact class for each feature type. These calculations enabled us to examine, for each temporal component, the numerical distribution of artifacts according to feature type and artifact class and to identify instances where artifact classes were associated with specific feature types. In the discussion of these metrics, we refer to this density as "overall volumetric density" in order to clearly differentiate this density from kernel density estimates made for the spatial analysis and from other artifact densities presented earlier in this chapter.

One of the questions we had about artifact distributions had to do with how FAR was distributed with regard to feature type. Our expectation was that FAR would primarily be associated with thermal features and FAR concentrations, but analysis showed that many FAR were found in other features, particularly nonthermal pits. Of course, FAR could have been removed from thermal features after use to access feature contents and subsequently deposited in features of other types. The finding of large amounts of FAR in nonthermal features led us to wonder if FAR was located significantly more often in thermal features or in features of other types. Moreover, because the identification of thermal activity was conservative, being based on positive evidence of in situ burning (i.e., oxidation of feature walls), some nonthermal pits could potentially have served an unrecognized thermal function (see Chapter 9). For temporal components with large numbers of thermal pits, we used chi-square tests to evaluate whether FAR was found significantly more often in thermal features or in features of other types and also evaluated the spatial distribution of FAR with respect to the location of thermal features and features of other types. We performed 2-by-2 chi-square tests by comparing the number of FAR artifacts in thermal features and in features of other types with the number of thermal features and the number of features of other types. Interestingly, these tests tended to show that although FAR was found in numerous nonthermal features, FAR was located in thermal features more often than expected, in comparison to features of other types. For cases where the distribution of other artifact classes (i.e., flaked stone, ground stone, or faunal specimens) appeared to correspond to particular feature types, we performed similar chi-square tests to determine whether the patterns were statistically significant.

After having evaluated artifact and feature distributions according to temporal component, we then evaluated the correspondence between artifact and feature distributions at the component level with artifact and feature distributions at the level of occupational episode. We did this by examining where features assigned to an occupational episode were located with respect to clusters of features assigned to more broadly defined temporal components. This analysis was most relevant for the Chiricahua temporal component, a component which included multiple occupational episodes and for which a large number of features were assigned to several occupational episodes. For most later periods, by contrast, features assigned to an occupational episode were few in number. In general, patterning in the location of features, according to occupational episode, showed some important spatial variation through time in the use of Falcon Landing during the Chiricahua temporal component, suggesting that some portions of the site were used primarily during one episode and that use of the site shifted spatially through time during the relatively lengthy Chiricahua temporal component.

A final question of interest was, were there significant differences in where features and artifacts assigned to different temporal components were located? In other words, were specific areas of the site used primarily during specific periods or did different temporal components typically overlap in space? Were there significant hot spots at Falcon Landing, or at the other sites, where earlier or later temporal components tended to be uniquely located? Where did use of the sites overlap for multiple periods? To what degree was the distribution of features according to temporal component a function of geologic context? In order to evaluate the overall distribution of temporal components, each temporal component was assigned a number corresponding to the temporal sequence. The earliest temporal component in this analysis, Chiricahua, was assigned a value of 1 and the latest temporal component, Classic/Protohistoric, was assigned a value of 10. We then created a raster with 1-by-1-m cell size in which each cell represents the most common temporal component assigned to the centroid(s) of extramural feature(s) or primary feature(s) located within the cell. (A primary feature is one that contains subfeatures, e.g., a house-in-pit [primary feature] and its postholes [subfeatures]). In other words, if there were three feature centroids (corresponding to primary or extramural features) located in a cell and two were assigned to temporal component 1 (Chiricahua) and the other was assigned a sequence value of 3 (San Pedro), then the cell was assigned a value of 1 because the majority of primary or extramural features were assigned to that value. In most cases, there was only one feature per 1-by-1-m cell, but multiple features in a single cell were possible.

This raster representing the most common temporal component in each 1-by-1-m cell was then used to create a focal majority raster and a focal variety raster using the Focal Statistics tool in ArcGIS. The focal majority raster was created by calculating the most common component found within a 25-by-25-m area around each feature centroid; the focal variety raster was created by calculating the variety, or richness, of temporal components found within a 25-by-25-m area around each feature centroid. The focal majority raster shows where the features corresponding to particular temporal components tended to be located across the sites. The map suggests that large areas were used primarily during one component, while some other relatively small areas were used repeatedly during multiple components. The focal variety raster shows which portions of the project area were more or less diverse in their temporal assignments. The map shows that temporal diversity for features was low for many areas of the project sites, but a high temporal diversity for features occurred in a few discrete locations that were repeatedly used during multiple periods. One potential deficiency of this approach is that some components had large numbers of pit features, and other temporal components had relatively few pit features and were characterized to a greater degree by larger structural features. These differences could have led to underrepresentation of components characterized primarily by structural features and overrepresentation of temporal components with large numbers of pit features. However, the results of Anselin Local Moran's I analysis (see below) conformed well to the distribution shown in the focal majority raster, suggesting the map represents a fair approximation of the spatial distribution of temporal components across the project sites.

We also performed a similar analysis using occupational episodes, but with less success, given the relatively small number of features assigned to occupational episodes and, perhaps, the greater tendency for occupational episodes to have been assigned to structural features. To perform this analysis, we created a similar focal majority raster as the one discussed above, but instead of using a numbering sequence assigned according to temporal component, we used a numbering sequence based on the sequence of occupational episodes (see Figure 98). The resulting raster was less specific or informative in delineating the spatial distribution of temporal components than the focal majority raster created using the numbering sequence based on the temporal components. In general, however, the focal majority raster based on occupational episodes showed a fairly good correspondence with the focal majority raster based on temporal component.

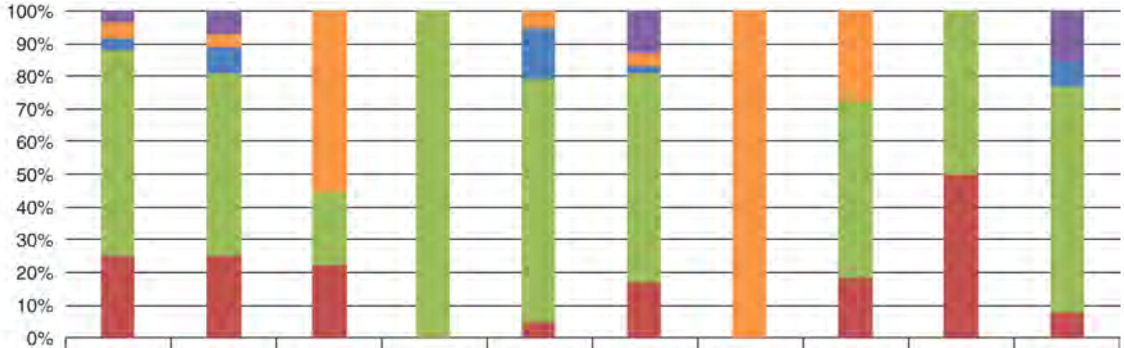
To further evaluate the overall distribution of temporal components, we performed Anselin Local Moran's I analysis in ArcGIS using the Cluster and Outlier Analysis (Anselin Local Moran's I) tool in ArcGIS. The tool calculates a local estimate of Anselin-Moran's I, a measure that depicts the degree to which point attributes (such as artifact count or occupational episode) are spatially autocorrelated. In other words, the tool assesses whether a value attributed to a point (such as occupational episode) is similar or different to the values attributed to other points located in the immediate vicinity of the point. As with other estimates, a fixed distance of 50 m was used to evaluate feature locations and their relative age. Results of the tool indicate whether each feature is surrounded by features with significantly high values, features with significantly low values, or features with values that are not significantly high or low. The tool also identifies cases where a point is a local outlier, being significantly higher or lower in value than most points in its immediate vicinity. For this particular analysis, outliers are cases where the temporal assignment of a feature is significantly different (older or younger) than the age of most nearby features.

Discussion: Aspatial Analyses

Chiricahua Phase (3500–1200 B.C.)

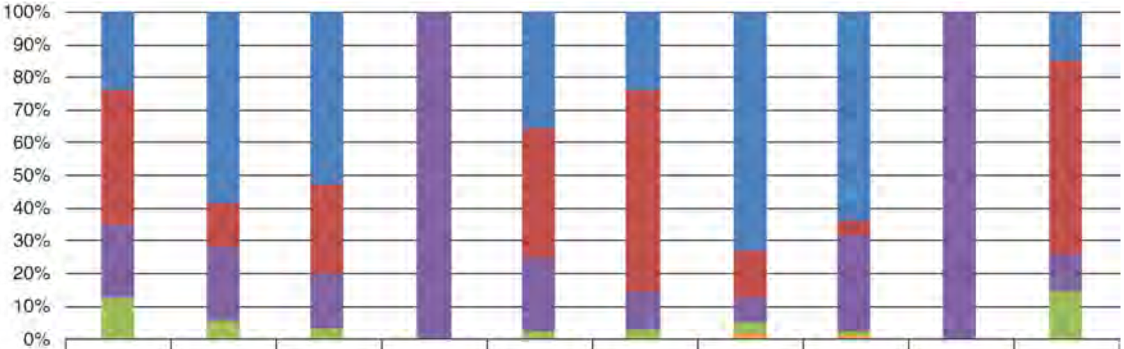
The Chiricahua phase occupational record in the project area was robust, with the greatest number of features assigned to the functional categories used in this analysis (n = 310), and the second-greatest combined number of artifacts and faunal remains (n = 2,931) (Figures 99 and 100). Features dated to the Chiricahua phase and used in this examination included 15 structures, 78 firepits, 195 processing/storage pits, 11 storage pits, and 11 FAR concentrations. When the 2,300-year duration of this phase was taken into account, this resulted in an average of only 0.13 features per year. This is, of course, a coarse-grained metric that undoubtedly masks the actual variance in occupational intensity over time, but it did allow a uniform method to compare occupational intensity over time based on the number of features dated to phase or period.

The most common artifact type recovered from these features was FAR, followed in decreasing order of abundance by flaked stone, faunal remains, and ground stone. Ground stone artifacts, however, were relatively abundant compared to all following phases and periods, except for the Classic/Protohistoric period transition.



	Chiricahua	Chiricahua /San Pedro	San Pedro	San Pedro /Cienega	Cienega	Cienega /Red Mountain	Red Mountain	Pre-Classic	Classic	Classic /Protohistoric
🟪 FAR concentration (N)	11	9				12				2
🟧 Structure (N)	15	5	10		2	4	2	3		
🟦 Storage (N)	11	10			6	2				1
🟩 Processing/storage (N)	195	71	4	1	29	61		6	1	9
🟥 Firepit (N)	78	32	4		2	16		2	1	1

Figure 99. Relative proportions of features by temporal component.



	Chiricahua	Chiricahua /San Pedro	San Pedro	San Pedro /Cienega	Cienega	Cienega /Red Mountain	Red Mountain	Pre-Classic	Classic	Classic /Protohistoric
🟦 Flaked stone (N)	706	1,596	347	0	243	348	256	101	0	22
🟥 FAR (N)	1,209	372	178	0	269	901	50	7	0	86
🟪 Faunal (N)	650	606	106	5	149	172	26	46	5	16
🟩 Ground stone (N)	365	152	20	0	17	43	11	2	0	21
🟧 Ceramics (N)	1	0	1	0	0	0	6	2	0	0

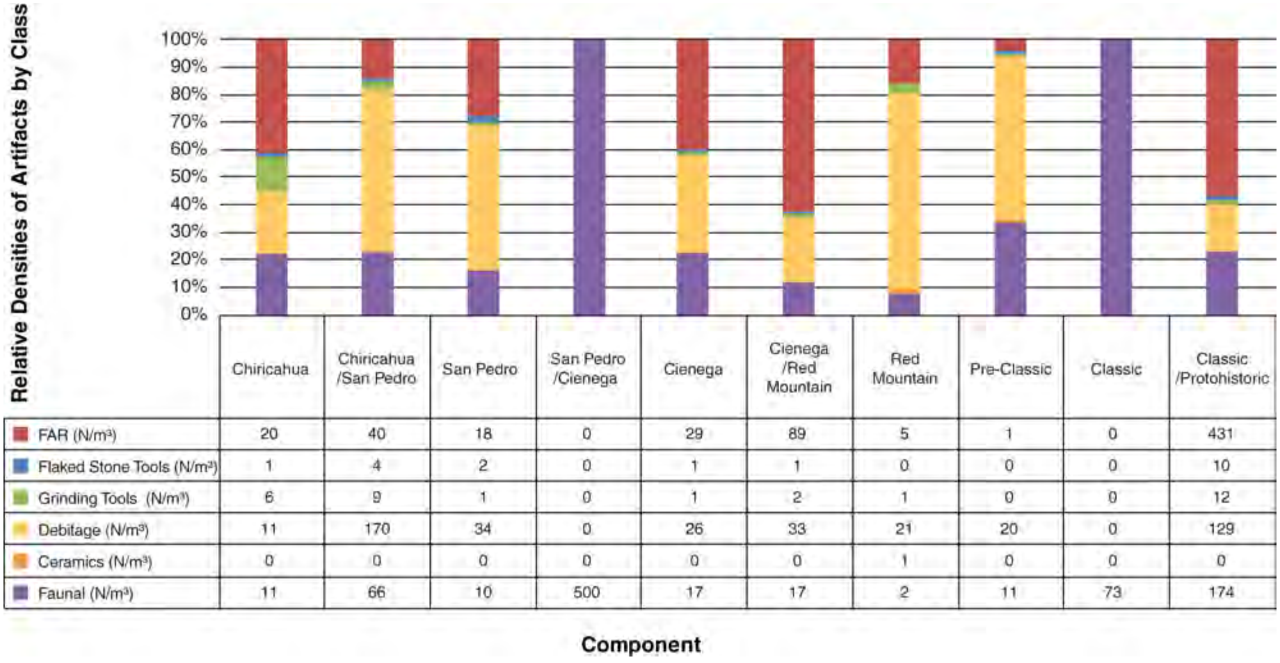
Figure 100. Relative proportions of artifacts and faunal remains per temporal component.

When density per cubic meter of feature fill excavated and dated to the Chiricahua phase was examined, the relative amounts of artifacts and faunal remains suggested occupational intensity was relatively moderate. The amount of ground stone, however, was relatively high when compared to the rest of the occupational sequence (Figure 101). The relative proportions of artifacts and faunal remains recovered per cubic meter of sampled fill from Chiricahua phase features also indicated that FAR was the most common artifact type, followed by debitage (which consisted almost entirely of biface-reduction and edge-maintenance flakes), ground stone, and flaked stone tools.

Taken together, these relative frequencies and proportions of feature types and artifacts suggest that over the 2,300 years encompassed by the Chiricahua phase, site function varied from a limited-activity locale, likely frequented by task groups where plant-food collection and processing were the primary site activities, to a short-term, likely warm-season habitation, as evidenced by the 15 structures and associated extramural features. Irrespective of these changes in site function, on-site activities focused on the collection and processing of mesquite and the small seeds of locally available grasses and weedy annuals (see Chapters 6 and 7), biface reduction and the maintenance of the hunting tool kit (see Chapter 3), and opportunistic leporid hunting and on-site leporid consumption (see Chapter 4). These activities generally characterize not only the Chiricahua phase but also the entire occupational record at Falcon Landing, and this record continued relatively uninterrupted until the Classic/Protohistoric period transition, dated to cal A.D. 1220–1520 at this site. Given this remarkable persistence in the primary on-site activities, the following discussions focus on variability in inferred occupational intensity; on-site activities; and site function over time, from the perspective of numbers of features of various types and the proportions of these feature types, and the artifacts and faunal remains they contained, as dated to the temporal components and occupational episodes.

Occupational Episodes A–D (various calibrated age ranges)

As detailed in the preceding methods section of this chapter, Occupational Episodes A–D offered the greatest temporal precision for the Chiricahua phase that could be obtained through a combination of direct radiocarbon dating of features and assigning ages to features based on the project geochronology at Falcon Landing.



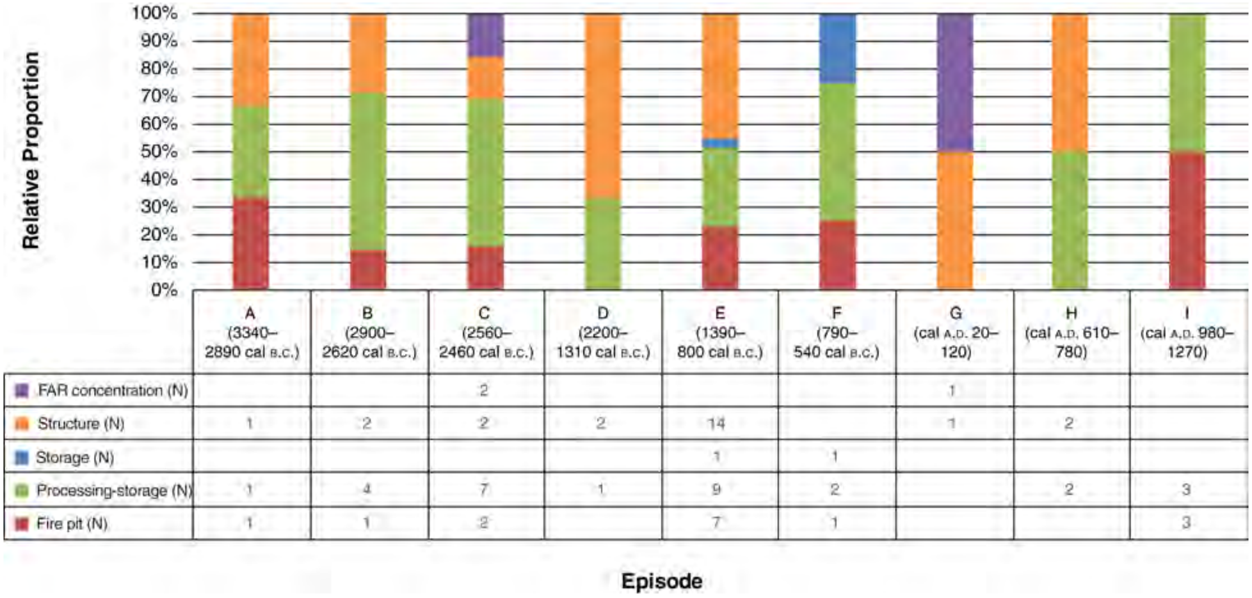
	Chiricahua	Chiricahua /San Pedro	San Pedro	San Pedro /Cienega	Cienega	Cienega /Red Mountain	Red Mountain	Pre-Classic	Classic	Classic /Protohistoric
🟥 FAR (N/m³)	20	40	18	0	29	89	5	1	0	431
🟦 Flaked Stone Tools (N/m³)	1	4	2	0	1	1	0	0	0	10
🟩 Grinding Tools (N/m³)	6	9	1	0	1	2	1	0	0	12
🟨 Debitage (N/m³)	11	170	34	0	26	33	21	20	0	129
🟧 Ceramics (N/m³)	0	0	0	0	0	0	1	0	0	0
🟪 Faunal (N/m³)	11	66	10	500	17	17	2	11	73	174

Figure 101. Artifact and faunal density proportions by temporal component.

Examining feature frequency over Occupational Episodes A–C suggested that occupational intensity increased over the course of the Chiricahua phase (Figure 102), and that the use of extramural pits for processing and/or storage intensified, as did the construction and use of firepits and the creation of discrete FAR concentrations. It is interesting to note that structures were also built and abandoned, beginning with Occupational Episode A (3340–2890 cal B.C.), and this suggests that Falcon Landing, at times, functioned not only as a plant-food collection and processing locale used by task or family groups, but also intermittently as a short-term, warm-season habitation (see Chapters 6 and 7). The relative proportions of structures to firepits during Chiricahua phase Occupational Episodes A–C, however, did decline to a limited extent, whereas FAR concentrations were only dated to Occupational Episode C (2570–2460 cal B.C.). Pits classifiable as processing/storage features were least numerous during Occupational Episode A, and processing/storage pits became more numerous and were used to nearly the same extent during Occupational Episodes B and C (see Figure 102).

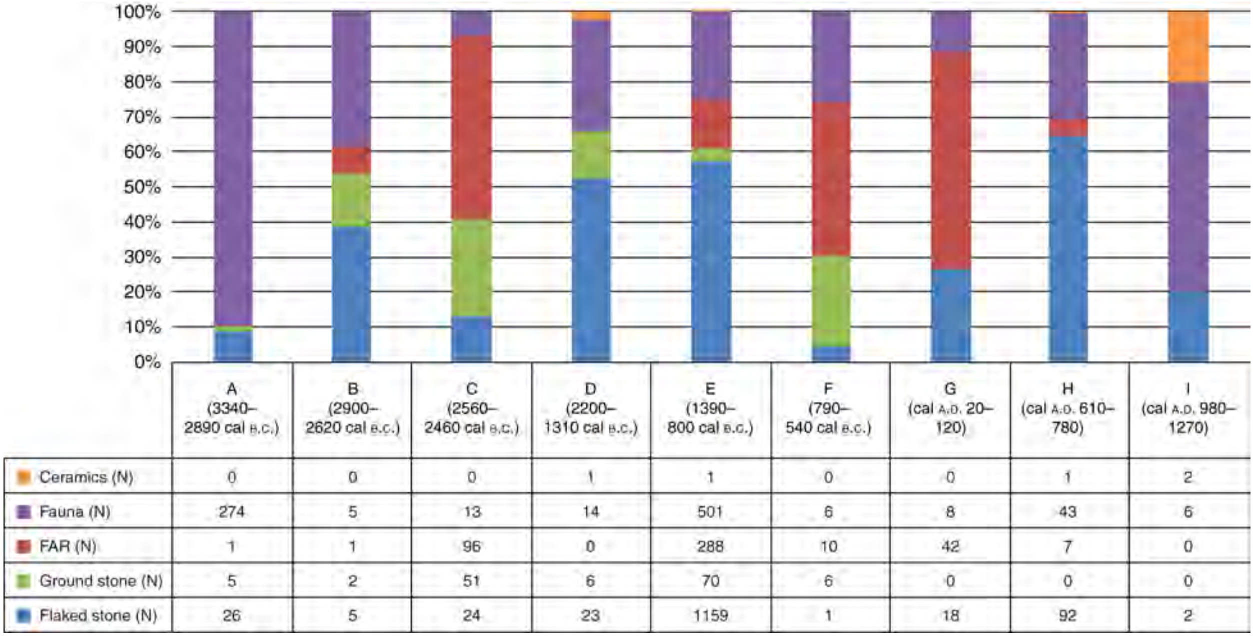
It is unlikely that the decrease in feature frequency and the absence of firepits and FAR concentrations during Occupational Episode D (2200–1310 cal B.C.), as shown in Figure 102, accurately reflect site activities or occupational intensity. This is because only one processing/storage pit and two structures could be dated to this interval, and the vagaries of sampling have in all likelihood resulted in a spurious result for Occupational Episode D. If Occupational Episode D is excluded from consideration, feature frequency increased starting with Occupational Episode A (3340–2890 cal B.C.) and culminated near the end of the Chiricahua phase between 1390 and 1200 cal B.C. or at some time during the San Pedro phase (1200–800 B.C.). The resolution of the project chronology does not allow further refinement of this observation.

A general paucity of artifacts and faunal remains from the features assigned to Occupational Episodes A–D made their interpretation unfortunately tenuous. Generally speaking, during Occupational Episode A, faunal remains were the most abundant in terms of number and their proportions compared to the artifact classes, and faunal use may have declined in importance over the course of the Chiricahua phase from the perspective of the number and density of faunal remains at Falcon Landing (Figures 103 and 104). Whereas faunal use and importance may have declined, the number and proportion of ground stone artifacts and FAR increased. This suggests that FAR production was a derivative of plant-food processing, and that the parching of mesquite pods and small seeds may have been a key component of on-site plant-food processing during the Chiricahua phase (see Chapters 6, 7, and 9). The amount and proportions of flaked stone artifacts over these three occupational



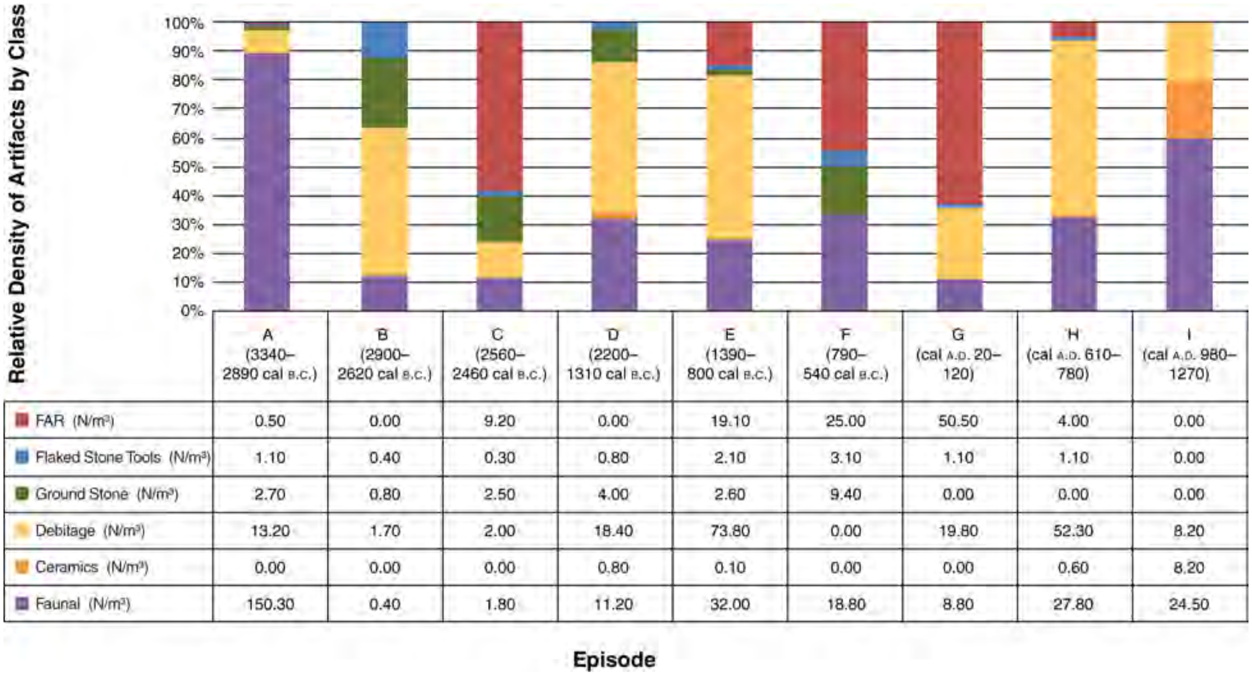
	A (3340–2890 cal B.C.)	B (2900–2620 cal B.C.)	C (2560–2460 cal B.C.)	D (2200–1310 cal B.C.)	E (1390–800 cal B.C.)	F (790–540 cal B.C.)	G (cal A.D. 20–120)	H (cal A.D. 610–780)	I (cal A.D. 980–1270)
🟪 FAR concentration (N)			2				1		
🟧 Structure (N)	1	2	2	2	14		1	2	
🟦 Storage (N)					1	1			
🟩 Processing-storage (N)	1	4	7	1	9	2		2	3
🟥 Fire pit (N)	1	1	2		7	1			3

Figure 102. Feature proportions by occupational episode.



	A (3340–2890 cal B.C.)	B (2900–2620 cal B.C.)	C (2560–2460 cal B.C.)	D (2200–1310 cal B.C.)	E (1390–800 cal B.C.)	F (790–540 cal B.C.)	G (cal A.D. 20–120)	H (cal A.D. 610–780)	I (cal A.D. 980–1270)
🟧 Ceramics (N)	0	0	0	1	1	0	0	1	2
🟪 Fauna (N)	274	5	13	14	501	6	8	43	6
🟥 FAR (N)	1	1	96	0	288	10	42	7	0
🟩 Ground stone (N)	5	2	51	6	70	6	0	0	0
🟦 Flaked stone (N)	26	5	24	23	1159	1	18	92	2

Figure 103. Proportions of artifacts and faunal remains per occupational episode.



	A (3340–2890 cal B.C.)	B (2900–2620 cal B.C.)	C (2560–2460 cal B.C.)	D (2200–1310 cal B.C.)	E (1390–800 cal B.C.)	F (790–540 cal B.C.)	G (cal A.D. 20–120)	H (cal A.D. 610–780)	I (cal A.D. 980–1270)
🟥 FAR (N/m³)	0.50	0.00	9.20	0.00	19.10	25.00	50.50	4.00	0.00
🟦 Flaked Stone Tools (N/m³)	1.10	0.40	0.30	0.80	2.10	3.10	1.10	1.10	0.00
🟩 Ground Stone (N/m³)	2.70	0.80	2.50	4.00	2.60	9.40	0.00	0.00	0.00
🟨 Debitage (N/m³)	13.20	1.70	2.00	18.40	73.80	0.00	19.80	52.30	8.20
🟧 Ceramics (N/m³)	0.00	0.00	0.00	0.80	0.10	0.00	0.00	0.60	8.20
🟪 Faunal (N/m³)	150.30	0.40	1.80	11.20	32.00	18.80	8.80	27.80	24.50

Figure 104. Artifact and faunal proportion densities by occupational episode.

episodes seem to have been independent of the amount and proportions of faunal remains and the other artifact classes, and flaked stone artifacts were most numerous during Occupational Episode B (2860–2620 cal B.C.).

Chiricahua/San Pedro Phase Transition (1380–920 cal B.C.) and San Pedro Phase (1200–800 B.C.)

Several trends are evident in Figures 99 and 100, including a decrease in the relative proportion of structures during the Chiricahua/San Pedro phase transition; an increase in FAR concentrations, storage pits, and flaked stone; a relatively uniform number of firepits; and a general decline in the number of processing/storage pits, ground stone, faunal remains, and FAR. The large increase in structures during the San Pedro phase suggests that Falcon Landing more frequently functioned as a short-term habitation compared to the preceding and much longer (nearly sixfold) Chiricahua phase. Indeed, this change in site function was relatively punctuated, when one considers that the San Pedro phase was only 400 years in duration compared to the 2,300-year duration of the preceding Chiricahua phase. Increased occupational intensity as reflected in the frequency of artifacts also supports this pattern as shown in Figure 100, with a total of 2,931 artifacts deposited in Chiricahua phase features, compared to 2,726 during the relatively short Chiricahua/San Pedro phase transition (dated to between 1380 and 920 cal B.C. at Falcon Landing and Site 68), and 652 during the San Pedro phase. Although not readily apparent in terms of artifact frequency, if the numbers of artifacts deposited per phase are divided by the duration of that phase, then 0.92 artifacts were annually deposited during the 2,300-year Chiricahua phase compared to 5.92 during the 460-year Chiricahua/San Pedro transition, and 1.63 during the 400-year San Pedro phase. Examination of the number of artifacts and ecofacts deposited per cubic meter of sampled feature fill assigned to these intervals reinforces this observation, with substantially greater artifact and ecofact density per cubic meter during the Chiricahua/San Pedro phase transition compared to the earlier Chiricahua and later San Pedro phases (see Figure 101).

Occupational Episode E (1390–800 cal B.C.)

Dating to 1390–800 cal B.C., Occupational Episode E encompasses the Chiricahua/San Pedro phase transition and the entirety of the San Pedro phase. Compared to other occupational episodes, this episode included the greatest number of features, especially structures, and this episode could be interpreted as the culmination of a period of increasing occupational intensity that began during Occupational Episode A (3340–2890 cal B.C.) (see Figure 102). Occupational Episode E was also the first episode in which pits of sufficient size and shape and classifiable as storage pits were built and used, and the presence of pit storage coincided with the increased number of structures, perhaps indicating a relatively greater amount of settlement permanence and site provisioning.

The relatively greater number of artifacts and faunal remains documented for this episode, however, was likely a direct consequence of the greater number of corresponding features. Flaked stone reduction and maintenance, leporid processing and consumption, and plant-food processing requiring the use of a relatively expensive and curated ground stone inventory were among the primary site activities (see Chapter 3 and Figure 103). In terms of artifact density, this occupational episode produced the second highest result in the relative proportion of artifacts to faunal remains (see Figure 104).

San Pedro/Cienega Phase Transition (920–720 B.C.) and Cienega Phase (800 B.C.–A.D. 50)

The examination of the San Pedro/Cienega phase transition was hindered by having only one processing/storage pit assignable to this 200-year transitional interval at Falcon Landing. A relatively low level of occupational intensity characterized the Cienega phase at Falcon Landing as evidenced by the 39 features dated to this 850-year phase. The relative proportions of feature types suggest a continuation of the same on-site activities documented during previous phases, with processing/storage pits dominating the recorded feature types, and a relative decline in the proportion of firepits (see Figure 99). The apparent increase in the relative proportion of structures compared to the preceding phase is misleading in that only two structures were dated to the Cienega phase, and Falcon Landing, in all likelihood, primarily functioned as a limited-activity locale during this phase and may have only functioned occasionally as a short-term habitation.

The number and relative proportions of artifacts and faunal remains dating to the Cienega phase compared very closely to the preceding San Pedro phase (see Figure 100), with a continued low number of ground stone implements and faunal remains, and a minimal reduction in the amount of flaked stone but an increased amount of FAR compared to the preceding San Pedro phase. Excluding the exceedingly small sample from San Pedro/Cienega, artifact density starting in the San Pedro phase and over the course of the Cienega phase remained essentially unchanged, although the density of faunal remains and FAR increased slightly during the Cienega phase, while the density of debitage and flaked stone tools subtly declined (see Figure 101). This increase in the relative proportion and density of FAR was somewhat at odds with the relative decline in the proportion of firepits, and the reasons for this are unclear.

Occupational Episode F (790–540 cal B.C.)

This occupational episode encompasses the Early Cienega phase and represents the 790–540 cal. B.C. interval at Falcon Landing. Only four features, a firepit, two processing/storage pits, and one storage pit, made up this occupational episode. This general paucity of features may represent a significant decline in occupational intensity compared to previous Occupational Episodes A–D and E, but the small sample size prohibits a meaningful and valid comparison. The presence of a storage pit during this interval, however, does suggest a continuation in the use of storage pits first documented during the preceding Occupational Episode E (see Figure 102). The lack of structures dating to this episode also suggests the presence of task groups focused on procuring and processing plant and animal resources (see Figures 102 and 103). Overall artifact density for this episode was comparatively moderate, with FAR, followed by faunal remains, being most abundant, followed by ground stone and flaked stone tools (see Figure 104).

Cienega/Red Mountain Phase Transition (160 B.C.–A.D. 340) and Red Mountain Phase (A.D. 50–400)

When the Cienega/Red Mountain phase transitional interval was compared to the preceding Cienega phase, there was a greater than twofold increase in the number of dated features at Falcon Landing (n = 95). This demonstrable increase in occupational intensity at Falcon Landing became fourfold when the total number of features dated to each interval was divided by the duration of each interval, with a resulting average of 0.05 features annually during the Cienega phase and 0.20 over the course of the 500-year Cienega/Red Mountain phase transition at Falcon Landing. This was also the period in time when Site 423 was intensively occupied.

The number and proportion of firepits increased during this transitional interval (see Figure 99), and the number of structures also increased to six compared to only two during the preceding Cienega phase, and both of the Cienega phase structures were abandoned prior to 160 cal. B.C. It is important to note that two of these six structures were the only features at Falcon Landing that dated solely to the Red Mountain phase. Both were house-in-pits; one was abandoned sometime between cal A.D. 130 and 330, and the other was abandoned sometime between cal A.D. 260 and 430. Except for a charcoal/ash lens dated to cal A.D. 70–250, no other features were dated to the 350-year interval encompassed by the Red Mountain phase.

A subtle increase in the proportions of storage and firepits coincided with the increased number of structures and a relatively greater number of artifacts and faunal remains dated to the 500-year Cienega/Red Mountain phase transition at Falcon Landing (see Figure 100). Together, these trends suggest increased occupational intensity, a greater possible range of domestic activities, and what was likely a more residential focus. Unlike the preceding Cienega phase, however, the number and relative proportion of FAR expectedly increased along with the increased number and relative proportion of firepits. Examination of artifact densities and relative proportions based on cubic meter sampled also mirrored the trends exhibited by the artifact counts, and the increases in the density metrics also likely signal increased occupational intensity (see Figure 101).

Occupational Episode G (cal A.D. 10–120)

This episode spans the early portion of the Red Mountain phase from cal A.D. 10–120 and was represented in this analysis by a single structure at Falcon Landing and an FAR concentration at Site 423. FAR was the predominant artifact type, followed by flaked stone and then faunal remains. The relatively high density of artifacts calculated for this episode should be considered biased by the small amount of sampled feature fill from the two features dated to this episode.

Pre-Classic (A.D. 400–1150), Classic (A.D. 1150–ca. 1450), and Classic/Protohistoric (A.D. 1220–1640) Periods

Occupational intensity declined significantly during the final century of the Red Mountain phase and remained persistently low thereafter. This reduction in occupational intensity was reflected by only 11 features dated to the pre-Classic period at Falcon Landing and Site 68, and these consisted of 3 relatively ephemeral structures, 6 processing/storage pits, and 2 firepits. All three of the structures were radiocarbon dated to the Snaketown phase (A.D. 650–750), but no extramural features dating to the Snaketown phase were identified. No features were dated to the Colonial period (A.D. 750–950), indicating a possible hiatus during the Colonial period, and only a mere 4 extramural pits were dated to the Sedentary period (A.D. 950–1150). The remaining features dated to the pre-Classic period were either radiocarbon or geologically dated to relatively broad intervals encompassing several pre-Classic and/or pre-Classic and Classic period phases.

The relative number and proportions of feature types during the pre-Classic period compare best with the San Pedro phase, although pre-Classic period occupational intensity was significantly lower (see Figure 99). This pre-Classic period decline in occupational intensity was also signaled by relatively low numbers of artifacts and faunal remains, although the relative proportion of faunal remains was greater than the preceding Red Mountain phase, while the relative proportions of flaked and ground stone and FCR declined (see Figure 100). When artifact density was considered (see Figure 101), the relative proportions of grinding implements and FAR declined significantly compared to preceding phases. At the same time, there was an apparent increase in biface reduction that coincided with an increase in faunal remains, suggesting that the production and maintenance of flaked stone tools, along with hunting, increased in relative importance. The presence of biface reduction debris in pre-Classic period contexts is somewhat peculiar, in that the production of bifaces declined dramatically with the introduction of the bow and arrow during the pre-Classic period. It is possible that the biface reduction debris was introduced to the pre-Classic period features by mixing, either by natural processes or the on-site collection of Archaic period biface flakes by the Hohokam.

Overall, over the course of the pre-Classic period, Falcon Landing and Site 68 probably continued to be intermittently used locales for collecting and processing plant foods, with concurrent biface reduction and maintenance, along with opportunistic leporid hunting. The only evidence supporting the use of Falcon Landing and Site 68 as a short-term habitation during the pre-Classic period was the three structures built and abandoned during the Snaketown phase (A.D. 650–750).

This low level of occupational intensity at Falcon Landing persisted over the course of the Classic period and the Classic/Protohistoric period transition as dated at Falcon Landing. However, the temporal overlap between the Classic period and the Classic/Protohistoric period transition at Falcon Landing complicates this interpretation. This is because the Classic/Protohistoric period transition at Falcon Landing can only be broadly dated to cal A.D. 1220–1520, and this interval encompasses the latter part of the Classic period. Falcon Landing was seldom frequented and for the most part could be characterized as a limited-activity locale during this transitional interval. Only one firepit and one processing/storage pit could be dated solely to the Classic period, and no stone or ceramic artifacts were encountered in these Classic period pit features, and only a few faunal remains were recovered. A greater number of features could be assigned to functional categories and dated to the Classic/Protohistoric period transition, including one firepit, nine processing/storage pits, and one storage pit. No structures were encountered that dated to this last occupational episode (see Figure 99). Artifacts and faunal remains from these features that dated to the Classic/Protohistoric period transition included all examined artifact categories (see Figure 100), with the highest overall density of recovered artifacts and faunal remains compared to preceding periods (see Figure 101). In fact, the relative proportions of artifact classes and faunal remains per cubic meter sampled most favorably compared to the Cienega phase and the Cienega/Red Mountain transition, and the range of represented activities in terms of on-site procurement, processing, and manufacture can be interpreted as effectively equivalent.

Occupational Episodes H (cal A.D. 610–780) and I (cal A.D. 980–1270)

Dated to cal A.D. 610–780, Occupational Episode H included two structures and two processing/storage pits. This episode encompasses the end of the Sweetwater phase (A.D. 550–650) and the entirety of the Snaketown phase, and it in all likelihood represents a pre-Classic period Hohokam occupation. The number of faunal remains recovered from these features was relatively moderate, and these faunal remains were associated with a large amount of flaked stone and a few ceramic artifacts (see Chapter 5, and Figure 103). Artifact density for this occupational episode was the third highest calculated, with flaked stone debitage being the most abundant, followed in decreasing order of abundance by faunal remains, FAR, flaked stone tools, and ceramics (see Figure 104). Interestingly, no ground stone artifacts were directly associated with these Ceramic period features.

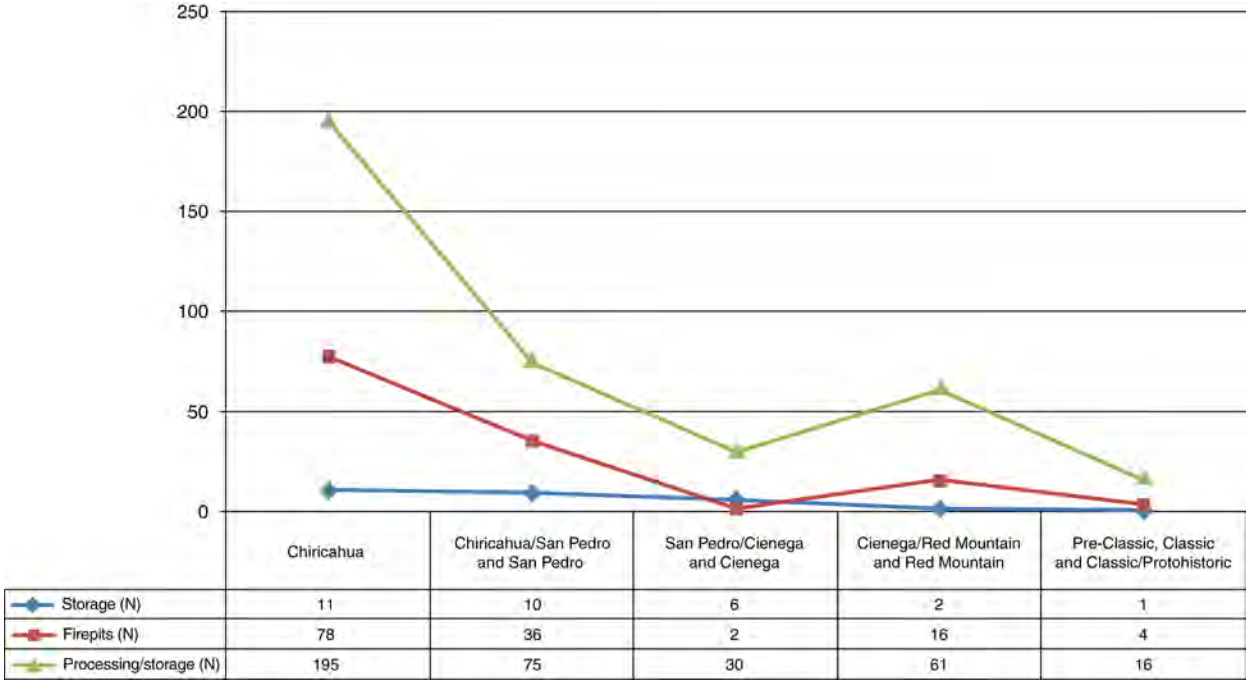
Occupational Episode I (cal A.D. 980–1270) encompasses the pre-Classic/Classic period transition and included only three firepits and three processing/storage pits. The smallest number of artifacts for any episode was recovered from these six features, with only two flaked stone artifacts, six faunal specimens, and two ceramic sherds assignable to this episode. Similarly, the calculated densities of artifact and faunal remains for this episode were also relatively low, with a relatively high density of faunal remains, and a moderately high density of ceramics and debitage (see Figures 103 and 104).

Pit Function Over Time

The three pit functions defined above—cooking, storage, and processing/storage—were examined for trends in frequency and morphometric attributes over time. Presented below is a comparison of the counts of pit types in the sample according to each temporal component. The absolute counts of feature types, and how they changed between phases and periods, provide interesting insight into the changing or unchanging needs over time. Of similar interest is how the distribution of pit types within each temporal component changed over time. In other words, the total number of pits in the sample per temporal component was divided among the different pit types. Examining the changes in the relative frequencies standardized each phase and allowed for comparisons irrespective of absolute counts.

The frequency of extramural pits followed different trajectories over time based on their function (Figure 105). Additionally, the relative distribution of pit types changed between temporal components (Figure 106). The frequency of storage pits remained consistently low throughout the temporal components. The Chiricahua phase contained 11 storage pits, which was 4 percent of the sample in this phase. The Chiricahua/San Pedro and San Pedro phases produced 10 storage pits, accounting for 8 percent of the sample for these phases. The counts declined through the San Pedro/Cienega and Cienega phases with 6 storage pits, but they represented 16 percent of the pits in these phases. The number and relative frequency declined further in the Cienega/Red Mountain and Red Mountain phases to 2 storage pits, accounting for just 3 percent of the sample in these phases. The remaining pre-Classic through Classic/Protohistoric periods saw just 1 storage pit, which represented 5 percent of pits in these periods. The total number of storage pits across all periods in the sample was 30, representing 6 percent of the entire sample.

Firepits followed a similar trend in their numbers over time. Seventy-eight firepits in the sample were dated to the Chiricahua phase, which was 27 percent of the sample in that phase. During the Chiricahua/San Pedro and San Pedro phases, the number of firepits more than halved to 36, but their relative contribution



	Chiricahua	Chiricahua/San Pedro and San Pedro	San Pedro/Cienega and Cienega	Cienega/Red Mountain and Red Mountain	Pre-Classic, Classic and Classic/Protohistoric
Storage (N)	11	10	6	2	1
Firepits (N)	78	36	2	16	4
Processing/storage (N)	195	75	30	61	16

Figure 105. Extramural-pit functions over time.

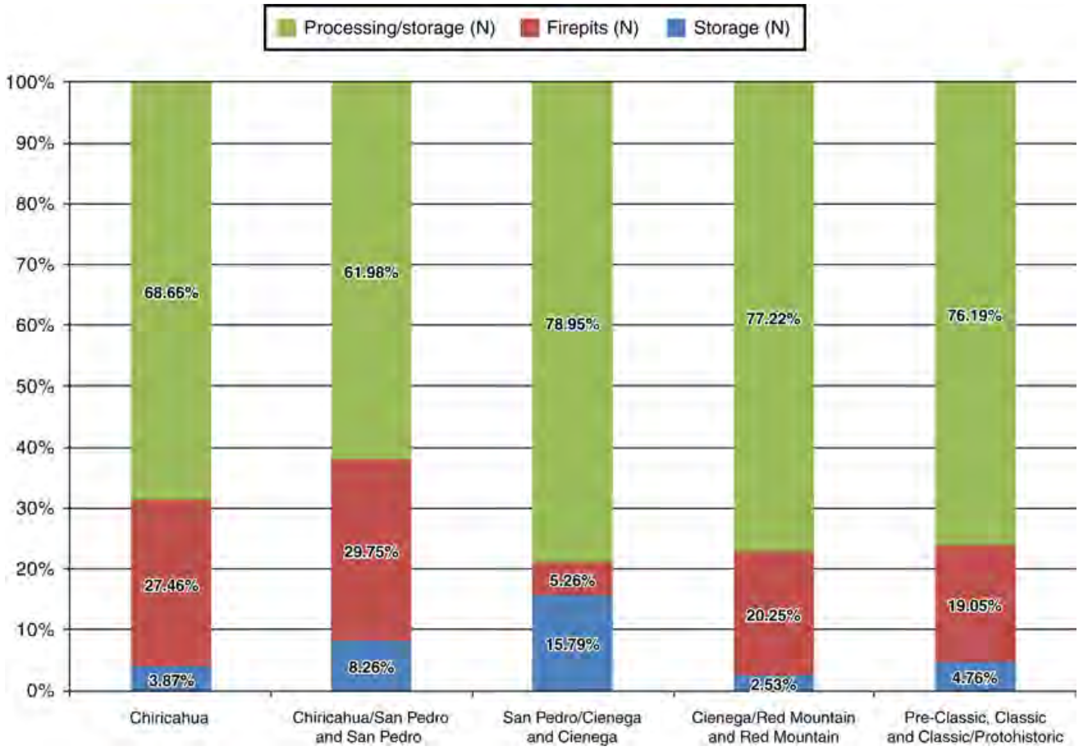


Figure 106. Relative frequencies of pit functions over time.

increased to 30 percent of the pits in these phases. The San Pedro/Cienega and Cienega phases saw a dramatic decrease in the numbers of firepits and their relative frequencies, producing just 2 pits (5 percent) in the sample. A notable increase in the number of firepits occurred during the Cienega/Red Mountain and Red Mountain phases, which saw 16 of this feature type, representing 20.25 percent of the sample. Finally, during the pre-Classic through Classic/Protohistoric periods, just 4 pits in the sample were firepits, accounting for 19 percent of the pits in these periods. The total number of firepits in the sample across all temporal components was 136, accounting for 25 percent of the pits in the sample.

The processing/storage pit was, by far, the most numerous of the three functional pit types in the sample. The Chiricahua phase contained 195 processing/storage pits, more than all storage and firepits from all other phases combined. These 195 processing/storage pits represented 69 percent of pits in the sample for the Chiricahua phase. In the Chiricahua/San Pedro and San Pedro phases, the number of processing/storage pits in the sample plummeted to 75, yet still accounted for 62 percent of the sample in these phases. This decline in numbers was similar to the one observed for firepits between the Chiricahua, and the Chiricahua/San Pedro and San Pedro phases. The number of processing/storage pits more than halved again moving into the San Pedro/Cienega and Cienega phases, with 30 pits of this type in the sample. Nevertheless, processing/storage pits accounted for 79 percent of the sample for these phases. The Cienega/Red Mountain and Red Mountain phases saw a slight increase in the number of processing/storage pits to 61 pits, accounting for 77 percent of the sample for these phases. This was similar to the increase in firepit counts from the San Pedro/Cienega and Cienega phases, to the Cienega/Red Mountain and Red Mountain phases. Finally, and again similar to what was observed for firepits, the number of processing/storage pits decreased in the pre-Classic through Classic/Protohistoric periods, producing 16 pits of this type in the sample. Unlike firepits, however, the relative contribution of processing/storage pits to the sample in these periods slightly increased, to 76 percent.

Extramural-Pit Volume Over Time

Mean volumes for the three functional groups of pits—cooking, storage, and processing/storage—were calculated for each of the temporal components (Figure 107; Table 91). Although sample sizes affected the reliability of some of the calculations (as will be discussed later), some interesting trends emerged when the overall sizes of the different pit types were examined over time. The mean volume of storage pits during the Chiricahua phase was notably small, just 0.0088 m^3. In the Chiricahua/San Pedro and San Pedro phases, mean volume for storage pits increased dramatically to 0.1565 m^3. The San Pedro/Cienega and Cienega phases saw a slight decrease in the mean volume of storage pits with 0.1230 m^3. In the Cienega/Red Mountain and Red Mountain phases, mean volume skyrocketed to 0.4135 m^3 before dropping to 0.006 m^3 in the pre-Classic through Classic/Protohistoric periods. The mean volume for storage pits across all temporal components was 0.1078 m^3, with a standard deviation of 0.2234 m^3. Although the size of storage pits varied widely through time, this was clearly a product of the effects of small sample sizes. As noted above, the sample set included only 30 storage pits, distributed among the five time periods. Indeed, the mean volume of storage pits in the Cienega/Red Mountain and Red Mountain phases, 0.4135 m^3, was derived from just two pits: one very small, deep basin-shaped pit (0.008 m^3) and a very large bell-shaped pit (0.819 m^3).

Similar to storage pits, firepits exhibited a great deal of variability across the temporal components (see Figure 107; Table 91). The mean firepit volume in the Chiricahua phase was 0.0981 m^3, much larger than storage pits in that phase. Firepit size decreased into the Chiricahua/San Pedro and San Pedro phases, with the mean volume of 0.0697 m^3. Firepits saw a dramatic increase in size in the San Pedro/Cienega and Cienega phases, with a mean volume of 0.2625 m^3. This was the largest mean volume for firepits across all time periods, and also the largest mean volume for the three pit types in the San Pedro/Cienega and Cienega phases. In the Cienega/Red Mountain and Red Mountain phases, the mean volume for firepits decreased to 0.1248 m^3, and then decreased to its smallest mean size during the pre-Classic through Classic/Protohistoric period, with mean volume of just 0.0390 m^3. As was seen with storage pits, firepit sizes fluctuated over time. Also like storage pits, however, much of the variability was the result of the large effects of small sample sizes. The peak size for firepits was seen during the San Pedro/Cienega and Cienega phases, with a mean volume of 0.2625 m^3.

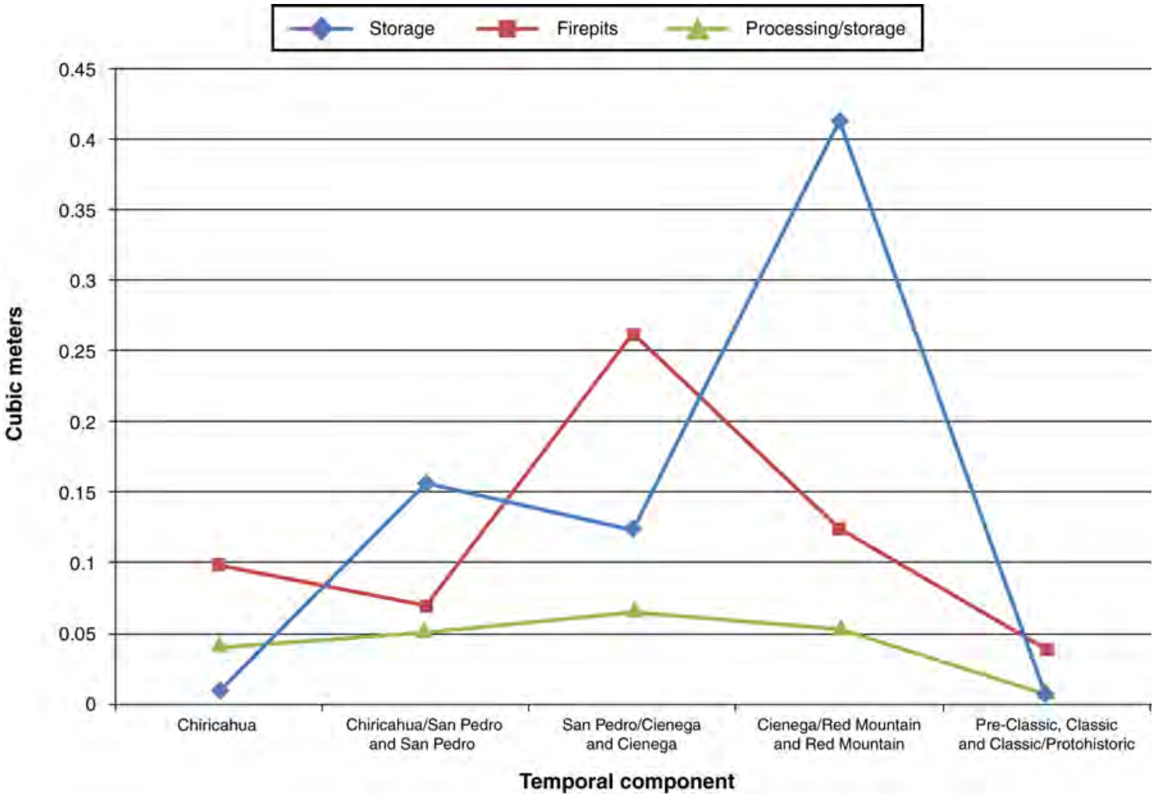


Figure 107. Extramural pit volumes by function over time.

Table 91. Mean Volumes for Extramural Pits, per Function, Over Time

Temporal Component	Mean Volume m³ (with counts)		
	Storage	Firepits	Processing/Storage
Chiricahua	0.0088 (11)	0.0981 (78)	0.0402 (195)
Chiricahua/San Pedro and San Pedro	0.1565 (10)	0.0697 (36)	0.0503 (75)
San Pedro/Cienega and Cienega	0.1230 (6)	0.2625 (2)	0.0646 (30)
Cienega/Red Mountain and Red Mountain	0.4135 (2)	0.1248 (16)	0.0526 (61)
Pre-Classic and Classic and Classic/Protohistoric	0.0060 (1)	0.0390 (4)	0.0064 (16)

Just two firepits in the sample dated to that phase, and one (Feature 6014) had the relatively large volume of 0.415 m^3. The mean volume for all firepits in the sample was 0.0944 m^3, with a standard deviation of 0.1260 m^3. The variability over time was less than that of storage pits, but this may be the result of increased sample size. Storage pits numbered 30 in the sample across all phases, whereas firepits numbered 136 across all phases.

Processing/storage pits contributed to the excavated sample in sufficient numbers to allow for more- reliable examinations of size changes over time (see Figure 107; Table 91). In the Chiricahua phase, the mean volume of processing/storage pits was 0.0402 m^3. This was larger than storage pits, but smaller than firepits during this phase. In the Chiricahua/San Pedro and San Pedro phases, mean volume for processing/storage pits increased slightly to 0.0503 m^3. This trend of slightly larger pits continued into the San Pedro/Cienega and Cienega phases, during which the mean volume for processing/storage pits was 0.0646 m^3. This phase constituted the high point in the size of processing/storage pits across the temporal components. During the Cienega/Red Mountain and Red Mountain phases, mean volumes for processing/storage pits decreased to 0.0526 m^3, just slightly larger than those of the Chiricahua/San Pedro and San Pedro phases. Finally, during the pre-Classic through Classic/

Protohistoric periods, mean volumes for processing/storage pits fell to just 0.0064 m^3. Interestingly, this was almost identical to the volume of the lone storage pit in the same phase (0.006 m^3).

As noted above, each phase under consideration included enough processing/storage pits in the sample to examine trends without undue influence of single pits. These trends, then, appear to be of consistency through time for the size of processing/storage pits, until the pre-Classic through Classic/Protohistoric periods. For all processing/storage pits, the mean volume was 0.0472 m^3, with a standard deviation of 0.0696 m^3, indicating more consistency for this pit type over time. This observation will be explored further in following sections.

Intramural and Extramural Pits

As has been noted elsewhere, the extramural pit was the most numerous feature type found at the Luke Solar sites. There were, however, many intramural pits, constructed in the floors of structures. The differences between intramural and extramural pits, and how those differences changed over time, can provide insight into the needs and the purposes served by the pits. Comparisons between intramural and extramural pits were complicated by small sample sizes in some instances. Although nearly all intramural pits were excavated, only 58 satisfied the sampling requirements of dating to a particular temporal component and having calculable volume from observed feature measurements.

Figure 108 shows that, across the phases, the number of intramural pits of all types was roughly one-tenth the number of extramural pits of all types. Both extramural and intramural pits were at their most frequent during the Chiricahua phase, then declined steadily through the Chiricahua/San Pedro and San Pedro phases, and the San Pedro/Cienega and Cienega phases. Indeed, no intramural pits dating to the San Pedro/Cienega and Cienega phases appeared in the sample. The frequencies of both intramural and extramural pits increased during the Cienega/Red Mountain and Red Mountain phases, before decreasing again in the pre-Classic through Classic/Protohistoric periods.

It is interesting that extramural and intramural pits mirrored each other's changes over time, albeit at different scales. This suggests uniformity in the changing purposes served by the pits, regardless of their location

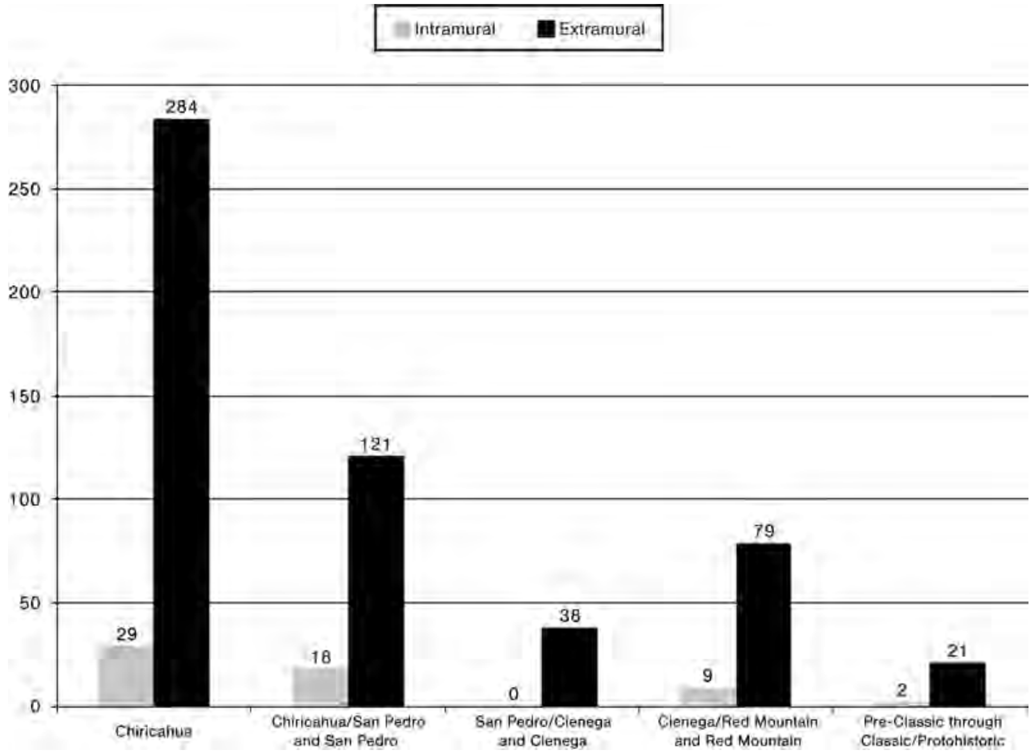
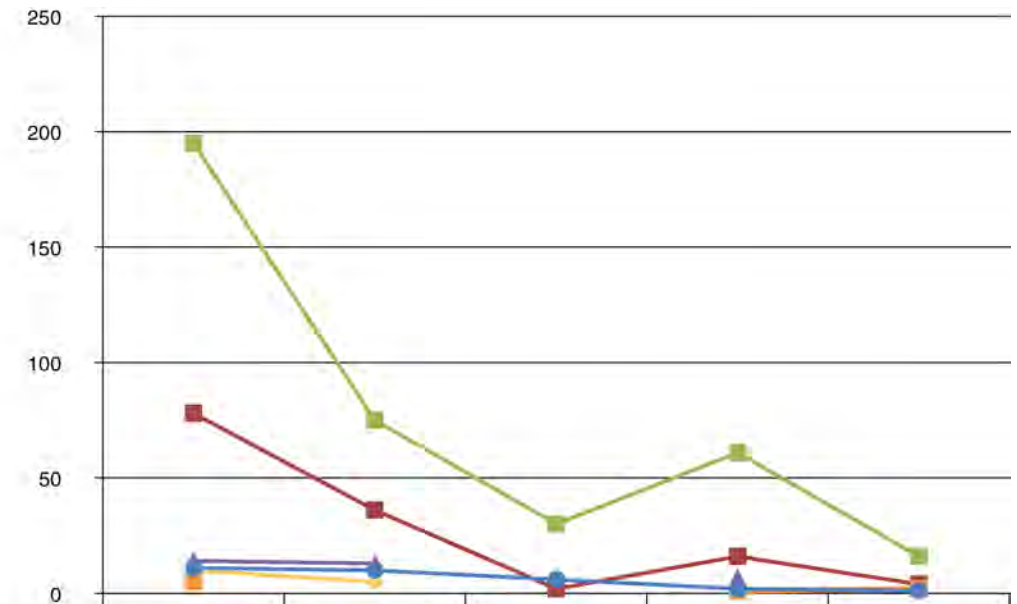


Figure 108. Counts of extramural and intramural pits over time.

inside or outside of structures. A closer examination of the different pit types (storage, firepit, processing/storage) based on their location (intramural vs. extramural) revealed some differences in the changes over time. The inferences drawn from these comparisons are cautious, of course, because of the widely disparate frequencies between intramural and extramural pits. Nevertheless, certain trends were observable (Figure 109).

Unlike all extramural and intramural pits combined, intramural storage pits and extramural storage pits did not exactly mirror each other in frequency. The Chiricahua phase saw the largest number of intramural storage pits (n = 5) and the highest number of extramural storage pits (n = 11). The sample included 10 extramural storage pits in the Chiricahua/San Pedro and San Pedro phases. No intramural storage pits dated to these phases. The number of extramural storage pits decreased through the rest of the sampled time periods, from 6 in the San Pedro/Cienega and Cienega phases, 2 in the Cienega/Red Mountain and Red Mountain phases, and 1 in the pre-Classic through Classic/Protohistoric periods. The absence of intramural storage pits continued in the San Pedro/Cienega and Cienega phases. A single intramural storage pit dates to the Cienega/Red Mountain and Red Mountain phases, and 2 intramural storage pits were associated with the pre-Classic through Classic/Protohistoric phases.

A total of 16 intramural firepits satisfied the sampling criteria. It should be noted that these were distinct from the subfeature type hearth, as hearths are unique to structures and have no extramural correlate. That said, there were 10 intramural firepits, and 78 extramural firepits associated with the Chiricahua phase. The frequencies of both intramural and extramural firepits declined in the Chiricahua/San Pedro and San Pedro phases, to 5 intramural pits and 36 extramural pits. The number of extramural firepits decreased to 2 in the San Pedro/Cienega and Cienega phases, while intramural firepits disappeared completely. During the Cienega/Red Mountain and Red Mountain phases, extramural firepits increased to 16 in number, and



	Chiricahua	Chiricahua/San Pedro and San Pedro	San Pedro/Cienega and Cienega	Cienega/Red Mountain and Red Mountain	Pre-Classic through Classic/Protohistoric
Firepits Intramural	10	5		1	
Firepits Extramural	78	36	2	16	4
Processing/storage Intramural	14	13		7	
Processing/storage Extramural	195	75	30	61	16
Storage Intramural	5			1	2
Storage Extramural	11	10	6	2	1

Figure 109. Extramural and intramural pits per function over time.

1 intramural firepit was observed in the sample. Extramural firepits decreased again to 4 in the pre-Classic through Classic/Protohistoric periods. Intramural firepits, however, disappeared from the sample again during the pre-Classic through Classic/Protohistoric periods.

Intramural and extramural processing/storage pits followed similar trajectories over time. Both saw their greatest number during the Chiricahua phase, with extramural pits totaling 195 in the sample, and intramural pits totaling 14. Moving into the Chiricahua/San Pedro and San Pedro phases, the number of extramural processing/storage pits dropped by more than half to 75, whereas intramural pits saw a more modest decrease to 13. Extramural processing/storage pits declined by more than half again in the San Pedro/Cienega and Cienega phases to 30 in the sample. No intramural processing/storage pits in the sample were observed during these phases. In the Cienega/Red Mountain and Red Mountain phases, the number of extramural processing/storage pits doubled to 61, and their intramural counterparts reappeared with 7 in the sample. The pre-Classic through Classic/Protohistoric periods saw another sharp decline in both extramural and intramural processing/storage pits. Extramural pits of this type decreased by over two-thirds to 16; there were no intramural processing/storage pits in the pre-Classic through Classic/Protohistoric sample. Notwithstanding differences in the magnitude and rate of changes over time in the frequency of extramural and intramural processing/storage pits, the increases and decreases were roughly comparable.

Processing/Storage Pit Volume Over Time

As noted above, the extramural processing/storage pit was the most numerous feature type at the Luke Solar sites (n = 1,060), and the largest component of the sample set for pit volume (n = 377). The frequency of this pit type allowed for examinations of change or stasis in attributes over time with greater statistical reliability than other feature types. Pit size, as expressed by volume, is an interesting avenue of examination to identify and explore trends throughout the lifespan of the site. As has been noted elsewhere, the morphometric characteristics of this pit class presuppose functional attributes.

The 377 extramural processing/storage pits in the sample were distributed among the five joined temporal components in sufficient numbers to compare their mean volumes by way of unpaired *t*-tests. Descriptive statistics for the volumes of extramural processing/storage pits according to temporal component appear in Table 92, and the *p* values for each comparison appear in Table 93. As can be seen, only the comparison of the mean volumes between the Chiricahua phase and the San Pedro/Cienega and Cienega phases produced results with statistical significance ($p < 0.05$). All other comparisons of means suggested consistency in the volumes of extramural processing/storage pits over the lifespan of the site.

These results shed light on an aspect of site formation and structure over time that is obscured by trends in relative and absolute frequencies of pit types over time. Indeed, the numbers of extramural processing/storage pits fluctuated in each temporal component, and their contribution to the total feature count reflected these variations. The number of extramural processing/storage pits in each phase reflects how the needs of the group were met during that time. Conversely, the attributes of the extramural processing/storage pits did not substantially change. In other words, the frequency of this pit type was dynamic, but the characteristics of the pit type were static. The attributes of the extramural processing/storage pits did not change significantly from the Chiricahua phase to the Protohistoric period. Thus, the changing needs of the group over time were met by adding or subtracting the number of pits, rather than changing the characteristics of those pits.

Architectural Analysis

A total of 50 structures were identified during the Luke Solar project, including 42 houses-in-pits, four surface structures, and four possible structures (see Table 2). Forty-eight of these structures were excavated at Falcon Landing, whereas two structures were excavated at Site 68. A physical description of each structure identified during the Luke Solar project is provided in Volume 1, Chapters 4 and 5. A house-in-pit structure is defined as an architectural feature that is fully contained within a shallow aboriginal pit, usually circular to oval in shape. House-in-pit structures are distinguished from true pit houses, wherein the walls are constructed outside the

Table 92. Descriptive Statistics of Pit Volume for Extramural Processing/Storage Pits

Temporal Component	n	Mean (m^3)	SD	SEM
Chiricahua	195	0.0402	0.06145	0.0044
Chiricahua/San Pedro and San Pedro	75	0.0504	0.07117	0.00822
San Pedro/Cienega and Cienega	30	0.0646	0.06896	0.01259
Cienega/Red Mountain and Red Mountain	61	0.0526	0.09005	0.01153
Pre-Classic through Classic/Protohistoric	16	0.0643	0.06376	0.01594

Key: SD = standard deviation; SEM = standard error of the mean.

Table 93. T-tests by Temporal Component for Volume of Extramural Processing/Storage Pits

	Chiricahua	Chiricahua/San Pedro and San Pedro	San Pedro/Cienega and Cienega	Cienega/Red Mountain and Red Mountain
Chiricahua/San Pedro and San Pedro	$p = 0.2454$ $t = 1.1641$ $df = 268$ SED = 0.009			
San Pedro/Cienega and Cienega	$p = 0.0475$ $t = 1.9930$ $df = 223$ SED = 0.012	$p = 0.3519$ $t = 0.9352$ $df = 103$ SED = 0.015		
Cienega/Red Mountain and Red Mountain	$p = 0.2238$ $t = 1.2195$ $df = 254$ SED = 0.010	$p = 0.8722$ $t = 0.1611$ $df = 134$ SED = 0.014	$p = 0.5213$ $t = 0.6438$ $df = 89$ SED = 0.019	
Pre-Classic, Classic and Classic/ Protohistoric	$p = 0.1336$ $t = 1.5060$ $df = 209$ SED = 0.016	$p = 0.4705$ $t = 0.7248$ $df = 89$ SED = 0.019	$p = 0.9890$ $t = 0.0138$ $df = 44$ SED = 0.021	$p = 0.6262$ $t = 0.4891$ $df = 75$ SED = 0.024

Key: SED = standard error of the difference.

aboriginal pit (see Wheat 1955:196). The walls of a house-in-pit structure are represented by a line of perimeter posts within the house pit. In the sample of Luke Solar structures, 14 of the 42 house-in-pit structures (33 percent) did not have identifiable postholes. These structures are still considered houses-in-pits, however, with the assumption that a posthole pattern existed but was obscured by postabandonment processes. A surface structure is defined as an arrangement of postholes that did not have an associated aboriginal pit. These surface structures are believed to have been constructed on the aboriginal ground surface, similar to a ramada. The four possible structures were identified in the profiles of backhoe trenches, but could not be further defined in plan view during mechanical stripping. The four possible structures are not included in the following discussion, as they lack the baseline information for size, shape, and interior characteristics. Two other structures from the Chiricahua phase sample, Features 2602 and 2605, are not considered in this analysis, as the interpretation of either as a houses-in-pit is questionable. Although they are considered houses-in-pits elsewhere in this volume, both of these structures have conflicting stratigraphic evidence that suggest they are not structures but part of a larger Chiricahua phase occupational surface. As a result, the excavated area, volume, and architectural characteristics associated with these possible structures is potentially misleading. A more in-depth discussion of these interpretations are presented in Volume 1, Chapter 4.

In general, the structures identified during the Luke Solar project are ephemeral, shallow foundations with few identifiable architectural elements such as postholes, entryways, walls, prepared floors, or hearths. As mentioned above, the lack of postholes in many of these features may be the result of poor preservation, particularly considering the age of these features, the shallow nature of the site sediments in which the structures existed, and the amount of rodent and insect disturbance. Overall, the sample size of Luke Solar structures is low per temporal component, which limits most interpretations. Attributes examined in this discussion include the number of intramural pits and postholes, structure volume, and effective floor area. The structure volume should be considered a minimum value, given at least some truncation of the upper levels of structure fill by mechanical stripping. Effective floor area refers to the useable amount of floor space available in a given structure (Table 94). Following Gregory's (2001:40–41) analysis of Late Archaic/Early Agricultural structures at Los Pozos, effective floor area was calculated by taking the surface area of a structure floor and subtracting the area incorporated by the wall (perimeter postholes) and the surface area of any interior postholes and intramural pits. For the Luke Solar sample, this calculation was completed in ArcGIS using digitized hand-drawn structure plan-view maps. As is evident in Table 94, the majority of structures identified at Luke Solar were constructed sometime between the Chiricahua and San Pedro phases. Eight of the structures in this sample were poorly dated, and are not assigned to a temporal component.

Of the 44 structures in this sample, only 28 (64 percent)—none of them surface structures—had intramural pits (see Table 94); 50 such pits were found within these 28 structures. A Chiricahua phase structure (Feature 1244) had the most intramural pits—a total of four. Of the 50 total intramural pits, 39 are nonthermal, 10 are thermal, and 1 is considered a hearth. The one example of a hearth is from a San Pedro phase structure (Feature 18192) and was characterized as a shallow, heavily-oxidized basin-shaped depression 70 cm in diameter; however, no formal hearth-pit preparation, such as slab- or clay-lined walls, was present. The majority of intramural pits (n = 32, or 64 percent) were circular, with a small number of oval (n = 9), indeterminate (n = 6), and irregular (n = 3) plan-view shapes. Similarly, 32 (64 percent) of the intramural pits were basin shaped, and a small number were irregularly shaped (n = 7), cylindrical (n = 4), conical (n = 4), and bell-shaped (n = 3). Forty-six of the 50 intramural pits had a calculable volume (Table 95). Intramural pit volume is quite variable, ranging from 0.001 m^3 to 0.21 m^3. Nonthermal intramural pits are interpreted as storage pits. The amount of intramural storage space is greatest during the Chiricahua and San Pedro phases. A steady decline in the number and size of intramural storage pits over time is evident. Intramural thermal pits (including one hearth, mentioned above) were likely used for cooking or heating, and like nonthermal pits, are most common during the Chiricahua and San Pedro phases. San Pedro phase structures had by far the highest intramural pit volume in the sample, including the two largest intramural pits. A thermal bell-shaped pit from a San Pedro phase structure (Feature 4308) had a volume of 0.2 m^3 but may have been used for storage. Oxidized pit walls and copious amounts of stratified burned material in the fill of this intramural pit prompted its interpretation as a thermal pit during fieldwork; however, the oxidation of the walls may have been a result of placing hot materials in the pit rather than direct firing. The largest intramural nonthermal pit, with a volume of 0.21 $m^{3,}$ was a deep, basin-shaped pit in the center of a San Pedro phase structure (Feature 13071). Overall, the amount of usable intramural storage space in Luke Solar structures is low compared to other Late Archaic/Early Agricultural sites. Gregory (2001:Figure 2.12) indicates a mean intramural pit volume of 0.87 m^3 at Los Pozos, compared to a mean intramural pit volume of 0.04 m^3 in the Luke Solar sample. This comparison suggests that intramural pit use (storage and cooking/heating) was much less important in the Luke Solar project area than for contemporaneous sites along the Santa Cruz River in the Tucson Basin.

Of the 44 structures in the sample, 30 had identifiable postholes—a total of 304 (see Table 94). The postholes were generally circular (n = 281, or 92 percent) in plan view, with a small number of oval (n = 17), irregular (n = 4), and subrectangular (n = 2) shapes. The majority of postholes were also cylindrical (n = 223, or 73 percent) in cross-section; smaller numbers were conical (n = 72), irregular (n = 6), and basin-shaped (n = 3). The depth of postholes is highly variable, ranging from 2 cm to over 70 cm. The average structure in this sample had about seven postholes. However, many of the structures , such as those truncated by backhoe trenches, were incomplete; therefore, the average number of postholes per structure is likely much higher. Feature 1498 had 56 postholes, the most of any structure. These lay within a floor groove that ran the perimeter of the floor, as well as along a protruding entryway. A radiocarbon date from Feature 1498 places it in the

Table 94. Structure Metrics

Temporal Component, by Structure Type[a]	Total Number of Structures	Total Number of Intramural Pits	Total Number of Postholes	Average Structure Volume (m^3)	Average Floor Area (m^2)	Average Effective Floor Area (m^2)	Effective Floor Area Standard Deviation (SD)
House-in-pit							
Chiricahua	10	14	98	0.87	4.48	4.13	2.26
Chiricahua/San Pedro	4	5	19	0.87	4.62	4.42	1.75
San Pedro	10	17	76	0.65	3.35	2.87	1.60
Cienega	1	—	—	1.47	5.68	5.68	N/A
Cienega/Red Mountain	4	6	16	0.49	3.30	3.01	0.86
Red Mountain	2	3	14	1.86	9.66	9.39	2.50
Pre-Classic	3	3	22	1.56	7.36	7.14	9.08
N/A	6	2	9	1.00	3.48	3.33	1.36
House-in-pit Total	40	50	254	0.92	4.45	4.14	3.08
Surface structure							
Chiricahua/San Pedro	1	—	4	—[b]	6.76	6.75	N/A
Cienega	1	—	15	3.65	10.57	9.91	N/A
N/A	2	—	31	0.07	10.65	10.45	8.35
Surface structure Total	4	—	50	1.86	9.66	9.39	5.14

[a] Does not include possible structures.

[b] Structure depth was zero, therefore volume could not be calculated.

Table 95. Intramural Pit Volume of House-In-Pit Structures

Temporal Component	Total Number of Nonthermal Pits	Total Volume (m^3) of Nonthermal Pits	Total Number of Thermal Pits	Total Volume (m^3) of Thermal Pits	Total intramural Pit Volume (m^3)
Chiricahua	9	0.397	4	0.093	0.49
Chiricahua/San Pedro	4	0.088	1	0.003	0.091
San Pedro	8	0.484	5	0.353	0.837
Cienega/Red Mountain	5	0.257	1	0.029	0.286
Red Mountain	3	0.062	—	0.000	0.062
Pre-Classic	2	0.07	—	0.000	0.07
N/A	2	0.016	2	0.091	0.107
Total	33	1.374	13	0.569	1.943

Chiricahua phase (1880–1690 cal. B.C.); however, the floor groove and protruding entryway is more indicative of later Hohokam-style architecture. The charcoal that produced the Middle Archaic date for Feature 1498 may have been intrusive into the fill of the structure. Unfortunately, the discrepancy between the radiocarbon age and the architectural characteristics of Feature 1498 cannot be reconciled with the available information.

As one can see from Figure 110, the average volume of house-in-pit structures in the Luke Solar sample remained relatively steady during the Chiricahua and San Pedro phases but increased dramatically during the Cienega phase. A sharp drop in volume is apparent during the Cienega/Red Mountain phase, but volume increases dramatically again during the Red Mountain phase and the pre-Classic period.

The distribution of effective floor area for Luke Solar structures shows a clustering between 2 and 5 m^2 (Figure 111). The mean effective floor area for Luke Solar structures is similar to the Early Agricultural structures identified at Los Pozos in the Tucson Basin (Gregory 2001:Figure 2.23). Over time, the total effective floor area of structures is highest during the Chiricahua phase (Figure 112). A gradual decline is witnessed from

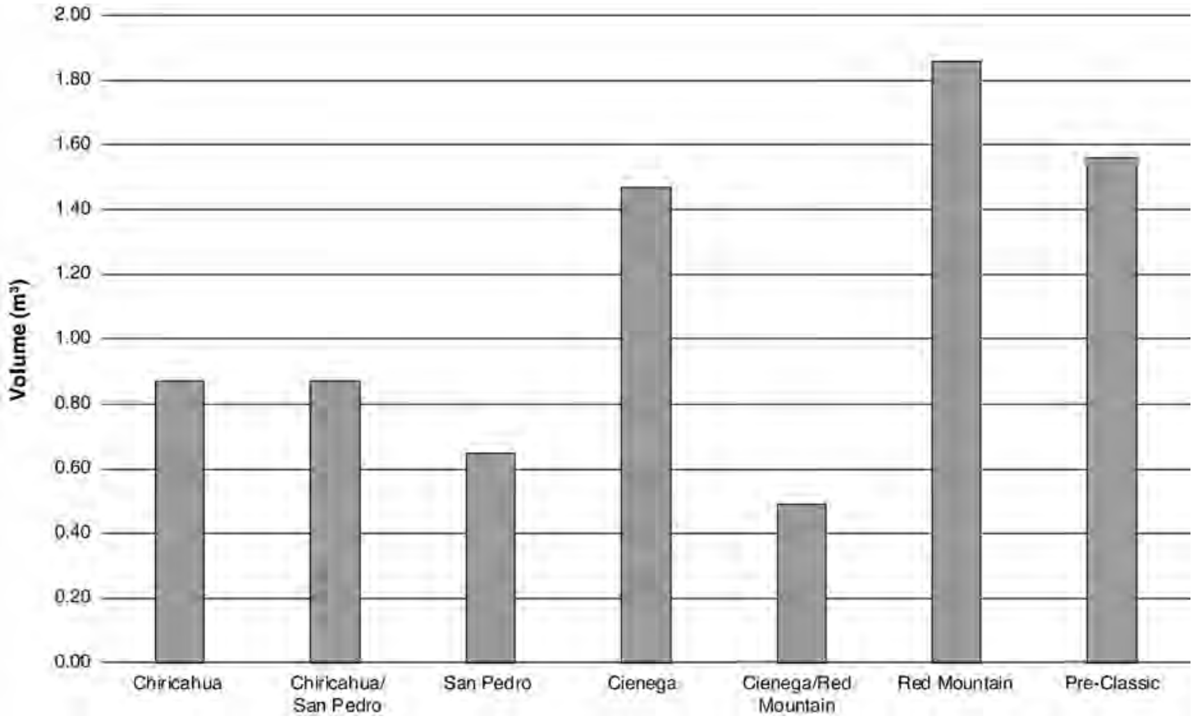


Figure 110. Average volume for house-in-pit structures per temporal component.

the San Pedro to Cienega/Red Mountain phases. A slight increase in total effective floor area is then apparent during the Red Mountain phase and pre-Classic period. Interestingly, the floor area of surface structures in the Luke Solar sample is almost double that of houses-in-pits (see Table 94). This may be due to the intended use of surface structures as shade for outdoor activities, as opposed to house-in-pit structures, which may have been used for storage or sleeping. Using the example of a ramada, this type of structure would require less investment of labor compared to a house-in-pit structure, but would provide a larger work area protected from the elements. Interestingly, unlike most house-in-pit structures, none of the surface structures had intramural pits, suggesting that storage was not an important component for this type of structure. A dramatic increase in the average effective floor area of structures is witnessed during the Cienega phase; this is due to a large rectangular surface structure (Feature 4621) that had almost 10 m^2 of usable floor area. Another large surface structure, Feature 11105, had an effective floor area of 16.35 m^2, but it does not have a direct date; it is assumed to date to the Cienega phase, because of its association with two adjacent extramural pits (Features 11106 and 11130) that were radiocarbon dated to the Cienega phase (790–520 cal. B.C., and 790–55 cal. B.C., respectively). The presence of two large Cienega phase surface structures is intriguing and may represent specialized activities during the Cienega phase. During the pre-Classic period, the standard deviation of effective floor area for houses-in-pits was significantly higher (see Table 94), indicating more architectural variability during this time. For example, the structure with the largest effective floor area (17.61 m^2) in the Luke Solar sample is Feature 3321, dating to cal. A.D. 650–770. This floor area is not considered an outlier, however, as Hohokam-age structures are much larger on average than Archaic and Early Ceramic period structures (see Ciolek-Torrello et al. 2000). For example, Feature 3321 fits well within the range of pre-Classic structures in the eastern Phoenix Basin (Ciolek-Torello and Wegener 2011:285), as well as structures excavated at Grewe (Craig 2001:91). It should be noted, however, that the pre-Classic structures in the Luke Solar sample were not necessarily indicative of standard Hohokam architecture. For example, Feature 3321 did not have a definable entryway, prepared floor, plastered hearth, or other architectural characteristics associated with Hohokam-style houses.

In examining architecture, another important thing to note is the presence of de facto assemblages—artifacts with residual utility located in intramural pits or on the floor of structures. Only three structures in the Luke Solar sample contained unbroken floor artifacts, including a manuport and three Lukeoliths on

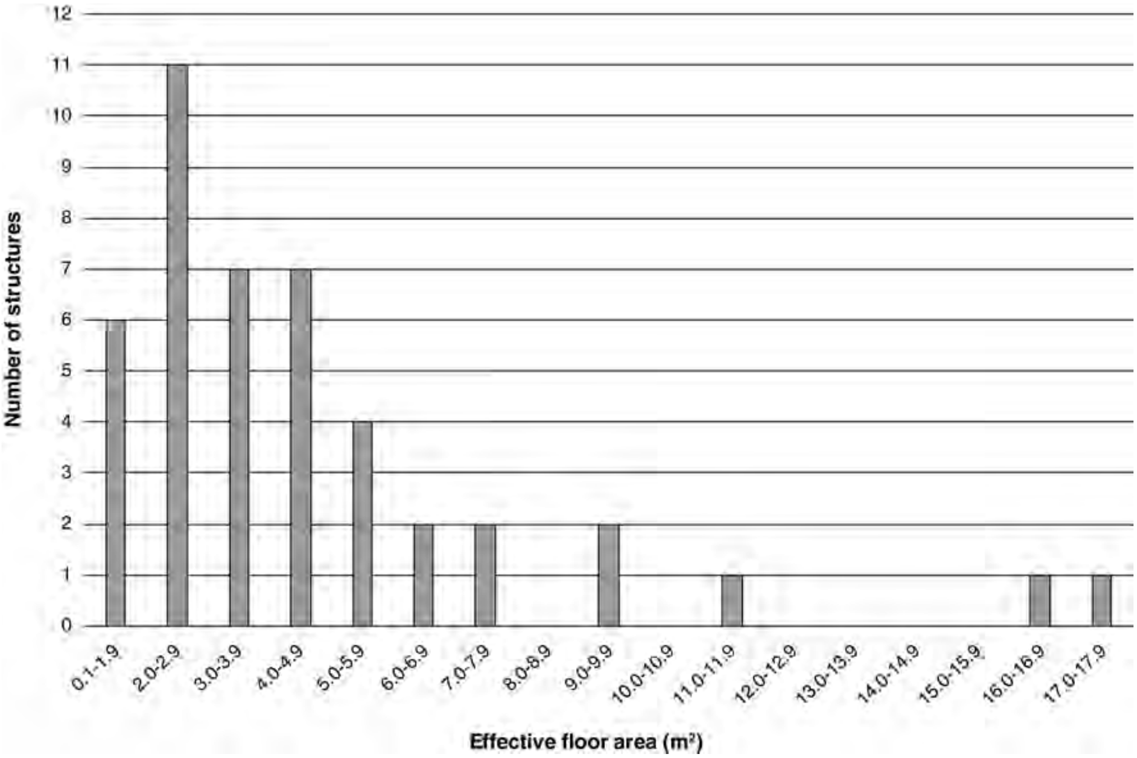


Figure 111. Effective floor area distribution for Luke Solar structures.

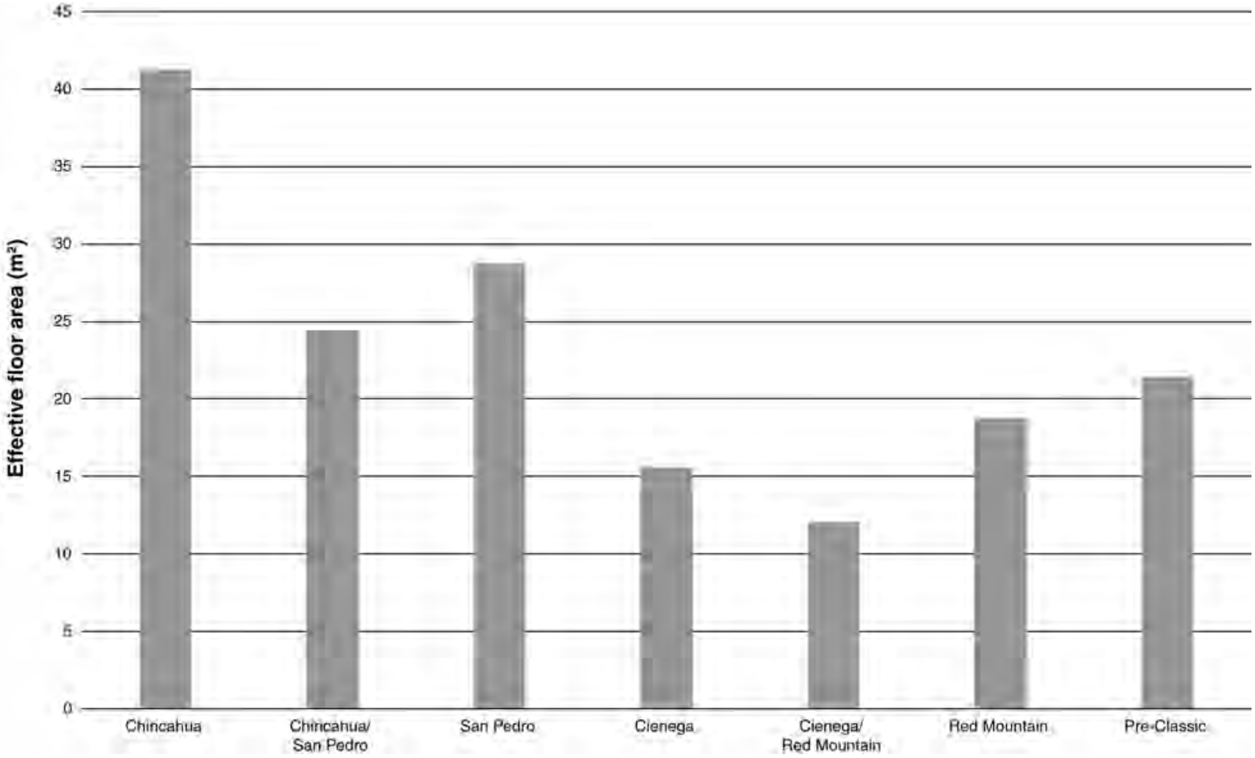


Figure 112. Total effective floor area of Luke Solar structures by temporal component.

the floor of a poorly dated structure (Feature 1313), a mano from the floor of another poorly dated structure (Feature 10735), and a hammerstone on the floor of a San Pedro phase structure (Feature 2628). Feature 1313 also had a complete cobble uniface recovered from a posthole. Two other structures had complete artifacts recovered from postholes, including a mano from a pre-Classic period structure (Feature 3321), and a cobble uniface from a San Pedro phase structure (Feature 2629). Similarly, few intramural pits contained complete or serviceable artifacts. For example, a mano was recovered from a nonthermal pit in a Red Mountain phase structure (Feature 10849), and a cobble uniface was recovered from a nonthermal pit in a Chiricahua phase structure (Feature 1244). This would indicate that the Luke Solar structures were likely not abandoned with planned or anticipated return. In fact, numerous examples of extramural caching have been identified at Luke Solar, where multiple large, intact ground stone items were found (see Chapter 3, this volume), indicating that extramural space was the preferred location for storing usable artifacts.

An ethnographic study of hunter-gatherer demography in California by Cook (1972) suggests that 2.3 m^2 of floor space is required for each of the first six people occupying a structure, with 9.3 m^2 required for each additional person. Only one structure assigned to a temporal component (Feature 3321) could have contained more than six individuals (13.8 m^2), but an additional 9.3 m^2 area was not available for a seventh individual, so Feature 3321 was defaulted to a value of six individuals. Cook's calculation indicates the largest number of people utilizing structures inhabited the project area during the Chiricahua phase (Figure 113). Following the Chiricahua phase, a gradual decline in the number of individuals using structures persists through the Cienega/Red Mountain phase. A slight resurgence in the number of site occupants occurs during the Red Mountain phase and pre-Classic period. Ten of the 44 structures in this calculation had less than the 2.3 m^2 of effective floor area used in Cook's calculation; therefore, these structures did not meet the minimum floor area for a single individual. These small structures may have functioned as storage structures rather than for habitation; these include two Chiricahua, four San Pedro, one Cienega/Red Mountain, one pre-Classic, and two poorly dated structures not assignable to a temporal component. This analysis of demography provides evidence of site use through time and may be taken as a general indicator of overall group size. Previous chapters in this volume have presented different lines of evidence for how the Luke Solar project area was used prehistorically. The evidence suggests small groups occupied the project area for the procurement and processing of wild plants, particularly mesquite. This important site function would not necessarily require the use of shelter. Therefore, using Cook's calculation to evaluate demography has the potential for underestimating the total number of individuals that occupied the project area over time.

The examination of Luke Solar architecture provides a few general patterns of site use over time. The number of structures per temporal component indicates that the site was likely occupied by residential groups during the Middle and Late Archaic periods and that later Ceramic period groups used the site logistically, with less frequency, for a shorter duration, and did not require as much shelter. Over half the structures date to the Chiricahua or San Pedro phases, suggesting that the most intense use of the project area occurred during this time. Although the number of structures declined during the Ceramic period, the size of these Ceramic period structures increased. The overall volume of structures generally increased over time; however, the potential number of structure occupants declines over time. This suggests that the Luke Solar project area was used by the largest number of people during the Chiricahua and San Pedro phases, but they constructed the smallest structures. Chiricahua and San Pedro structures also contained the highest number and most substantial intramural features. Along the same lines, the least number of people inhabited the site during the Ceramic period, but they constructed the largest structures. These Ceramic period structures are smaller than the typical structures found at Hohokam residential sites, and they also lack intramural firepits or substantial interior storage pits. The low number of Ceramic period houses and their overall lack of intramural storage suggests that these structures were used by individuals or small logistical groups. Although the number of people occupying the project area varied over time, and the number of structures generally decreased over time, the characteristics of these structures remained very similar. Shallow, ephemeral, pole-and-brush architecture characterizes the Luke Solar structures, regardless of time period. The information gathered from the analysis of Luke Solar structures suggests that use of the site changed little over time (see Chapter 11, this volume).

The evidence from Luke Solar structures suggests that during the Middle and Late Archaic periods, residential groups consisting of small households occupied the project area. Figures 112 and 113 show that the

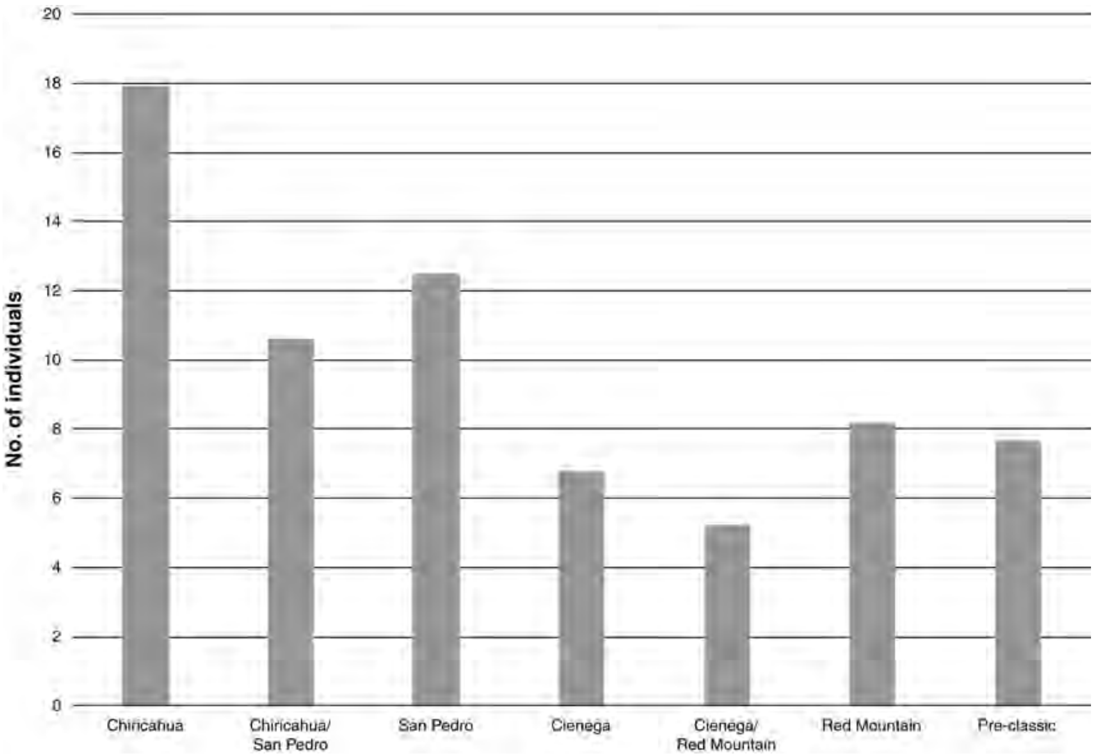


Figure 113. Potential group composition per temporal component.

greatest usable floor area and potential group composition is highest during the Chiricahua and San Pedro phases. Table 95 shows that the majority of intramural pits are within Chiricahua and San Pedro phase structures. These Chiricahua and San Pedro pits also have the greatest capacity for storage and heating/cooking. Therefore, the Chiricahua and San Pedro phases represent the most intense use of the site for the greatest number of activities by the highest number of people. Further evidence for residential household groups during the Middle and Late Archaic period includes the presence of clusters of contemporaneous structures and extramural pits in different areas of the project area. In the sections that follow, a spatial analysis of features by time period is presented. This analysis shows conspicuous groups of structures assigned to the Chiricahua, San Pedro, and Cienega/Red Mountain phases.

Discussion: Spatial Analyses Results

Chiricahua Phase (3500–1200 cal B.C.) Spatial Distribution

Features dated to the Chiricahua phase were among the most numerous of features, and they clustered in multiple parts of the Falcon Landing site. Extramural and primary features assigned to the Chiricahua component at Falcon Landing included 4 activity areas, 11 charcoal/ash lenses, 7 FAR concentrations, 12 house-in-pit features, a midden, 232 nonthermal pits, 2 possible structures, 89 thermal pits, and 2 bell-shaped thermal pits (Table 96). Ripley’s *K* estimates indicated that Chiricahua features clustered across a range of scales, from 5 to 145 m. The most intense clustering occurred at a scale of 35 m and clustering decreased rapidly in intensity at distances exceeding 50 m.

Kernel density estimates indicated that the greatest intensity of feature construction was in the northeastern portion of the site, centered on Grid Cell I5 (Figure 114). Here, several house-in-pit features were identified, along with an activity area and multiple pits, charcoal/ash lenses, and FAR concentrations. This intensively used area of the site extended north into Grid Cell J5, where a midden, multiple pits, and FAR concentrations were located. The intensity of feature construction was similar to Grid Cell J5 in three other areas of the site during the Chiricahua phase: (1) a cluster that centered on the division between Grid Cells B4 and B5 and contained two house-in-pit features, an activity area, a thermal feature, and a nonthermal feature; (2) an activity area centered on the division between Grid Cells D5 and D6 that included an activity area and numerous thermal and nonthermal pits; and (3) a cluster centered on the northeastern quadrant of J3 that contained two possible structures, an activity area, and numerous thermal and nonthermal pits. Interestingly, the feature cluster centered on the division between Grid Cells D5 and D6 was surrounded by a halo of extramural artifacts. Pairs of house-in-pit features were present in Grid Cells F1 and D2, along with a house-in-pit feature in F4. Kernel density estimates made using estimated artifact counts, per artifact class, suggested variation across the site in the location of activities involving different artifact classes during the Chiricahua phase.

In total, 1,940 pieces of FAR were estimated to have been located within sampled or excavated features assigned to the Chiricahua temporal component (see Table 96). FAR was found within 3 activity areas, 2 charcoal/ash lenses, 5 FAR concentrations, 5 house-in-pit features, a midden, 39 nonthermal pits, a possible structure, 25 thermal pits, and a bell-shaped thermal pit. Kernel density estimates calculated using FAR counts indicated that the highest areal density of FAR was in Grid Cell J5, followed by I5, but that FAR was concentrated in multiple other locations at Falcon Landing. In the northern portion of the site, FAR tended to have been concentrated around structures and a midden (Feature 14587). The location of thermal features was fairly consistent with the distribution of FAR across Falcon Landing, although, as noted, the highest densities of FAR also were found in and around the midden (Feature 14587) located in Grid Cell J5 (see Appendix 10.1, Interactive PDF, Layer 10.1). Here, no thermal features dated to the Chiricahua temporal component were identified, but FAR was found in the midden and in 5 nonthermal pit features and an FAR concentration, all located within the immediate vicinity of the midden. By far, the most FAR was estimated to have been contained within the midden, although the volumetric density of FAR within features was higher in surrounding features that contained FAR than it was in the midden. Conceivably, FAR from other thermal features located in the general area, such as the numerous thermal features located 50 m to the south in Grid Cell I5, was deposited in the midden. Alternatively, it could be the case that FAR found within the midden and in other nearby features represents thermal activity in the area of the midden that went unrecognized in terms of evidence for in-situ burning.

Substantial numbers of thermal features were also located in areas of Falcon Landing where FAR density was estimated as low. It is plausible that FAR from cleaned-out thermal features was moved away from thermal features by cultural or natural processes or both, thus potentially explaining the low FAR density in some areas of the site where thermal features were located. Another possibility is that some use of thermal features did not involve the use of lithic materials as thermal mass. The count estimates of FAR, based on estimated feature volumes and FAR densities, indicated that 33 percent of FAR in Chiricahua phase features may have been deposited in the Feature 14587 midden, whereas 31 percent was deposited in thermal pits, and 24 percent was deposited in nonthermal pits. Overall volumetric density estimates, per feature type, indicated that FAR occurred at the highest density within the midden and in FAR concentrations, and at a lower, but still relatively high density, in thermal pits, followed by nonthermal pits. A chi-square test comparing the number of thermal features with and without FAR and the number of nonthermal features with and without FAR indicated that FAR was found within thermal features significantly more often than expected (Yates $\chi^2 = 4.65$, $df = 1$, $p = 0.0311$. Cramer's *V*, however, suggested the strength of association is weak (Cramer's $V = 0.1301$).

In total, 422 ground stone artifacts were estimated to have been located in sampled or excavated features assigned to the Chiricahua temporal component (see Table 96). Ground stone artifacts were found in 4 activity areas, 2 FAR concentrations, 8 house-in-pit features, a midden, 19 nonthermal pits, and 16 thermal pits. Kernel density estimates of ground stone were, by far, highest in Grid Cell J5, but also suggested the presence of lower-density concentrations of ground stone artifacts in Grid Cells J3, H3, B4, and B5

Table 96. Percentage and Densities of Estimated Artifact and Faunal Specimen Counts, according to Artifact Class and Feature Type, for Features Assigned to the Chiricahua Temporal Component at Falcon Landing

Feature Type	Feature Count (Sampled or Excavated)	Total Estimated FAR Count (%)	FAR Density (Artifacts/m^3)	Total Estimated Ground Stone Artifact Count (%)	Ground Stone Density (Artifacts/m^3)	Total Flaked Stone Artifact Count (%)	Flaked Stone Artifact Density (Artifacts/m^3)	Total Estimated Faunal Specimen Count (%)	Faunal Specimen Density (Specimens/m^3)
Activity area	4	4.7	9.8	5.0	2.3	18.5	24.1	3.4	2.7
Charcoal/ash lens	11	1.5	14.0		—	0.2	2.0	0.5	2.0
FAR concentration	7	2.2	102.1	3.6	36.3	0.4	12.9	0.8	13.4
House-in-pit	12	3.7	1.8	42.4	4.5	5.4	3.9	9.8	1.8
Midden	1	33.0	100.7	1.9	1.3	66.8	25.3	3.8	4.4
Nonthermal pit	229	23.9	51.1	14.9	7.0	0.5	27.6	57.5	47.4
Nonthermal pit (bell shaped)	3		—		—		—		—
Posthole	161		—		—		—		—
Structure (possible)	2		—		—		—		—
Thermal pit	89	31.0	71.0	32.2	16.2	0.7	17.3	22.9	20.3
Thermal pit (bell shaped)	2	0.1	4.7		—	7.5	84.2	1.3	23.4
Total	521	100.0	24.6	100.0	5.4	100.0	12.5	100.0	9.5

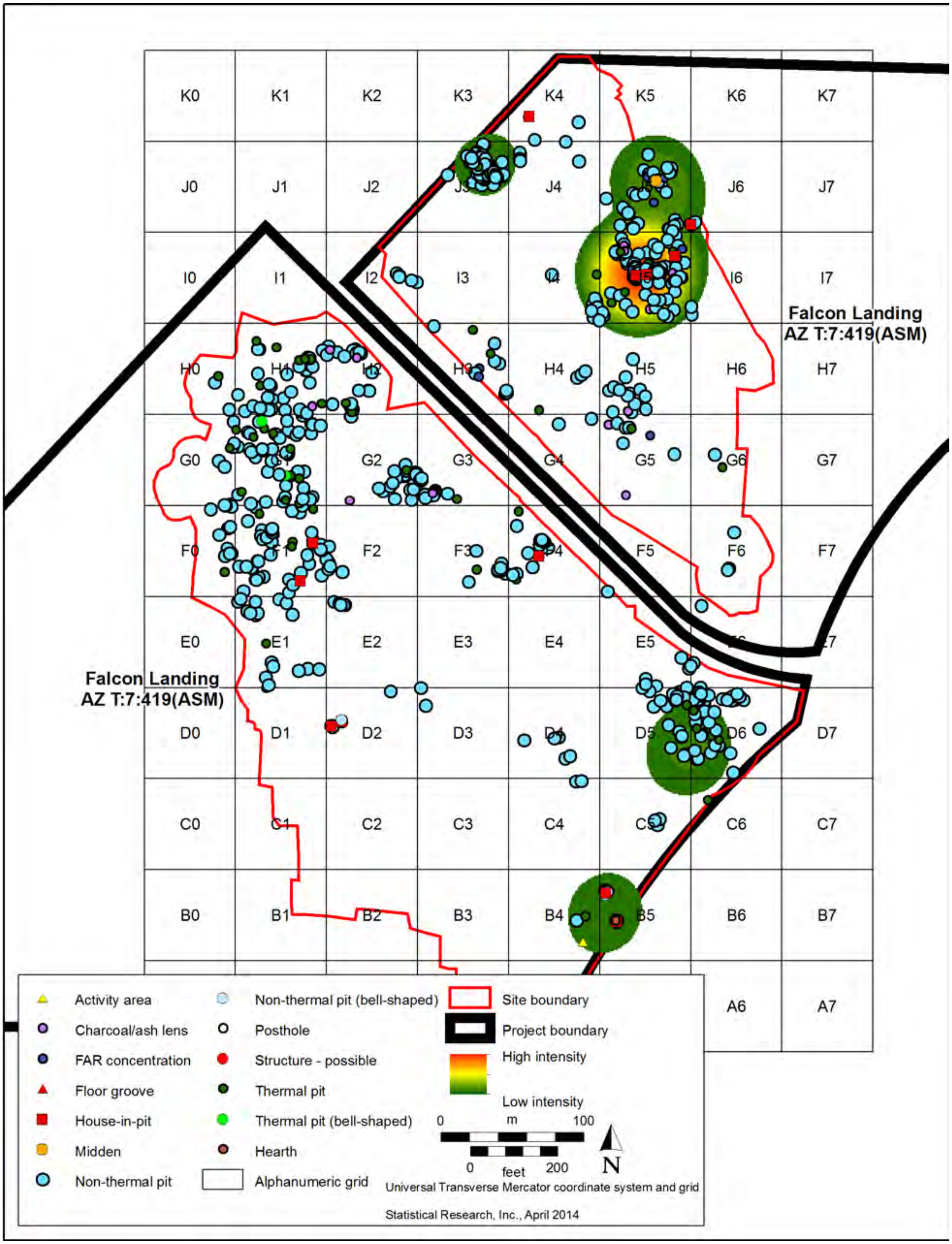


Figure 114. Spatial distribution of features assigned to the Chiricahua temporal component.

(see Appendix 10.1, Interactive PDF, Layer 10.2). In Grid Cell J5, ground stone artifacts were located either within structures, or in pit features or activity areas located within 20 m of structures. This suggests that ground stone artifacts in this area of the site were typically used or stored in and around structures. In Grid Cell J3, ground stone also was concentrated in an area where 2 possible structures were located, but all of the ground stone was contained within 4 pit features located south of the potential structures, but within 11 m of those structures. It is also worth noting that the potential structures in Grid Cell J3 were located within a dense cluster of some 90 pit features. However, little is known about the content or function of these pits as 69 of them were only examined, rather than sampled or partially or completely excavated. The limited information on pit content in this area creates some uncertainty about how ground stone artifacts were distributed in this area. Ground stone was also abundant in a pit in Grid Cell H3, which contained 24 ground stone artifacts, and occurred in lower frequencies in 2 pit features in Grid Cell B4 and in two structures in B5. Overall, the distribution of ground stone within features suggests that ground stone artifacts were typically located in structures or in features located near structures. Estimates of ground stone artifacts, based on estimated feature volume and ground stone density, indicated that approximately 42 percent of ground stone artifacts in features were located within house-in-pit features, 32 percent were located in thermal pits, 15 percent were located in nonthermal pits, and the remainder located in features of other types. The highest ground stone densities were calculated for FAR concentrations and thermal pits, however.

In decreasing order of abundance, extramural artifacts dated to the Chiricahua temporal component consisted of complete manos, metates, pestles, netherstones, and a manuport. Eighty-four percent of extramural artifacts were found in Stratigraphic Units II and IIA (in relatively even numbers between these strata), 15 percent were discovered on the surface of Unit II, and 1 percent was found on the surface of Unit IIA. Extramural ground stone artifacts were widely distributed across Falcon Landing and were often located near pit features (see Appendix 10.1, Interactive PDF, Layer "Chiricahua extramural artifact"). Extramural ground stone artifacts were discovered at the highest densities in the west-central portion of Falcon Landing across a broad area centering on Grid Cell G1 and in the southeastern portion of the site centering on Grid Cells D5 and D6, but they also were discovered in lower densities in other portions of the site. Extramural artifacts appeared to cluster at a variety of scales, with relatively large clusters centered on Grid Cells G1, D5, and D6, and smaller clusters located within the larger clusters. Ripley's *K* suggested that extramural artifacts assigned to the Chiricahua component clustered at a wide range of scales. The intensity of clustering of extramural artifacts peaked at a scale of 58 m, but small breaks in slope suggested clustering at smaller scales as well, such as between 2 and 4 m and between 8 and 30 m. Visual examination of the distribution of extramural ground stone artifacts suggested that manos and metates often were located in proximity to one another and that manos or metates tended to cluster together or with each other. Manos tended to be closest to other manos or, secondarily, to metates. Metates tended to be closest to manos or, secondarily, to other metates. There were also multiple, small isolated clusters of metates. This suggests that (1) manos and metates may have been stored in caches or concentrations consisting of multiple sets of manos and metates; (2) grinding activities were recurrent in specific site areas, but manos and metates in extramural space were frequently buried between site occupations; or, possibly, (3) multiple sets of manos and metates were used concurrently and left near the locations of their use.

Patterning in the distribution of extramural artifacts suggests that manos and metates tended to be stored together in extramural space and may have sometimes been stored together as small collections of multiple manos and metates. Neither netherstones nor pestles clustered, but both artifact types tended to be located closest to manos and, secondarily, to metates. Nearest neighbor statistics indicated that manos (NNI = 0.79) and metates (NNI = 0.65) were individually clustered in space and that manos and metates also tended to cluster with each other (NNI = 0.66). Netherstones (NNI = 1.94) and pestles (NNI = 1.11) were dispersed, by contrast, although they tended to be located closest to manos or metates, as opposed to being located close to other netherstones or pestles. Overall, the spatial distribution of ground stone in extramural space overlapped fairly closely with the distribution of pits, suggesting that ground stone artifacts in extramural space may have been used to process materials stored or further processed in pits (Figure 115).

In total, 980 flaked stone artifacts were estimated to have been located in features assigned to the Chiricahua temporal component. Flaked stone artifacts were found in 3 activity areas, 2 charcoal/ash lenses, 2 FAR concentrations, 9 house-in-pit features, a midden, 33 nonthermal pits, 20 thermal pits, and 2 bell-shaped thermal pits.

Of the flaked stone artifacts dating to the Chiricahua phase, 67 percent were located in the midden, 18 percent in activity areas, 8 percent in thermal pits, and 5 percent in house-in-pit features. The highest overall volumetric density of flaked stone artifacts was found in thermal pits, while substantially lower (and similar) densities were found in activity areas, the midden, and nonthermal pits.

Flaked stone artifacts were located within structures, activity areas, and a midden, as well as in pits, particularly thermal pits, which were often located near domestic features. Kernel density estimates for flaked stone suggested that the highest densities of flaked stone artifacts were found in Grid Cells J5 and B4/B5 (see Appendix 10.1, Interactive PDF, Layer 10.3). In Grid Cell J5, high quantities of flaked stone artifacts were located in a midden (Feature 14587) and in numerous features surrounding the midden. To the south, in Grid Cell I5, flaked stone artifacts were also found within structures, an activity area, and in several features located in the vicinity of these features. In Grid Cell B4, flaked stone artifacts were found in 2 structures and an activity area as well as in 2 pit features. A large area with a high density of flaked stone was also located on the west-central portion of Falcon Landing centered on Grid Cell G1, in an area where numerous pits and 2 structures were located. Here, flaked stone artifacts were located in numerous pits, approximately half of which were identified as thermal pits, as well as in 2 structures. Another area where flaked stone artifacts were concentrated, albeit at a relatively low density, was in Grid Cell D6, near an activity area. There, flaked stone artifacts were discovered in relatively low quantities within 5 pits, 4 of which were identified as thermal pits.

Interestingly, although only 15 percent of pits were identified as thermal in function for the Chiricahua temporal component, 40 percent of pit features with flaked stone artifacts were identified as thermal in function. Moreover, 47 percent of pits with 5 or more estimated flaked stone artifacts were determined to have been thermal in function. A 2-by-2 chi-square test was performed using counts of sampled or excavated pit features to test if flaked stone was distributed differently between thermal and nonthermal features. The test result indicated there was a significant difference ($\chi^2 = 5.204$, $df = 1$, $p < 0.022$) between thermal features and nonthermal features in the presence of flaked stone artifacts. Thermal features contained flaked stone artifacts more often than expected and nonthermal features contained flaked stone artifacts less often than expected. The preferential distribution of flaked stone in thermal pits, as opposed to nonthermal pits, suggests that flaked stone may have been deposited preferentially in thermal pits. This could suggest that flaked stone artifacts made from suitable materials such as chert and chalcedony were heat-treated in pits, although the paucity of chert and chalcedony artifacts suggests that flaked stone artifacts tended to be reduced next to thermal pits, leaving on the site surface flaked stone artifacts that were later washed into or intentionally disposed of in open pits.

In total, 748 faunal specimens were estimated to have been located within sampled or excavated features assigned to the Chiricahua temporal component. Faunal specimens were found within 2 activity areas, a charcoal/ash lens, 2 FAR concentrations, 9 house-in-pit features, a midden, 34 nonthermal pits, a possible structure, 17 thermal pits, and 2 bell-shaped thermal pits. Kernel density estimates of faunal specimens indicated that the greatest density of faunal specimens was in a single feature located in Grid Cell D2, a deep processing/storage pit that contained 270 faunal specimens (Feature 4235). Relatively high densities of faunal specimens also were located in Grid Cell I5, where faunal specimens were found in 2 structures, an activity area, 2 charcoal/ash lenses, 3 thermal features, and 3 nonthermal features. The density of faunal specimens decreased somewhat to the north, in Grid Cell J5, where faunal specimens were found in the midden and several nearby nonthermal pit features. Lower densities of faunal specimens were concentrated in the west-central portion of Falcon Landing, where they tended to be located either in thermal pits or in processing/storage pits; in an area centering on Grid Cell G5, where faunal specimens were discovered in several processing/storage pits and a firepit; and in Grid Cells B4 and B5, where they were found in one of 2 structures, an activity area, and a processing/storage pit (see Appendix 10.1, Interactive PDF, Layer 10.4). These data suggest that faunal specimens were found in wide variety of locations, but they tended to concentrate in features located near activity areas, structures, or the midden, as well as in nearby pits—a substantial proportion of which were thermal pits. Estimates of the number of faunal specimens suggested that as much as 57 percent of faunal specimens were found in nonthermal features. However, if we remove the one anomalously large case (Feature 4235) from consideration, then approximately 33 percent of faunal specimens were found in nonthermal features, 36 percent were found in thermal features, and 15 percent were found in structures, with most of the remainder found in activity areas and the midden. Similarly, the highest volumetric density was calculated for nonthermal features, but if

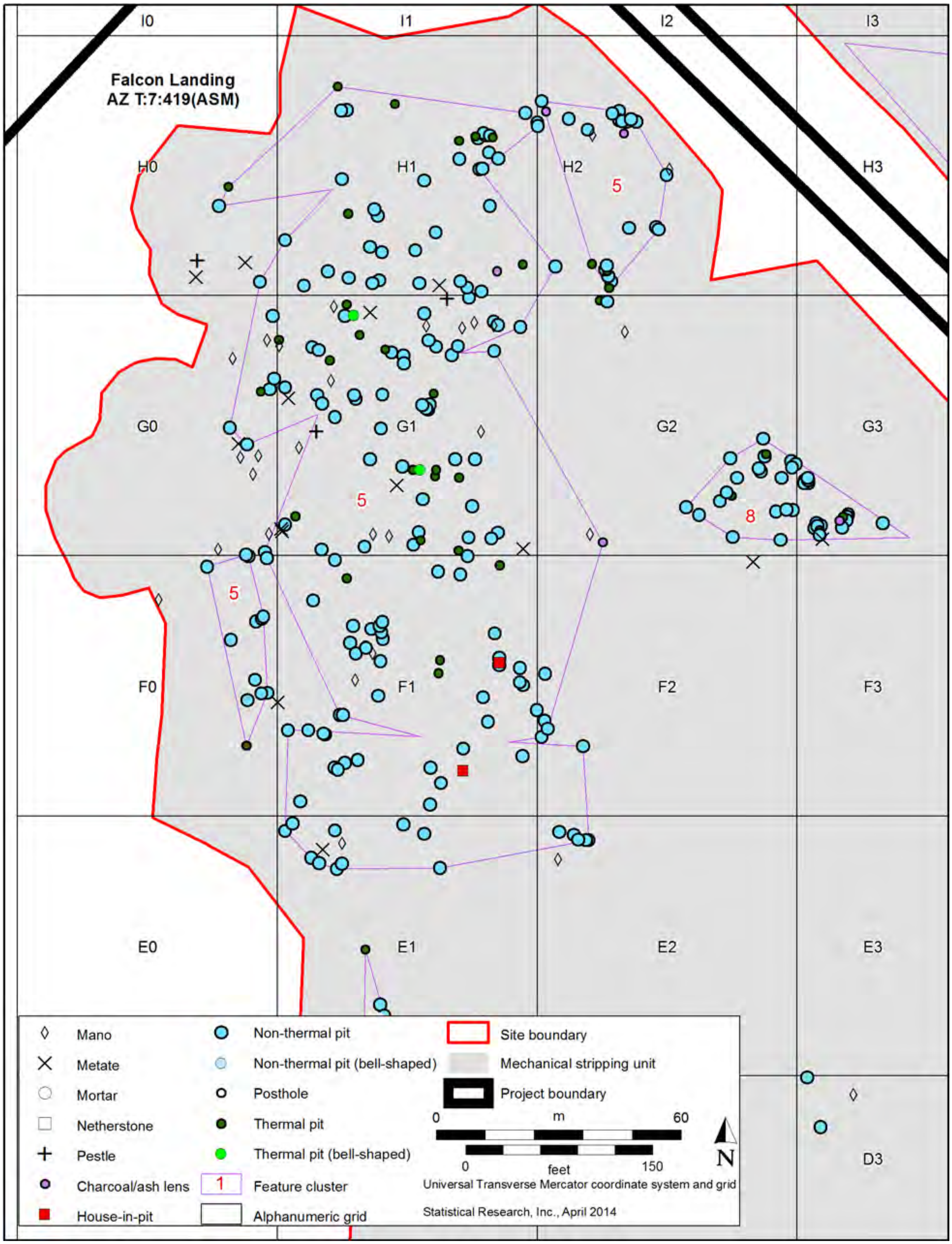


Figure 115. Spatial distribution of extramural artifacts and features assigned to the Chiricahua component located in Cluster 5 and nearby clusters.

Feature 4235 is removed from consideration, then the volumetric density of faunal specimens is similar in thermal and nonthermal features and is slightly higher in thermal features, in comparison to nonthermal features.

Delineation of Chiricahua Feature Clusters

Using ZNNHC, we were able to identify a series of 15 clusters or cluster aggregates using a fixed distance of 50 m for calculations (Figure 116). Several of the clusters that were immediately adjacent to each other were subjectively lumped into a single cluster to facilitate analysis (Cluster 5). Six of the 15 clusters contained house-in-pit features (Table 97). Three of the clusters with one or more house-in-pit features also contained an activity area (Clusters 1, 3, and 15), and Cluster 3 contained a midden and two possible structures. With the exception of Cluster 14, which contained no structures but did contain an activity area, clusters that included structures had the highest estimated feature volumes and the highest feature richness. Four of the clusters consisted only of small numbers of nonthermal pits (Clusters 2, 4, 10, and 14), but most clusters included both thermal and nonthermal features. In most clusters where both thermal and nonthermal features were present, there were four to six nonthermal features for each thermal feature.

Chiricahua Occupational Episodes

Occupational episodes could be assigned to most features dating to the Chiricahua temporal component (Figure 117). However, occupational episodes could not be assigned to most features in Cluster 9 and to a handful of features located in other parts of the project sites. The earliest occupation of the sites occurred in Cluster 12, where a structure (Feature 4388) dating to Occupational Episode A was discovered, and in the southern portion of Cluster 5, where a single thermal feature was identified as dating to this episode. Many of the features dating to Occupational Episodes A and/or B were also located in the southern portion of Cluster 5, suggesting that use of this area of Falcon Landing may have been roughly contemporaneous with

Table 97. Counts of Chiricahua Features, According to Cluster and Feature Type

Cluster	Activity Area	Charcoal/Ash Lens	FAR Concentration	Floor Groove	Hearth	House-in-Pit	Midden	Non-thermal Pit	Non-thermal Pit (Bell-shaped)	Posthole	Structure - Possible	Thermal Pit	Thermal Pit (Bell-shaped)	Total
None	—	1	1	—	—	—	—	10	—	—	—	2	—	14
1	1	—	—	—	—	1	—	78	—	—	2	19	—	101
2	—	—	—	—	—	—	—	3	—	—	—	—	—	3
3	2	6	7	—	1	4	1	126	1	72	—	30	—	250
4	—	—	—	—	—	—	—	5	—	—	—	—	—	5
5	—	4	—	—	—	2	—	176	—	—	—	30	2	214
6	—	—	2	—	—	—	—	8	—	—	—	2	—	12
7	—	2	1	—	—	—	—	23	—	—	—	2	—	28
8	—	1	—	—	—	—	—	34	—	—	—	5	—	40
9	—	—	—	—	1	1	—	19	—	—	—	3	—	24
10	—	—	—	—	—	—	—	4	—	—	—	—	—	4
11	—	—	—	—	—	—	—	4	—	—	—	2	—	6
12	—	—	—	—	—	2	—	7	1	24	—	—	—	34
13	—	—	—	—	—	—	—	7	—	—	—	—	—	7
14	1	—	—	—	—	—	—	75	—	—	—	7	—	83
15	1	—	—	2	1	2	—	5	1	62	—	1	—	75

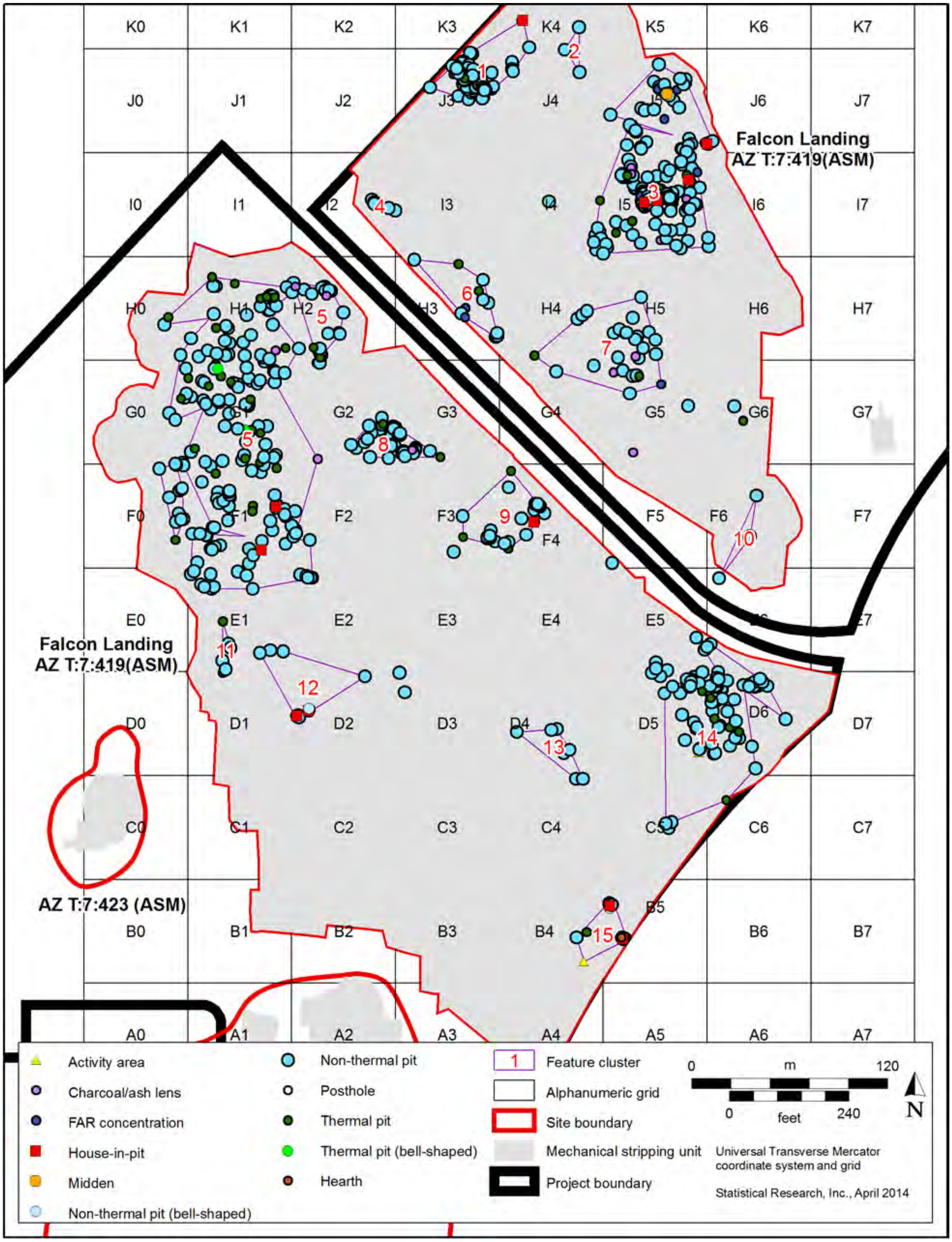


Figure 116. Clusters of features assigned to the Chiricahua temporal component using Zonal Nearest Neighbor Hierarchical Cluster Analysis.

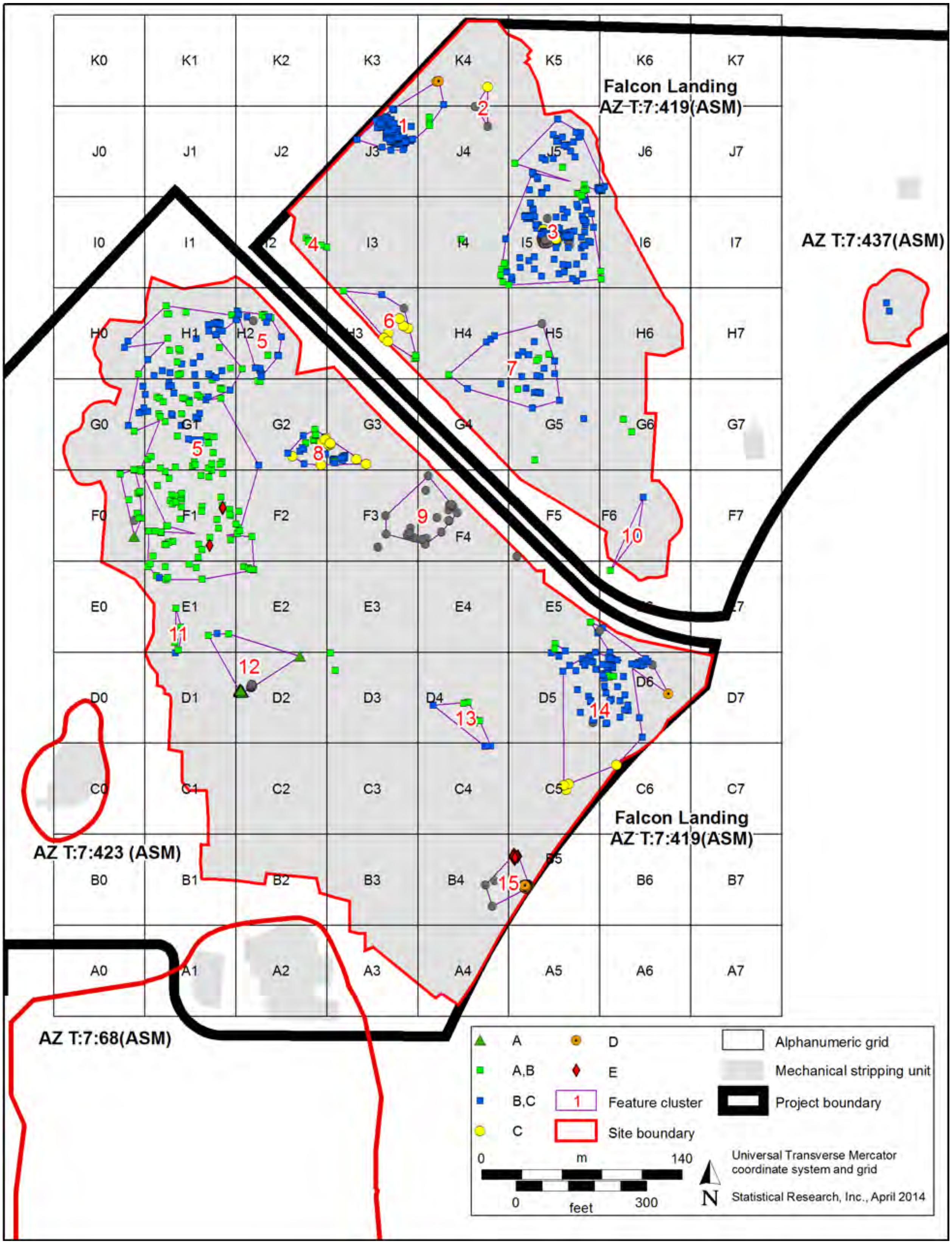


Figure 117. Spatial distribution of features assigned to the Chiricahua temporal component, based on occupational episode.

the use of Feature 4388. Small clusters of features dating to Occupational Episodes A and/or B were also located in many other areas of the site. These typically consisted of several nonthermal pits, suggesting that use of Falcon Landing during Occupational Episodes A and/or B often involved the use of small, isolated clusters of closely spaced pits for processing and/or storage activities.

Large numbers of features were also assigned to Occupational Episodes B and/or C. These features were concentrated in Clusters 1, 3, 7, 8, and 14, and in the northern half of Cluster 5. The shift in spatial distribution across Falcon Landing from features dated to Occupational Episodes A and/or B to features dated to Occupational Episodes B and/or C suggests that use of Falcon Landing during Episodes B and/or C shifted away from previously occupied areas to involve more-intensive occupation in areas where small isolated clusters of nonthermal features had previously been used for processing or storage activities. The vast majority of features in Cluster 3—including the two smaller structures, the midden, and the activity area—dated to Occupational Episodes B and/or C, and one of the two larger structures dated to Occupational Episode C (Figure 118). The other large structure in Cluster 3 was not dated to an occupational episode. Similarly, in Cluster 1, one possible structure dated to Occupational Episode B and the other possible structure to Occupational Episode C, while most of the pit features date to Occupational Episodes B and/or C. In Cluster 14, most features dated to Occupational Episodes B and/or C, but the activity area dated to Occupational Episode B.

Features dated to Occupational Episode D were relatively isolated and few in number. In the northern portion of Falcon Landing, one isolated structure on the far eastern edge of Cluster 1 dated to Occupational Episode D (Feature 2642). One nonthermal pit in Cluster 14 dated to Occupational Episode D and one structure in Cluster 15 (Feature 1498) dated to Occupational Episode D. The sparse distribution of features dated to Occupational Episode D potentially suggests less-intensive use of Falcon Landing during this period. However, because two of the few features dated to Occupational Episode D were structures, it could also be the case that many features associated with this occupation could not be dated and may not have been assigned to a temporal component.

Features dated to Occupational Episode E and assigned to the Chiricahua temporal component consisted of three structures. Two of these (Features 10114 and 11229) were located in the southern half of Cluster 5, and the other (Feature 1244) was located in Cluster 15, 20 m distant from a structure occupied during Occupational Episode D. The location of these features, exclusively in the southern portion of Falcon Landing, suggests that residential use of the site had shifted south. This is consistent with the distribution of Chiricahua/San Pedro features, as Chiricahua/San Pedro features were found in the same area of Falcon Landing, between Features 10114 and 11229 and Feature 1244.

Chiricahua/San Pedro Phase (1380–920 cal B.C.) Spatial Distribution

Extramural and primary features assigned to the Chiricahua/San Pedro temporal component included an activity area, a burial, 2 caches, 2 charcoal/ash lenses, 8 FAR concentrations, 4 house-in-pit features, 83 nonthermal pits, 3 bell-shaped nonthermal pits, 1 surface structure, 32 thermal pits, and a bell-shaped thermal pit (Table 98). Ripley's *K* estimates indicated that Chiricahua/San Pedro features clustered across a broader range of scales than Chiricahua features, clustering in the ranges of 5 m to 220 m. The most intense clustering was found at a scale of 80 m, apparently because most of the features were in one large cluster that centered on Grid Cells E2 and D2. Change in slope in the clustering curve suggested several clustering regimes: 5–20 m, 20–45 m, 45–50 m, and 50–80 m.

Kernel density estimates of feature volume showed that the construction of most Chiricahua/San Pedro features was confined to the southern portion of Falcon Landing (Figure 119). A few isolated features assigned to this temporal component also were located in the northern portion of Falcon Landing, however (see Appendix 10.1, Interactive PDF, Layer "Chiricahua/San Pedro feature type"). Kernel density estimates of feature volume calculated using a 50-m distance suggested that three peaks in the intensity of feature construction occurred in Grid Cells E2 and D2 and another peak was in Grid Cell A2, associated with Site 68. Areas of lower intensity of feature construction occurred in Grid Cell A1 in Site 68 and in Grid Cell A3 in Falcon Landing. Peaks in the intensity of feature construction centered around an activity area and multiple FAR

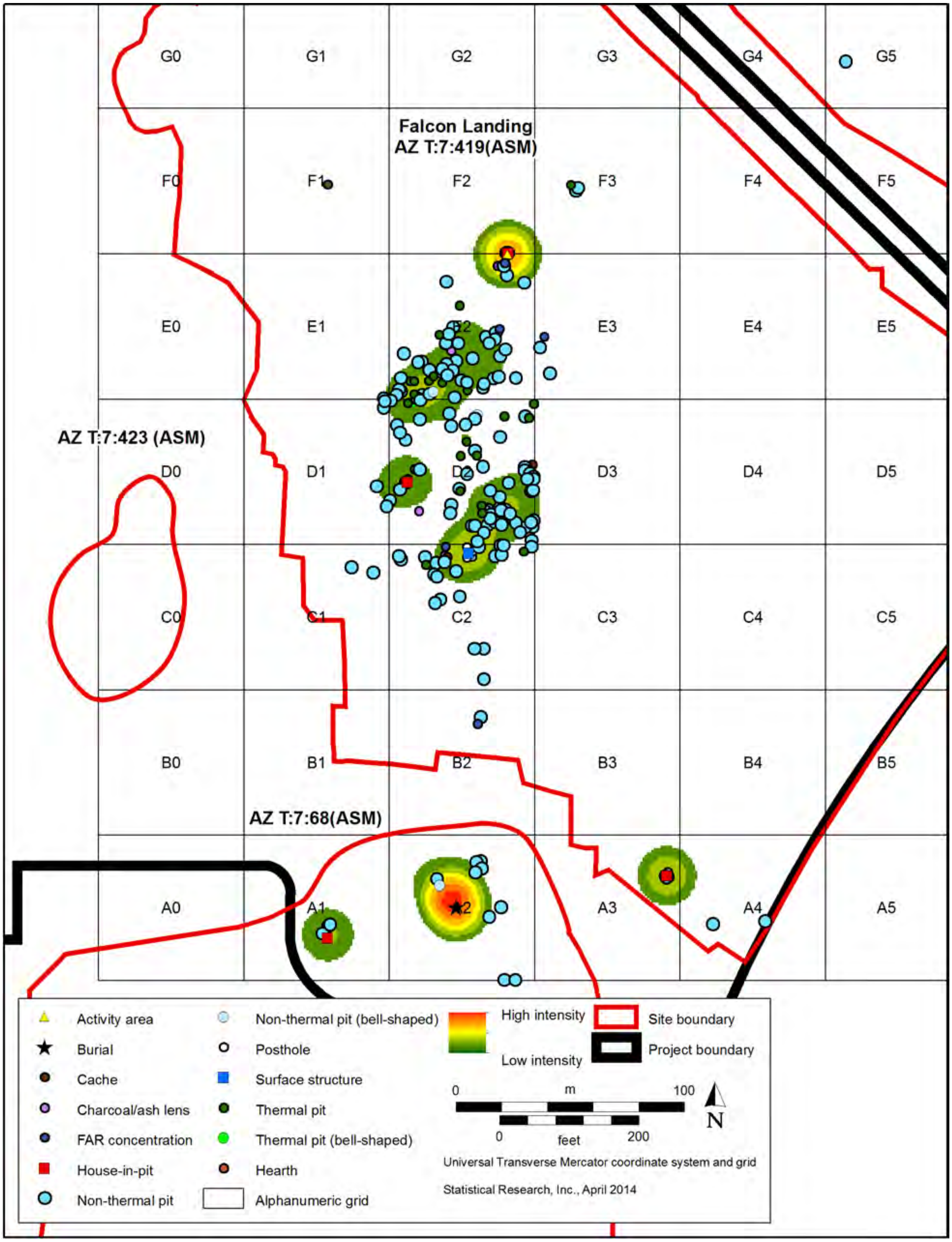


Figure 118. Spatial distribution of features assigned to the Chiricahua temporal component in Cluster 3 of the Chiricahua feature distribution.

Table 98. Percentage and Densities of Estimated Artifact and Faunal Specimen Counts, according to Artifact Class and Feature Type, for Features Assigned to the Chiricahua/San Pedro Temporal Component

Feature Type	Feature Count (Sampled or Excavated)	Total Estimated FAR Count (%)	FAR Density (Artifacts/m^3)	Total Estimated Ground Stone Artifact Count (%)	Ground Stone Density (Artifacts/ m^3)	Total Flaked Stone Artifact Count (%)	Flaked Stone Artifact Density (Artifacts/m^3)	Total Estimated Faunal Specimen Count (%)	Faunal Specimen Density (Specimens/m^3)
Activity area	1	19.0	123.2	13.6	29.6		—		—
Burial	1		—	0.6	0.4	13.9	101.8		—
Cache	2	0.2	16.1	2.3	64.5	0.1	16.1	1.4	72.6
Charcoal/ash lens	2		—		—		—		—
FAR concentration	8	10.3	161.7	10.1	53.3	0.1	3.7	0.6	1.4
House-in-pit	4	3.2	4.9	1.7	0.9	10.9	51.6	10.2	4.7
Nonthermal pit	83	41.8	64.6	67.7	34.9	48.5	234.9	76.1	1.8
Nonthermal pit (bell shaped)	3		—		—	1.6	21.8	0.2	0.3
Posthole	23		—		—		—		—
Surface structure	1		—		—		—		—
Thermal pit	32	25.1	73.9	4.0	3.9	24.4	224.9	10.3	1.2
Thermal pit (bell shaped)	1	0.4	8.5		—	0.5	34.2	1.3	34.2
Total	161	100.0	46.1	100.0	12.9	100.0	120.8	100.0	3.3

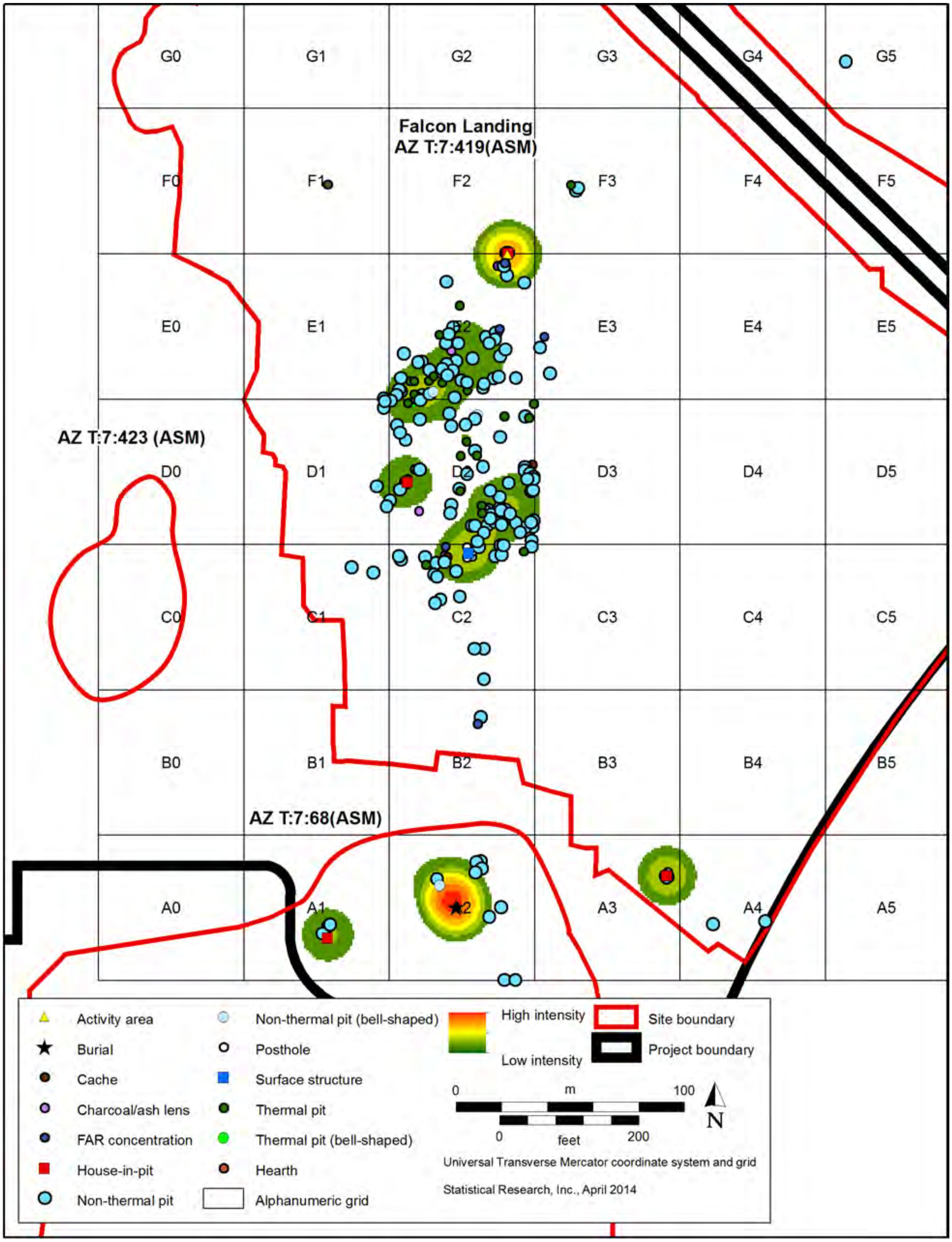


Figure 119. Spatial distribution of features assigned to the Chiricahua/San Pedro temporal component.

concentrations in the northern part of Grid Cell E2, two bell-shaped pits surrounded by pit features in Grid Cells E2 and D2, numerous pits and a surface structure and house-in-pit in the southern half of Grid Cell D2, and several pits and a bell-shaped pit in Grid Cell A2. Features in Grid Cell A1 consisted of a house-in-pit (Feature 88) and three nonthermal features; features in Grid Cell A3 consisted of a house-in-pit (Feature 3521) with two intramural nonthermal pits.

When calculated using a smaller distance of 20 m, kernel density estimates showed clustering in the same areas, but at a finer level of detail. Kernel density estimates using feature volume and the distance of 20 m suggested the presence of multiple small clusters in the core area of Chiricahua/San Pedro occupation. These included clusters centering on an activity area, a house-in-pit, and several clusters of pit features. This suggests the presence of some fine-scale clustering that may signal the presence of different activity loci within larger clusters of Chiricahua/San Pedro features.

In total, 526 pieces of FAR were estimated to have been located in sampled or excavated features assigned to the Chiricahua/San Pedro temporal component (see Table 98). FAR was found in an activity area, a cache, a house-in-pit, an FAR concentration, 8 nonthermal pits, 8 thermal pits, and 1 bell-shaped thermal pit. FAR was found mostly in individual features or small groups of features that were widely separated from each other. FAR was not discovered in the southernmost portion of the distribution of Chiricahua/San Pedro features, although most of the features in that area of the site were either sampled or excavated. Interestingly, many of the clusters defined with ZHNNC analysis using a 20-m distance (see below) in the northern part of the distribution had one or two features with FAR in them and these often occurred near the edge of a cluster defined using ZHNNC. Estimates of FAR counts indicated that during the Chiricahua/San Pedro temporal component, 42 percent of FAR was located in nonthermal features, 25 percent in thermal features, 19 percent in an activity area, and 10 percent in FAR concentrations. While thermal features constituted only 22 percent of the pit features that were tested or excavated, slightly more than half of pit features with FAR were thermal features as opposed to nonthermal pit features. In other words, whereas more FAR overall was found in nonthermal pit features, a larger percentage of thermal pit features contained FAR than did nonthermal features. To test if FAR was deposited more often than expected in thermal features or in nonthermal features, we calculated the number of thermal and nonthermal pit features that contained FAR and the number of those features that had been subject to testing or excavation. The results indicated that, in comparison to nonthermal features, FAR was discovered in thermal features more often than expected, whereas FAR was found in nonthermal features less often than expected ($\chi^2 = 6.84$, $p = 0.0089$). The overall density of FAR per feature type was highest in FAR concentrations and an activity area. The density of FAR in pits was lower for thermal features and somewhat lower in nonthermal features and was much lower for other feature types. A chi-square test using the total estimated FAR count in thermal and nonthermal features and the estimated volume of thermal and nonthermal features also suggested that the amount of FAR in thermal features was greater than expected, whereas the amount of FAR in nonthermal features was, in comparison, less than expected ($\chi^2 = 8.10$, $p = 0.0004$). These data suggest that FAR was found more often than expected in thermal pit features in comparison to nonthermal pit features, despite the fact that more FAR overall was found in nonthermal pit features, which were more numerous than thermal pit features. FAR was seldom encountered in the many thermal features located in Grid Cells E2 and D2. By contrast, thermal features dating to Chiricahua/San Pedro in other parts of the site typically did contain FAR. This could suggest that thermal features in Grid Cells E2 and D2 were frequently cleaned out or, perhaps, that their use rarely included the use of FAR as thermal mass (see Appendix 10.1, Interactive PDF, Layer 10.5).

In total, 176 ground stone artifacts were estimated to have been located in sampled or excavated features assigned to the Chiricahua/San Pedro temporal component. Ground stone artifacts were found in four thermal pits, nine nonthermal pits, two caches, four FAR concentrations, a house-in-pit, and an activity area (which overlapped with the house-in-pit). Ground stone artifacts were most heavily concentrated in the northeastern quadrant of Grid Cell E2, where they were found in an activity area, a house-in-pit, within two nonthermal features overlapping the activity area and house-in-pit, and in two nearby FAR concentrations. Ground stone artifacts were also discovered in scattered pit features located to the south of this concentration in Grid Cells C1, C2, D2, and E2 (see Appendix 10.1, Interactive PDF, Layer 10.6). Overall, most ground stone artifacts dating to Chiricahua/San Pedro were discovered in nonthermal features, with smaller numbers located in an activity area, FAR concentrations, thermal pits, a burial, and a house-in-pit feature. Interestingly, ground stone was comparatively rare in house-in-pit features but was comparatively more common in such features during the preceding Chiricahua phase A chi-square test of total estimated ground stone counts and feature volumes for nonthermal features and all other features indicated that ground stone artifacts were deposited more often in nonthermal pits than they were in features of other types ($\chi^2 = 89.15$, $p < 0.001$). Overall volumetric densities calculated per feature type, however, indicated that the highest densities of ground stone artifacts were found in a cache and FAR concentrations, and ground stone artifacts were found at somewhat lower densities in nonthermal pits and an activity area.

Extramural artifacts assigned to the Chiricahua/San Pedro temporal component consisted entirely of manos, metates, or pestles and were distributed primarily within one portion of the distribution of Chiricahua/San Pedro features at Falcon Landing. Nearest neighbor statistics suggested that extramural artifacts were not clustered (NNI = 1.00). However, nearly all extramural artifacts were found in the vicinity of pit features containing ground stone, often within 5–10 m of a feature containing ground stone. Moreover, in the northern part of the distribution, in Grid Cells E2 and D2, pestles and metates were primarily located between clusters of features identified with ZHNNC using a 20-m fixed distance, rather than within them, suggesting that such artifacts may have been stored or used in extramural space located immediately surrounding concentrations of pit features. Also, although the sample size was quite low, pestles were concentrated on the west, metates in the center, and manos on the eastern side of the distribution of extramural artifacts at Falcon Landing. This suggests there was some patterning in extramural ground stone artifacts with respect to artifact types and feature clusters.

In total, 1,650 flaked stone artifacts were estimated to have been located in sampled or excavated features assigned to the Chiricahua/San Pedro temporal component. Flaked stone artifacts were found in 2 house-in-pit features, an FAR concentration, 10 thermal pits, 20 nonthermal pits, and 2 nonthermal bell-shaped pits. The highest density of flaked stone artifacts was in the southwestern portion of Grid Cell D2 where flaked stone artifacts were found in several closely spaced features, including a house-in-pit, 3 nonthermal features, and a thermal feature (see Appendix 10.1, Interactive PDF, Layer 10.7). Another high-density cluster of flaked stone artifacts was approximately 50 m to the north where it centered on the southwestern quadrant of Grid Cell E2. This cluster of flaked stone was recovered from a cluster of features consisting of 5 nonthermal features, 2 thermal features, and a thermal bell-shaped pit, all with flaked stone artifacts, that surrounded 2 nonthermal bell-shaped pit features with flaked stone. A high density of flaked stone artifacts also was located in Grid Cell A2, where a burial feature (Feature 106) contained 229 flaked stone artifacts and a mano. Moderately high densities of flaked stone artifacts were found in a thermal feature in Grid Cell F1 and in a thermal feature and a nonthermal feature in Grid Cell F3. Flaked stone artifacts were found in multiple other features outside these higher-density areas, but most of these were confined to the northern part of the distribution of Chiricahua/San Pedro features. Most of the areas where flaked stone artifacts were found in features, but at comparatively lower kernel densities, had few features that were tested or excavated, however. Variation in the level of effort expended on the features could account for the lower density of flaked stone in these areas, suggesting that variation in kernel density estimates for flaked stone artifacts was a by-product of sampling intensity and that, possibly, flaked stone densities in these areas were higher than was estimated. Although not distinguished as a higher density area of flaked stone artifacts, features with flaked stone artifacts in this area of the Chiricahua/San Pedro feature distribution appeared to cluster around a surface structure (Feature 8561) in the northern portion of Grid Cell C2. The overall density of flaked stone was quite similar between thermal and nonthermal pits, however, suggesting that deposition of flaked stone artifacts may have occurred at similar rates in both thermal and nonthermal pits during the Chiricahua/San Pedro. Overall density in other feature types was several times lower than that calculated for thermal or nonthermal pits.

With the exception of the large number of flaked stone artifacts in a single burial feature (Feature 106) at Site 68, few flaked stone artifacts were found in the southern portion of the distribution—in Grid Cells A1, A2, and A3—where small numbers of flaked stone artifacts were found in a house-in-pit and in a nonthermal pit. Many of the features in this area were tested or partially or fully excavated, suggesting that the low densities of flaked stone in the southern portion of the project area may be an accurate reflection of the distribution of flaked stone artifacts during the Chiricahua/San Pedro use of the project area. Overall, the distribution of flaked stone artifacts suggests that flaked stone artifacts were found primarily in the northern portion of the project area where 32 percent of tested or excavated features contained flaked stone artifacts. In the southern portion of the project area, 20 percent of tested or excavated features contained flaked stone. As noted, however, one of these features, a burial (Feature 106) from Site 68, contained 229 flaked stone artifacts. Features with flaked stone artifacts appear to have been clustered around a house-in-pit (Feature 4349), two bell-shaped nonthermal pits (Features 4288 and 4291), and around a surface structure (Feature 8561). Moreover, clusters of features containing flaked stone appear to have been relatively confined in space, spanning a distance of 15–40 m. This suggests that the use or maintenance of flaked stone tools may have been concentrated in particular sections of the project area, focused around particular features or activity areas.

In total, 638 faunal specimens were estimated to have been located in sampled or excavated features assigned to the Chiricahua/San Pedro temporal component. Faunal specimens were found in 2 caches, an FAR concentration, 3 house-in-pit features, 20 nonthermal pits, a bell-shaped nonthermal pit, 10 thermal pits, and a bell-shaped thermal pit. Faunal specimens were more widely distributed across Falcon Landing than were artifacts of other classes. Interestingly, the highest density of faunal specimens was in an isolated feature (Feature 18880) located in Grid Cell I4, 300 m or more distant from other concentrations of faunal specimens dating to the Chiricahua/San Pedro temporal component (see Appendix 10.1, Interactive PDF, Layer 10.8). This completely excavated feature was interpreted as a deep, basin-shaped nonthermal pit used for storage and contained some 268 faunal specimens (238 of which were marine-shell beads), as well as 13 stone beads and 7 flaked stone artifacts. Farther to the south, in the core area of the Chiricahua/San Pedro distribution, faunal specimens were densely distributed in a house-in-pit and 3 closely situated pit features in Grid Cell D2 and in a broad array of thermal and nonthermal pits (including 2 bell-shaped pits) in Grid Cell E2. These two areas overlapped fairly closely with higher-density areas of flaked stone artifacts, suggesting a possible association between the deposition of faunal specimens and flaked stone artifacts in these areas. A small area of moderate faunal density also was found in Grid Cell C2, where small numbers of faunal specimens were found in a cache, a charcoal/ash lens, an FAR concentration, a thermal pit, and a nonthermal pit. Interestingly, this area was located immediately west of a surface structure that also contained faunal material, suggesting that deposition of faunal specimens in this area may have been associated with use of the surface structure. This same area also had a cluster of features with flaked stone artifacts, suggesting a possible association between faunal specimen deposition and flaked stone artifact deposition. Although not identified as having a dense concentration of faunal specimens, a house-in-pit and 2 nearby nonthermal features in Grid Cell A1 (Site 68) contained faunal material as did the isolated house-in-pit in Grid Cell A3 (Falcon Landing).

The majority of faunal specimens dating to Chiricahua/San Pedro were discovered in nonthermal features, with smaller numbers found in thermal pits and house-in-pit features. If we remove the anomalous case of Feature 18880, which contained 42 percent of all estimated faunal material, the majority of faunal material was still found in nonthermal pits (59 percent), while 18 percent were found in thermal pits, and another 18 percent were found in house-in-pit features. The overall density of faunal material, however, was by far the highest in caches and bell-shaped pits, and secondarily in house-in-pit features; it was substantially lower in features of other types. Given the interpretation of Feature 18880 as having been used for storage and the relatively high density of faunal specimens in caches, nonthermal bell-shaped pits, and to a lesser degree in house-in-pit features—as well as the discovery of most faunal specimens in nonthermal pits (interpreted as having been used for processing or storage)—it appears that faunal material was sometimes stored as shell beads in pits and was less often deposited in pits in the context of cooking activities. Faunal material also appears to have been concentrated in and around houses-in-pits as well as near a surface structure, suggesting an association between faunal deposition and areas adjacent to structures.

Delineation of Chiricahua/San Pedro Feature Clusters

Using ZNNHC, we were able to identify a series of 7 clusters or cluster aggregates defined by using a fixed distance of 50 m. These calculations suggested that at this scale (50 m) there were 4 large clusters in the northern part of the Chiricahua/San Pedro feature distribution (centering on Grid Cells C2, D2, and E2) and 3 small clusters of features in the southern part of the distribution (centering on Grid Cells A1, A2, and A4). Because Ripley's *K* analysis suggested that Chiricahua/San Pedro features also clustered at the scale of 20 m, we ran the same analysis using a fixed distance of 20 m (Figure 120). This analysis, conducted at a scale of 20 m, suggested the presence of as many as 10 clusters of features in the northern part of the distribution of Chiricahua/San Pedro features as well as 4 small clusters in the southern part of the distribution. The clusters defined at a scale of 20 m, particularly in the northern part of the distribution, appear to be more meaningful than the clusters defined at a scale of 50 m because they appear to be more discrete, consisting of clusters of pit features, FAR concentrations, and other features. In several cases, clusters appear to have been organized around bell-shaped pits, a house-in-pit, or a surface structure, suggesting the clustering of processing and storage activities around larger features that may have focused these activities in specific parts of the site.

Occupational Episode E (1390–800 cal B.C.) of Chiricahua/San Pedro Features

Only 10 features assigned to the Chiricahua/San Pedro temporal component were assigned to Occupational Episode E (1390–800 cal. B.C.) (Three Chiricahua phase structures were assigned to Episode E as were all features assigned to the San Pedro temporal component). Curiously, 7 of 10 of these features were relatively isolated, located to the north of the vast majority of features assigned to this temporal component, in areas where no other features dated to this component were located. Indeed, all of these features were located amongst dense distributions of features that could not be assigned to a temporal component, suggesting that some of the undated features may have been coeval with Chiricahua/San Pedro use of Falcon Landing and Site 68.

San Pedro Phase (1200–800 cal B.C.) Spatial Distribution

Extramural and primary features assigned to the San Pedro temporal component (1200–800 cal B.C.) included 10 house-in-pit features, a midden, 16 nonthermal pits, a reservoir, and 8 thermal pits (2 of which were bell shaped) (Table 99). Unlike earlier components, which included many more features, many of which were only examined, all of the San Pedro houses-in-pits were completely excavated and nearly all other features were also completely excavated. The few remaining features assigned to the component were partially excavated or sampled.

Ripley's *K* estimates indicated that San Pedro phase features clustered in the range of 5 to 80 m, a more narrow range of scales than Chiricahua or Chiricahua/San Pedro features. Clustering was pronounced at scales of 15 m and 55 m. The lower-confidence envelope, calculated with 99 permutations, indicated that clustering may only occur at scales less than 50 m, however. The more irregular intensity of clustering across a comparatively narrow range of scales, in comparison to the clustering of Chiricahua or Chiricahua/San Pedro features, probably resulted from the much smaller number of features assigned to the San Pedro temporal component and the comparative rarity of pit features, which made up the majority of clustered features for earlier components.

The San Pedro temporal component was substantially different from earlier components in that it consisted of a much smaller number of features, the features were widely separated across the site (with clusters of features separated on average by over 200 m), and half of the primary features were house-in-pit features (Figure 121). By contrast, features for previous components were far more numerous, clusters of features were more closely spaced, and the most common features were pits. The reservoir feature (Feature 10278) was located in Grid Cell H6 in the northeastern quadrant of the site. The feature closest to the reservoir was a house-in-pit (Feature 18887) located approximately 60 m to the southwest of the reservoir. Features clustered

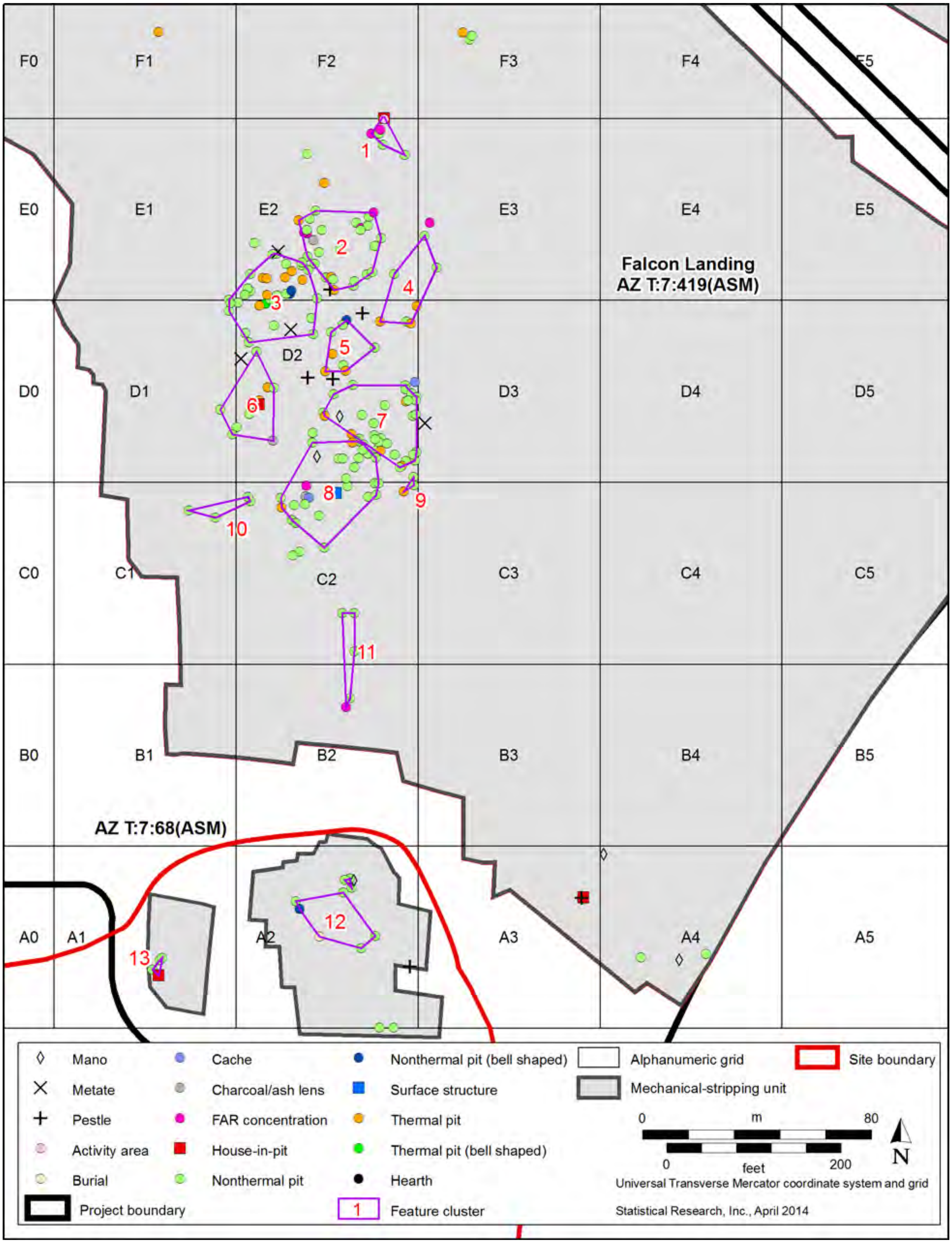


Figure 120. Clusters of features assigned to the Chiricahua/San Pedro temporal component using Zonal Nearest Neighbor Hierarchical Cluster Analysis and a Fixed Distance of 20 m.

Table 99. Percentage and Densities of Estimated Artifact and Faunal Specimen Counts, according to Artifact Class and Feature Type, for Features Assigned to the San Pedro Temporal Component

Feature Type	Feature Count (Sampled or Excavated)	Total Estimated FAR Count (%)	FAR Density (Artifacts/m^3)	Total Estimated Ground Stone Artifact Count (%)	Ground Stone Density (Artifacts/m^3)	Total Flaked Stone Artifact Count (%)	Flaked Stone Artifact Density (Artifacts/m^3)	Total Estimated Faunal Specimen Count (%)	Faunal Specimen Density (Specimens/m^3)
House-in-pit	10	96.8	27.2	74.1	2.6	52.1	30.0	56.0	10.4
Midden	1		—	17.4	1.3	10.2	12.5	20.1	7.9
Nonthermal pit	16	3.2	5.2	8.5	1.7	29.1	96.8	19.2	20.6
Posthole	76		—		—		—		—
Reservoir	1		—		—	3.1	4.4	1.4	0.6
Thermal pit	6		—		—	5.4	34.8	3.3	7.0
Thermal pit (bell shaped)	2		—		—		—		—
Total	112	100.0	12.7	100.0	1.6	100.0	26.0	100.0	8.4

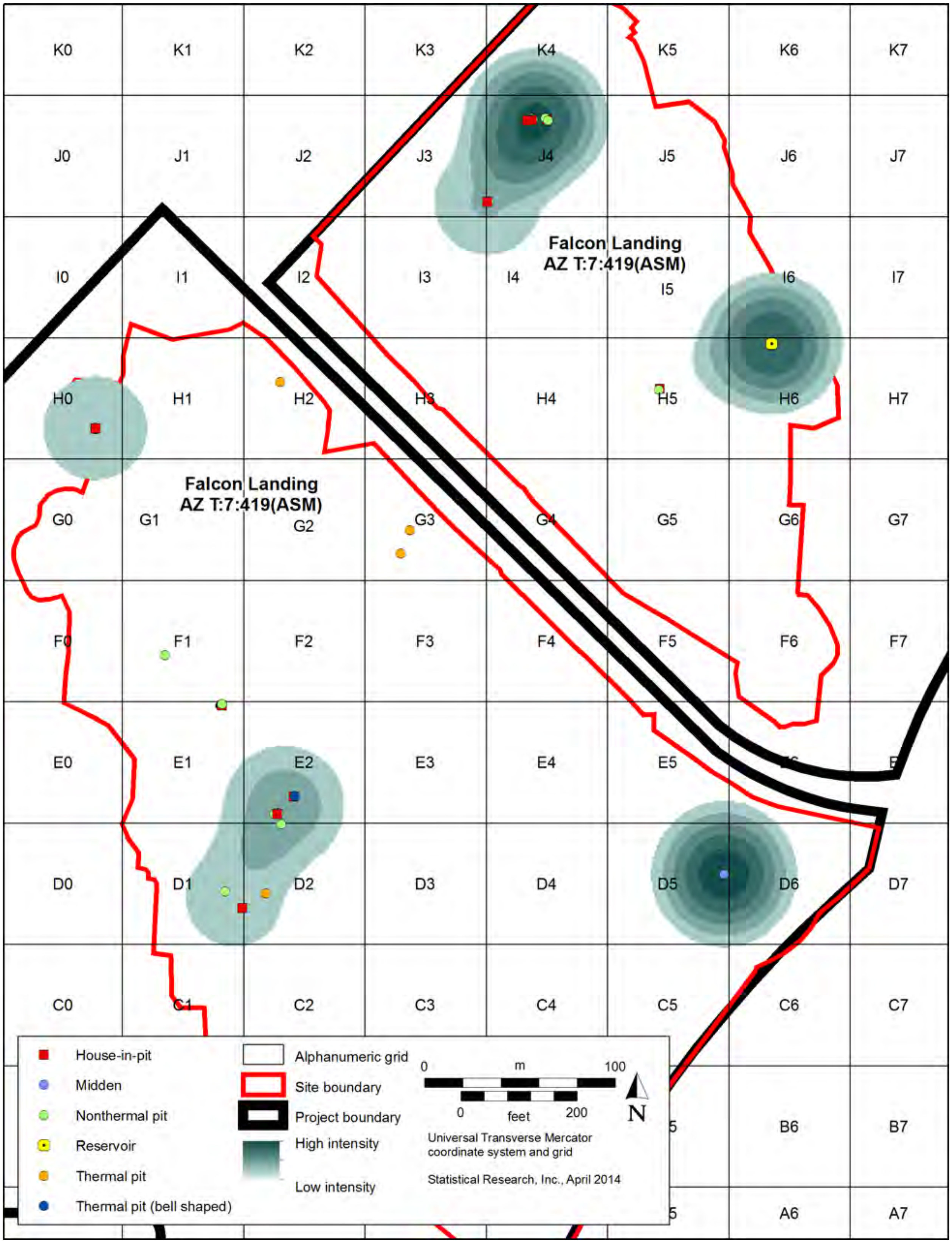


Figure 121. Spatial distribution of features assigned to the San Pedro temporal component.

most in the southwestern and northernmost areas of the distribution of San Pedro features, but also occurred in Grid Cells D5, H0, H5, and H6. In Grid Cell E2, 2 San Pedro house-in-pit features were located within 11 m of each other, and 2 other house-in-pit features were located within 60 m of the 2 more closely spaced structures. These features fell within or were adjacent to clusters defined for the Chiricahua/San Pedro temporal component (Clusters 2, 3, and 6) (see Figure 120), suggesting that features in this area represent serial occupation of a previously used locale or were potentially coeval with Chiricahua/San Pedro features located in this area of Falcon Landing.

In Grid Cell J4, two San Pedro house-in-pit features overlapped slightly with each other, and another was located just 4 m away from these two structures. Another structure was located 45 m to the southwest of these three tightly clustered house-in-pit features (Figure 122). Perhaps, these tight groupings of structures represent serially occupied locations or multiple, closely spaced residences occupied at the same time. Features in this area were located within a short distance of Clusters 1 and 2 defined for the Chiricahua component. Most other San Pedro features were located within or along the edges of clusters defined for the Chiricahua component, suggesting that during the San Pedro phase, seasonal residences were established in some of the same areas of the site that had been used logistically during the Chiricahua phase (Figures 123 and 124).

In total, 181 pieces of FAR were estimated to have been located within features assigned to the San Pedro temporal component (see Table 99). All FAR was concentrated in two areas of the site: (1) within three house-in-pit features and a nonthermal pit in Grid Cells E1, E2, and F1; and (2) within four house-in-pit features in Grid Cell J4 (see Appendix 10.1, Interactive PDF, Layer 10.9). The largest amount of FAR was found in a house-in-pit (Feature 13071) in the southwestern corner of Grid Cell J4. Ninety-seven percent of FAR was found in house-in-pit features; the remaining 3 percent was found in nonthermal pits. The overall density of FAR in house-in-pit features was 5.6 times higher than had been calculated for Chiricahua/San Pedro features, and the overall density of FAR in nonthermal features was only 8 percent of the overall density of FAR in nonthermal features calculated for Chiricahua/San Pedro features. This suggests that FAR may have been deposited substantially more often in house-in-pit features than in other features during the San Pedro phase, in comparison to the Chiricahua/San Pedro temporal component. However, the small number of pits and other nonstructural features attributed to the San Pedro component likely influenced this pattern.

In total, 23 ground stone artifacts were estimated to have been located within features assigned to the San Pedro temporal component. Ground stone artifacts were found in small numbers in five house-in-pit features, a nonthermal pit, and a midden. Ground stone artifacts were distributed at the highest densities in the same areas as was FAR but were also found in a midden in Grid Cell G5, where the largest number of ground stone artifacts was estimated to have been deposited during the San Pedro component (see Appendix 10.1, Interactive PDF, Layer 10.10). In all of these areas, from one to five ground stone artifacts were found in individual features containing ground stone. Seventy-four percent of ground stone artifacts were found in house-in-pit features, 17 percent in the midden, and 8 percent in nonthermal pits. The overall volumetric density of ground stone artifacts was quite low and was a little more than a tenth of the density calculated for Chiricahua/San Pedro features. No extramural artifacts were attributed to the San Pedro temporal component.

In total, 371 flaked stone artifacts were estimated to have been located within features assigned to the San Pedro temporal component. Flaked stone artifacts were found in 75 percent of primary features. The largest amounts of flaked stone were located in a house-in-pit (Feature 4302) in Grid Cell E2 and a nonthermal pit (Feature 4355) in Grid Cell D1 (see Appendix 10.1, Interactive PDF, Layer 10.11). Incidentally, these features were located in the same area where flaked stone artifacts were found at their greatest density for the Chiricahua/San Pedro temporal component. Because San Pedro features in the southern area of the sites were located in proximity to Chiricahua/San Pedro features and dated to Occupational Episode E as did nearby Chiricahua/San Pedro features, it seems plausible that flaked stone artifacts in Chiricahua/San Pedro and San Pedro features were derived from the same sets of activities. The next highest density of flaked stone was located in a midden more than 230 m to the west of Features 4302 and 4355, suggesting that activities involving the deposition of flaked stone artifacts were concentrated in the south-central portion of Falcon Landing during the San Pedro phase. For all feature types combined, the overall volumetric

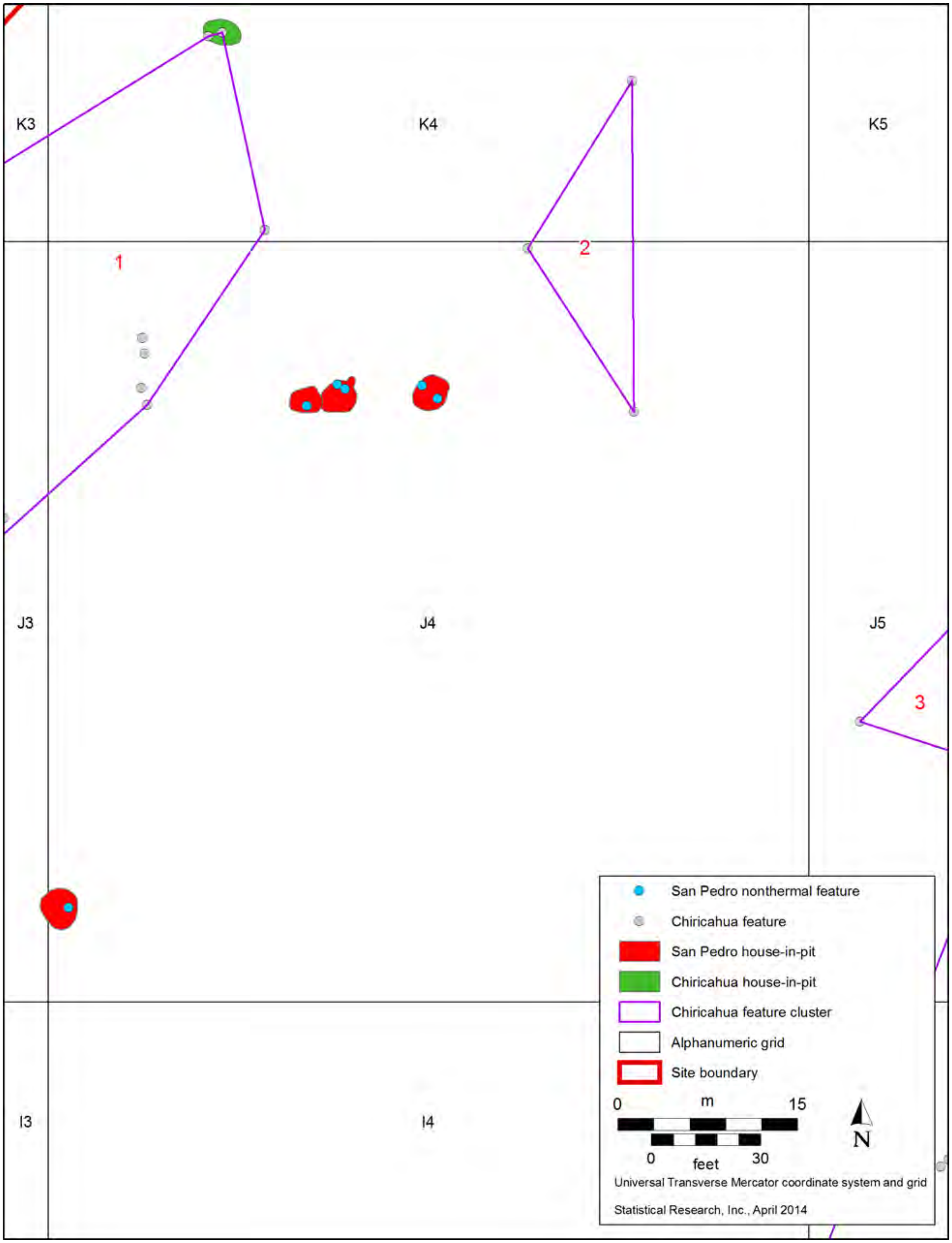


Figure 122. Clustered San Pedro house-in-pit features in Grid Cell J4.

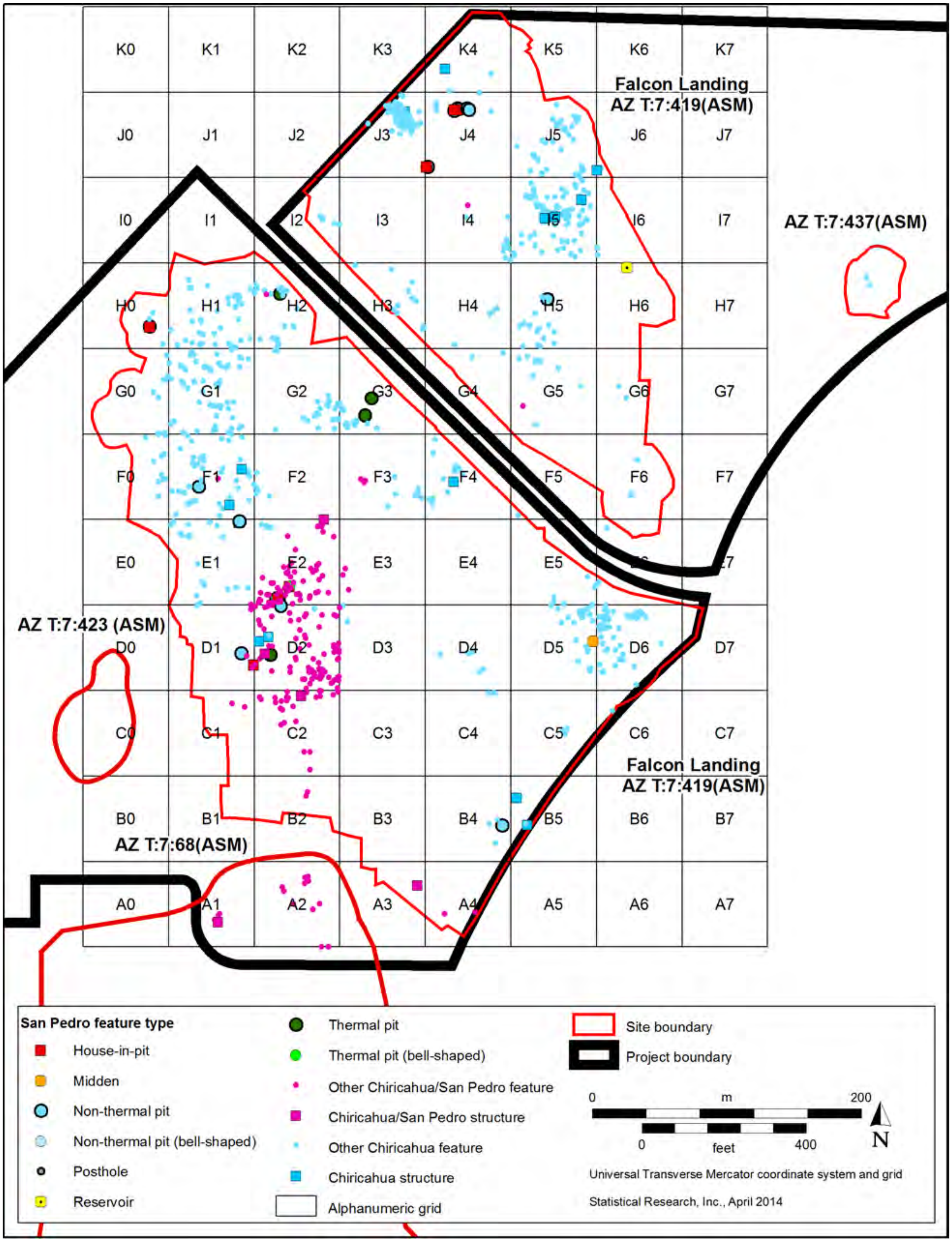


Figure 123. Comparison of San Pedro feature locations with Chiricahua and Chiricahua/San Pedro feature distributions.

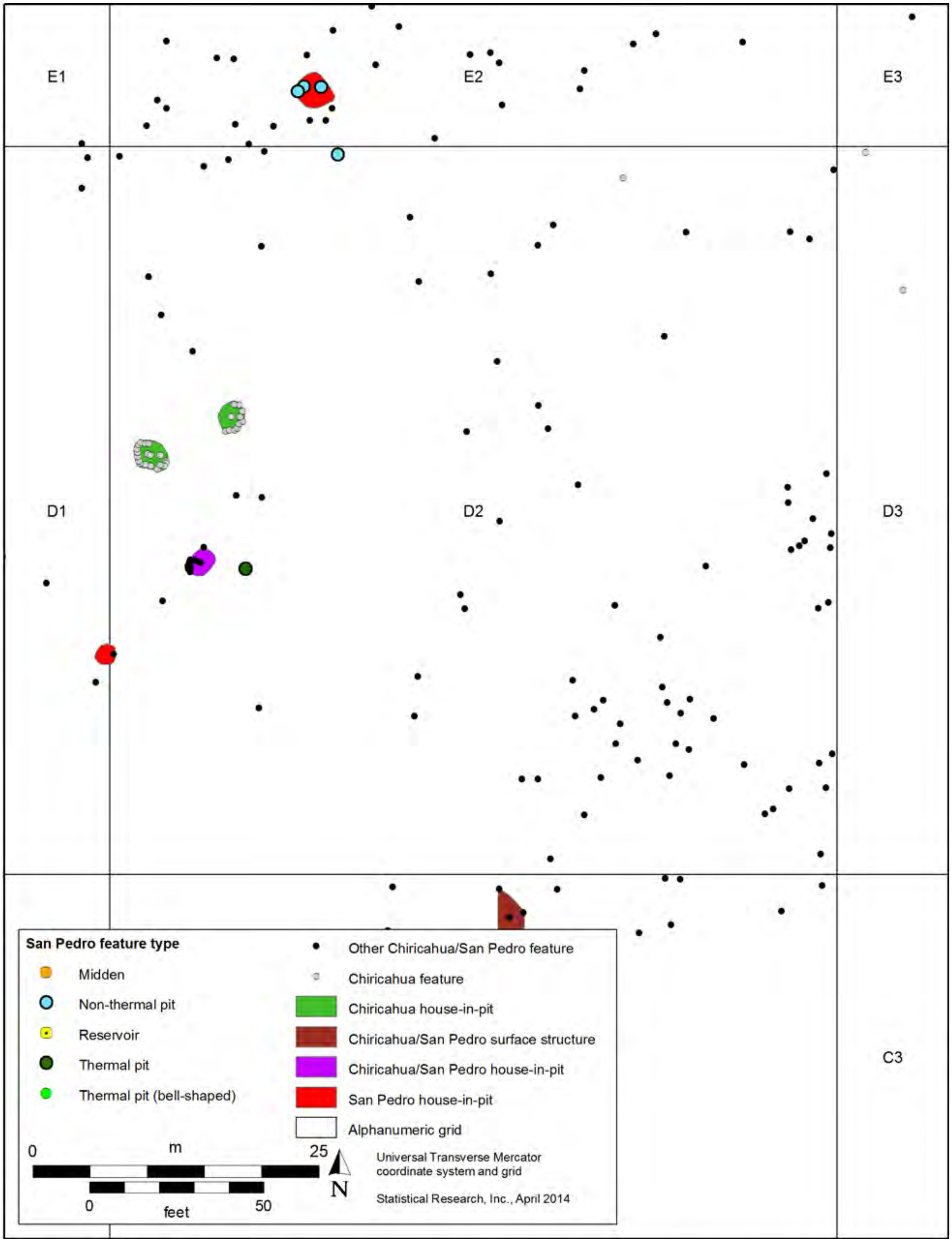


Figure 124. Comparison of San Pedro feature locations with Chiricahua and Chiricahua/San Pedro feature distributions in Grid Cells D2 and E2 and Neighboring Cells.

density for flaked stone was substantially lower for the San Pedro component than was calculated for the Chiricahua/San Pedro component. However, among feature types, overall volumetric density of flaked stone was much higher for house-in-pit features and nonthermal pits assigned to the San Pedro component, in comparison to the density of flaked stone in the same feature types for the Chiricahua/San Pedro component.

In total, 120 faunal specimens were estimated to have been located within features assigned to the San Pedro temporal component. Like flaked stone artifacts, faunal specimens were found in 75 percent of primary features assigned to the San Pedro component. Faunal specimens were found in seven house-in-pit features, the midden, four nonthermal pits, the reservoir, and two thermal pits. The highest density of faunal specimens from the San Pedro phase was found in Grid Cell E2, in the same area where faunal specimen density was also high for features assigned to the Chiricahua/San Pedro component (see Appendix 10.1, Interactive PDF, Layer 10.12). Faunal density was also relatively high in a house-in-pit (Feature 18192) in Grid Cell H0 and in a midden feature (Feature 3256) in Grid Cell D5. The highest volumetric density of faunal specimens was found in nonthermal pits, however, with lower densities found in house-in-pit features and the midden. Faunal specimen volumetric density was substantially higher in nonthermal pits and house-in-pit features for the San Pedro phase than was calculated for features of these types assigned to the Chiricahua/San Pedro component and was 2.5 times higher overall for all San Pedro features, in comparison to Chiricahua/San Pedro.

All primary features assigned to the San Pedro component were assigned to Occupational Episode E. As discussed above, this is the same episode to which were assigned 10 of the features assigned to the Chiricahua/San Pedro component, including a house-in-pit, 6 nonthermal pits, and 3 thermal pits. Nearly all of the Chiricahua/San Pedro features assigned to Occupational Episode E were within 50 m of a San Pedro feature, and many were within 20 m, suggesting that the features may have been part of the same component, or that this area of Falcon Landing was repeatedly reoccupied during portions of Chiricahua and San Pedro phases of the Archaic period.

San Pedro/Cienega (920–720 cal B.C.) and Cienega Phase (800 cal B.C.–cal A.D. 50) Spatial Distribution

Only six features, all of them nonthermal pits located in Grid Cell A4, were assigned to the San Pedro/Cienega (920–720 cal B.C.) temporal component. Moreover, only one of these was excavated, yielding five faunal specimens; the rest of the features were only examined. Thus, there is limited information regarding the San Pedro/Cienega temporal component.

The Cienega (800 cal B.C.–cal A.D. 50) temporal component, by comparison, was substantially larger. Extramural and primary features assigned to the Cienega temporal component consisted of 33 nonthermal pits, 4 nonthermal bell-shaped pits, 2 thermal pits, 2 charcoal/ash lenses, an activity area, a cache, a house-in-pit, and a surface structure (Table 100). Ripley's *K* estimates indicated that Cienega phase features clustered across the same range of scales as Chiricahua features, from 5 to 145 m. Clustering was most intense at 55 m. Changes in slope suggested multiple clustering regimes (5–30 m, 30–40 m, and 40–55 m), although the relatively small sample size might also suggest sample-size effects could have generated variation in slope. The greatest intensity of feature construction occurred in the vicinity of a large activity area (Feature 1239) in the southeastern corner of Grid Cell B4 and around a house-in-pit feature (Feature 1413) located 30 m to the southwest of Feature 1239 in Grid Cell A4.

Cienega features were located across the entire north-south extent of the site but were concentrated on the eastern half of the site (Figure 125). Clusters of features centered on Grid Cells B4, D6/D6, and H5, and isolated features were located in Grid Cells G6 (a nonthermal pit) and K5 (a surface structure). The largest cluster was located in the southern portion of the site, centering on Grid Cell B4, and it contained 77 percent of the features assigned to the Cienega temporal component. The vast majority of features in this cluster were nonthermal pits, but 3 nonthermal bell-shaped pits, 3 thermal pits, 2 charcoal/ash lenses, an activity area, a cache, and a house-in-pit feature were also located within this cluster. However, more than a third of nonthermal pits were only superficially examined, suggesting there could have been greater variation in pit types in this area than was documented. Interestingly, the 6 nonthermal pits assigned to the San Pedro/Cienega

Table 100. Percentage and Densities of Estimated Artifact and Faunal Specimen Counts, according to Artifact Class and Feature Type, for Features Assigned to the Cienega Temporal Component

Feature Type	Feature Count (Sampled or Excavated)	Total Estimated FAR Count (%)	FAR Density (Artifacts/m^3)	Total Estimated Ground Stone Artifact Count (%)	Ground Stone Density (Artifacts/m^3)	Total Flaked Stone Artifact Count (%)	Flaked Stone Artifact Density (Artifacts/m^3)	Total Estimated Faunal Specimen Count (%)	Faunal Specimen Density (Specimens/m^3)
Activity area	1	1.1	1.4	9.1	0.7	67.2	89.6	14.4	12.3
Cache	1		—	9.1	69.0		—		—
Charcoal/ash lens	2		—		—	0.6	116.7		—
House-in-pit	1		—		—	8.0	21.1	2.4	4.1
Nonthermal pit	33	92.6	141.5	36.4	3.5	15.7	26.8	20.1	22.0
Nonthermal pit (bell shaped)	4	4.6	27.4	18.2	6.8	4.9	32.7	57.6	247.1
Posthole	15		—		—		—		—
Surface structure	1	0.9	0.8	9.1	0.5	0.5	0.5	3.6	2.5
Thermal pit	2	0.9	5.7	18.2	7.6	3.1	22.9	2.0	9.5
Total	60	100.0	30.1	100.0	1.9	100.0	33.6	100.0	21.6

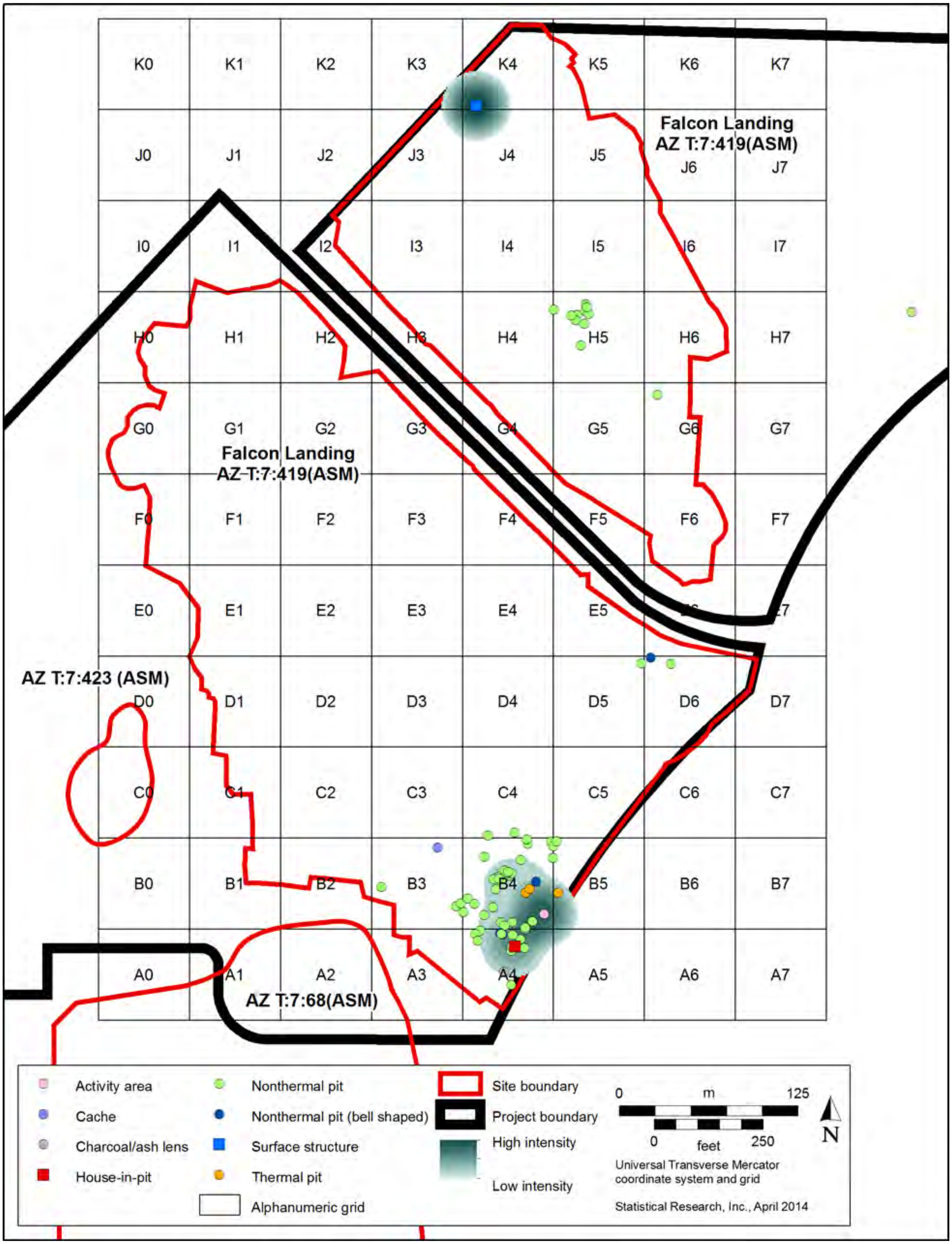


Figure 125. Spatial distribution of features assigned to the Cienega temporal component.

temporal component were found at the southern edge of this cluster and appear to have been part of the same cluster of features. The cluster centering on Grid Cell D6/D6 contained 2 nonthermal pits and a nonthermal bell-shaped pit. The cluster of features centering on Grid Cell H5 consisted of 10 nonthermal pit features, 9 of which were only superficially examined; the tenth was sampled.

In total, 349 pieces of FAR were estimated to have been located in sampled or excavated features assigned to the Cienega component (see Table 100). FAR was found in one-third of primary features that were sampled or excavated. FAR was found in 12 nonthermal pits, 2 thermal pits, a nonthermal bell-shaped pit, an activity area, and a surface structure. FAR was found in features in most areas of the site where Cienega component features were located, with the exception of the features in Grid Cell H5, where only 1 of 9 pit features was sampled, and the remainder only superficially examined (see Appendix 10.1, Interactive PDF, Layer 10.13). Features with FAR were most common in Grid Cells A4 and B4. Ninety-three percent of FAR artifacts were located in nonthermal pits, 5 percent were located in a nonthermal bell-shaped pit, with the remainder found in an activity area, a surface structure, and in thermal pits. Overall volumetric density for FAR was, by far, highest for nonthermal pits and was much higher for Cienega phase nonthermal pits than was calculated for San Pedro phase nonthermal pits. Given the very low number of thermal pits identified for the Cienega component and the relatively large number of pits that were only superficially examined, it is not possible to come to any conclusions regarding the distribution of FAR in thermal vs. nonthermal pits.

In total, 22 ground stone artifacts were estimated to have been located in sampled or excavated features assigned to the Cienega component. Ground stone artifacts were found in eight features dated to the Cienega phase: an activity area, a cache, three nonthermal pits, a nonthermal bell-shaped pit, a surface structure, and a thermal pit. Features with ground stone contained from 1 to 4 ground stone artifacts; the largest numbers of ground stone artifacts were found in a nonthermal pit, a nonthermal bell-shaped pit, and a thermal pit. Ground stone artifacts were found in features spread broadly across the site, but the highest kernel density was in the southeastern corner of Grid Cell B4 where an activity area, nonthermal pit, and thermal pit containing ground stone artifacts were located (see Appendix 10.1, Interactive PDF, Layer 10.14). Overall volumetric density of ground stone artifacts was highest in a cache at a density very similar to that calculated for caches attributed to the Chiricahua/San Pedro temporal component. Overall volumetric density in features of other types was substantially lower.

In all, 39 extramural artifacts were assigned to the Cienega temporal component; none was assigned to the San Pedro/Cienega temporal component. Extramural artifacts assigned to the Cienega temporal component consisted of 1 piece of FAR, 13 manos, 1 manuport, 12 metates, 1 mortar, 5 netherstones, and 6 pestles. The vast majority of extramural artifacts were located in the southern portion of Falcon Landing in Grid Cells A4, B4, and C4, and they were particularly clustered in proximity to a house-in-pit and an activity area. A mano and a metate were also found in Grid Cell H5, where they were in close proximity to a cluster of nonthermal pits in the same grid cell (most of which were only superficially examined). Extramural artifacts were clustered (NNI = 0.4), located, on average, 5 m from the nearest extramural artifact. Extramural artifacts also tended to be located within a few meters of the nearest pit feature, particularly nonthermal pit features. One or more manos tended to be located within several meters of a metate, suggesting a possible association between manos and nearby metates. Pestles also clustered near manos in a few cases, and there appears to have been possible patterning in the spacing of metates, as several metates were spaced approximately 14–22 m apart from each other.

In total, 309 flaked stone artifacts were estimated to have been located in sampled or excavated features assigned to the Cienega component. Flaked stone artifacts were found in an activity area, a charcoal/ash lens, a house-in-pit, 14 nonthermal pits, 3 nonthermal bell-shaped pits, a surface structure, and a thermal pit. Kernel density estimates indicated that flaked stone artifacts were concentrated in Grid Cells B4 and B5, where all but two of the features containing flaked stone artifacts were located (see Appendix 10.1, Interactive PDF, Layer 10.15). It appears that much activity involving the use of flaked stone during the Cienega temporal component occurred in a relatively discrete area of the site that included a house-in-pit (Feature 1413) in Grid Cell A4 and an activity area (Feature 1239) in Grid Cell B4. By far, the largest number of flaked stone artifacts was found in the activity area, which contained an estimated 262 flaked stone artifacts, suggesting that flaked stone may have been preferentially worked in and around this area, and the resulting debris washed into nearby features. The highest overall volumetric density was found in the charcoal/ash lens (located adjacent to the house-in-pit), and the second highest volumetric density was found in the activity area. Overall volumetric density of flaked stone artifacts was lower and similar among the house-in-pit, nonthermal pits, nonthermal bell-shaped pits, and thermal pits. Perhaps, activities involving flaked stone were most intensive in the activity area and in the area adjacent to the house-in-pit.

In total, 251 faunal specimens were estimated to have been located in sampled or excavated features assigned to the Cienega component. Faunal specimens were found in an activity area, a house-in-pit, 11 nonthermal pits, 3 nonthermal bell-shaped pits, a surface structure, and 2 thermal pits (see Appendix 10.1, Interactive PDF, Layer 10.16). The largest number of faunal specimens was found in a nonthermal bell-shaped pit (Feature 1361), followed by the activity area, which was located 33 m from the nonthermal bell-shaped pit. The house-in-pit was also nearby, located 14 m away from this nonthermal bell-shaped pit. Kernel density estimates suggested that faunal specimens were concentrated most around Feature 1361 in Grid Cell A4. By far, the highest overall volumetric density of faunal specimens was calculated for nonthermal bell-shaped pits due to the large number found in Feature 1361.

Cienega/Red Mountain (160 cal B.C.–cal A.D. 340) and Red Mountain Phase (A.D. 50–400) Spatial Distribution

Cienega/Red Mountain phase features consisted of an activity area, 4 charcoal/ash lenses, 10 FAR concentrations, 4 house-in-pit feature, 67 nonthermal pits, 1 nonthermal bell-shaped pit, 3 postholes not associated with a primary feature, and 17 thermal pits (Table 101). Red Mountain phase features were far less numerous, consisting of a charcoal/ash lens and 2 house-in-pit features. Ripley's *K* estimates suggest that Cienega/Red Mountain phase features clustered most intensely at a scale of approximately 50 m.

Cienega/Red Mountain and Red Mountain phase features were clustered in two areas: an area centering on Grid Cell D1 and an area centering on Grid Cell H5 (Figure 126). The area centering on Grid Cell D1 contained a minority of features assigned to the Cienega/Red Mountain or Red Mountain component: 2 FAR concentrations, 10 nonthermal pits, and 2 thermal pits. One of the Red Mountain house-in-pit features (Feature 3963) was located to the east of this cluster in Grid Cell D2. An isolated Cienega/Red Mountain nonthermal pit was also located to the southwest of the cluster in Grid Cell C0. The area centering on Grid Cell H5 contained the majority of Cienega/Red Mountain and Red Mountain phase features. From center to center, these two clusters of Cienega/Red Mountain and Red Mountain phase features were separated by approximately 350 m. Not surprisingly, kernel density estimates showed that the highest intensity of feature construction during Cienega/Red Mountain and Red Mountain times centered on Grid Cell H5 and were most focused in an area where house-in-pit features, an activity area, and numerous pits were located. Four Cienega/Red Mountain house-in-pit features in this area were tightly clustered and partially overlapping, along with an activity area, and multiple thermal and nonthermal pits. This tight cluster of features, which spanned the small distances of 11–15 m, suggests highly redundant use of one small area of Falcon Landing during the Cienega/Red Mountain or Red Mountain phases, which could suggest the establishment of land tenure at Falcon Landing by this time (Figure 127).

In total, 1,283 pieces of FAR were estimated to have been located in sampled or excavated features assigned to the Cienega/Red Mountain component (see Table 101). FAR was found in a total of 47 Cienega/Red Mountain phase features (an activity area, a charcoal/ash lens, 6 FAR concentrations, 5 house-in-pit features, 24 nonthermal pits, and 10 thermal pits) and 2 Red Mountain house-in-pit features. The vast majority of features with FAR, as well as most FAR artifacts, were discovered in Grid Cells I5, H4, and H5 (see Appendix 10.1, Interactive PDF, Layer 10.17). The highest density of FAR was found in thermal pits, followed by nonthermal pits. Two Red Mountain phase features contained FAR: a house-in-pit in Grid Cell D2 (Feature 3963), which contained a single FAR artifact, and a house-in-pit feature (Feature 10849) in Grid Cell H4, which contained 49 FAR artifacts. Thermal features were interspersed with features of other types containing FAR, suggesting that FAR could have originally been deposited in thermal features before it was incorporated in the fill of other nearby features. To test if FAR was located significantly more often

Table 101. Percentage and Densities of Estimated Artifact and Faunal Specimen Counts, according to Artifact Class and Feature Type, for Features Assigned to the Cienega/Red Mountain Temporal Component

Feature Type	Feature Count (Sampled or Excavated)	Total Estimated FAR Count (%)	FAR Density (Artifacts/m³)	Total Estimated Ground Stone Artifact Count (%)	Ground Stone Density (Artifacts/m³)	Total Flaked Stone Artifact Count (%)	Flaked Stone Artifact Density (Artifacts/m³)	Total Estimated Faunal Specimen Count (%)	Faunal Specimen Density (Specimens/m³)
Activity area	1	2.1	66.2	1.6	2.5	1.4	17.2	2.8	17.2
Charcoal/ash lens	4	1.1	3.0		—	2.8	3.0	3.2	1.7
FAR concentration	10	4.7	45.9	9.7	4.5	3.0	11.3	1.6	3.0
House-in-pit	4	16.9	95.3	22.9	6.1	14.3	31.2	19.9	21.9
Nonthermal pit	67	37.3	148.8	13.5	2.6	44.8	69.2	43.2	33.7
Nonthermal pit (bell shaped)	1		—		—		—		—
Posthole	19		—		—		—		—
Thermal pit	17	37.9	243.5	52.3	16.0	33.7	83.7	29.3	36.8
Total	123	100.0	87.2	100.0	4.2	100.0	33.7	100.0	17.1

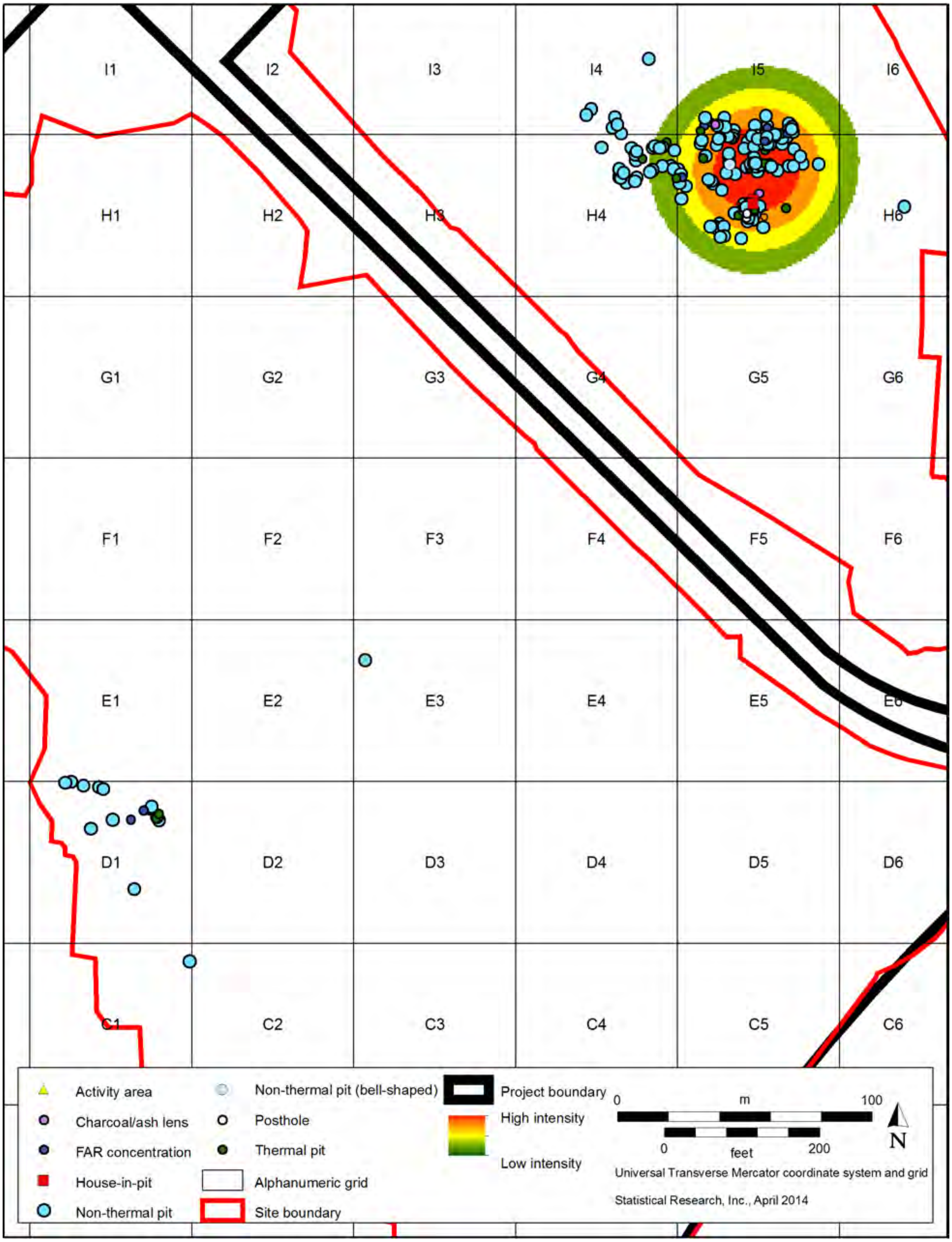


Figure 126. Spatial distribution of features assigned to the Cienega/Red Mountain temporal component.

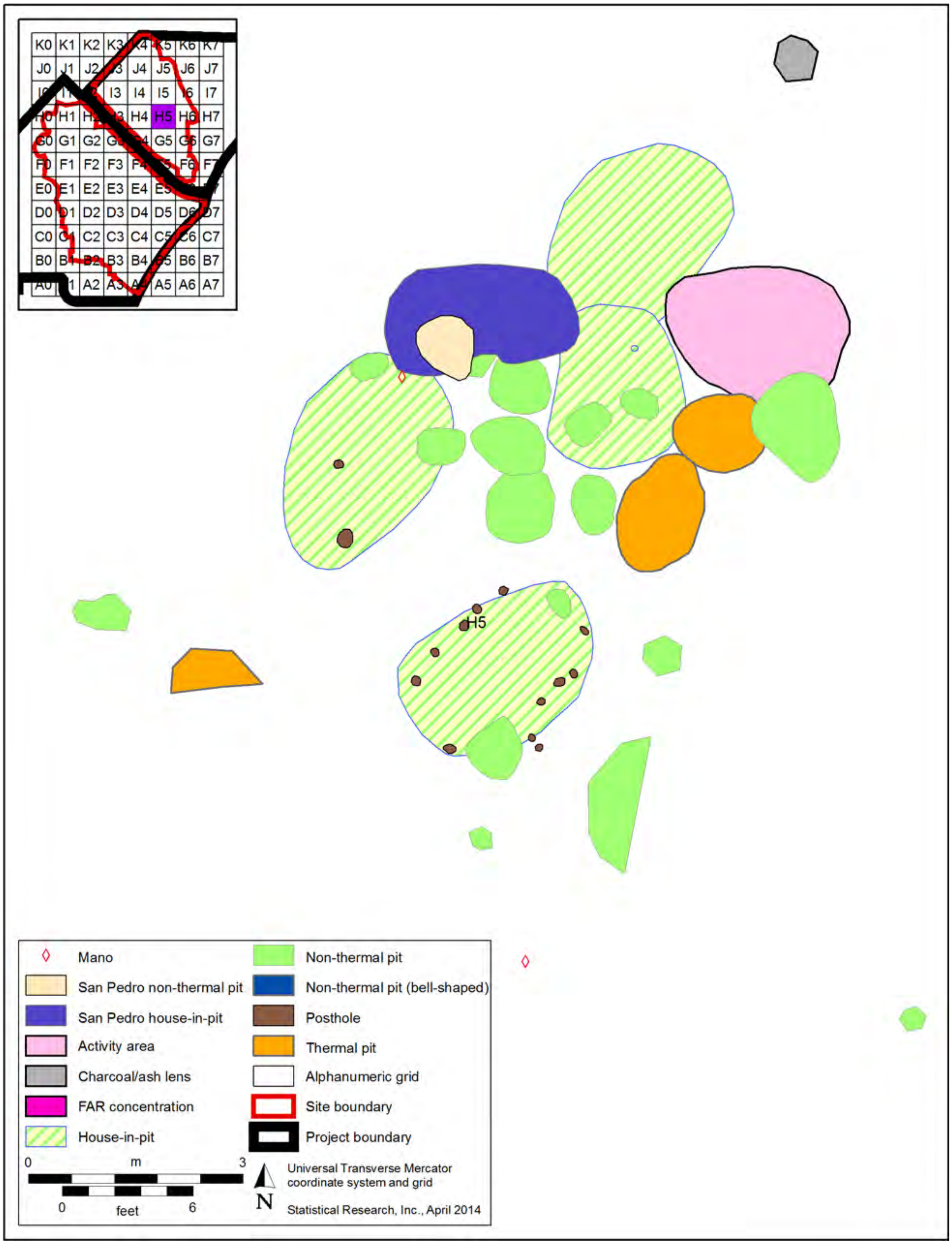


Figure 127. Spatial distribution of Cienega/Red Mountain features in Grid Cell H5, showing cluster of closely situated San Pedro and Cienega/Red Mountain house-in-pit features suggestive of serial re-occupation.

in thermal pits, in comparison to nonthermal pits, we performed a chi-square test comparing numbers of thermal pits and nonthermal pits with and without FAR, restricting the test to only those features that had been sampled or excavated. The results indicated that FAR was found in thermal pits significantly more often than expected ($\chi^2 = 3.9791$, $p = .046$). Cramer's V (0.2177) suggested a weak-to-moderate association between pit type and FAR presence.

In total, 61 ground stone artifacts were estimated to have been located in sampled or excavated features assigned to the Cienega/Red Mountain component. Ground stone artifacts associated with Cienega/Red Mountain use of the site were found in an activity area, two FAR concentrations, three house-in-pit features, four nonthermal pits, and six thermal features. Ground stone artifacts were concentrated primarily within features in Grid Cells H5 and I5, where they were found primarily in house-in-pit features and in a cluster of pit features and FAR concentrations located immediately to the north of the house-in-pit features (Figure 128; see also Appendix 10.1, Interactive PDF, Layer 10.18). Ground stone artifacts were also found in a nonthermal pit in Grid Cell D1. Ground stone artifacts were found in the same two Red Mountain phase house-in-pit features in which FAR artifacts were found. Fifty-two percent of the ground stone artifacts were found in thermal pits, 22 percent in house-in-pit features, 13 percent in nonthermal pits, and 10 percent in FAR concentrations, with the remainder located in features of other types. The highest overall volumetric density of ground stone artifacts was found in thermal pits, followed by house-in-pit features, and FAR concentrations. The distribution of ground stone artifacts suggests that they may have been frequently stored in and around house-in-pit features and may have frequently been deposited in thermal features, perhaps in order to use spent items as thermal mass. This makes sense because large numbers of previously used ground stone artifacts would have been available for reuse as thermal mass by this time. A chi-square test comparing the number of thermal pit features and primary features of all other types, in terms of whether they contained or did not contain ground stone artifacts, indicated that ground stone artifacts were found significantly more often in thermal pits, in comparison to features of other types (Yates $\chi^2 = 4.9$, $df = 1$, $p = .0269$; Fisher's exact two-tailed $p = .019$; Cramer's $V = 0.2574$). Cramer's V suggests a moderate association between thermal pits and the presence of ground stone artifacts, which may be an indication of their reuse as thermal mass.

Extramural artifacts associated with Cienega/Red Mountain use of the site consisted of 13 manos, 15 metates, 1 mortar, 2 netherstones, and 7 pestles. No extramural artifacts were associated with the Red Mountain temporal component. Despite the fact that most features associated with the Cienega/Red Mountain use of Falcon Landing were located in the northeastern quadrant of the site, in an area centering on Grid Cell H5, more than half of the extramural artifacts were located in the southwestern quadrant of the site in Grid Cells C1, D1, and E1. The NNI statistic indicated that extramural artifacts were clustered (NNI = 0.519). In the northern portion of Grid Cell D1, extramural artifacts, consisting mostly of manos or metates, were located within 5 m of the nearest pit feature. South of this area, extramural artifacts were not located in proximity to any Cienega/Red Mountain phase features and consisted mostly of metates or pestles. In the northeastern quadrant of Falcon Landing, most extramural artifacts were located within a few meters of the nearest feature and were typically closest to nonthermal pits.

In total, 496 flaked stone artifacts were estimated to have been located in sampled or excavated features assigned to the Cienega/Red Mountain component. Flaked stone artifacts found in Cienega/Red Mountain phase features were found in approximately half of sampled or excavated features, including an activity area, 3 charcoal/ash lenses, 3 FAR concentrations, 5 house-in-pit features, 25 nonthermal pits, and 13 thermal pits. Flaked stone artifacts were also found in 2 Red Mountain phase house-in-pit features and in a Red Mountain charcoal/ash lens located in Grid Cell H5 (see Appendix 10.1, Interactive PDF, Layer 10.19). Flaked stone artifacts were most common within features in Grid Cells H4, H5, and I5. The highest overall volumetric density of flaked stone artifacts was found in thermal pits, followed by nonthermal pits and house-in-pit features. A chi-square test comparing the number of thermal pits with primary features of all other types, according to whether they did or did not contain flaked stone artifacts, indicated that flaked stone artifacts were located in thermal pits far more often than expected, in comparison to other features (Pearson $\chi^2 = 7.66$, $p = .005646$; Yates $\chi^2 = 6.23$, $df = 1$, $p = .01256$; Fisher's exact two-tailed $p = .006538$; Cramer's $V = 0.2754$). Cramer's V suggests a moderate association between thermal pits and the presence of flaked stone artifacts. Perhaps, flaked stone artifacts were frequently worked or used adjacent to thermal features,

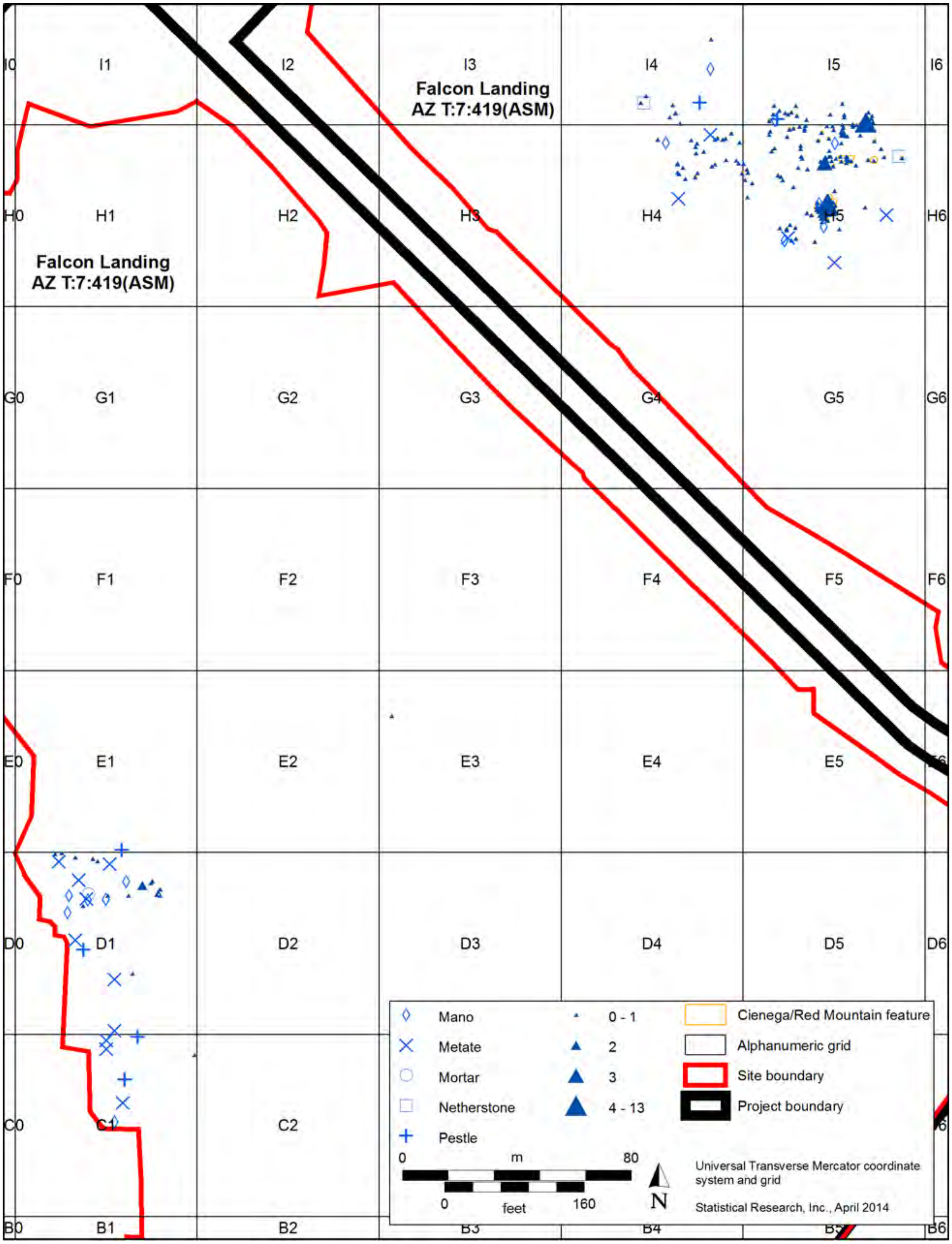


Figure 128. Spatial distribution of ground stone and features in Grid Cell H5 and neighboring cells.

resulting in debitage eventually washing into the features, or waste materials were intentionally deposited into open pits during clean-up activities. Since chert was rarely used at the site for flaked stone reduction, it is unlikely that the distribution of flaked stone artifacts in thermal pits reflects heat-treatment efforts.

In total, 251 faunal specimens were estimated to have been located in sampled or excavated features assigned to the Cienega/Red Mountain component. Faunal specimens found in Cienega/Red Mountain phase features were found in an activity area, a charcoal/ash lens, 2 FAR concentrations, 5 house-in-pit features, 13 nonthermal pits, and 7 thermal pits (see Appendix 10.1, Interactive PDF, Layer 10.20). Faunal specimens were also found in the same 3 Red Mountain phase features in which flaked stone artifacts were found. Faunal specimens were most common in the same areas of Falcon Landing where flaked stone artifacts were found and were found in more than 75 percent of features that contained flaked stone artifacts, suggesting a possible association between deposition of flaked stone and faunal specimens. The highest overall volumetric density of faunal specimens was calculated for thermal pits, although the density in nonthermal pits was similar and only slightly lower. A chi-square test comparing the number of thermal pits with the number of primary features of all other types, according to whether they did or did not contain faunal specimens, indicated that faunal specimens were not located in thermal pits more often than expected, in comparison to other features (Pearson $\chi^2 = 2.1$, $p = 0.1473$; Yates $\chi^2 = 1.32$, $df = 1$, $p = .2506$; Fisher's exact two-tailed $p = 0.226105$; Cramer's $V = 0.1442$).

Six ceramic artifacts were found in a house-in-pit feature (Feature 3963) that was assigned to the Red Mountain phase and was located in Grid Cell D2. Ceramic artifacts were not found in any other Cienega/Red Mountain or Red Mountain phase features.

Pre-Classic Period (A.D. 400–1150) Spatial Distribution

Features assigned to the pre-Classic temporal component included a cache, three house-in-pit features, and five nonthermal pits affiliated with the Snaketown phase (A.D. 650–750); a nonthermal pit affiliated with the Pioneer period (A.D. 400–750); two nonthermal pits affiliated with the Early Ceramic to Pioneer periods (ca. A.D. 340–610); and two thermal pits and two nonthermal pits affiliated with the Sacaton phase (A.D. 950–1150). Three additional nonthermal pits were only superficially examined; the remaining features were sampled, partially excavated, or completely excavated.

Features assigned to the pre-Classic temporal component were widely dispersed across the project area (Figure 129). Sample size was too small to calculate Ripley's *K*, but the broad distribution of a limited number of features suggests that pre-Classic features were dispersed and might represent relatively infrequent use of the sites during the pre-Classic period, with the greatest intensity of use occurring during the Snaketown phase. The Snaketown phase features were all located in the southern half of Falcon Landing, as well as at Site 68, in Grid Cells A1, A2, A4, B4, and D6; the Pioneer period feature was located farther to the north in Grid Cell F5. All of the house-in-pit features were affiliated with the Snaketown phase. The Snaketown phase features and the Pioneer period feature were assigned to Occupational Episode H (cal A.D. 610–780). The Sacaton phase features were widely dispersed in the eastern half of Falcon Landing and were assigned to Occupational Episode I (cal A.D. 980–1270). Kernel density estimates suggested that the greatest intensity of feature construction occurred in Grid Cell D6, where a house-in-pit feature and a cache, both affiliated with the Snaketown phase, were located.

Only one feature assigned to the pre-Classic temporal component contained FAR (Table 102). The feature was a partially excavated nonthermal pit located in Grid Cell F5 that contained an estimated total of 14 FAR and was affiliated with the Pioneer period.

Only one feature assigned to the pre-Classic temporal component contained ground stone artifacts. The feature was a partially excavated cache located in Grid Cell D6 that contained an estimated total of four ground stone artifacts and was affiliated with the Snaketown phase. Three extramural artifacts were assigned to the pre-Classic component: a mano and two metates.

In total, 103 flaked stone artifacts were estimated to have been located in sampled or excavated features assigned to the pre-Classic temporal component. Flaked stone artifacts were found in a cache, two house-in-pit

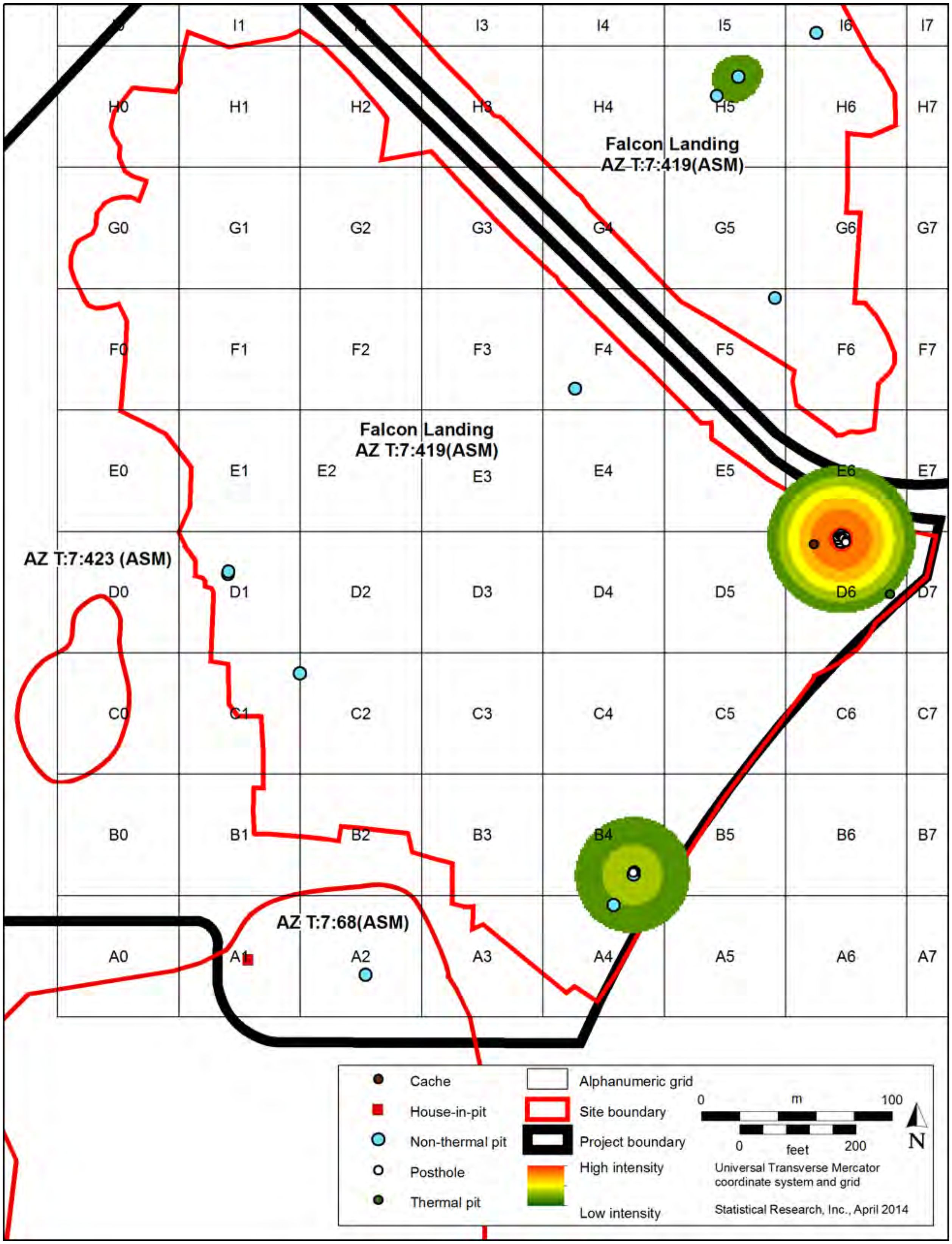


Figure 129. Spatial distribution of features assigned to the pre-Classic temporal component.

Table 102. Percentage and Densities of Estimated Artifact and Faunal Specimen Counts, according to Artifact Class and Feature Type, for Features Assigned to the Pre-Classic Temporal Component

Feature Type	Feature Count (Sampled or Excavated)	Total Estimated FAR Count (%)	FAR Density (Artifacts/m^3)	Total Estimated Ground Stone Artifact Count (%)	Ground Stone Density (Artifacts/m^3)	Total Flaked Stone Artifact Count (%)	Flaked Stone Artifact Density (Artifacts/m^3)	Total Estimated Faunal Specimen Count (%)	Faunal Specimen Density (Specimens/m^3)
Cache	1		—	100.0	47.6	1.9	23.8		—
House-in-pit	3		—		—	93.2	20.5	76.6	7.7
Nonthermal pit	10	100.0	21.7		—	3.9	6.2	21.3	15.3
Posthole	23		—		—		—		—
Thermal pit	2		—		—	1.0	24.4	2.1	24.4
Total	39	100.0	2.6	100.0	0.7	100.0	18.6	100.0	8.5

features, two nonthermal pits, and a thermal pit. Four of these features were assigned to the Snaketown phase, and two were assigned to the Sacaton phase. The largest estimated number of flaked stone artifacts was calculated for a house-in-pit feature (Feature 1290) that was affiliated with the Snaketown phase and was located in Grid Cell B4. The highest kernel density of flaked stone artifacts was located in Grid Cell B4 (see Appendix 10.1, Interactive PDF, Layer 10.21). Almost all of the flaked stone artifacts were found in house-in-pit features. The highest overall volumetric density of flaked stone artifacts was found in thermal pits, however; the cache and house-in-pit features had a slightly lower density of flaked stone artifacts.

In total, 47 faunal specimens were estimated to have been located in sampled or excavated features assigned to the pre-Classic temporal component. Faunal specimens were discovered in the house-in-pit features, two nonthermal pits, and a thermal pit. Four of the features with faunal specimens were affiliated with the Snaketown phase (including the three house-in-pit features), one with the Pioneer period and one with the Sacaton phase. The largest number of faunal specimens was found in a house-in-pit feature (Feature 1290) that was affiliated with the Snaketown phase and was located in Grid Cell B4, the same feature where the largest number of flaked stone artifacts was discovered. As with flaked stone artifacts, the highest kernel density of faunal specimens was located in Grid Cell B4 (see Appendix 10.1, Interactive PDF, Layer 10.22). The great majority of the estimated total of faunal specimens were located in house-in-pit features and most of the remainder in nonthermal pits. The highest density of faunal specimens was found in thermal pits, followed by nonthermal pits, and house-in-pit features.

Only two ceramic artifacts were found in features assigned to the pre-Classic temporal component. One was found in a nonthermal pit (Feature 19067) assigned to the Pioneer period and located in Grid Cell F5; the other was found in a thermal pit affiliated with the Sacaton phase (Feature 4626) and was located in Grid Cell K4.

Classic (A.D. 1150–1450) and Classic/Protohistoric Periods (cal A.D. 1220–1640)

Only two features were assigned to the Classic component: a thermal pit in Grid Cell F4 and a nonthermal pit in Grid Cell B4. Features assigned to the Classic/Protohistoric component consisted of 2 FAR concentrations, 24 nonthermal pits, and 2 thermal pits. Less than half of these features were sampled, partially excavated, or completely excavated. Kernel density estimates indicated that the highest intensity of feature construction was located in Grid Cell K4 and a relatively high intensity of feature construction was also located in Grid Cells G2, G3, and J3 (Figure 130). Most activities involving features were confined to the northern half of Falcon Landing.

In total, 154 pieces of FAR were estimated to have been located in sampled or excavated features assigned to the Classic/Protohistoric temporal component (Table 103). FAR was found in 2 FAR concentrations, 5 nonthermal pits, and a thermal pit assigned to the Classic/Protohistoric component; FAR was not found in either of the 2 features assigned to the Classic temporal component. The largest amounts of FAR were estimated to have occurred in a partially excavated thermal pit (Feature 18279) located in Grid Cell G2 and a partially excavated nonthermal pit (Feature 4591) located in Grid Cell J4. Substantially fewer FAR artifacts were located in other features with FAR artifacts. The kernel density of FAR was also highest in the area surrounding Features 18729 and 4591 (see Appendix 10.1, Interactive PDF, Layer 10.23). Almost half of FAR was located in thermal pits; most of the remainder was in nonthermal pits. The overall volumetric density of FAR was highest in thermal pits and was lower and similar in nonthermal pits and FAR concentrations. The sample size was too small for a chi-square test structured in the same way as the chi-square tests performed for earlier temporal components; that is, testing if FAR was preferentially located in thermal features, in comparison to features of other types. However, the distribution of FAR, in terms of feature types, was consistent with previous temporal components insofar as a relatively large amount of FAR was located in comparatively few thermal features. Although only 2 thermal features were sampled or excavated and 11 nonthermal features were sampled or excavated for the Classic/Protohistoric temporal component, more FAR was located in thermal features than was located in nonthermal features. A chi-square test comparing the number of thermal and nonthermal pits that were sampled or excavated with the number

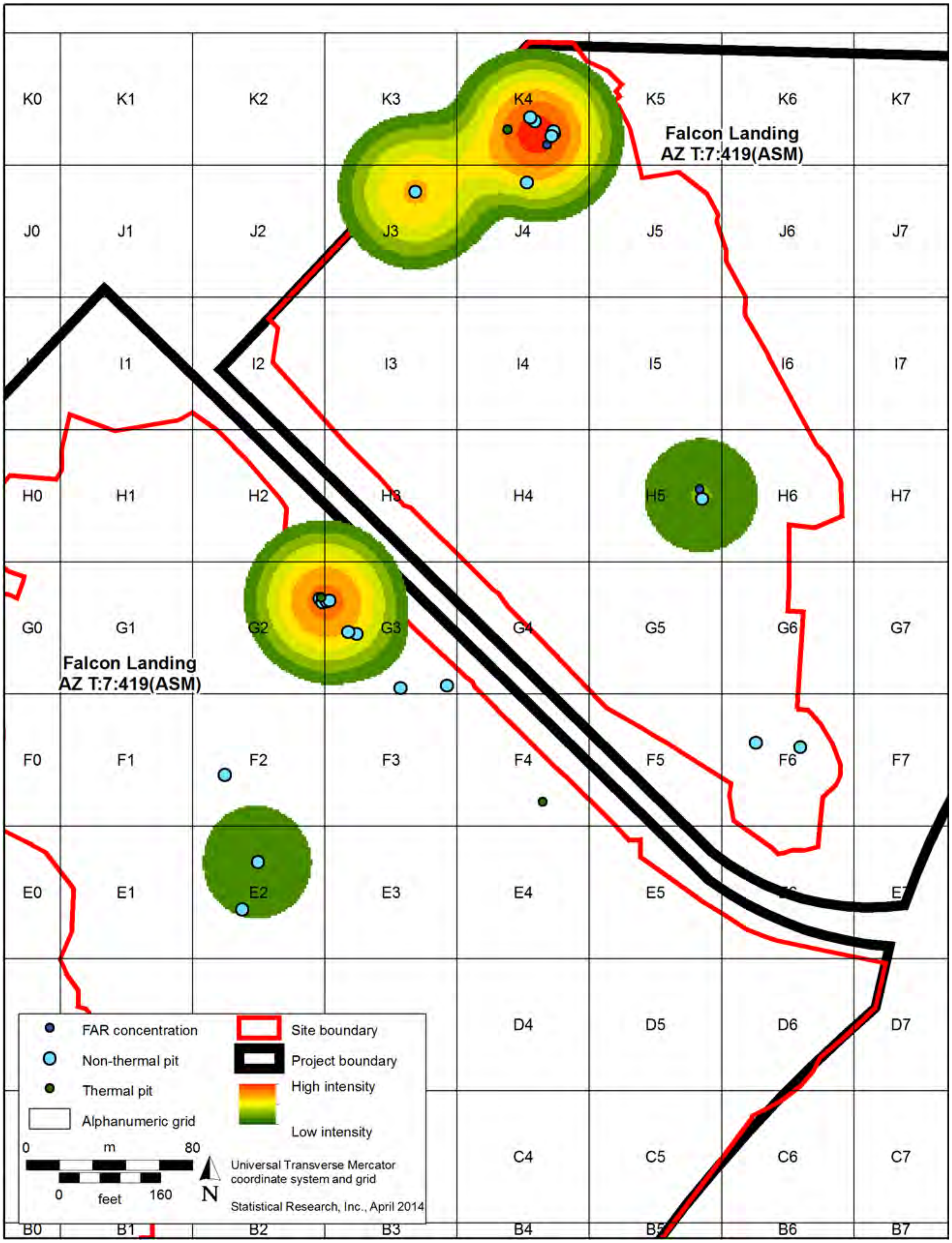


Figure 130. Spatial distribution of features assigned to the Classic and Classic/Protohistoric temporal component.

Table 103. Percentage and Densities of Estimated Artifact and Faunal Specimen Counts, according to Artifact Class and Feature Type, for Features Assigned to the Classic and Classic/Protohistoric Temporal Components

Feature Type	Feature Count (Sampled or Excavated)	Total Estimated FAR Count (%)	FAR Density (Artifacts/m³)	Total Estimated Ground Stone Artifact Count (%)	Ground Stone Density (Artifacts/m³)	Total Flaked Stone Artifact Count (%)	Flaked Stone Artifact Density (Artifacts/m³)	Total Estimated Faunal Specimen Count (%)	Faunal Specimen Density (Specimens/m³)
FAR concentration	2	10.3	97.5	10.3	18.4	29.3	61.3	17.9	30.7
Nonthermal pit	10	42.4	108.0	82.7	39.7	23.4	13.2	71.4	33.1
Thermal pit	1	47.3	422.6	7.0	11.7	47.3	93.9	10.7	17.4
Total	15	100.0	163.8	100.0	30.9	100.0	36.4	100.0	29.8

of FAR estimated to have been located in thermal or nonthermal pits suggested that significantly more FAR was found in thermal features, in comparison to nonthermal features (Yates $\chi^2 = 5.27$, $df = 1$, $p = 0.0217$; Cramer's $V = 0.2105$). Cramer's V suggests a weak-to-moderate association between thermal pits and FAR.

In total, 29 ground stone artifacts were estimated to have been located in sampled or excavated features assigned to the Classic/Protohistoric temporal component. Ground stone artifacts were found in an FAR concentration, four nonthermal pits, and a thermal pit. The largest number of ground stone artifacts was located in a nonthermal pit (Feature 4591) located in Grid Cell J4. Kernel density estimates indicated that ground stone artifacts were most common in features in Grid Cells J4 and K4, but also occurred at lower frequencies in Grid Cells E2, G2, and G3 (see Appendix 10.1, Interactive PDF, Layer 10.24). The great majority of ground stone artifacts were located in nonthermal pits; the overall volumetric density of ground stone was also highest in nonthermal pits. Only one extramural artifact, a cobble mano made on quartzite, was assigned to the Classic/Protohistoric temporal component, and no extramural artifacts were assigned to the Classic temporal component.

In total, 34 flaked stone artifacts were estimated to have been located in sampled or excavated features assigned to the Classic/Protohistoric temporal component. Flaked stone artifacts were found in an FAR concentration, three nonthermal pits, and a thermal pit. The largest number of ground stone artifacts were located in a nonthermal pit (Feature 4591) located in Grid Cell J4, the same nonthermal pit in which the largest number of FAR and ground stone artifacts were located. Kernel density estimates indicated that flaked stone artifacts were most common in features in Grid Cells G2, G3, J4, and K4 (see Appendix 10.1, Interactive PDF, Layer 10.25). Almost half of the flaked stone artifacts were found in thermal pits; the remainder were split between FAR concentrations and nonthermal pits. The overall volumetric density of flaked stone artifacts was highest in thermal pits and lowest in nonthermal pits.

In total, 28 faunal specimens were estimated to have been located in sampled or excavated features assigned to the Classic/Protohistoric temporal component. Faunal specimens were found in an FAR concentration, five nonthermal pits, and a thermal pit. The largest number of faunal specimens was estimated to have been in a nonthermal pit in Grid Cell E2 (Feature 4624), but overall, the number of faunal specimens in features assigned to the Classic or Classic/Protohistoric temporal components was low, ranging from 2 to 6 faunal specimens. Kernel density estimates indicated that faunal specimens were most common in features in Grid Cells J4 and K4 and, to a lesser degree, in Grid Cell E2 (see Appendix 10.1, Interactive PDF, Layer 10.26). The great majority of faunal specimens were found in nonthermal pits; the remainder were split between FAR concentrations and thermal pits. The overall volumetric density of faunal specimens was similar and highest in FAR concentrations and nonthermal pits and was lowest in thermal pits.

Despite common use of ceramic vessels during the Classic and Protohistoric periods, no ceramic artifacts were recorded in features assigned to these time periods.

Temporal Component Distribution

The foregoing analyses have suggested that, although many of the same kinds of activities were performed redundantly at Falcon Landing, and to a lesser degree at Site 68. Despite these broad similarities in site use over the course of thousands of years, different areas of the sites were used for different sets of activities and at different intensities through time. Up to now, we have considered the distribution of features and artifacts assigned to individual temporal components and, in a more limited sense, differences between temporal components in the spatial distribution of features and artifacts. To gain a more holistic understanding of the spatial distribution of features through time, we used the Focal Statistics tool in ArcGIS 10 to create a raster with 1-by-1-m cell size that shows for each 1-by-1-m cell the majority component. In most cases, there was only one feature per 1-by-1m cell, but calculating the focal majority allowed us to account for those few cases where multiple feature centroids were located within the area of a single raster cell. This raster thus represents, at fine level of detail, the most common temporal component located within each raster cell. The raster was then used again with the Focal Statistics tool to create focal majority and focal variety rasters over a broader area of 25-by-25-m around each 1-by-1-m raster cell in order to visualize which areas of the site were used predominantly during a specific temporal component and which areas of the site were used repeatedly during multiple temporal components. These rasters depict, respectively, the (1) most common temporal component within a 25-by-25-m rectangular area around each raster cell and (2) the variety or richness of temporal components located in a 25-by-25-m rectangular area around each raster cell.

The results indicate that many areas of Falcon Landing were used primarily during one temporal component although it was not uncommon for different temporal components to overlap in space (Figure 131). Focal majority calculations showed that the largest area of the site was used during the Chiricahua temporal component. Fifty-nine percent of the area assigned to temporal components in the focal majority raster was assigned to the Chiricahua component. The Chiricahua component covered large areas of the northern half of the site as well as contiguous areas in the southwestern quadrant of the site. Intensive use of the site may have shifted southward at some point during the Chiricahua or San Pedro temporal components (as represented by the Chiricahua/San Pedro component), when many activities were located in the southwestern quadrant of the site. The second-largest area of the focal majority raster, 17 percent, was assigned to the Chiricahua/San Pedro component.

During the San Pedro temporal component, some of the same areas assigned to the Chiricahua/San Pedro component continued to be used, while isolated features also appeared in many other areas of the site, often adjacent to areas occupied during the Chiricahua phase, suggesting that people had returned to some of the same loci to establish seasonal residences. Many of these features were structures, rather than pit features, suggesting more-intensive use of the site for residential activity. The rarity of pit features assigned to the San Pedro component, however, might stem from the vagaries of sampling and the difficulty in dating features from this complex site. For example, there were numerous undated features located within the vicinity of San Pedro features and the majority of these were located at the surfaces of Units I, II, IIA, or IIs/sf, but were overlain by Units IV or V (see Chapter 2). Conceivably, at least some of these undated features may have been used during the San Pedro component and their presence may account for the relatively low number of pit features assigned to the San Pedro component. Because it is represented mostly by house-in-pit features and a few thermal or nonthermal pits, the San Pedro component only covered 1.5 percent of the area in the focal majority raster.

During the San Pedro/Cienega and Cienega phases, the most intensive use of Falcon Landing shifted farther south, where it centered on Grid Cell B4. Consisting of only six nonthermal pit features, the San Pedro/Cienega component covered only a very small area (0.2 percent), while the Cienega component covered 8 percent of the area assigned to temporal components in the focal majority raster.

For the Cienega/Red Mountain and Red Mountain components, the distribution of features appears to have shifted again, now centered on Grid Cell D1 in the southwestern quadrant of Falcon Landing and an area centered on Grid Cell H5 in the northeastern portion of the site. The area covered by the Cienega/Red Mountain component comprised approximately 7.5 percent of the area covered by temporal components in the focal majority raster, and the areas covered by the Red Mountain component covered less than 0.1 percent of the area.

The pre-Classic component covered small, scattered areas in the southern and northeastern quadrants of Falcon Landing, typically within or on the edge of clusters of features assigned to earlier components. The pre-Classic component covered 1.5 percent of the site.

The Classic and Classic/Protohistoric components of the site covered several small areas of the northern half of Falcon Landing. The Classic component covered 0.5 percent of the area covered by temporal components in the focal majority raster, while the Classic/Protohistoric component covered 3.5 percent of the area.

The focal variety raster shows where the number of temporal components was high or low across the project sites (Figure 132). Many of the areas with a low richness in the focal variety raster were areas of the site that were used primarily during the Chiricahua temporal component. This raster also indicates there were multiple areas of the site where features assigned to multiple distinct temporal components were located close to each other. In other words, these are areas of the site that were repeatedly reused during multiple periods. Areas used repeatedly during multiple temporal components tended to be concentrated in a few areas of Falcon Landing, such as in Grid Cells B4, I5, J4, and K4. Why these relatively small areas were repeatedly used over such a long period is not clear. However, it is worth noting that many of the areas repeatedly used during multiple periods were the same areas where house-in-pit features, middens, activity areas, and surface structures

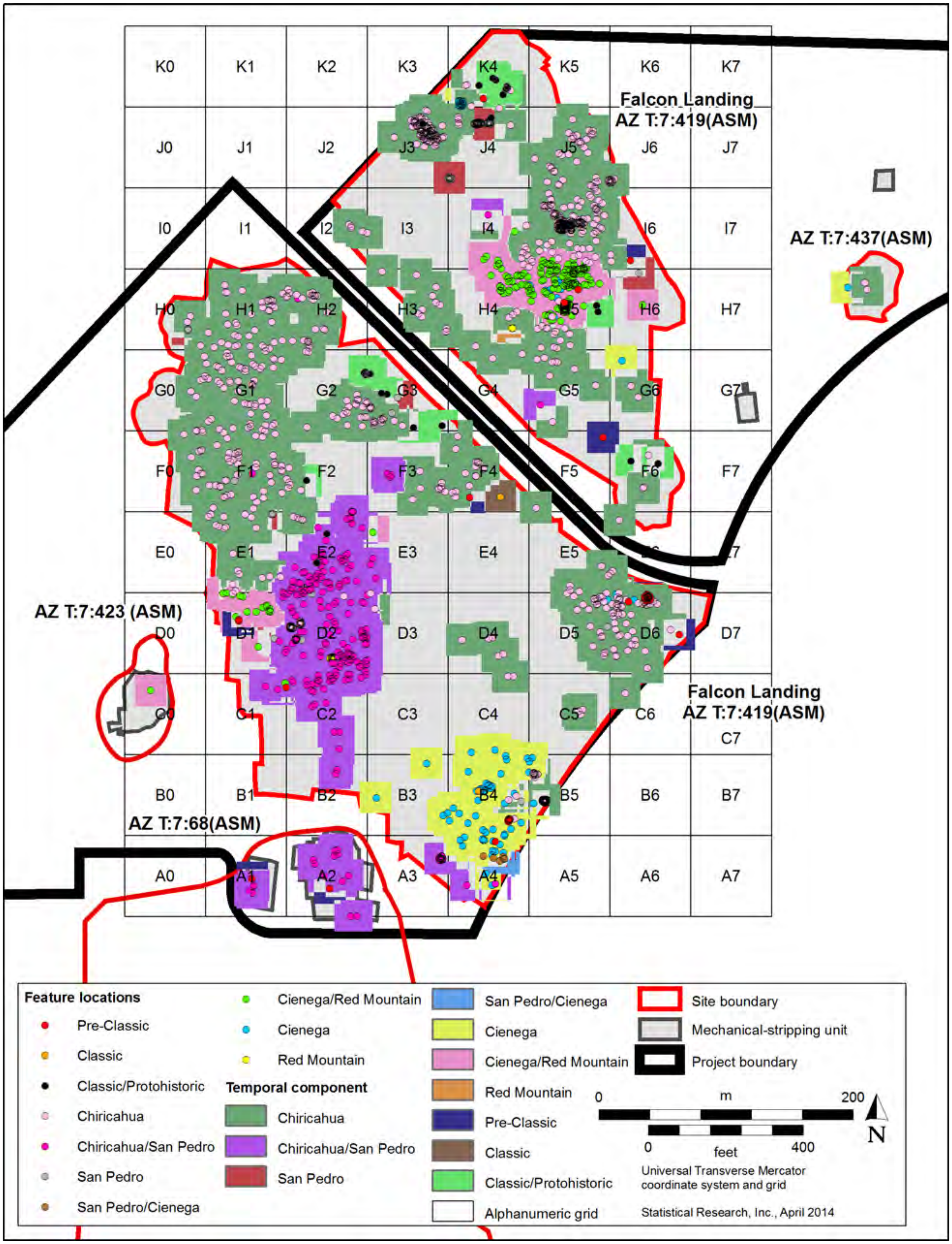


Figure 131. Map depicting the most common temporal component located within a 25-by-25-m focal area of each 1-by-1-m raster cell.

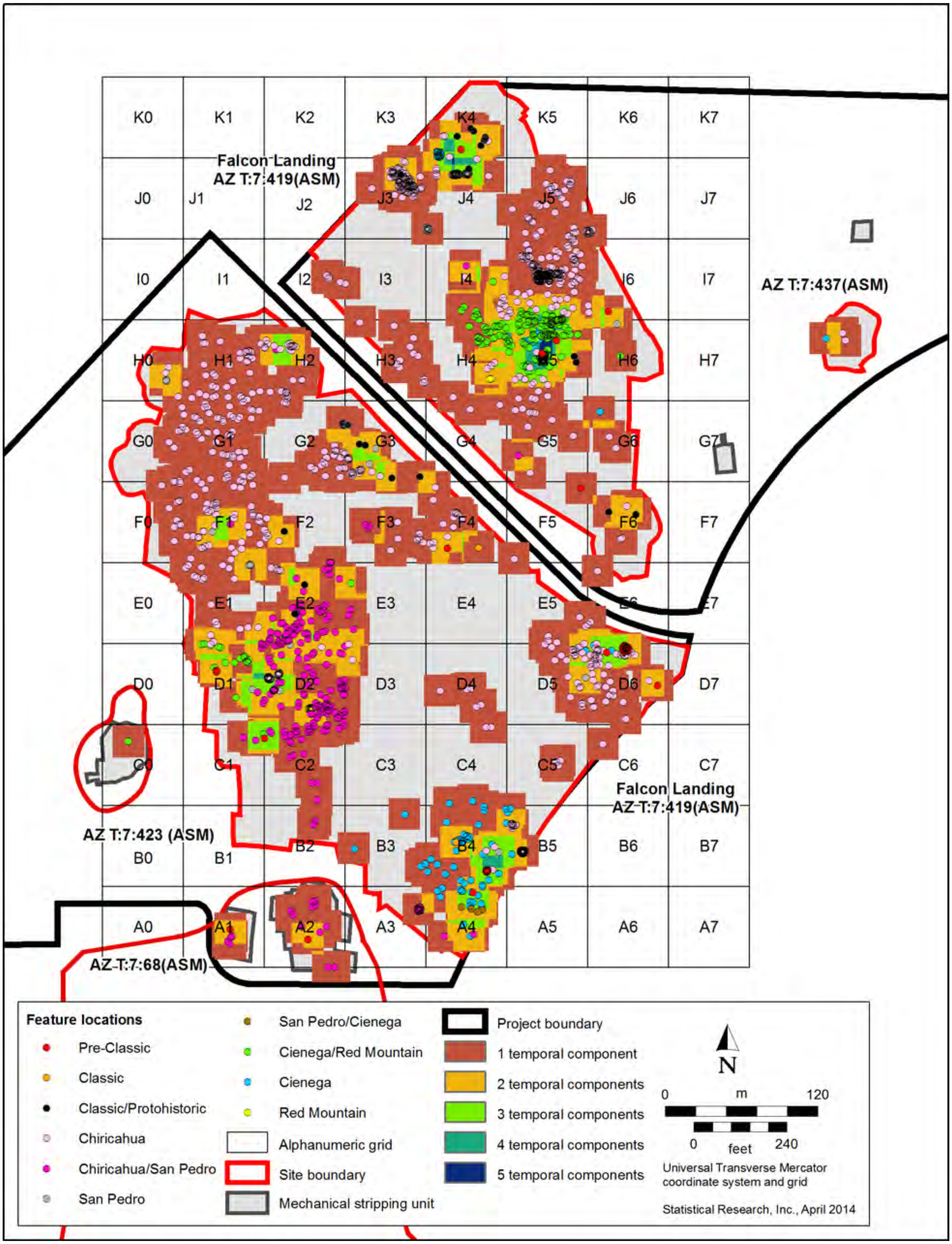


Figure 132. Map depicting the variety, or richness, of temporal components located within a 25-by-25-m focal area of each 1-by-1-m raster cell. Numbers 1–5 in legend indicate number of temporal components in cell.

clustered. Possibly, these were areas of Falcon Landing that were particularly suited to the placement of structures and associated features.

To gain further understanding of the distribution of temporal components, we performed a local Anselin-Moran's I analysis of features using temporal-component sort order and a 50-m fixed distance. Local Anselin-Moran's I is a local autocorrelation statistic that determines, within a specified distance, whether point features cluster in terms of an associated attribute. The Cluster and Outlier tool available in ArcGIS 10 was used to conduct the analysis. The tool calculates whether point features located within a specified distance of each point had similar or dissimilar values. The values, in this case, are the ordinal sort order values assigned to each component in the temporal sequence, varying from 1 (Chiricahua) to 10 (Classic/Protohistoric). For each point in a point layer, the tool identifies whether the point is (1) located in a cluster of points with similarly high values (e.g., late ages), (2) is located in a cluster of points with similarly low values (e.g., early ages), (3) is an outlier whose value is significantly higher than the value attributed to other nearby points (e.g., a feature assigned to a late temporal component that is near features dating mostly to earlier temporal components), (4) is an outlier whose value is significantly lower than the value attributed to other nearby points (e.g., a feature assigned to an early temporal component that is near features dating mostly to later temporal components), or (5) has a value that is not significantly high or low with respect to other nearby points. The results provided statistical support for the idea that large areas of the site were preferentially used earlier or later in the temporal sequence (Figure 133). Many of the hot spots identified conformed closely to focal majority areas identified above. There were also a few large areas of the site where there were no significant hot spots, although the majority of features in several areas lacking significant differences were affiliated with one or two components. For example, Anselin-Moran's I statistics did not indicate the appearance of significant hot spots for Chiricahua/San Pedro features in the areas where such features were found, despite the high concentration of Chiricahua/San Pedro features in this area. This result appears to stem from the sporadic appearance in the same area of various features dated to later components in the sequence, as represented by significant outliers in this area corresponding to features dating to later components, and the overlap in this area of Chiricahua/San Pedro and San Pedro components. In a few other areas, where features were not significantly clustered according to age, there was a great diversity of temporal components. These were relatively confined areas that appear to have been repeatedly used over thousands of years and are consistent with several of the areas identified with the focal variety raster as having features assigned to a high diversity of temporal components.

Spatial Distribution of Features and Allostratigraphic Units

Table 104 shows the number of primary features per temporal component, according to stratigraphic unit (see Chapter 2). The earliest features, dating to the Chiricahua temporal component, were found primarily in Stratigraphic Units II and IIA. Smaller numbers of features dating to the Chiricahua temporal component were also found at the surface of units: Unit I surface, Unit II surface, and Unit IIA surface. Only two features were found within Unit IIs/sf, which consisted of alluvial fan swale/channel (s) fills and sheet-flood deposits (sf) acting on Unit II. Overall, features were quite rare in Unit IIs/sf, suggesting that these parts of the site were more active geologically than other parts of the site and were either avoided for feature construction or the features constructed within Unit IIs/sf tended to be obliterated by alluvial activity. Features documented in Unit I were relatively rare and were widely dispersed across the site, suggesting that they may have been constructed in areas where remnants of Unit I were located close to the surface. Unit II contained a Bk soil horizon and represents alluvial-fan deposition in a distributary flow environment. Features found in Unit II were also widespread, but were concentrated mostly in the northern half of Falcon Landing and were particularly concentrated in the west-central portion of the site between Grid Cells E1 and H1. Unit IIA contained an ABk soil horizon, with a thickness up to 50 cm, which developed in a silt loam sheet-flood deposit that represents the up-fan migration of the fan toe. Features found in Unit IIA were highly clustered in a few areas: areas focused on Grid Cells D5 and D6, G1 and H1, G2 and G3, G5 and H5, I5 and J5, and J3. These tight spatial clusterings of features found

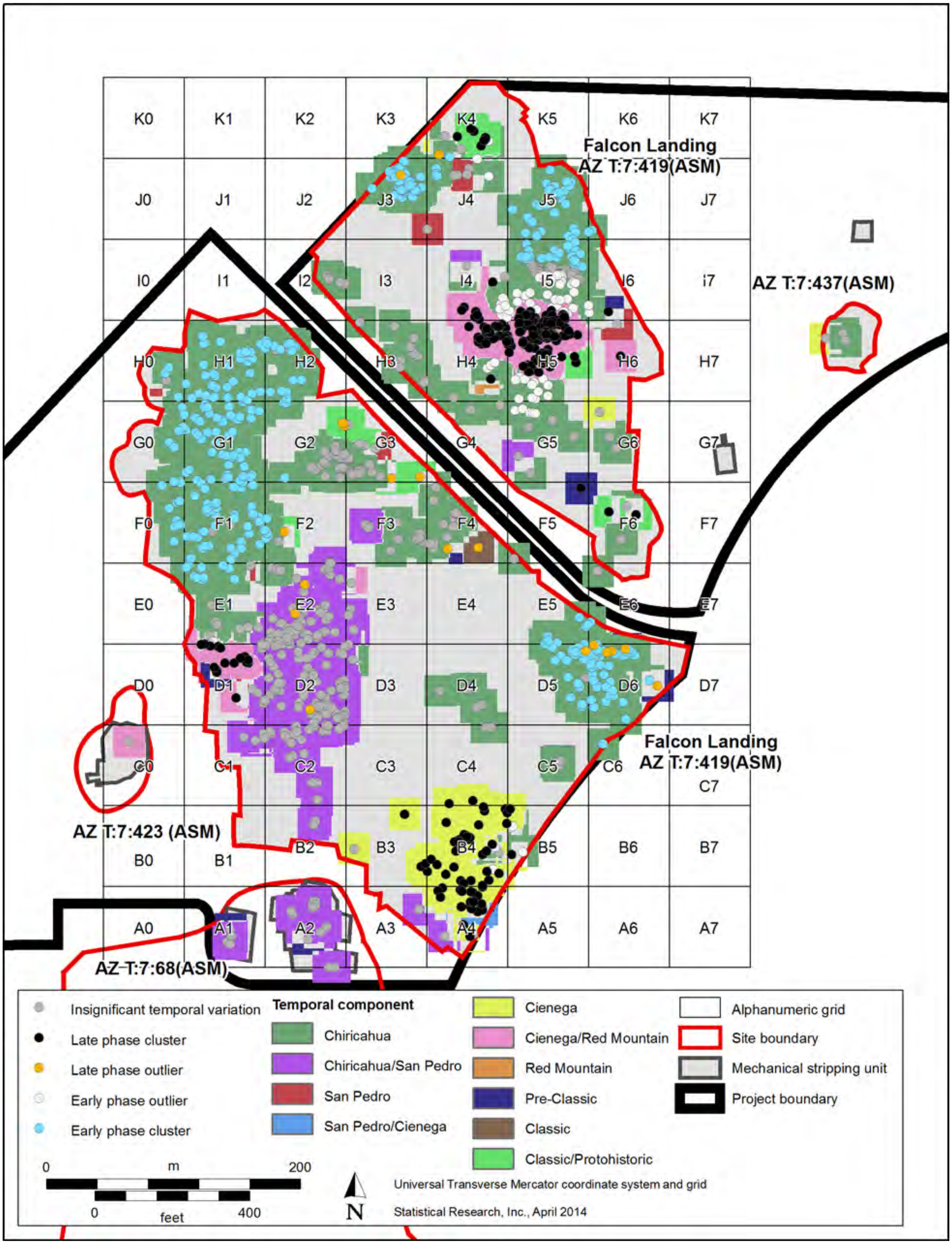


Figure 133. Spatial distribution of hot spots identified with local Anselin-Moran's I analysis of feature locations, according to temporal component.

Table 104. Distribution of Features, according to Temporal Component and Stratigraphic Unit

Stratigraphic Unit	Chiricahua	Chiricahua/ San Pedro	San Pedro	San Pedro/ Cienega	Cienega	Cienega/Red Mountain	Red Mountain	Pre-Classic	Classic	Classic/ Protohistoric	Total
I surface	11	—	2	—	1	1	—	—	—	—	15
II	214	—	—	—	—	—	—	—	—	—	214
IIs/sf	2	4	1	—	—	—	—	—	—	—	7
IIs/sf surface	—	1	7	—	10	—	—	1	1	—	20
II surface	44	1	2	—	—	—	—	—	—	—	47
IIA	420	—	—	—	—	—	—	—	—	—	420
IIA surface	28	1	3	—	4	—	—	1	—	—	37
III1	—	196	5	—	—	—	—	—	—	—	201
III1 surface	—	—	—	6	1	—	1	2	—	—	10
III1/III2	—	—	—	—	1	—	—	—	—	—	1
III2	—	—	—	—	56	—	—	1	1	—	58
III2 surface	—	—	—	—	—	—	—	1	—	—	1
III2/IV surface	—	—	—	—	—	—	—	—	—	2	2
III2cf	—	1	—	—	—	183	1	—	—	—	185
III2cf surface	—	—	—	—	—	—	1	5	—	—	6
IV	—	—	—	—	—	—	—	3	—	—	3
IV surface	—	—	—	—	—	—	—	2	—	26	28
Total	719	204	20	6	73	184	3	16	2	28	1,255

within Unit IIA suggest that these clusters may have been located in remnants of IIA soils and perhaps, that these soils were targeted for use in feature construction.

Although Chiricahua/San Pedro phase features were found in rare cases at the surfaces of Units II, IIA, and IIs/sf, and in four cases within Unit IIs/sf and one case within IIIscf, all other Chiricahua/San Pedro phase features were found in Unit III1. The only other features dated to a temporal component that were located in Unit III1 were five San Pedro features. The tight clustering of these features in the southwestern quadrant of Falcon Landing, particularly in the area of Grid Cells C2, D2, and E2, suggests that the spatial distribution of these features may have been purely the result of geomorphic processes that preserved these relatively early features. All San Pedro phase features were located in the same units as Chiricahua or Chiricahua/San Pedro phase features. However, seven were found on the Unit IIs/sf surface, a rare context for Chiricahua or Chiricahua/San Pedro phase features. Although these features, five of which were house-in-pit features and two of which were thermal features, were confined to the northern half of Falcon Landing, they were not particularly clustered. Perhaps these features were placed on surfaces considered suitable for constructing house-in-pit features.

San Pedro/Cienega phase features, which included only 6 nonthermal pits, originated at the upper weathered surface of Unit III2. Cienega phase features were found primarily in Unit III2, but they were also found in appreciable numbers at the Unit IIs/sf surface. Unit III2 was a widespread master channel–alluvial-fan deposit in the southeastern portion of Falcon Landing. Small numbers of Cienega phase features were also found at the surfaces of Units I, IIA, and III1, and in Unit III1/III2. Features located in Unit III2 were highly clustered in the southernmost portion of the site in Grid Cells A4 and B4. This suggests that the features may have been clustered in this location because of differential preservation of Unit III2 deposits.

Except for a single feature found at the Unit I surface, all Cienega/Red Mountain phase features were located in Unit III2cf. Unit III2cf represented smaller alluvial-fan reaches in the north-central and southwestern portions of Falcon Landing. Features in Unit III2cf were highly clustered in the northeastern portion of the site in Grid Cells H4, H5, I4, and I5, as well as in the southwestern portion of the site in Grid Cell D1.

Pre-Classic period features were found in small numbers in a wide variety of units but were primarily found at the surface of geologic units. These features were found at the surfaces of Units IIs/sf, IIA, III1, III2, III2cf, and IV as well as in Units III2 and IV. More than half were found in the latest of units: III2cf surface, IV, and IV surface. These features were widely dispersed across the site.

The two Classic period features were found at the Unit IIs/sf surface and in Unit III2.The vast majority of Classic/Protohistoric period features were found at the Unit IV surface, although two were found at the III2/IV surface. These features were weakly clustered in multiple locations.

The tight spatial clustering of some features identified in particular strata suggest that geological factors may have partly regulated the preservation of features and that the appearance of discrete clusters during different temporal components may be partly a result of preservation issues and the variation in our ability to date particular features based on stratigraphic context. For any temporal component, there could have been substantial numbers of features that either could not be dated using available evidence or, perhaps, were obliterated as a result of alluvial activity subsequent to the use of the feature.

One of the results of the geoarchaeological analysis of the project area was the creation of a map showing the horizontal distribution of allostratigraphic units across the sites, as revealed through mechanical stripping and geoarchaeological analysis. Polygons in the map were defined according to units and stripping areas. The map does not indicate the distribution of underlying strata; it only indicates the distribution of stratigraphic units encountered as a result of mechanical stripping. To gain further understanding of the spatial distribution of features according to geology, we used z-score tests of proportion to test whether features were proportionally more or less numerous than expected in each of the defined polygons. To do this, the proportional area of each polygon in square meters and the proportion of all primary features located in each polygon were used to calculate z-scores. A z-score value above 1.96 or below −1.96 was used to interpret whether there were significant differences between the area covered by an allostratigraphic mapping unit and the number of features found in the unit.

The results indicated that, at least insofar as these allostratigraphic units were concerned, more features were discovered than expected in the southwestern half of Falcon Landing as well as in a few small pockets in the northern half of the site (Figure 134). Although many features were discovered in the northeastern portion of the site, fewer features than expected were discovered overall throughout much of the northeastern portion of the site. Fewer features than expected were also discovered in multiple, relatively small areas in the southwestern portion of the site. Altogether, z-score tests did not seem to indicate a lot of patterning in feature abundance with respect to the relative age or depositional characteristics of allostratigraphic units discovered at the stripped site surface of the project sites, but they did suggest a general tendency for larger numbers of features to have been discovered in the southwestern portion of the site, in comparison to the northeastern portion of the site.

A very different result was obtained when the same analysis was conducted using only features that had been assigned to one of the nine components discussed earlier in this chapter (Figure 135). This analysis suggested that features that could be dated tended to be found more often in Units I, II, III1, and III2cf in the southwestern, central, and northeastern parts of the site. By contrast, fewer datable features were discovered in Units I, II, IIs/sf, and III2/IV at other site locations. The substantial difference between these results and those obtained using all primary features suggests that the ability to assign features to temporal components was constrained across the site by the distribution of allostratigraphic units. Additional radiocarbon dating and further refinement of the project geochronology, therefore, would undoubtedly change the distribution of features assigned to each temporal component.

In order to further examine whether features that could be assigned to a temporal component were distributed differently from the distribution of all extramural and primary features, we ran the same tests as above using the alphanumeric 1-acre grid established for Falcon Landing, instead of the layer showing the distribution of stratigraphic units across the site. We restricted the area investigated in each cell of the alphanumeric grid to only that area covered by the allostratigraphic-unit mapping layer. Comparison of the results for all extramural and primary features with the results for all extramural and primary features assigned to a temporal component revealed important differences between the two distributions. The results for all primary features suggest that there were more features than expected along a series of bands extending across Falcon Landing along a northwest-southeast axis. Perhaps, this pattern reflects the long-term history of fluvial activity across the site. As with the distribution of features with respect to the distribution of stripped allostratigraphic units, the pattern for all primary features assigned to a temporal component differs from all primary features combined, suggesting some of the areas were preferentially used in order to make use of stable site surfaces and/or that features tended to preserve in areas less affected by fluvial activity.

Summary

In summary, we have examined spatial patterning in the distribution of artifacts and features at the project sites using a variety of complementary analytical methods. For each temporal component, we examined and described the distribution of features according to type and estimated volume and evaluated variation in the distribution of artifacts, according to artifact class and in relation to the distribution of features and feature types. For the Chiricahua and Chiricahua/San Pedro temporal components, we also defined specific feature clusters using ZNNHC and examined the relationships of feature clusters to the distribution of features assigned to more-fine-grained occupational episodes.

For each temporal component and artifact class, we estimated total numbers of artifacts for each sampled or excavated feature and used these estimates to calculate kernel density estimates of the distribution of artifacts within features across the site. To gain a more thorough understanding of the distribution of artifacts with respect to artifact class and feature type, we calculated, for temporal components, the percentage of artifacts of a given class found in each feature type and the overall volumetric density of artifacts in each feature type. In cases where the distribution of artifacts appeared to be patterned by feature type, we used chi-square tests to evaluate the statistical significance of such patterning. Particular attention was paid to the distribution of FAR in and around features. In general, chi-square tests repeatedly showed that FAR

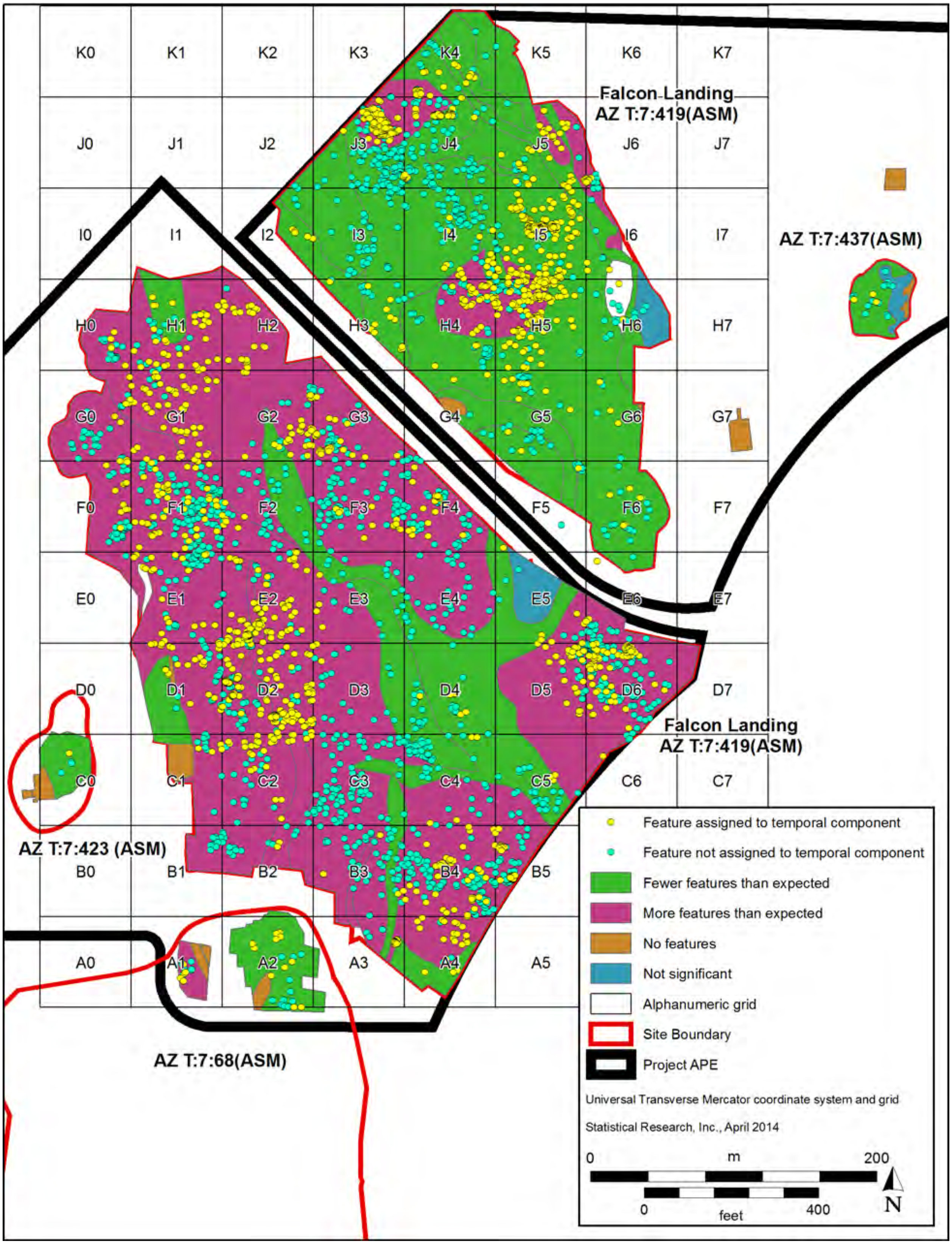


Figure 134. Z-score rendering of the distribution of all extramural and primary features, with respect to the distribution of stripped allostratigraphic units.

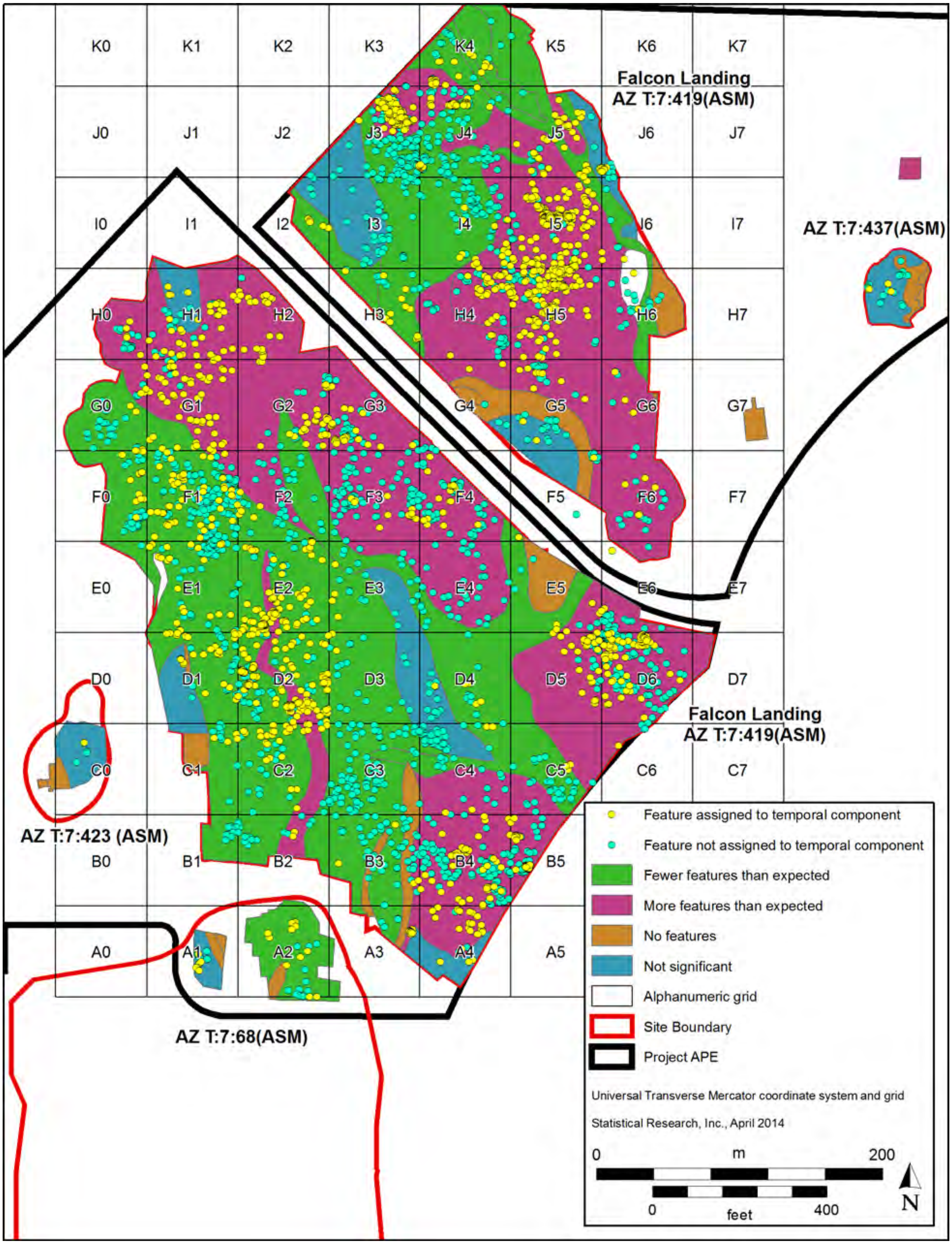


Figure 135. Z-score rendering of the distribution of all extramural and primary features assigned to a temporal component, with respect to the distribution of stripped allostratigraphic units.

tended to be located more often than expected in thermal features, although FAR was often found in other kinds of features as well. Examination of the spatial distribution of FAR tended to show that FAR was often distributed amongst clusters of features of diverse types. These clusters typically included FAR concentrations and thermal pits, suggesting that lithic materials could have been affected by fire within thermal pits, removed from the pits, and were subsequently reincorporated into other nearby features, including those not assigned a thermal function. In a somewhat similar pattern, ground stone artifacts tended to be located within structural features as well as in nearby features, suggesting that ground stone was often stored in structures and in nearby features. Extramural artifacts assigned to individual temporal components consisted primarily of ground stone artifacts. These artifacts were often, but not always, clustered in space and tended to be located in proximity to pit features, suggesting they were used or stored adjacent to features where ground plant materials were further processed or stored. Flaked stone and faunal specimens tended to be found within a variety of feature types but also tended to be located within clusters of features, suggesting that these artifacts, in some cases, were deposited on the ground surface during manufacturing or processing activities and were subsequently washed into nearby pits. In some cases, flaked stone and faunal specimens shared similar distributions, suggesting these artifacts were deposited during similar or overlapping sets of activities.

Spatial patterns in the distribution of temporal components and episodes seem to imply possible shifting through time and across space in how Falcon Landing was used. However, the interpretation of this patterning is complicated by the fact that many features could not be assigned to a temporal component and that some patterning in feature distributions, according to time, was likely to have been affected by the distribution of allostratigraphic units across the site. Although such patterning is to be expected, given that the vast majority of features could not be directly dated and had to be assigned to temporal components based on stratigraphic relationships, some clustering of features could have been strongly affected by the distribution of allostratigraphic units and is likely to represent only a portion of the features generated during a given temporal period. These caveats notwithstanding, the broadest and most expansive use of Falcon Landing for processing activities appears to have occurred during the Chiricahua and Chiricahua/San Pedro component as well as, to a lesser degree, during the Cienega and Cienega/Red Mountain components. Most other temporal components were represented by smaller numbers of features and with a greater emphasis on the use of small clusters of house-in-pit features and other potentially related features, in comparison to the large number of thermal and nonthermal pit features that characterized Chiricahua and Chiricahua/San Pedro temporal components. Given the large number of undated features, however, the validity of our interpretations of these patterns in the variation of site use through time is difficult to ascertain.

However, the available evidence suggests that the most intensive and redundant use of Falcon Landing occurred during the Middle and Late Archaic periods and that use of the site after the Late Archaic period, although it may have involved continued use of the site for many of the same subsistence activities, may have become more sporadic by the Pioneer period of the Gila-Salt Hohokam.

Synthesis and Conclusions

The preceding aspatial and spatial analyses document the complexities and also remarkable similarities of more than 5,000 years of prehistoric use within the Luke Solar project area and especially at the massive 44-acre excavated area of the Falcon Landing site. Aspatial examination of the number and relative proportions of feature types and artifact classes in many ways corresponds with the results of the detailed spatial examination of the distribution of feature types and artifact classes per temporal component and occupational episode. Overall, the detailed analyses presented in this chapter indicate that the greatest variability was in the relative permanence of site occupation, although the site was likely never occupied by more than a handful of family groups on a seasonal basis, as evidenced by the preserved features and artifacts recovered from the identified feature clusters in the spatial analysis.

It is clear that the most extensive occupation occurred during the Middle Archaic period Chiricahua phase between ca. 3300 and 1200 cal B.C., and that the project area was primarily used by logistically organized task groups drawn to the site during the early warm season to collect and process mesquite and the seeds and greens of native weedy annuals (see Chapters 6, 7, and 9). During punctuated, short-term periods of higher effective precipitation, aggradation, and biotic productivity (see Chapter 2), however, the site also clearly served a residential purpose as evidenced by structures and extramural facilities built and abandoned beginning with Occupational Episode A (3340–2890 cal B.C.) and occupation continued on an intermittent basis throughout the Chiricahua phase into the Late Archaic period San Pedro phase (1200–800 cal B.C.), culminating with strong evidence for serial reoccupations of the same locales—possibly representing land-tenure practices—during the Late Cienega/Red Mountain phase (160 cal B.C.–cal A.D. 340).

Occupational intensity as determined by the number of features and artifacts and their distribution declined substantially beginning with the last century of the Red Mountain phase (A.D. 50–450), although the project area continued to be used during the Pioneer period Snaketown phase (A.D. 650–750). Interestingly, the only evidence of Colonial period (A.D. 750–950) occupation of the project area was a Colonial Stemmed projectile point recovered from the surface at Falcon Landing. The project sites continued to be used during the following Hohokam Pioneer, Sedentary, Classic, and even the following Protohistoric period, but to a much lesser extent compared to the preceding Archaic and Early Ceramic periods. Regardless of these documented changes in occupational intensity, the project area was used for the same purposes, with the application of the same ground stone technology and subsistence strategy.

Site furniture in the form of an expensive and diverse ground stone technology characterized the bulk of the identified feature clusters regardless of temporal component. The spatial analysis also indicated that serviceable ground stone implements were preferentially cached in structures or in extramural nonthermal pits located near structures beginning in the Chiricahua phase, a pattern that continued throughout the Middle and Late Archaic periods. Furthermore, extramural ground stone artifacts, especially manos and metates, tended to be located in proximity to extramural pit features that also contained ground stone artifacts. Plant-food collection and processing were clearly primary site activities during all periods of occupation. Flaked stone artifacts, consisting almost entirely of biface- reduction flakes, dominated all temporal components, and this debris is indicative of a gearing-up locale where the hunting tool kit was fashioned and maintained in support of future hunting at other locations (see Chapter 3). Spatial analysis of the distribution of flaked stone artifacts indicated that these lithic-reduction activities tended to take place in small, discernible areas, and that the resultant debris was preferentially deposited in extramural nonthermal and thermal pits that often were constituent members of inferred relatively small work areas that during certain temporal components tended to be associated with extramural activity areas and/or structures.

The footprint of individual clusters of features, potentially representing identifiable occupational loci, tended to be approximately 50 m in diameter, suggesting a relatively compact and focused use of space during all periods of occupation within the project area. Additional radiocarbon dates on substantially more features would undoubtedly refine and also dispel many of the uncertainties in both the aspatial and spatial analysis results, especially as they concern the number of features and artifacts assigned to temporal component, occupational episode, and feature clusters. Additional radiocarbon dates would also allow further examination of how the complex geological setting and the resolution of the project geochronology have acted as potential confounding variables, as suggested by the results of comparing the spatial distribution of features to the allostratigraphic units. Even with these caveats, however, it is clear that the use of the project area involved the establishment of numerous work areas and residential loci during nearly all periods of occupation, in different locations over time, independent of the project area geology and the vagaries of preservation. The spatial analysis in particular was successful in identifying and quantifying Middle Archaic Chiricahua phase habitation loci and their likely constituent facilities and artifacts (see Figure 118). This in itself is a major contribution toward our understanding of the Middle Archaic period in the Sonoran Desert. Similarly, the excavated San Pedro phase residential loci, identified and described in this chapter, are the first reported for the Phoenix Basin. These Middle and Late Archaic period residential loci, feature clusters, and artifacts, and their spatial arrangements provide a baseline for future comparisons and interpretations.

Documented changes during and between temporal components in occupational intensity and the use of select locales within the excavated footprint are the primary results of this chapter. Variation in the amount and distribution of artifact classes over time and across the excavated footprint generally corresponds with the inferred functions of individual features and feature clusters, and also corresponds with the logistical use of the project area as a resource-procurement and processing site and staging locale, as well as its use as an intermittently occupied warm-season residential site. What remains remarkable are the shared similarities in the primary site activities and the associated lithic, earthen pit feature, and architectural technologies that were employed. The primary site activities—mesquite processing, biface reduction and maintenance of the hunting tool kit (i.e., gearing up), and the embedded procurement of leporids on an encounter basis—characterize the entire 5,000-year record of occupation.

This stability in site and land use undoubtedly reflects a fundamental component of the prehistoric lifeway in the Sonoran Desert, because it persisted effectively unchanged in the context of dramatic regional cultural change. These regional cultural changes were profound and included the introduction of domesticates during the Middle Archaic period, the development of utilitarian ceramic containers in the Early Ceramic period, and increasing sedentism and emergent complexity, culminating in North America's largest prehistoric canal irrigation network—a hallmark of the pre-Classic period Hohokam culture—in the surrounding Phoenix Basin. The prehistoric occupants of the Luke Solar project area were undoubtedly participating in these regional developments and availed themselves of newfound opportunities and overcame newfound challenges, but the way in which they used the Luke Solar project area was effectively unchanged. The detailed record of stability in site and land use documented in this chapter is in effect a testimony to the success and importance of this highly successful subsistence strategy focused on a lower-*bajada* setting, a strategy with a now-documented 5,000-year record of successful application in the Luke Solar project area. Now that the corresponding archaeological signatures of this aspect of the land use have been documented for the Middle Archaic through Ceramic periods, it is very likely that additional examples will be documented at other lower-*bajada* sites throughout the Sonoran Desert, as future archaeological research is conducted. Of particular interest is determining the antiquity of this aspect of land use, as it is possible that it has been practiced since the Early Archaic period—a possibility that only future research can evaluate.

CHAPTER 11

Summary, Interpretations, and Directions for Future Research

Robert M. Wegener, John D. Hall, Rein Vanderpot, Jesse A. M. Ballenger,
Eric Eugene Klucas, and Jason D. Windingstad

This chapter addresses the project research themes by summarizing and interpreting the information from the previous chapter—the geoarchaeological, artifact, ecofact, ethnographic, and spatial analyses. Originally defined in the HPTP (Hall et al. 2011), the research themes are also presented in Chapter 2 of Volume 1. These include the three broad themes of chronology, prehistoric cultural affiliation, and land use.

Overall, the Luke Solar project has produced substantial and much-needed additional baseline data concerning the Middle and Late Archaic periods of not only the Phoenix Basin but also the Sonoran Desert and U.S. Southwest. In particular, the Luke Solar project has resulted in the excavation, analysis, and reporting of the largest single Chiricahua phase data set to date. Prior to the Luke Solar project, the most meaningful reporting on the poorly understood Chiricahua phase and the Archaic period in the Phoenix Basin involved four excavation projects at the Last Ditch site (AZ U:5:33 [ASM]) in Paradise Valley along the southern middle–lower *bajada* of the McDowell Mountains near Scottsdale, Arizona (Adams et al. 1996; Hackbarth 1998; Phillips et al. 2001; Rogge, ed. 2009). The Last Ditch excavations provided important insights into Middle Archaic period use of the lower-*bajada* setting in the Sonoran Desert. Restricted to the confines of a newly proposed highway right-of-way, however, the Last Ditch excavations were necessarily limited in terms of plan-view exposure and sampling. In total, 210 buried features were documented at the Last Ditch site, of which 92 were excavated (Rogge et al. 2009:Table 3), and the combined total area of mechanical stripping was 1,133 m^2 (0.28 acres). The Last Ditch and exponentially larger Luke Solar project together represent the most substantial excavations concerning the 2,300-year Chiricahua phase (3500–1200 B.C.) in the Phoenix Basin—the period that witnessed the beginnings of maize horticulture at ca. 2100 cal B.C. along the middle Santa Cruz River in Tucson (Gregory, ed. 1999:118), and shortly thereafter throughout the U.S. Southwest (Diehl and Waters 2006; Huber 2005; Huckell 2006; Kohler et al. 2008). As discussed and explored in the remainder of this chapter, it is primarily in this context and within the framework of the project HPTP that the Luke Solar project results are interpreted.

Chronological Patterns

Over time, prehistoric groups were drawn to the Luke Solar project area for several reasons. Key among them was the ecological setting surrounding the Luke Solar project area, which was distinctive and supported a prehistoric lower-*bajada* occupation in the western Phoenix Basin, previously thought to have been an unlikely location for a site. The major occupations at Luke Solar were correlated with periods of alluvial-fan aggradation, suggesting groups occupied the project area during periods of increased winter and summer precipitation. Examination of recovered plant macro- and microfossils indicated that the project sites were primarily frequented during the early warm season (see Chapters 6 and 7). As discussed in Chapter 2, these periods of aggradation correlated with the stratigraphic units defined within the Luke Solar project area, including Unit I (7040–5320 cal B.C.), Units II–IIA (2970–2420 cal B.C.), Units III1, III2, and III2cf

(1380 cal B.C.–cal A.D. 340), and Unit IV (cal A.D. 610–1220). The increased surface runoff traversing the lower *bajada* and the Luke Solar project area during periods of active fan aggradation ultimately encountered the salt domes just south and southeast of LAFB where water was impeded and then accumulated for short periods of time. This produced an elevated or perched water table associated with the salt domes that supported a niche community of mesquite (probably a mesquite bosque) just south of the project area, like that found today and documented in historical aerial photographs. Furthermore, as fresh alluvium was seasonally deposited in the project area, economically important plants such as cheno-ams, sunflower, and grasses likely colonized and prospered on the new fan deposits.

In total, 120 radiocarbon dates were obtained by the Luke Solar project, with 97 features chosen for radiocarbon analysis, as well as 23 nonfeature (geologic) contexts (see Chapter 2). These radiocarbon dates not only provided precise dates for a limited number of features but were also used to construct the geochronological model. Using the OxCal program, the stratigraphic units were correlated across space using a combination of radiocarbon-dated features and dates on natural sediments, and each stratigraphic unit was assigned an age range (see above). As a result, many of the undated cultural features could be assigned a stratigraphic age. Fortunately, many of the stratigraphic units were deposited over large portions of the project excavation footprint over relatively short periods of geologic time, making them very useful for stratigraphic dating. Unfortunately, however, the lateral complexity of the stratigraphy in some areas created age assignments that were simply too broad to be analytically useful.

The geochronology analysis indicated the majority of occupations at Luke Solar occurred during the Chiricahua phase of the Middle Archaic period, or ca. 3500–1200 B.C. Other important prehistoric occupations included the Late Archaic period San Pedro (ca. 1200–800 B.C.) and Cienega phases (ca. 800 B.C.–A.D. 50), and the transition between the Cienega and Early Ceramic period Red Mountain phase, a transitional interval dated at Falcon Landing to between 160 cal B.C. and A.D. 340. Prehistoric use of the project area and Falcon Landing continued during the Early Ceramic (A.D. 50–400), Pioneer (A.D. 400–750), late Sedentary and Classic (ca. A.D. 1000–ca. 1450), and Protohistoric (ca. A.D. 1450–1800) periods, but overall site occupation was substantially less frequent and less intensive.

Archaic Cultural Chronology of the Phoenix Basin

Until recently, the Archaic cultural chronology of the Phoenix Basin relied completely on cross-dating projectile points from rare Middle and Late Archaic isolates and sites. Huckell (1996:Figure 4) summarized eight subregional cultural chronologies in the Southwest; the nearest one in proximity to the Phoenix Basin is Ventana Cave (Haury 1950), where Middle and Late Archaic deposits were not directly radiocarbon dated. Continued research in the Phoenix Basin, and at the Falcon Landing site, have significantly expanded our understanding of Middle and Late Archaic land use and cultural chronologies. The paucity of Archaic sites in the Phoenix Basin has been attributed to erosion and limited survey (Waters 2008; Wilcox 1979), but recent testing indicates the preservation of rare Early Holocene alluvial deposits (Graves et al. 2011), and an increasingly rich collection of small, limited-activity sites and inferred base camps have come to light in the surrounding *bajadas*, foothills, and ranges (Adams et al. 1996; Hackbarth 1998, 2001; Phillips et al. 2001; Rogge, ed. 2009). As reviewed by Hall and others (see Chapter 2, Volume 1, and Chapter 3 of this volume), these sites indicate hunting-and-gathering activities marked by plant-processing tools, roasting features, and ephemeral, round house-in-pits. The frequency of Late Archaic sites in Paradise Valley is comparable to that of the Tucson Basin (Hackbarth 2001:86).

The Falcon Landing site provides evidence for the existence of regional populations, centered in the southern U.S. Southwest (Irwin-Williams 1979), which used Chiricahua and San Pedro–style points and occasionally projectile point types common to the Great Basin and southern Colorado Plateau (see Chapter 3). Although the Chiricahua-San Pedro phase boundary dates at Falcon Landing were derived primarily from mesquite charcoal, and therefore are not as precise as dates obtained from annual plant parts, it appears that

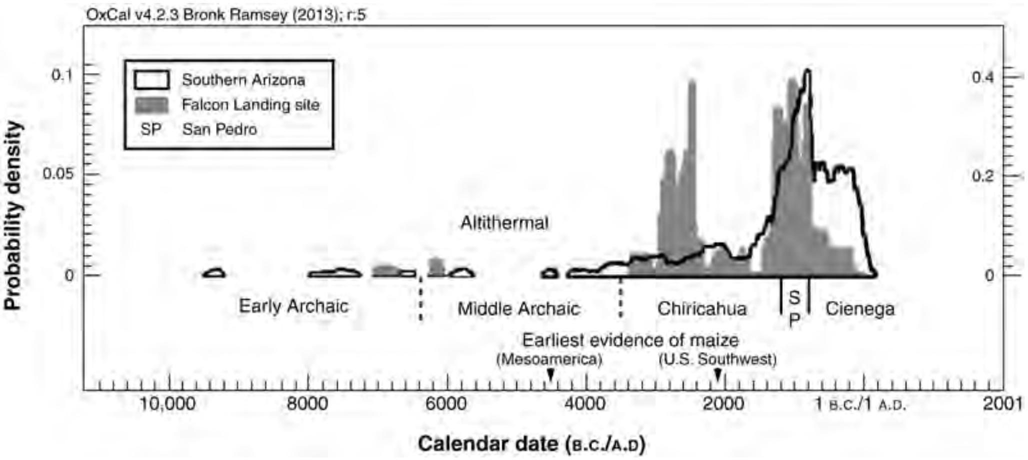


Figure 136. Summed probability distribution of a representative sample of Early Archaic period to early Cienega phase radiocarbon dates from southern Arizona compared to archaeological radiocarbon dates from the Falcon Landing site.

Chiricahua projectile points persisted in use until 1440–1310 B.C., whereas San Pedro projectile points appeared by 1260–1050 B.C. and were still in use as late as A.D. 330. In light of the frequency and age of Chiricahua and San Pedro projectile points at Falcon Landing, the cultural chronology shows strong continuity with that of the southern U.S. Southwest (Bayham et al. 1986; Carpenter et al. 2008; Haury 1950; Mabry 2005a; Sayles 1983). Cortaro-type projectile points (Roth and Huckell 1992) represent another southern variety of point type recovered at the site in contexts dated to sometime before the end of the San Pedro phase. Regionally distinctive styles from outside the southern U.S. Southwest include Elko Corner-notched forms indirectly dated to between 1380 and 920 B.C. The geographic origin of stemmed points described as the Datil type is uncertain, but one is associated with a radiocarbon date of 2810–2420 B.C. at Falcon Landing. Datil and Elko Corner-notched points are both directly dated between 1110 and 1000 B.C. Based on a limited number of dates from Falcon Landing, the incorporation of Elko forms may have been most common in the centuries before and after the beginning of the San Pedro phase.

Figure 136 represents the summed probability distribution of a representative sample of Early Archaic period to early Cienega phase radiocarbon dates from southern Arizona compared to archaeological radiocarbon dates from the Falcon Landing site. The data are based on a sample of 717 radiocarbon dates assembled by Ballenger and Mabry (2011) from alluvial settings in the upper San Pedro and the middle Santa Cruz River valleys. The database was expanded to include nearly 1,000 archeological radiocarbon dates assembled by the late David Gregory, especially from Archaic and Early Agricultural period sites located throughout the U.S. Southwest. The data were limited to a geographic area extending east–west from Sulphur Spring Valley to the San Cristobal Valley, and north–south from the middle Gila River to the Mexico border. The data were further trimmed by including only those dates between 10,000 and 2000 B.P. Radiocarbon dates with uncertainties greater than 200 years were omitted. This resulted in a sample of 405 radiocarbon dates from throughout southern Arizona, in addition to the 74 radiocarbon dates from the Falcon Landing site. The regional radiocarbon sample is not exhaustive, but it is highly representative of the total population of radiocarbon dates in southern Arizona. The radiocarbon summed probability distribution is annotated to show the initial dispersal of maize sometime between 4300 and 2100 B.C., and Altithermal warming/drying between approximately 6400 and 3900 B.C. (i.e., Merrill et al. 2009).

The meaning and significance of summed radiocarbon dates is an important topic because a large volume of literature correlates the frequency of dated features or sites with changes in human activity and demography (Buchanan et al. 2008; Holdaway et al. 2009; Gamble et al. 2005; Peros et al. 2010; Surovell et al. 2009). Ballenger and Mabry (2011) used the radiocarbon records from alluvial landforms in the upper San Pedro and middle Santa Cruz River valleys to show that summed radiocarbon frequency distributions are the result of several variables, especially preservation, scientific bias, and the shape of the radiocarbon calibration curve. That said, the human prehistory of southern Arizona between 10,000 and 2000 B.P., as quantified by the intensity of radiocarbon sampling, shows that nearly 0.8 of the probability density (80% of the distribution) occurs after the beginning of the San Pedro phase. The spike and trough centered on the San Pedro and Cienega phases is attributed to a research bias favoring the introduction of maize at alluvial sites, large-scale cultural resource management (CRM) projects in the Tucson Basin, and the shape of the radiocarbon calibration curve around 2500 B.P. (Ballenger and Mabry 2011). The Luke Solar radiocarbon chronology spans a significantly undersampled portion of the regional radiocarbon chronology between 3300 and 1200 B.C.

Huckell (1984b) proposed a three-part Early-Middle-Late Archaic period nomenclature in place of the Cochise cultural sequence and recommended that Middle Archaic evidence from southern Arizona be lumped into the Pinto-oriented Western Archaic tradition, and Late Archaic sites would define a San Pedro–using Southwestern Archaic tradition (i.e., Irwin-Williams 1979). Huckell predicted, however, that continued research may demonstrate that a discrete Middle Archaic tradition existed. The Falcon Landing site is compelling evidence that such groups did exist in the Arizona Sonoran Desert, and that their projectile points were found at sites dedicated to processing plants in low-productivity settings vs. caves and other "meeting places" (Haury 1950:532). Huckell (1995:16) later introduced the Early Agricultural period as a means to describe preceramic agriculturalists in southeastern Arizona, reserving Late Archaic "for those groups that did not adopt agriculture." The Early Agricultural period is defined as the period of time spanning the initial appearance of agriculture, including the San Pedro and Cienega phases in the southern U.S. Southwest. As summarized by Mabry (2005a:50–51), large-scale CRM projects in the Tucson Basin have refined the Early Agricultural period chronology, bracketing the San Pedro phase between 1200 and 800 B.C. and the Cienega phase between 800 B.C. and A.D. 50. An "unnamed interval" describes the period of time between the appearance of maize and the beginning of the San Pedro phase (2100–1200 B.C.) (Mabry 2008:71).

The Falcon Landing site shows that hunter-gatherers, with the same basic architecture and material culture, used the site principally between 3300 B.C. and A.D. 50, and that the appearance of maize in the regional archaeological record at 2100 B.C. had no measurable impact on subsistence, settlement, or technological patterns observed at the site. During the Middle Archaic period, local Chiricahua and Cortaro-style projectile point traditions characterized Falcon Landing prior to the San Pedro phase. Mabry (2005a:54) points out that these types were associated with early maize (2100 B.C.) at McEuen Cave (Huckell et al. 1999). The probable Chiricahua-Cortaro association at Los Pozos (Gregory, ed. 1999) and Falcon Landing suggests that the bimodal Archaic/Early Agricultural period taxonomy is appropriately applied to the Middle Archaic period. The Falcon Landing site does not justify incorporating a Chiricahua phase into the Early Agricultural period because no evidence for pre-San Pedro phase agriculture was found, and because that would create a new dilemma for describing pre-agricultural and nonagricultural sites containing Chiricahua and Cortaro-type points. The quandary might be resolved if maize is discovered to date to the appearance of Chiricahua or Cortaro-style points, perhaps shortly before about 3500 B.C. That scenario would extend the Early Agricultural period to the beginning of the post-Altithermal repopulation of the southern U.S. Southwest and limit the Middle Archaic to a shorter window of time centered on the Altithermal.

Prehistoric Cultural Affiliation

Even with the remarkable stability and similarity in how Falcon Landing was used from ca. 3300 cal B.C. until as late as A.D. 1800 (see Chapter 10), it is a reasonable expectation that this 5,000-year record of intermittent occupation would reflect the activities of numerous aboriginal peoples of various affiliations. The task and family groups that used and/or occupied Falcon Landing made and fashioned regionally distinctive Chiricahua, Cortaro, San Pedro, and Datil dart points that have been routinely attributed to the Cochise culture (Sayles and Antevs 1941) or Middle Archaic period of the U.S. Southwest (Huckell 1984b, 1996). As presented in Chapter 3, the distinctive side-notched Chiricahua type is the common recurring Middle

Archaic dart-point form found throughout the Sonoran Desert, the Papaguería, and southeastern Arizona. The routine association of Chiricahua points with a robust ground stone technology used to process grass seeds, the seeds of weedy annuals, and legumous tree pods (especially mesquite [*Prosopis* sp.]) is indicative of a broad-spectrum foraging strategy that should be considered an underpinning of a highly successful aboriginal approach that not only persisted throughout what is now southern Arizona but flourished. At Falcon Landing, the collection and processing of these plant foods was the predominant site activity during all periods of occupation, irrespective of the introduction of maize, development of floodplain irrigation networks during the Early Agricultural period, the appearance of ceramic container technology, the establishment of sedentary village life and increased social complexity, and the appearance of the Hohokam culture.

The presence of incipient plainware ceramics at Falcon Landing indicates that the site occupants did share in the use of ceramics and contributed to the development of the earliest ceramic technology in the U.S. Southwest, a technology that, based on current data, was pioneered as early as 2100 B.C. along the middle Santa Cruz River in Tucson (Heidke 1999, 2005, 2006; see also Garraty 2011). Other documented ceramics included typical Gila–Salt Basin Hohokam plainwares and a few Sacaton Red-on-buff sherds made from materials obtained from the Agua Fria and middle Gila River valleys. Though few in number (n = 122), these Gila–Salt Basin Hohokam ceramics provided the strongest direct evidence of a conventional archaeological cultural affiliation.

Establishing Archaic Period Cultural Affiliation

As defined by Fortier and Schaefer (2010:1–8), cultural affiliation refers to ethnographically known cultural groups and can be established for prehistoric groups only when there is a preponderance of evidence through a number of different methods, e.g., geographical, kinship, biological, archaeological, linguistic, folklore, oral tradition, historical evidence, or expert opinion. Broadly, ancestry, historical records, cultural knowledge, languages, archaeology, and/or genetics are relied upon to help determine cultural affiliation. In the absence of formal architecture and iconography, evaluating the cultural affiliation of pre-ceramic hunter-gatherer groups generally relies on finding stone tool correlates across time and space. Geographic, material culture, and behavioral correlates of ethnic identity generally increase through time, with subsistence patterns distinguishing Papago (Tohono O'Odham) "bean eaters" from Hia Tadk Ku:mdam (Hia C-ed O'Odham) "Sand Root Crushers" (Bell et al. 1980; Nabhan 1985).

Archaeological constructs of Middle Archaic period cultural affiliation are founded on two principal variables: (1) the spatial and temporal distribution of projectile point types, and (2) the appearance of diverse plant-food-processing technologies (Haury 1950; Huckell 1984b; Irwin-Williams 1979; McGuire 1982; Rogers 1939; Sayles 1983). The former of these reflects male knowledge, technology, and stylistic expression recorded on transported hunting gear, whereas the latter represents subsistence choices based on plant-foraging opportunities. Consequently, cultural affiliations based on projectile points can be expected to be far-reaching, whereas cultural affiliations based on plant-processing technologies will always appear local. Archaeological evidence for cultural affiliation shifts from potential non-kin, male-oriented technologies (projectile points) to kin-based, female-oriented technologies (pottery) after the development of decorated ceramics (Gladwin and Gladwin 1929).

The cultural identity of Archaic period populations in the southern U.S. Southwest was originally perceived under the Cochise culture rubric (Sayles and Antevs 1941), a regional archaeological manifestation of hunter-gatherers with broad similarities in subsistence and organization shared throughout the American West and U.S. Southwest (e.g., Irwin-Williams 1967; Jennings 1956). Haury (1950:532) identified Ventana Cave as a location shared by western (Amargosa) hunters and eastern (Cochise culture) gatherers, followed by the expansion of Cochise culture San Pedro phase groups, who developed into the Hohokam and Mogollon. He later argued that the Hohokam were migrant southern farmers (Haury 1976). Irwin-Williams (1979) identified the Cochise culture as one of four cultural traditions in the Southwest: (1) western (Pinto-Amargosa), (2) southern (Cochise), (3) northern (Oshara), and southeastern (Chihuahua) branches of a widespread cultural entity she described by the acronym "Picosa." Huckell (1984b:204) later attributed the cultural and economic significance placed on Cochise culture ground stone technologies to undersampling, pointing out that it does not reflect the value placed on hunting in montane and upper piedmont settings (e.g., Agenbroad 1970). He argued further that the Cochise culture be abandoned as a means for describing cultural affiliation.

The archaeological record of the Cochise culture (Sayles 1983) does not demonstrate 9,000 years of continuous, in-situ cultural development (Waters 1985), but cultural continuity in the form of redundant subsistence, land use, and technological patterns is apparent at multicomponent sites by the Middle Archaic period (Huckell 1996). The post-Altithermal social environment of the U.S. Southwest was complex and, aside from similar land-use and subsistence practices, the level of interaction and competition that existed among groups is unknown. Wills (1988) has argued that population pressure and increased boundary maintenance was responsible for stylistic variation in Middle Archaic period projectile points, whereas Huckell (1996) describes the Middle Archaic as a period of increased coherence among previously regional populations. Both of these statements point to a diverse social landscape, although not one characterized by violence or other evidence of defended territories (Cashdan 1983).

The wide variety of projectile points associated with Chiricahua phase sites has confounded traditional culture area definitions, but they lend valuable insight into the social landscape of the southern Southwest. The diversity of projectile point types associated with the Chiricahua phase must be intimately connected to postmarital residence customs as well as chronology and mobility. Peregrine (2001) asserts that Southwest hunter-gatherer groups were probably patrilocal based on the frequency of patrilocality among hunter-gatherers worldwide (e.g., Ember 1978). The postmarital residence patterns of foragers are difficult to identify even among living groups, but the sexual division of labor is generally thought to play a large part in hunter-gatherer residence patterns (Korotayev 2001; Murdock 1949). Ember (1978:447) noted that a higher dependence upon gathering predicts a tendency toward matrilocality (uxorilocality), and that competition and warfare favor patrilocality (virilocality). The marriage and residence patterns of ethnographic groups in the U.S. Southwest were highly flexible, but among recent O'odham groups patrilocality was common (Bahr 1983:182).

Owen (1965:687) drew attention to the fact that in patrilocal band organizations, it is the females who move, taking with them female "culture." In southern California, grinding tools, gravers, cutting tools, and scrapers, which might have been used by women more frequently than men, show little distinctive variation over wide areas. In the same region, however, considerable local distinctiveness may be seen in such things as projectile points, fishhooks, and ceremonial objects ("plummet stones," "doughnut" stones, "cogstones," etc.). Owen (1965) argued that this is the sort of pattern one would expect if males tended to be relatively localized and isolated from the culture of foreign males, but where females and female culture were relatively mobile.

A related issue in reconstructing the cultural affiliation of prehistoric populations in the U.S. Southwest revolves around the origins of the Uto-Aztecan language group. A southern California homeland for Uto-Aztecan is supported by the amount of linguistic diversity there (Fowler 1983); however, the Proto-Uto-Aztecan homeland is suspected to have been somewhere in southern Arizona or northern Mexico (Campbell 1997; Wichmann et al. 2010). Glottochronological estimates indicate that the initial Uto-Aztecan break up and expansion began around 3500 B.C. (Miller 1983). Hill (2001) identified central Mexico as the source for Uto-Aztecan migrant populations responsible for introducing maize farming into the U.S. Southwest, arguing that maize itself was responsible for the rapid diffusion of Uto-Aztecan. Archaeologists have approached the problem from the opposite direction, arguing that language accommodated the rapidity of maize dispersals into the U.S. Southwest (Merrill et al. 2009). MtDNA surveys show greater than expected variation between the main Uto-Aztecan branches, however, suggesting that entire family groups (females) were not part of a mass prehistoric migration. Malhi et al. (2003) interpret the mtDNA data as evidence that archaeological (cultural) traditions explain prehistoric gene flow more so than language, and that this reflects the prehistoric movement of males rather than females.

Widespread, diverse, exogamous hunter-gatherer populations sharing a post-Pleistocene broad-spectrum adaptation, and probably a distant language group, represent the hallmark of the Middle Archaic period in the U.S. Southwest. The extension of female labor and plant processing that characterized the Chiricahua stage may have favored matrilocality (uxorilocality) and the incorporation of non-kin male technologies into local hunting, plant-processing, and habitation sites. The widespread and overlapping distribution of coeval, regionally distinctive projectile point types may be explained by the dispersal of male technologies not only during long-range hunting and mate-selection forays (Haury 1950:532; Shackley 2005:122–125), but also as a consequence of postmarital residence patterns that would have contributed to the high linguistic and genetic diversity of the U.S. Southwest.

A Structuralist Approach to Cultural Affiliation: Deep Structures and Habitus

When the occupational record at Falcon Landing is examined as a whole, the remarkable persistence of the same subsistence strategy using the same lithic technology at the same location for nearly half the Holocene is itself distinctive and important. As documented ethnographically and presented in Chapter 9, these essentially techno-economic activities were undoubtedly a key foundational element of what can only be considered a remarkable Native American heritage of considerable antiquity within the Sonoran Desert. This heritage was shared by family groups at Falcon Landing and in all likelihood by numerous aboriginal groups throughout the vast low-desert region of the U.S. Southwest. One of the most intriguing analytical possibilities afforded by the data from the Luke Solar project was the opportunity to examine these shared commonalities over five millennia of human activity at a single location. From the Early Archaic period (9500–3500 B.C.) through the entirety of the Late Archaic (1200 B.C.–A.D. 50) and Hohokam periods, the sites constituting the Luke Solar project represent periods that witnessed profound changes in nearly every aspect of human existence. From a subsistence economy focused exclusively on the acquisition of wild plants and animals, through the Early Agricultural period when people experimented with the potentials of domesticated resources, to the nearly fully agricultural Hohokam periods, this area bore witness to changes that in other parts of the world have been classified as revolutionary. Similar changes can be seen in social and domestic organization, with the early periods characterized by small, mobile family groups eventually giving way to settled village life. Similarly profound changes have also been documented in technological focus and sophistication in every aspect of material culture.

Given the opportunity to examine these changes over a 5,000-year interval, it is not surprising that a main focus of the Luke Solar project has been to examine changes in subsistence, technology, and social life through time. Indeed, this is precisely the path pursued in this volume. As the analyses progressed, it became clear that, although temporal variability could be identified in a number of areas, what was more striking was the overall similarity in the data throughout the occupation of the site, which in turn suggested long-term stability in the kinds of activities that were performed at the Luke Solar sites. These activities included the collection and processing of mesquite pods, evidenced by an extensive ground stone collection and numerous processing pits; the production and maintenance of bifacially flaked stone tools, reflected in an abundance of bifacial-thinning flakes; and the opportunistic hunting of leporids, as evidenced by their nearly exclusive representation in the faunal collection. Although the data suggest variability through time in the frequency of use, the overall pattern appears to represent the seasonal use of the site by small groups of individuals. Given the low intensity of occupation evident for much of the sequence, it is possible that this seasonal reuse was sporadic at best, with multiple years separating individual occupational events.

Although it is clear that the uniformity of behavior through time reflected in the archaeological data from the project sites may have been influenced by the unique physical attributes of this location (see Chapter 2), it is unlikely that any single set of environmental factors can fully account for the continuation of the activities discussed above in light of the profound changes in nearly all other aspects of life during the five millennia that the Luke Solar sites were occupied. Even though we are referring here to a set of rather mundane activities, these activities likely represented something much more important because they likely promoted aspects of personal and group identity. It is this aspect of social existence as expressed in the Luke Solar data that is examined in the remainder of this section.

Although most anthropological theory has been devoted to providing models to explain how societies change through time, the work of Pierre Bourdieu and others beginning in the 1970s explored an approach to culture that looked instead to explain the continuation and reproduction of practices and beliefs (Bourdieu 1977, 1988). Simply stated, these approaches focused on the power of cultural rules, laws, norms, and practices that taken together were referred to simply as its structure. Many of the more formal rules and practice, such as marriage rules, inheritance, and other familial rights and responsibilities, became part of the "natural order" of a particular society, a concept Bourdieu referred to as the habitus (Bourdieu 1977:78 Giddens 1979, 1984). Bourdieu argued that these kinds of behaviors were exceptionally stable, continuing relatively unchanged across generations.

These aspects of the structuralist approach, specifically its explicit focus on cultural stability and unconscious transmittal of behaviors, were the main sources of criticism of the approach. For scholars interested in how new cultural formations arise, this emphasis on cultural stability had minimal appeal. Secondly, many anthropologists took exception to its relegation of human actors to passive participants rather as potential agents of change. As such, the model had limited utility for explaining cultural change.

William Sewell responded to these criticisms of the structuralist approach in a 1992 article that attempted to return human agency to the structuralist concept of culture. Sewell presented a reformulation of Anthony Giddens's concept of the duality of structure, which was proposed in part to address the absence of human agency in Bourdieu's work, and Bourdieu's concept of habitus. In Giddens's model (1979, 1984), the concept of "structuration" was defined to describe the interplay of structure and agency as two interacting concepts. As outlined by Sewell, Giddens argued that rather than placing constraints on behavior, structures can provide a framework where knowledgeable individuals can act in innovative ways, even to the point of altering the structures that enable them to act. Structure, therefore, can be characterized as a process rather than an immutable set of conditions (Sewell 1992:4). In Sewell's words, structures, in this view, are "virtual," and "are put into practice in the production and reproduction of social life" (Sewell 1992:6). Sewell further argued that human societies comprise a multitude of individual structures of varying scale, each with its own organizational logic. This stands in contrast to Bourdieu's position that treated cultural structures as a more integrated whole. Many of these structures were extremely dynamic and could be manipulated by individuals or groups as a means of acquiring or enhancing power (e.g., capitalism).

In spite of this emphasis on the dynamic nature of many social structures, Sewell also acknowledged that some structures, which he refers to as deep structures, can be extremely durable. These stable, deep structures, such as marriage rules, elements of personal adornment, ritual activities, or language, are often acted upon unconsciously and generally lack significant structural power or the ability to be used to enhance power relations. As such, the behaviors that they represent can continue to exist, relatively unchanged, while other less stable structures are transformed (Sewell 1992:22).

Structuralism and Agency

Recent work on identity and community in the U.S. Southwest may provide an interpretive framework for exploring and understanding the cultural dynamics suggested by the archaeological record at the Luke Solar project sites. In the introduction to their edited volume on southwestern communities, Varien and Potter (2008) present a model of human behavior with strong ties to the structuralist concepts of Bourdieu, Giddens, and Sewell discussed above, addressing some of the model's perceived shortcomings while maintaining its strength as a means of explaining cultural reproduction. Varien and Potter emphasized the importance of human agency that, they argued, functioned in areas where individual choice was limited, such as those structures that would fall under Bourdieu's definition of habitus, as well as behaviors that allowed for more reflexive, individual decision-making (Varien and Potter 2008:7). This relationship between agency and structure simultaneously allows for long-term cultural stability as well as providing a means through which individual human decisions can affect significant cultural change.

The brief exploration of the concepts of structure presented above suggests one possible explanation for the apparent long-term stability of behaviors reconstructed for the Falcon Landing site. It is apparent that throughout the occupational history of the site, the core suite of activities attested to in the archaeological record were performed by relatively small groups, perhaps individual families or related task groups. Behaviors at this scale are likely to meet the requirement of deep structures in their lack of structural power. While clearly serving an important economic role in the lives of the people who created the archeological record at Falcon Landing, these deep structures may not have provided an opportunity for participating social actors to manipulate the activities in such a way as to enhance their economic, social, or political power. As such, the potential may have existed for these activities to enter the realm of deep structure and continue relatively unchanged through time.

If the activities reconstructed for the Falcon Landing site do in fact represent deep structures as discussed above, this would have important implications for understanding questions of cultural identity across the five millennia represented in the site's archaeological record. Perhaps most significantly, these data would imply a remarkable level of continuity between the various archaeologically defined cultures represented at the site, reflecting a shared history of at least a core group of people. While not precluding periodic inmigrations of peoples with differing cultural practices, the local traditions appear to have won out and were adopted by any new arrivals.

Land-Use Patterns

The Luke Solar project land-use theme as presented in the HPTP included the topical subthemes of subsistence patterns; technological trends; settlement, demography, and social organization; interaction, exchange, and cultural boundaries; and regional considerations. The ways in which the Luke Solar project results contribute toward our understanding of these themes are presented and explored and presented.

Subsistence

The data on subsistence activities in the Luke Solar project area were primarily derived from preserved plant and animal remains, ground stone tools, and characteristics of the earthen pit features. As described above, the natural environment surrounding the Luke Solar project area afforded a localized and high-value resource zone within an otherwise relatively unproductive and monotonous lower-*bajada* setting. The presence of a perched water table immediately south of the project area was apparently attractive to human groups for thousands of years. Although intermittent occupations persisted for millennia, the subsistence pursuits remained largely unchanged. It appears that groups primarily inhabited the Luke Solar project area for the purpose of procuring and processing wild-plant material, particularly mesquite and other weedy annuals. The macrobotanical record (see Chapter 6) indicated that groups were drawn to the area to benefit from a number of wild plants with edible parts, including the fourwing saltbush (*Atriplex canescens*); mesquite (*Prosopis* spp.); annual plants such as Indianwheat (*Plantago* spp.), goosefoot (*Chenopodium* spp.), pigweed (*Amaranthus* spp.), purslane (*Portulaca* spp.), and horse purslane (*Trianthema portulacastrum*); and at least one type of grass, panicgrass (*Panicum* spp.). Mesquite and saltbush were also heavily used for fuelwood and construction material consistently through time, as well as saguaro, ocotillo, and creosote bush to a lesser extent.

The Luke Solar pollen record (see Chapter 7) indicated an overwhelming cheno-am signature that in all likelihood represented numerous plant species, but the most logical candidate was saltbush (*Atriplex* spp.), a dominant shrub in the modern vegetation. Economically important plants identified in the Luke Solar pollen record included mesquite, palo verde (*Parkinsonia* [*Cercidium*] spp.), Indianwheat, hackberry (*Celtis* spp.), wolfberry (*Lycium* spp.), and grass seeds. These plants have a wide variety of documented and important ethnographic uses (see Chapter 9) and can also aid in interpreting the seasonality of the prehistoric occupations. A single grain of maize pollen was identified from the floor of a San Pedro phase structure, suggesting that during the San Pedro phase, the prehistoric inhabitants of the project area had access to this domesticated crop; but the lack of maize elsewhere in the Luke Solar pollen record indicates groups were not actively engaged in agriculture within the project area. The analysis of pollen washes from select buried metates in the project area also contributed some interesting results. Traces of palo verde, wolfberry, and grasses were identified, as well as two riverine taxa: cottonwood and a possible cattail grain. The presence of these riverine taxa indicate groups maintained a close connection to a well-watered setting, but it is not clear if this location was the mesquite bosque located immediately south of LAFB or the Agua Fria River located 6.7 km (3 miles) to the east. Both the pollen and macrobotanical records indicated that the Luke Solar project area was likely occupied during the early spring to late summer. Occupations may have occurred sporadically or occasionally as different plants matured on the landscape.

Animal remains recovered from the Luke Solar sites (see Chapter 4) strengthened the interpretation derived from the botanical evidence: the project area was used primarily as a plant-food-processing locale. Effectively there was no evidence for hunting parties travelling to higher elevations or other environmental zones to bring back deer, pronghorn, or mountain sheep. The faunal collection indicated that people opportunistically caught small leporids, rodents, and other small animals consistently over time, but—given the collection's modest size—hunting never played an important role in the vicinity of the project area. Leporid carcasses were heavily processed, as evidenced by highly fragmented bone in all contexts. Examination of bone densities per volume excavated and assigned to a temporal component generally indicated low intensity of faunal exploitation over time, as might be expected if the site population was focused on the gathering and processing of apparently abundant plant resources.

The paleobotanical and faunal materials were important for knowing what kinds of plants and animals were used across the site, but they did not inform on what was processed, used, or stored in the specific extramural pits in which they were preserved. This, of course, was because these features were cleaned out after their original use and then filled with trash and/or wind and water-lain sediments. Yet, it was important to determine, to the extent possible, the original purposes of the pit features. On a coarse level, functions of the project's food-processing and storage-pit features were determined by creating a morphological typology (see Chapter 4, Volume 1). This typology was then narrowed down to a few functional types (see Chapters 9 and 10). Analysis of the project's extensive and diverse ground stone collection has singled out mesquite as a primary focus of the subsistence activities (see Chapter 3). Another subsistence focus was the manufacture and refurbishing of bifacial tools. Like the materials used for local ground stone manufacture, stone for these bifacial tools was predominantly procured from the cobble beds along the nearby Agua Fria River. Compared to the bifacial debitage counts, few bifacial tools were found at the project sites. People provisioned and emplaced site furniture for long-term use, including pounding and grinding implements and serviceable cores, but they departed the project area with refurbished and replenished tools, including both mobile bifaces and, possibly, flake blanks.

Earthen Pit Technology and FAR

Chapter 9 looked at food-processing activities in the ethnographic record and their expected archaeological signatures, with a focus on features and ground stone. But the expected feature types were for ideal circumstances with perfect preservation, whereas nearly all of the Luke Solar features had lost a critical component—their original fill, including diagnostic plant remains, faunal bone, and FAR. All that was left to characterize the original pits was their size and shape and whether they were oxidized. This was enough information to determine whether they were used for storage, cooking, or processing/storage, but there was not sufficient information to determine more-precise functions. In previous chapters, we made some strides towards this goal by narrowing down the options of the foods most likely processed in significant quantities at the project sites. These foods were mesquite, small seeds, cholla, and meat, with palo verde, greens, and berries among the plants that were used in smaller amounts.

Most of the subsistence data, primarily about plants, came from Falcon Landing—the focus of this summary. The subsistence features were extramural and intramural pits (both thermal and nonthermal), activity surfaces, FAR concentrations, and in some cases, house floors. Of the 2,738 extramural pits found at Falcon Landing, 2,408 had a likely food-processing or storage function. Morphologically, they were classified as nonthermal pits (n = 2,373), thermal pits (n = 330), bell-shaped nonthermal pits (n = 25), and bell-shaped thermal pits (n = 10). Similar pits with similar presumed functions were also excavated in structures, although in much smaller numbers—the number of intramural pits of all types was roughly one-tenth the number of extramural pits of all types. As shown in Chapter 10, the frequency and relative distribution of the pit types changed through time, at times dramatically, but all types were used throughout the 5,000 years of site occupation. Because bell-shaped pits can only be identified in cross-section, more were likely present in the inventory of unexcavated pits exposed in plan view during mechanical stripping. Of the identified extramural pits, 1,396 were excavated or sampled; these included 1,098 nonthermal, 272 thermal, 17 bell-shaped nonthermal, and 9 thermal bell-shaped pits. The extramural pits were assigned to 16 mutually exclusive classifications based on four attributes—in-situ burning, profile shape, volume, and shallowness (see Table 73, Volume 1, and Table 90, this volume). Based on these criteria, each of the 16 pit types was then assigned one of three functions—cooking, storage, or processing/storage (see Chapter 10). Processing/storage pits—all of which were nonthermal, shallow pits regardless of diameter—formed the largest functional category (n = 1,060). Most of these were regular basin-shaped pits, but irregular, conical, and cylindrical shapes also were recorded (as they were for thermal pits). Although in Chapter 10, all thermal pits, regardless of diameter, cross-sectional shape, or content, were classified as cooking pits, we here reclassify bell-shaped thermal pits as storage features. As discussed in Chapter 9, thermal pits with bell or deep basin shapes in cross section likely were storage pits whose walls and bases were made stronger by firing (and thus oxidizing) them. Thus, in this chapter, only basin-shaped (or variants thereof) thermal pits were classified as firepits (n = 271), and accordingly, all bell-shaped pits (nonthermal and thermal) and nonthermal pits that were deep, as determined by their depth index, were classified as storage pits (n = 78).

Next to oxidized features, FAR was the best indicator of thermal activities (i.e., parching and baking). As a rule, FAR was found outside its original context in concentrations or redeposited in extramural pits, structure fill, and middens. Because FAR would not have moved over long distances, we expected that the greatest densities of FAR would be in areas that experienced the most intensive thermal activities. Chapter 9 discusses the possibility that much of the FAR was the result of parching, with parching features showing little or no oxidation because low heat was used. If so, some or even many of the project's nonthermal pits might have had a thermal function. In those cases, nonthermal pits would be associated with high densities of FAR, perhaps as high as that expected for thermal pits. Spatial patterning showed FAR to be located more often in thermal pits than in nonthermal ones, although not by a great margin (see Chapter 10). The amount of FAR in thermal vs. nonthermal pits fluctuated through time, with nonthermal pits containing more FAR during certain periods. The common association of nonthermal features with FAR makes sense because most of these features were interpreted as mortar, metate, or basket supports. The pounding, grinding, and storing activities went hand in hand with the parching or baking activities. With all these activities happening in the same place, FAR would have been easily incorporated into all of these features.

Mesquite and Seed Processing

As hypothesized, at Falcon Landing there were five main plant-processing activities using features: parching, baking, grinding support, cake forming, and storage. Most of the several thousand nonthermal features at the site likely served as mortar or metate supports (small shallow pits) and basket rests (small to medium-sized shallow pits). These clearly correspond to the "cooking/storage" category named above. Fewer features were storage pits (deep medium-sized, bell-shaped, or basin-shaped pits), or perhaps earthen mortars (small deep pits) or cake molds (small but deep elliptical or cylindrical pits). Of all extramural pits at the site, storage pits were the least nebulous as to function. We know that food products were stored in them, and at Falcon Landing, most of these products were likely the cakes made or baked from the flour from mesquite pods and seeds. Storage would have been for the stay at the site, with all products packed up and taken away after finishing the mesquite harvest.

Thermal pits were the second-most-numerous feature type at Falcon Landing. Parching of mesquite pods and various small seeds (e.g., mesquite, grasses, and weedy annuals) likely was the most common thermal activity at Falcon Landing. In ethnographic accounts, mesquite pods and small seeds were parched using four different methods: (1) in a basket with hot coals, (2) in a ceramic vessel on hot coals or rocks, (3) on hot earth (in a shallow but large pit for pods; on a broad surface for bundles of plants), and (4) on a surface of hot stones (for pods and bundles of plants). Under ideal preservation conditions, these methods would have resulted in eight different feature types, distinct from each other in size and shape and by the presence or absence of ceramics, FAR, and diagnostic paleobotanical materials in the fill. For Falcon Landing, we can eliminate the method using ceramics. Because the original feature fill was gone, we can also discard FAR and plant remains, and thus, we are left with only three parching feature types: small thermal pit (for Method 1), large but shallow thermal pit (for Method 3, pods), and broad thermal surface (for Method 3, plant bundles).

Baking likely was the second-most-common thermal activity at Falcon Landing, necessary to make cakes, remove the salty taste of saltbush seeds, prepare cholla buds, and cook meat. Cakes were primarily made from the flour of seeds. Although cakes were sometimes baked from mesquite-pod flour, it was not necessary because mesquite-pod-flour cakes harden by themselves. Making cakes was important because they were highly transportable, preserved for a long time, and were easy to store. Disregarding the lost original fill (which might have contained FAR and/or diagnostic plant remains), baking at Falcon Landing would have resulted in only a few different types of thermal pits. Cake-baking pits would have been small and relatively deep, and similarly, baking pits for saltbush seeds would have been small and relatively deep. Cholla-baking pits would have been medium sized, deep, and possibly rock lined. Meat-baking pits would have been small to medium sized and moderately deep. Clearly, it is their greater depth that distinguishes the baking pits from the parching features.

Thus, we can tentatively link thermal features to parching, baking, and storage by size and/or shape. Small-to-large, shallow pits and broad surfaces were likely parching features; small-to-medium-sized, and deep pits may have been used for baking, and bell-shaped pits were used for storage. The most important distinction between parching and baking features was their difference in depth, with the first shallow to surficial and the second deep. With this distinction in mind, decoding the numerous excavated thermal pits at the site was a somewhat less-daunting task. Spatial relationships between contemporaneous features also informed on subsistence activities. For instance, parching usually occurred in the same area where temporary storage in baskets and pounding and grinding took place. It follows that we could expect a spatial relationship between shallow thermal pits (parching) and small shallow or deep nonthermal pits (metate and basket supports, mortar supports or earthen mortars), as well as with in-situ ground stone artifacts or caches. "Thermal surface" was not a feature type at Falcon Landing, but at least two of the activity areas at the site (Features 10180 and 18782) contain oxidized areas (see Chapter 4, Volume 1). The oxidation may have been the result of the burning of a ramada or other superstructure, but the absence of postholes suggested this oxidation may have been remnants of parching surfaces.

Ground Stone Correlates of Mesquite and Seed Processing

The second important signature of plant processing was ground stone. Ground stone from Falcon Landing consisted of 575 metates, 760 manos, 7 mortars, 94 pestles, 68 Lukeoliths, 43 netherstones, and 537 indeterminate pieces (see Chapter 3). Ground stone tended to be located within structures and closely associated extramural pit features (see Chapter 10). Most of the recovered metates were basin and flat/concave forms, typically used for processing wild-plant foods. The netherstones were moderate sized and showed little or no pecking. They may have been used for similar grinding tasks as the metates, or different tasks. The manos were primarily made of large, oval-shaped cobbles. Most of the mortars were made of vesicular materials and most were large (two boulder mortars weighed more than 28.8 kg each); their deep basins suggested they were used to hold large volumes. The large and deep vesicles suggest that the mortars were used to crush hard and coarse materials, such as mesquite endocarps (see below). Thirteen times more pestles than mortars were found, with different types that spanned the entire spectrum from pounding to grinding. Most were large and heavy, averaging 30–40 cm in length and 9 cm in diameter, with a mean weight around 3 kg. They would have been used with equally large mortars. A diverse range of raw materials was used for pestles, but in contrast to the mortars, vesicular stone was rare. Three basic forms of pestles were identified—round-, flat-, and irregular-ended—with the first two most common. Round-ended pestles were cylindrical to oval, usually long, and were suited to pound soft materials (such as mesquite pods); generally, this shape would be associated with round-bottomed wooden mortars. Flat-ended pestles were conical or barrel shaped, and fit a more flat-bottomed mortar. They had a wide range of sizes, likely reflecting different tasks. Conical, flat-ended varieties are suited for mashing and stirring (such as done with the pulp of mesquite pods), whereas the small flat ends of barrel-shaped pestles focus the tool on a small area and make them better for crushing (such as hard seeds). Irregular-ended pestles may have functioned in many different ways, but one globular-shaped example was found with a boulder mortar. The 13-to-1 ratio of pestles to mortars at Falcon Landing supports the arguments made in Chapters 3 and 9 of this volume: most mortars used at the site were probably made of wood and did not survive in the archaeological record.

Lukeoliths, a subtype of pestle, were similarly used with mortars. They generally were subrectangular to almond shaped with convex to slightly concave faces, and as a group, they were homogenous in size. Most were made of vesicular basalt. Use wear always included end polish or pecking, and nearly one-third of the tools showed light to moderate grinding on one or both faces, indicating additional use as a bottom stone. The end wear extended a short distance up the face, but often much higher on the margins, indicating that the tools had come in contact with the walls of a mortar. The smooth rounding and polish was similar to that commonly evidenced by pestles. Vesicular basalt specimens with heavy polish showed wear extending a short distance into vesicles but without affecting the sharp crystalline bottom edges. This was taken as evidence that the contact material was wood and not stone.

Ethnographic accounts indicate that processing mesquite involved the use of a highly diverse ground stone tool kit, including not just different types of mortars and pestles, but also metates and manos. The tool kit for processing mesquite was more diverse than that known for the processing of any other plant species in the Sonoran Desert. What also made mesquite-processing tools so different was that they were not just made of stone but also wood. The great tool diversity was dictated by the particular makeup of the mesquite pod, which contains two different food sources—the sugary pulp and the protein-rich seed, both needing mortar and pestle for initial processing, followed by the use of metate and mano for grinding into flour. Grinding into flour was done with simple shallow-to-deep basin metates and associated cobble manos, similar to those used for grinding other plant materials. It was the use of various mortars and pestles that sets mesquite processing apart. Because mesquite pods and seeds are so different from each other, both in mass (pods are bulky, seeds are not) and texture (pods are relatively soft but sticky, seed coats are hard and difficult to crack), different mortars and pestles were needed for each process. Large mortars were used for large quantities of mesquite pods, with pounding done in a standing position. These mortars were often made of wood, and so were the long pestles, although a combination of wood and stone was common. For smaller quantities of pods, smaller mortars and pestles were used (usually stone on stone or wooden mortars with stone pestles), with pounding done sitting down. Importantly, this was only the first step in mesquite processing: separating the husk, pulp, and endocarp-coated seeds. The second step was to obtain the seed enclosed within the endocarp. Ethnographic examples of mesquite-seed processing—which involves cracking the seed endocarp—are rare. Most data are for hunter-gatherers, such as the Seri; sedentary agriculturists generally did not bother to take this arduous step, which had little return for much work. In the few known examples, this processing step was done with smaller mortars and pestles made of stone, not of wood. Archaeological evidence suggests that prehistorically, gyratory crushers (a distinctive kind of mortar, either in slab or block form, with a hole in its bottom), likely paired with wooden pestles, were used to do the same thing, crushing the seeds together with the pods (see Chapter 9). But no gyratory tools were found at the project sites, so we must look at the different mortars and pestles to determine whether mesquite seeds were processed, and if so, how.

The Luke Solar mortars and pestles fit the ethnographic evidence well, with the exception of the wooden mortars, which would not have preserved. It is interesting that the few mortars found at Falcon Landing were mostly made of vesicular material, which is very different from a hard wood such as that of mesquite or fine-grained bedrock mortars, both commonly associated with mesquite-pod processing. Vesicular stone, either as pestle used on a stone or wooden mortar, or as mortar used with a wooden or stone pestle, may have had the perfect abrasive quality to help crack the endocarps. Another explanation may simply be that vesicular material weighed less and allowed larger blocks of stone to be hauled to the project area. The different pestle forms were so distinctive that each may represent a special stage in mesquite processing. The round-, flat-, and irregular-ended pestles were mostly made of fine-grained materials, and overall they were similar to the pestles used for the first stage—crushing and meshing the pods to separate the husk (exocarp), pulp (mesocarp), and hard seed coat (endocarp)—as discussed in the ethnographic studies. Lukeoliths were very different from the other pestles, suggesting that their use was also different. Were they used for the second stage of pounding to break the endocarp? Or were they a multitask tool used for both? The preferred stone for Lukeoliths—like for the mortars—was vesicular basalt. Vesicular stone is highly abrasive and was preferred for the grinding of maize kernels on metates and likely also for breaking the mesquite endocarps in mortars. Crushing the pods, which made a sticky mess, was more easily accomplished with fine-grained stone or wooden pestles and mortars. Likely, then, Lukeoliths were used to crush mesquite endocarps and obtain the seeds inside. Future work on Lukeoliths should include plant-residue analysis and also experimental studies to ascertain the validity of this hypothesis. At this juncture, the best interpretation is that Lukeoliths represent a distinct variety of pestle that was used to process the endocarp-coated seeds of mesquite in large wooden mortars.

What is clear from the features, lithics, and plant and animal remains is that the project area witnessed the same subsistence strategies for five millennia; the same types of features and tools were used to process mesquite, produce and maintain a hunting tool kit for use at other locations, and opportunistically gather other edible plants and hunt various small animals in the project vicinity. In ethnographic accounts, concentrated areas of mesquite trees were considered a shared resource. The yearly mesquite harvest attracted different families, traveling to these places from their main residences for a time of coming together. Men would participate in the harvest but also take care of other tasks, e.g., gearing up for future hunting trips, as suggested at the Luke Solar sites. No doubt, for Native Americans such mesquite groves were a big part of the collective, remembered landscape, traditional places used in the same way since time immemorial.

Technological Trends

Technological trends witnessed in the project collection show an interesting redundancy over time, particularly in regard to the stone artifacts. The flaked stone debitage was consistently dominated by bifacial-reduction debris. The amount of bifacial-reduction debris suggests the site occupants were primarily engaged in manufacturing or maintaining bifaces. Flaked stone artifacts were almost exclusively derived from locally available, waterworn volcanic cobbles, particularly basalt and rhyolite. These materials were likely obtained from the nearby Agua Fria River channels and indicate a preference for local material for all aspects of flaked stone tool manufacture and use. Ground stone items included predominantly manos and metates, but mortars and a large number of pestles were also present. The ubiquity of ground stone implements corresponds well to the botanical evidence presented above, indicating that the record of occupation in the Luke Solar project area was consistent with plant-food procurement and processing. There was also evidence for a heavy investment in ground stone tool manufacture; many of these large, shaped implements were cached within the project area to provision future processing needs. On-site biface reduction and maintenance were also primary site activities, as evidenced by the numerous biface-reduction flakes and relatively few broken bifaces and abandoned or lost projectile points recovered from the excavations. The flaked stone technology practiced at Falcon Landing was focused on provisioning in anticipation of upland artiodactyl hunting. It is important to note, however, that there was no evidence of artiodactyl carcasses or carcass portions at any of the project sites. The relatively limited amounts of faunal remains recovered from the project sites were not sufficient to explain the amount of bifacial-reduction debris in the stone artifact collection, and the project faunal collection is best interpreted as the result of opportunistic encounter hunting of leporids at or near the site. This disparity perhaps indicates the occupants were not solely engaged in processing plants, and that biface manufacture was also an important activity in the project area. Interestingly, there were not many bifaces in the stone artifact collection, further indicating that these tools were manufactured and maintained on-site but were transported off-site for other purposes. Some of these bifaces may have also functioned as easily transported cores that could be used during upland hunting forays (see Kelly 1988).

A small number (n = 125) of ceramic artifacts were recovered from the Luke Solar sites, including 109 sherds from the modern ground surface, 12 from feature contexts, and 4 buried sherds from nonfeature contexts. Remarkably, 2 sherds from San Pedro and Cienega phase contexts (ca. 1200–200 cal B.C.) at Falcon Landing represent the earliest stages of ceramic technology in the U.S. Southwest. The majority of the sherds (n = 122), however, were Gila–Salt Basin Hohokam ceramics, including plainwares, some Sacaton Red-on-buff, and a few indeterminate buff and red-on-buff wares. Sherd inclusions also suggested the presence of both decorated and plainware pottery made within the local area (i.e., somewhere within the vicinity of the Agua Fria River valley) and vessels that were tempered with crushed micaceous schist and imported from areas to the south and east of the project area, likely along the Gila River. The overall paucity of ceramics recovered from the Luke Solar sites can be explained in two ways. First, most of the occupations in the Luke Solar project area predated the adoption and use of a ceramic container technology. Second, groups occupying the project area during the Ceramic period only imported ceramic vessels for specific tasks, and ceramic vessels were neither produced nor regularly discarded within the project area. The use of ceramic vessels within the project area was likely only occasional, used to support subsistence activities such as the acquisition of resources.

Introduction of Maize: Archaeological Correlates and Implications

A single grain of maize pollen was recovered from the floor of a San Pedro phase structure at Falcon Landing (see Chapter 7), possibly arriving at the site as detritus carried from a nearby riverine occupation. Questions about how maize agriculture was introduced into the U.S. Southwest include an explicit "by whom" component that alludes to yet-unnamed Middle Archaic group(s) sometime before 2100 B.C. (Mabry 2005a). The prevailing models point to either the rapid diffusion of maize-farming knowledge among regional hunter-gatherer populations (Haury 1962; Irwin-Williams 1973; Merrill et al. 2009; Wills 1988), or the in-migration of maize agriculturalists (Berry and Berry 1986; Haury 1983; Hill 2001; Huckell 1990). Although archaeologists have relied on projectile points (traditionally associated with males) to assign pre-ceramic cultural identities, it is acknowledged that the adoption of new plant foods may indicate that female relationships should also be considered (Roth 2006). Gypsum Cave–style points have been offered as evidence of a possible Mesoamerican projectile point style associated with early maize (Berry and Berry 1986; Carpenter et al. 2005), but the style is widespread and still predates the introduction of maize by several centuries (Huckell 1984b; Mabry, ed. 1998b:111; Matson 1991). In the middle Santa Cruz River valley, Cortaro and "Pinto-like" projectile points have been associated with early maize (Gregory, ed. 1999), although one of the projectile points clearly resembles the Chiricahua type (see Chapter 3).

Merrill et al. (2009) have proposed that Uto-Aztecan speakers played a crucial part in the diffusion of maize farming, not as a wave front, but as a preexisting medium of would-be farmers. Tepiman language group members, including Yuman and Piman societies that lived in or near the project area, have a high incidence of the "Albumin Mexico" mutation, a Mesoamerican trait variably shared among Uto-Aztecan populations (Hill 2001). The lack of mtDNA evidence for a Mesoamerican origin of Uto-Aztecan speakers supports the potentially significant role of traveling males. Although all-male migrations from central Mexico to the northern limits of the Great Basin are considered unlikely, band-to-band diffusion is regarded as a likely scenario. Merrill et al. (2009:21,024) have proposed a post-Altithermal Uto-Aztecan repopulation of the U.S. Southwest from north and south around 3900 B.C. that created a cultural continuum through which maize diffused.

There is a high likelihood that the Middle Archaic people(s) that introduced maize to the U.S. Southwest were also the makers of one or more distinctive projectile point types (e.g., Chiricahua, Cortaro, etc.). The age and geographic distribution of individual Middle Archaic projectile point types are not well documented, but the life zones of the Southwest can be expected to show fundamentally different behaviors over short distances, a point made by Huckell (1984b) in his critique of the Cochise culture. Middle Archaic sites are both rare and multicomponent, however, so linking early direct dates on maize with projectile point types may be a long process and may not prove to be meaningful for understanding the propagation of maize.

As a foraging site dedicated to the intensive processing of native-plant foods, and in light of extensive and intensive sampling, the Falcon Landing projectile point collection is significant in terms of what types were represented and what types were missing. Assuming that Middle Archaic hunters would not travel great distances to participate in the activities at Falcon Landing, then the projectile points associated with nondescript but long-term plant-processing sites can be expected to be dominated by local traditions. For example, Pinto, San Jose, and Gypsum-style projectile points are common components at Middle Archaic sites in *cienega*, dunal, cave, and upper piedmont sites (e.g., Bayman 1986a; Gregory, ed. 1999; Haury 1950; Huckell 1984b; Roth and Freeman 2008; Sayles and Antevs 1941; Whalen 1971, 1975), but unambiguous examples of those types were not found at the Falcon Landing site. If the initial dispersal of maize into the Phoenix Basin happened between 4300 and 2100 B.C. (Merrill et al. 2009), then the women argued to be responsible for incorporating maize into their foraging economies were probably directly related to men that made Chiricahua, Cortaro, Datil, and other dart points (i.e., Mabry 2005a; Roth 2006).

Settlement, Demography, and Social Organization

For over 5,000 years, the project area primarily functioned as a mesquite-processing camp and at times also as a seasonal habitation. It was used most intensively during the Middle and Late Archaic and Early Ceramic periods. The same subsistence strategy persisted successfully all this time, with the reliable mesquite crop as the primary targeted food source. At the same time, another, very different resource was procured nearby—stone from the Agua Fria riverbed, 6 km (3.7 miles) to the east for making bifacial flaked and ground stone tools. Ground stone tools were used in the project area, primarily for processing mesquite. Flaked stone tools were taken elsewhere to be used for animal procurement and processing. These two different resources—mesquite and stone—and perhaps also the availability of water were the raison d'être of Falcon Landing and nearby sites, although people also collected other plants and opportunistically hunted small animals in the site vicinity. The nearby river has no associated floodplain in this part of the valley, and agriculture was not an option, explaining the dearth of maize and other cultivars in the archaeobotanical record.

Based on the known inventory of available resources, Chapter 9 discusses Archaic period seasonal movement on the *bajada* between the White Tank Mountains and the Agua Fria River. A series of cold-season base camps are presupposed along the mountains, specifically in the east-facing canyons that contain permanent water sources, including *tinajas*. Rockshelters and other protected places would have been prime locations for these residences. From here, people could procure acorn and artiodactyls in the fall and agave in late winter/early spring, among other mountain food resources. Stored foods (such as mesquite, saguaro, and other plant products) collected during the summer would form part of the food supply. In spring, people left these base camps and descended to the lower *bajada* for the harvest of spring plants, particularly mesquite, setting up camps along mesquite bosques such as at Falcon Landing. Mesquite harvesting and processing might take 1 month, completed before the start of the monsoon rains around mid-July. While women were busy collecting, parching, and baking plant foods at Falcon Landing, men headed to the nearby river to collect stone needed for making grinding implements and bifacial tools. With the mesquite harvest done, ground stone tools cached, and cakes and finished flaked stone tools packed for transport, people would head back towards the upper *bajada* where saguaro fruits were now ready to be picked. If different families had converged in the project area for the mesquite harvest, they would set up individual processing camps to collect and process saguaro. Finally, after the saguaro harvest, families went back to their base camps along the mountains. Of course, this inferred seasonal pattern is just for vertical movement between mountains and river, and should not be interpreted as a comprehensive regional mobility model for the groups using the project area. As discussed in Chapter 9, people also moved horizontally, likely over great distances, even within the same biotic community (e.g., lower *bajada*). Ascertaining the scale of mobility for prehistoric land use is a complex task, however, which is why our discussion of seasonal mobility has focused on the immediate catchment area—the *bajada* between the White Tank Mountains and the Agua Fria River. In the following section, we will compare this settlement pattern with others in similar settings across the region.

The Summer-Lowland and Winter-Upland Settlement Pattern

How does the inferred land-use pattern described above compare to the archaeological data? As reviewed in Chapter 2, Volume 1, survey and testing along the eastern flanks of the White Tank Mountains and adjacent upper *bajada* has yielded little evidence of Archaic period occupation. Most prehistoric sites have been attributed to the Hohokam and date to the late Colonial–Sedentary periods (A.D. 700–1150) (Breternitz 2004; Ellis 1997; Potter and Garrotto 2000). Sites include rockshelters and small habitations—several with small ball courts—and features include large roasting pits, which may have been used to process agave. No evidence was found for agriculture, and people residing here were thought to have subsisted on the local wild-plant and animal resources. Overall, the sites had higher proportions of ceramics than flaked stone, with little evidence of flaked stone and ground stone procurement and manufacture. Potter (2002:199) has suggested that this is because most lithic sources in the area are granite—not a good material for flaked stone tools. Most ground stone was vesicular basalt, likely imported from the banks and channel bars of the Agua Fria River. Part of the preponderance of Hohokam signatures may be because of their greater visibility, and this would certainly be true for the reconnaissance of the White Tank Mountains Regional Park conducted in the early 1960s (Johnson 1963). But it is surprising that two large surveys (together covering nearly 10,000 acres, with 74 sites recorded, of which 33 were tested) conducted by Soil Systems, Inc. (Breternitz 2004; Ellis 1997) and SWCA (Potter and Garrotto 2000) found no Archaic period sites or site components. Likely, desirable places such as rockshelters and sites near water (*tinajas* or rock tanks) contain underlying Archaic period materials. Indeed, the presence of Middle and Late Archaic projectile points found at some of the sites or as isolates indicates that the area was certainly used during the times that Falcon Landing was occupied, supporting the land-use model offered above.

Because data on Archaic period use of the White Tank Mountains/Agua Fria *bajada* are so sparse, we need to look elsewhere to substantiate our proposed model. For comparison, we selected four relevant Middle Archaic, Late Archaic, and/or Red Mountain settlement systems, located in the Phoenix Basin, the Tucson Basin, along the San Pedro River, and along the Rio Grande in Texas. Environments range from lower to upper Sonoran Desert to Chihuahuan Desert grassland, but all these systems involve sites on the lower and upper *bajada* and along mountains. Most comparable to Falcon Landing is Last Ditch (AZ U:5:33 [ASM]), a site located approximately 40 km (25 miles) away on the middle–lower *bajada* west of the McDowell Mountains in Paradise Valley of the northern Phoenix Basin. The site was occupied during the Middle and Late Archaic periods as well as in the Red Mountain phase. Excavations exposed four small structures (likely brush-covered shelters), several middens, numerous extramural features, FAR scatters, and relatively few artifacts, all in a 115-acre area. Macrobotanical samples contained charred amaranth seeds and fragments of mesquite pods and seeds. The site also showed slightly elevated counts of cheno-ams, spurge, mustard, *Liguliflorae*, tidestromania, and cholla. Phillips et al. (2009:63–64) theorized that Middle Archaic period gatherers targeted small seeds from grasses and annual herbs then parched them in baskets using heated rocks, which explains the many thermal pits found at Last Ditch. After parching, seeds were believed to have been transported to a base or field camp to be ground into meals for consumption.

Rogge's (ed. 2009:70–77) archival search for all Archaic period sites within a 25-km radius of Last Ditch identified 23 sites, consisting of 4 base camps, 7 field camps, 11 locations, and 1 station—functional site types derived from Binford's (1980) model of foraging strategies. Base camps are residential sites containing the highest artifact and feature diversity and typically are associated with vital resources such as permanent water, rockshelters, and rich food-resources patches. From these camps, groups would make excursions to different places to procure various resources, which were brought back to their residence. Two base camps near Last Ditch were open-air sites with substantial middens in the southern McDowell Mountains and two others were rockshelters (Rogge, ed. 2009). Field camps are sites that were visited regularly on a temporary basis for resource procurement and processing. They may include ephemeral structures but have less artifact diversity than base camps. Field camps were found exclusively in middle–upper *bajada* settings (Rogge, ed. 2009). Last Ditch was considered a field camp, where task groups processed resources that were returned to base camps. Locations are places that were visited briefly by small groups to procure and process resources, similar to field camps but not occupied with the same regularity. Field camps and locations were distributed evenly through the study area (Rogge, ed. 2009). Stations are places visited by individuals or small groups to gather information (such as game monitoring) or for ritual activities (such as creating rock images). Overall, Rogge (ed. 2009) found that Archaic period groups preferred the Arizona Upland Subdivision over the Lower Colorado Valley Subdivision of the Sonoran Desert, where Falcon Landing is located. These settlement data are not unlike our model of seasonal movement involving Falcon Landing, although previous research has found little evidence of Archaic period occupation on the White Tank

Mountains *bajada*. However, we should keep in mind that for most of the 23 sites in this study, diagnostic projectile points and ground stone or the absence of ceramics were taken as evidence for Archaic period use; only two sites (both rockshelters) were dated based on excavations (Rogge, ed. 2009). Very likely, some of the rockshelters and others sites recorded along the eastern flanks of the White Tank Mountains will prove to be Archaic in age when excavated.

One question this comparison brings up is how Falcon Landing articulates with this functional site typology. In spite of its numerous residential features, it does not qualify as a true base camp because the site did not function as a central hub for multiple, different activities in the area. In general, products left Falcon Landing rather than being brought to it. For instance, although provisioning groups with hunting tools was an important site function, all tools left the site, and game was never brought back. Also, saguaro fruits were a critical food resource gathered not far away on the upper *bajada*, but no charred saguaro seeds were found in the project samples. Thus, in the above typology, Falcon Landing—like Last Ditch—best fits the field camp category, be it one with an extensive residential component. Coffee Camp, located on the Santa Cruz Flats north of Tucson, is another comparable field camp (Halbirt and Henderson 1993). Coffee Camp was a nonriverine, Late Archaic period plant-processing locale where agriculture had no role, even though agriculture did play a role at many nearby and contemporaneous sites in the region. Instead, the large ground stone collection and archaeobotanical evidence indicated the importance of small seeds of grasses and weedy annuals throughout the site's history, combined with some mesquite and cholla. The relevance of Coffee Camp to Falcon Landing is not just that both contained Archaic period components that included numerous plant-processing features and ground stone artifacts, but also that both sites remained untouched by nearby revolutions in subsistence practices.

Based on surveys on the *bajada* between the San Pedro River and the Huachuca Mountains, located in the Chihuahuan grasslands, Vanderpot (1997) described a Late Archaic land-use pattern driven by small-seed procurement and processing on the lower *bajada* in summer and hunting artiodactyls (deer) and exploitation of mountain plants on the upper *bajada* in the winter. The middle *bajada* had the fewest sites and was basically just passed through on the way to other places. In terms of the site typology in Rogge (ed. 2009), large central field camps on the lower *bajada* were surrounded by numerous locales used to collect and parch seeds. Storage features (e.g., rock rings that served as supports for large baskets) at the field camps indicate they likely functioned as logistical collection centers for wild-grain procurement. The field camps were tethered to large, residential base camps located nearby along the river. A different kind of settlement was found on the upper *bajada*, where base camps (associated with small numbers of field camps) were found at the mouths of canyons in the Huachuca Mountains. These mountain camps had a hunting focus, and some also contained large roasting pits, likely used for agave, and bedrock mortars suggestive of acorn processing. This dual upland-lowland (mountain-riverine) settlement pattern was first recognized by Whalen (1971, 1975), based on his work at nearby Archaic sites in the same valley along the Whetstone Mountains (see Chapter 3). But in contrast to the settlement pattern noted for the Huachuca Mountains, Whalen (1971) found that upland sites were more numerous and represented much more intensive occupation than sites on the lower *bajada* or along the river. Likely, this difference was because the San Pedro River has a much wider floodplain along the Huachuca Mountains than along the Whetstone Mountains (several large habitation sites have been recorded along the Huachuca Mountains, including several dating to the Late Archaic). This dual-zone pattern of seasonal land use was common throughout the southern Southwest, but as shown by the San Pedro Valley example, the emphasis on use of either zone differed per geographic area.

For the Tucson Basin, Roth and Freeman (2008) similarly modeled seasonal movement of Middle Archaic foragers between floodplains and upper *bajada*/montane sites. Base camps on the Santa Cruz River floodplain were used in late spring to harvest spring plants and mesquite. By summer, people moved to the upper *bajada* to collect saguaro, returning to the floodplain base camps in late summer to exploit weedy annuals, grasses, and more mesquite until winter, when they moved to the mountains to collect higher-elevation plants and to hunt. In this scenario, and very different from that noted for the lower *bajada* along the San Pedro River, the Santa Cruz River lower *bajada* ranks as a poor resource area. This difference reflects a major contrast between the Chihuahuan and Sonoran Deserts: the lower *bajada* of the first was covered with lush grassland and that of the second with mostly unproductive desert thornscrub. The Tucson Basin model resembles the model for the White Tank Mountains/Agua Fria *bajada* in many ways. The lower *bajada* along the Agua Fria River similarly was a poor resource, except for the presence of mesquite bosques in certain better-watered areas and the availability of grasses and seed-bearing annuals during short periods in summer. A main difference is that the local Agua Fria River floodplain is narrow to nonexistent, with this zone having little attraction except for its stone. Clearly, each geographic area has its own unique circumstances, reflected in its Archaic period settlement.

Some of the best archeological data on mesquite processing come from Texas, with charred mesquite pods, endocarps, and seeds found at a variety of open-air sites and rockshelters, dating to different time periods and found in different geographical areas (Alexander 1974; Dering 1994, 1999, 2001, 2005; Irving 1966; O'Laughlin 1980). A good example of a mesquite-pod-parching feature was excavated at the Arroyo de la Presa site in Presidio County, Texas (Cloud 2004) (see Chapter 9). The Keystone Dam site in the northwestern part of El Paso forms the best comparison to Falcon Landing. This site has evidence of mesquite processing (and other plants) and also some of the earliest houses documented in the southern U.S. Southwest. The Keystone Dam site is located on the lower *bajada*, adjacent to the floodplain of the Rio Grande and west of the Franklin Mountains (O'Laughlin 1980). The primary component was an intermittent residential base camp dating to the Middle Archaic period (2500–1800 B.C.). A second, more ephemeral component was a Ceramic period (160 B.C.–A.D. 1500) seasonal processing camp focused on desert succulents. About 40 Middle Archaic period structures were built in shallow pits, roofed with brush domes, and had unprepared floors that contained small, informal hearths. The structures were about 3 m in diameter and were clustered in small groups. FAR features were found interspersed among the houses. The site is close to six distinct environmental zones, each with a different mix of important plant foods, including mesquite, weedy annuals, and desert succulents. Hunting was not very important, given the sparse faunal collection of mostly rabbit bones. Simple ground and flaked stone tools were made from local raw materials, with flaked stone tools extensively reworked and reused. As O'Laughlin (1980) interpreted this component, during late spring, summer, and fall, the structures were used to store locally gathered plant resources; during winter and early spring, they were used as dwellings. The Middle Archaic period record from Keystone Dam is remarkably similar to that of Falcon Landing. In particular, the emphasis on summertime residence at Falcon Landing for wild plant-food procurement and processing, as well as the architectural characteristics, compare closely to that identified at Keystone Dam. For example, the architecture at Falcon Landing consisted of small, ephemeral brush structures likely used for storage and/or short-term dwellings. The majority of structures at Falcon Landing were constructed during the Chiricahua and San Pedro phases (ca. 3300–800 B.C.), corresponding to the highest intensity of site occupation. A gradual decline of site occupation occurs following the Archaic period, with occupations of shorter duration and less intensity continuing throughout the Ceramic period (ca. A.D. 300–1450).

Our review of Archaic period land use shows that each of these settlement systems was unique. All reflect the riverine-mountain zone dichotomy, with the mountains used as cold-season resource zones in all cases. The main differences were in the use of the lower *bajada*. In the Chihuahuan Desert, this zone was often covered with lush grasslands, making it an important area for summer procurement of wild cereals. But in the Sonoran Desert, the lower *bajada* is mostly covered with thornscrub with few edible species, and—as shown by the Paradise Valley and Tucson Basin examples—was an area mostly passed through on the way to or from the river and upper *bajada*. As noted by Rogge (ed. 2009), the lower-*bajada* setting within the Lower Colorado Valley Subdivision is generally a poor resource zone. Falcon Landing, located in this poor zone, owed its existence primarily to a perched water table and the resulting presence of the nearby mesquite. The questions of whether similar hydrological conditions encouraged mesquite bosques elsewhere along the Agua Fria River, and whether similar mesquite-processing camps were established there, will have to await further research (see following Directions for Future Research). In the meantime, Falcon Landing is considered unique on several levels. First, it was a vast residential site intermittently occupied for over three millennia throughout the Archaic periods, thus giving a tremendous boost to our knowledge of settlement during this poorly understood time. Second, the site provides an unsurpassed archaeological opportunity for the single-focused study of mesquite use—the first time in the U.S. Southwest that this economy can be isolated over such a long period of time. In particular, the project's extensive and varied ground stone collection has provided researchers with food for thought for many years to come. Third, the concurrent manufacture of bifacial tools, not for local use but for provisioning in anticipation of upland hunting, shows a very different site use as a gear-up camp. No doubt, hunting camps along the White Tank Mountains contain the very tools manufactured in the project area. Together, Falcon Landing's mesquite-processing and lithic-provisioning components well illustrate the site's special place in the winter-upland and summer-lowland settlement pattern characterizing the Archaic period in much of the U.S. Southwest.

Mortuary Patterns

Two human burials were identified in the Luke Solar project area, including one secondary inhumation and one secondary cremation (see Chapter 8). A review of Archaic period mortuary practices in southern Arizona demonstrates that the Luke Solar burials were not dissimilar from other sites. In other words, secondary cremations and inhumations have been documented previously for the Archaic period. Differences between the burial features at Luke Solar and those of the comparative sites, however, are significant. As a result of postdepositional taphonomic processes, the Luke Solar burials contained relatively few human remains and also a fundamental absence of definable mortuary behavior. The rarity of human burials in the project area likely reflects the prehistoric land-use practices. Short-term, seasonal occupations would preclude the normal mortuary behavior practiced by groups during this time. The deceased were likely transported out of the project area and interred at a base camp where the proper rituals and customs could be performed with the larger community. The association of an Elko and a side-notched San Pedro projectile point with the secondary cremation may be significant in this regard, possibly indicating the absence of a larger kin-based community and prescribed burial place.

Interaction, Exchange, and Cultural Boundaries

The Luke Solar project represents a distinctive lower-*bajada* resource zone that was routinely exploited by both Archaic and Ceramic period groups for at least 5,000 years. As human groups positioned themselves across the landscape to optimize the economic potential of the region, the perched water table and mesquite bosque associated with the Luke Solar project area became an important location for plant procurement and processing. It stands to reason that this positioning on the landscape would correspond to seasonally available plant and animal resources. According to the botanical record described in Chapters 6 and 7, the project area was likely occupied during the early spring to late summer to exploit the available wild-plant resources. The proximity of the Luke Solar sites to the Agua Fria River may have also played an important part in this seasonal transhumance. The gravels of the Agua Fria River obviously provided an inexhaustible supply of raw lithic material for flaked and ground stone tools. The Agua Fria may have also acted as a natural north–south corridor for groups traveling between lowland (Phoenix Basin) and upland (Central Highlands or Coconino Plateau) areas. The only evidence of upland resources in the Luke Solar sites was a negligible amount of obsidian artifacts. EDXRF analysis demonstrated that a total of 17 obsidian flakes originated from the Government Mountain obsidian source located 200 km (124 miles) to the north of LAFB near Flagstaff, Arizona. The only other nonlocal lithic source identified in the project collection included 9 pieces of obsidian from the Vulture geologic source, located about 70 km northwest of LAFB. Another nonlocal commodity recovered from the Luke Solar sites was *Olivella* shell; numerous *Olivella* shells were acquired from the Gulf of California, located about 250 km (155 miles) to the southwest. Both the Government Mountain obsidian and the *Olivella* shells may have been directly procured, but they likely indicate the presence of regional exchange networks that allowed the movement of goods to and from the uplands as well as the Pacific Coast.

Evidence of middle–upper-*bajada* resources included the presence of nonlocal plant remains identified in the pollen and macrobotanical records from the Luke Solar project. Plant remains such as charred saguaro and ocotillo wood, as well as traces of other types of cactus pollen, were identified in several Chiricahua phase structures and extramural pits, indicating their use as construction material or fuelwood.

These middle–upper-*bajada* plants may have existed closer to the project area during the Middle Archaic period but likely not within the project area.

Regional Considerations

The archaeological record preserved in the project area is unique for now, but other examples of it are likely preserved in not only the western Phoenix Basin (see following predictive geologic model) but also in numerous lower-*bajada* settings throughout the Sonoran Desert. The earlier excavations at the Last Ditch site in Paradise Valley are interpretable as but one example of this possibility (Hackbarth 1998; Phillips et al. 2001; Rogge, ed. 2009). As discussed in the preceding cultural affiliation section and presented in Chapter 9, the importance of mesquite collection and processing and the associated earthen pit features and stone tool technology are well documented ethnographically throughout the Sonoran Desert and now archaeologically at Falcon Landing.

The spatial and temporal extent of this phenomenon—what could be considered an archaeological complex—are currently unknown. It is clear, however, that the evidence from Falcon Landing indicates that it is an archaeological phenomenon that persisted relatively unchanged between ca. 3300 cal B.C. and ca. A.D. 1800. This 5,000-year record is impressive on its own, but it is just as likely that a reliance on mesquite and closely associated native weedy annuals were a primary focus of the Native American lifeway beginning by 8,000 years ago, with the establishment of present vegetational regimes across the low-desert regions of Arizona and the U.S. Southwest (Van Devender 1990). In effect, the parts of the prehistoric lifeway represented at Falcon Landing are perhaps best considered a single expression of a specific aspect of a widely practiced land-use strategy that encompassed the entirety of the low-desert regions of the U.S. Southwest. Only future research will allow us to determine if this adaptation persisted through the Altithermal.

Discussion and Conclusions

As presented in Volume 1 of this project series, the Luke Solar project involved an essentially unprecedented 44 acres of contiguous mechanical stripping that allowed the identification of 3,006 buried features at Falcon Landing. Of these, 1,638 features (55 percent) were selected for controlled sampling, including the complete excavation of 44 structures and partial excavation of 4 possible structures (see Table 7, Volume 1). Grouping the 3,006 features at Falcon Landing into the temporal components defined in Chapter 10, 717 were dated to the Chiricahua phase, 189 to the Chiricahua/San Pedro phase transition, 98 to either the San Pedro or Cienega phases, 183 to the Cienega/Red Mountain phase transition, only 19 to the Ceramic period, and 28 to the Classic/Protohistoric period. The remaining 1,772 features could only be geologically dated to very broad intervals encompassing more than two phases or periods. Nonetheless, the number of dated Archaic period features and associated artifacts and ecofacts at Falcon Landing exponentially increases the available data concerning the Middle and Late Archaic periods in the Phoenix Basin. The exceedingly large plan-view exposure also allowed a detailed examination of site history and site structure (see Chapter 10).

Even given the relative enormity of the Luke Solar project excavations and excavated sample, similarities and stability were the clear and dominant project trends noted early during the fieldwork, with the identification and sampling of thousands of small, nonthermal, basin-shaped Middle and Late Archaic period extramural pits across the vast 44-acre mechanically stripped area at Falcon Landing. Stability and similarities also characterized the relatively limited numbers and kinds of artifact types, faunal remains, and plant remains (see Chapters 3–7). Early during the postfield analyses, it was clear that a core set of limited but focused and persistent activities characterized the occupational record at Falcon Landing. Key among these activities was the processing of native-plant foods with the aid of a robust, expensive, and curated ground stone technology. During all periods of site use, however, the production and the maintenance of the hunting tool kit essentially occurred alongside the plant-food-processing activities, as evidenced by relatively large amounts of biface-reduction debitage that was consistently deposited on-site over the course of the entire intermittent 5,000-year occupational record.

Among the project's greatest challenges and accomplishments was establishing the project geochronology (see Chapter 2). Located on a lower *bajada* of the White Tank Mountains, Falcon Landing was expectedly characterized by a dynamic and complex depositional history. The development of the project geochronology indicated that occupational intensity increased during periods of aggradation, and these periods of aggradation in turn coincided with periods of increased effective precipitation and biotic-carrying capacity. For most of its occupational history, task or family groups primarily used Falcon Landing and the other project sites as plant-food processing and lithic-reduction loci. Starting at least as early as ca. 3300 cal B.C., however, Falcon Landing also functioned, at times, as a short-term habitation site as evidenced by the remains of houses-in-pits and surface structures. The physiographic setting of the project area also largely explains why Falcon Landing is located where it is; the presence of the distinctive salt domes in this part of the Luke Basin resulted in an elevated water table and the establishment of a bosque-like setting just south of the project area. This elevated water table and the high-density and productive resource patch it promoted are the focus of a predictive model presented later in this chapter. These techno-economic observations and trends are relatively demonstrable, straightforward, and pragmatic.

The social context of the occupational record at Falcon Landing, however, included a regional history characterized by relatively dramatic economic, social, and cultural changes. The introduction of domesticates to the U.S. Southwest at ca. 2100 cal. B.C. had no meaningful effect on the aboriginal use of Falcon Landing. On-site activities at Falcon Landing proceeded effectively unchanged for nearly 5,000 years. This 5,000-year interval witnessed the pioneering and expansion of canal irrigation agriculture along the middle Santa Cruz River floodplain in Tucson, followed by the florescence of ceramic container technology for utilitarian purposes by ca. A.D. 1, and ensuing increased agricultural dependence and the establishment of sedentary village life by the Early Ceramic period (ca. A.D. 50–400). No Early Agricultural period settlements with deposits chronicling what is effectively the Neolithic Revolution in the Sonoran Desert as documented in the Tucson Basin have been located along the relict floodplains of the Phoenix Basin, and the extent and timing of Early Agricultural period technology in the Phoenix Basin unfortunately remains unknown.

The emergence of the distinctive Hohokam culture (Gladwin and Gladwin 1933; Haury 1976), however, and the construction and maintenance of unprecedented canal irrigation systems is an integral aspect of Phoenix Basin prehistory. The Pioneer period (A.D. 400–750) included the construction of the most technologically sophisticated and largest irrigation systems in North America (Doolittle 2001:79–80). Interestingly, a significant decline in occupational intensity at Falcon Landing begins with this Pioneer period achievement, and the emergence of the distinctive Hohokam culture at the onset of the Colonial period at A.D. 750 coincides with an occupational hiatus at Falcon Landing that persisted until sometime between cal A.D. 1000 and 1150. Falcon Landing was used thereafter, but much less intensively and less frequently, and the 5,000-year record of aboriginal occupation at Falcon Landing ends during either the Protohistoric or early Historical periods (see Chapters 2 and 10). Overall, the Luke Solar project and especially the archaeological record documented at Falcon Landing are probably best interpreted as reflecting a persistent and foundational aspect of the aboriginal lifeway led in the Sonoran Desert.

Directions for Future Research

With practical limits on the overall schedule and budget, many avenues of analysis and investigation were unrealized during the Luke Solar project. In an ideal world, many more samples and artifacts from a project of this size and importance would have been scrutinized carefully, and our interpretations could have developed over years of coordination and collaboration. In reality, the Luke Solar project was an ambitious effort that mobilized fieldwork in four stages over the course of 4 years. The mechanical excavation of 132 backhoe trenches, the mechanical stripping of 46.2 acres, and the excavation of over 3,000 prehistoric features at four sites was completed in just under 9 nonconsecutive months (264 work days). These field achievements were followed by the rapid preparation of both Volumes 1 and 2 in only a year's time. This challenging schedule necessitated great efficiency, as well as difficult decisions regarding the prioritization and application of project resources, and some potential research options were necessarily sidelined. The following are but a few examples of possible research opportunities that exist from this project.

Chronometry

One of the limitations of the Luke Solar project was the inability to precisely and directly date the thousands of features representing 5,000 years of prehistoric occupation. As described in Chapter 2 and above, nearly every feature was assigned to a temporal component, but many of the features were poorly dated, based solely on their geologic context. This was especially true for features that originated at erosional unconformities. Additional radiocarbon analysis of select contexts would undoubtedly reveal numerous occupational episodes that were otherwise masked by the existing project chronology. For example, about 45 percent of the geologically dated features (n = 1,334) were located at a stratigraphic boundary or unconformity. In other words, these features were intrusive into the weathered upper surface of a stratum and covered by younger alluvium. Consequently, many of these features are currently dated to long, imprecise periods precluding their assignment to one of the temporal components. A useful research opportunity exists here to obtain radiocarbon dates for many of these poorly dated features. Dating a select number of these features would not only help assign the particular features to periods, phases, and occupational episodes, but it would also help to increase the precision of the geochronological model. In particular, the earliest and latest components in the project area remain poorly understood. A single Early Archaic (Sulphur Spring phase) feature was identified by radiocarbon analysis at Site 437, and this feature was the only cultural feature in the project area identified within (coeval with) the Unit I stratum. Based on the geochronology presented in Chapter 2, Unit I is believed to have been deposited between 7040 and 5320 cal B.C. Additional radiocarbon dates from features intrusive into the surface of Unit I may reveal more Early Archaic features in the project area, which could add vital information to our understanding of this poorly understood period. In addition, a limited record of Hohokam and Protohistoric occupation was identified in the project area. Further radiocarbon analysis of features in younger deposits, such as in Units IV and V, could potentially bolster our understanding of how and when the later Hohokam and historical-period Native Americans used the project area.

Another potential tool to expand the chronology of the Luke Solar project is through archaeomagnetic (AM) studies. Scheduling and budgetary constraints prevented the analysis of AM samples. Instead, these resources were diverted to radiocarbon analysis in order to obtain as many direct dates as possible in order to strengthen the geochronology. In total, 72 cultural features that contained heavily oxidized sediment were sampled for AM analysis. Conventional AM dating has been used to produce calendrical dates (i.e., A.D. or B.C. of the Christian calendar) for sampled features. Evaluating an AM measurement and calculating a calendrical date requires comparing the AM value against the Southwestern calibration curve (SWCV595) developed by Labelle and Eighmy (1997) and most recently extended by Lengyel (2010). However, with the relative antiquity of the Luke Solar features, many of the cultural contexts may predate the Southwestern curve. As an alternative scenario, the Luke Solar AM samples may be used as a relative-dating technique. In this scenario, AM measurements could be used to define the relationships among archaeological events. The AM measurements could be statistically compared and evaluated as either contemporaneous or noncontemporaneous based on the similarity of multiple AM results. This relative-dating technique is likely to be a useful tool for the Luke Solar project. In the current study, determining contemporaneous groups of features at Luke Solar was accomplished through radiocarbon dates and geochronology. Addressing contemporaneity using AM analysis may provide much insight into the already established temporal groups for Luke Solar. An additional product of AM analysis would be to further extend and refine the Archaic period portion of the Southwestern calibration curve. Lengyel (2010) was able to successfully extend the Southwest calibration curve using data from the U.S. 60 project located in the eastern Phoenix Basin (see Wegener et al. 2011), a project that resulted in numerous Late Cienega and Red Mountain phase features with paired radiocarbon and AM dates. The Luke Solar project has documented a large number of significantly older Chiricahua and San Pedro phase features, which have the potential to extend the Southwest calibration curve back to ca. 3000 B.C.

Archaeobotanical Evidence

Subsistence was one of the key components in interpreting land use for the Luke Solar project. The subsistence data for the Luke Solar sites were derived partially from the analysis of pollen and macrobotanical samples, recovered from a variety of feature and nonfeature contexts (see Chapters 6 and 7). However, schedule and budgetary constraints limited the number of pollen and flotation samples that could be analyzed. As described in Chapter 6, only 145 (6.4 percent) of the 2,269 flotation samples collected from the project sites underwent analysis. Additionally, 1,228 macrobotanical and ^{14}C (i.e., charcoal) samples were collected, but only 48 (3.9 percent) were analyzed. As Adams states in Chapter 6, the flotation and macrobotanical samples preserved a relatively limited record of plant use for the Luke Solar sites. The opportunity to analyze a larger sample of the remaining flotation or macrobotanical samples may present researchers with a more robust suite of plant remains that could be correlated with prehistoric subsistence. Pollen remains, on the other hand, expectedly provided a slightly higher diversity of plant taxa than the macrobotanical analysis (see Chapter 7). Of the 2,145 pollen samples collected from the Luke Solar sites, only 117 samples (5.5 percent) were analyzed. The pollen record for Luke Solar included a single grain of maize pollen from a San Pedro phase structure, representing the only direct evidence of a cultigen in the project area. The Luke Solar pollen analysis also detected several other possible economic plant resources (see Chapter 7). The opportunity to analyze pollen from a larger sample of cultural contexts would undoubtedly add to our understanding of the subsistence practices in this lower-*bajada* environment.

Buried Lower-*Bajada* Archaeology in the Phoenix Basin: A Preliminary Predictive Geologic Model

The geoarchaeological analysis of the Luke Solar project area revealed favorable conditions for prehistoric settlement during periods of increased surface runoff in the Middle to Late Archaic and Early Ceramic periods (see Chapter 2). Similar conditions were also present at the Last Ditch site (AZ U:5:33[ASM]) on the McDowell Mountain piedmont during the Middle Archaic (Phillips et al. 2001; Rogge and Phillips 2009a). The discovery of buried Archaic period habitations on the *bajadas* surrounding the Phoenix Basin suggests a significant portion of the regional archaeological record is not visible and remains largely undiscovered. This brief analysis looks at the paleoenvironmental and geomorphic context of these two sites and attempts to identify similar conditions on the eastern White Tank Mountains *bajada*. It is expected that these locations will have some potential for buried Archaic period (or older) cultural resources. Although it is beyond the scope of this analysis, the geomorphic conditions favoring the burial and preservation of archaeological resources on other distal-*bajada* surfaces surrounding the Phoenix metropolitan area likely exist. This should be taken into consideration for all future CRM projects in *bajada* settings.

Soils in the vicinity of the Luke Solar project area and the Last Ditch site were placed into four categories based on county soil-survey data and correlation with the radiocarbon-dated Falcon Landing/Last Ditch stratigraphy (Table 105). These categories include Torrifluvents greater than 150 cm in total thickness (Category 1), Torrifluvents with buried soils within 150 cm of the modern surface (Category 2), late Pleistocene through middle Holocene soils at or very near the modern surface (Category 3), and relict soils with indurated horizons (Category 4). Based on the radiocarbon chronology of Falcon Landing and Last Ditch, many Torrifluvents mark areas of the *bajada* that aggraded during the late Holocene (younger than 3000 cal B.C.) (Categories 1 and 2 in Figures 137 and 138). These soils, however, likely represent a wide range of ages, with some probably dating to less than 1000 yr B.P. Radiocarbon dates from buried features in the Gilman soil series Torrifluvent at the Last Ditch site indicate that some of these soils could have alluvial soil parent

Table 105. Soil Series in the Luke Solar and Last Ditch Project Areas

Soil Series	Mapping Category	Soil classification	Age
Agualt loam	1	Torrifluvent	late Holocene (< 5000 yr B.P.)
Antho sandy loam	2	Torrifluvent	late Holocene (< 5000 yr B.P.)
Antho gravelly sandy loam	2	Torrifluvent	late Holocene (< 5000 yr B.P.)
Anthony sandy loam	1	Torrifluvent	late Holocene (< 5000 yr B.P.)
Avonda clay loam	1	Torrifluvent	late Holocene (< 5000 yr B.P.)
Avondale clay loam	1	Torrifluvent	late Holocene (< 5000 yr B.P.)
Brios loamy sand	1	Torrifluvent	late Holocene (< 5000 yr B.P.)
Brios sandy loam	1	Torrifluvent	late Holocene (< 5000 yr B.P.)
Brios loam	1	Torrifluvent	late Holocene (< 5000 yr B.P.)
Carrizo gravelly sandy loam	1	Torriorthent	late Holocene (< 5000 yr B.P.)
Casa Grande loam	3	Natrargid	latest Pleistocene through middle Holocene
Estrella loam	2	Torrifluvent	late Holocene (< 5000 yr B.P.)
Gilman fine sandy loam	1	Torrifluvent	late Holocene (< 5000 yr B.P.)
Gilman loam	1	Torrifluvent	late Holocene (< 5000 yr B.P.)
Glenbar loam	1	Torrifluvent	late Holocene (< 5000 yr B.P.)
Glenbar clay loam	1	Torrifluvent	late Holocene (< 5000 yr B.P.)
Gunsight-Rillito complex	3	Haplocalcid	latest Pleistocene through middle Holocene
La Palma very fine sandy loam	4	Petrocalcid	Pleistocene or older
Laveen sandy loam	3	Haplocalcid	latest Pleistocene through middle Holocene
Laveen loam	3	Haplocalcid	latest Pleistocene through middle Holocene
Laveen clay loam	3	Haplocalcid	latest Pleistocene through middle Holocene
Maripo sandy loam	1	Torrifluvent	late Holocene (< 5000 yr B.P.)
Mohall loam	3	Calciargid	latest Pleistocene through middle Holocene
Mohall clay loam	3	Calciargid	latest Pleistocene through middle Holocene
Momoli gravelly sandy loam	3	Haplocambid	latest Pleistocene through middle Holocene
Perryville sandy loam	4	Petronodic haplocalcid	relict basin fills
Perryville gravelly loam	4	Petronodic haplocalcid	relict basin fills
Pinal loam	4	Haplodurid	Pleistocene or older
Pinal-La Palma loams	4	Haplodurid-petrocalcid	Pleistocene or older
Rillito sandy loam	3	Haplocalcid	latest Pleistocene through middle Holocene
Rillito loam	3	Haplocalcid	latest Pleistocene through middle Holocene
Rillito-Perryville complex	4	Haplocalcids	primarily eroded relict basin fills on salt domes
Toltec loam	4	Haplocalcid	latest Pleistocene through middle Holocene
Tremant loam	3	Calciargid	latest Pleistocene through middle Holocene
Tremant clay loam	3	Calciargid	latest Pleistocene through middle Holocene
Tremant gravelly loam	3	Calciargid	latest Pleistocene through middle Holocene
Tremant-Rillito complex	3	Calciargid-haplocalcid	latest Pleistocene through middle Holocene
Trix clay loam	2	Torrifluvent	late Holocene (< 5000 yr B.P.)
Valencia sandy loam	3	Haplocambid	latest Pleistocene through middle Holocene
Vecont loam	3	Haplargid	latest Pleistocene through middle Holocene
Vecont clay	3	Haplargid	latest Pleistocene through middle Holocene
Vint fine sandy loam	1	Torrifluvent	late Holocene (< 5000 yr B.P.)

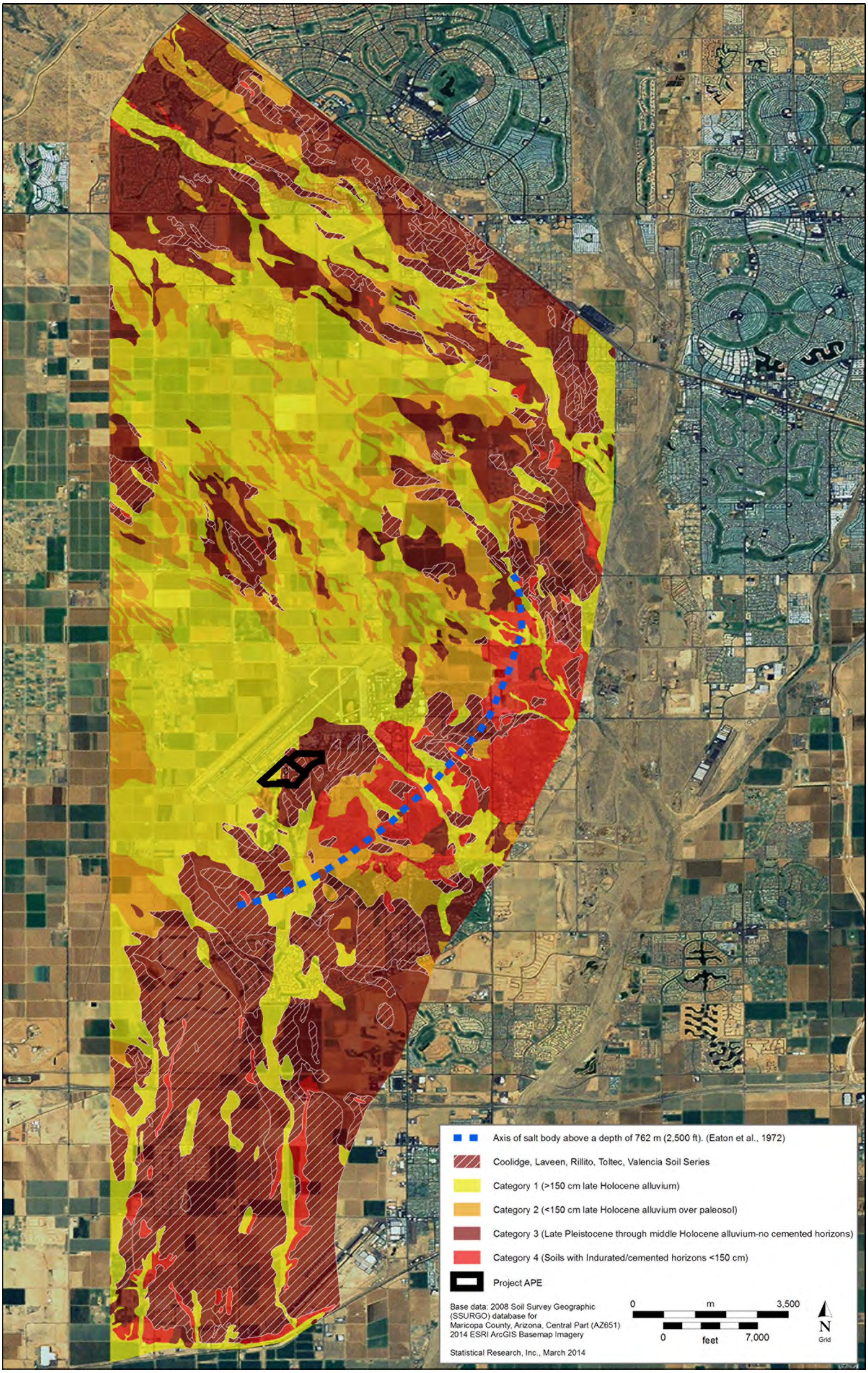


Figure 137. Distribution of soil types and ages in the vicinity of the Luke Solar APE, distal eastern White Tank Mountains *bajada*.

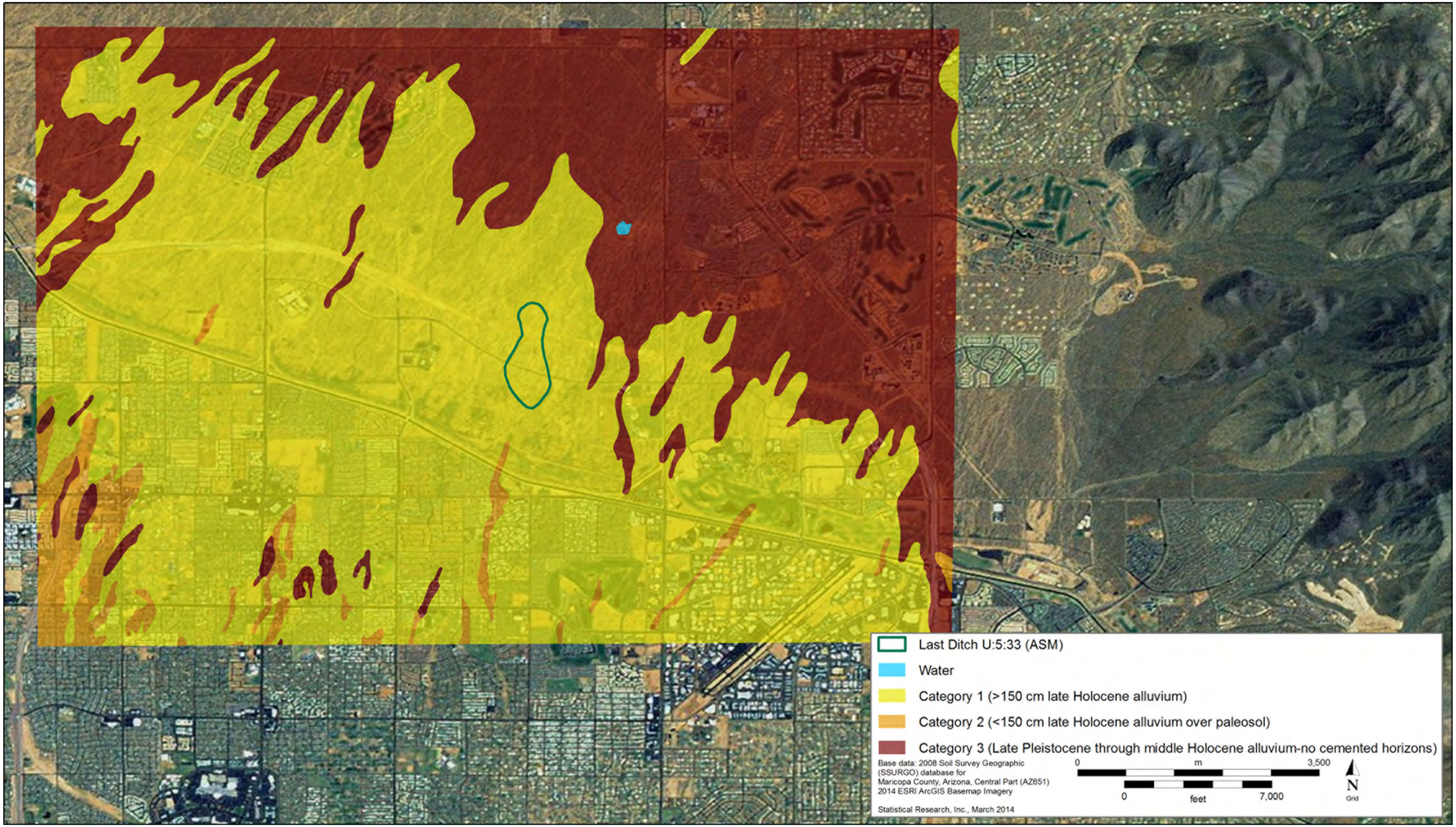


Figure 138. Distribution of soil types and ages at the Last Ditch site (AZ U:5:33 [ASM]), middle–distal McDowell Mountains *bajada*.

material (C horizons) dating to the Middle Archaic (Last Ditch Unit III). Interestingly, the Gilman series is also mapped extensively west of LAFB. Some of these Torrifluvents might also contain deposits that correlate with Units III and IV (1380 cal B.C.–cal A.D. 1220) at the Luke Solar project area and Units I and II (1600 cal B.C.–cal A.D. 500) at Last Ditch. The buried paleosols in Category 2 represent relict land surfaces that primarily date to the late Pleistocene through the middle Holocene. Some of these buried soils likely correlate to the LR Formation (Btk soil horizon, 16,680–16,080 cal B.C.) and/or Unit I (weak Bk soil horizon, 7040–5320 cal B.C.) at Luke Solar. The Category 3 mapping unit identifies areas where the late Pleistocene–middle Holocene soils are located at or on the modern surface (late Holocene alluvium is thin) (see Figures 137 and 138). This mapping unit includes the Laveen soil series, the primary soil mapped across the Luke Solar project area. The Laveen series contains an over-thickened A horizon (Unit IIA, Luke Solar) over a Bw horizon (Unit II, Luke Solar). The Laveen A–Bw horizon sequence buries a Bk soil horizon, which at Luke Solar marks either Unit I or the LR Formation. Local soils that are similar (similar classification and soil horizon sequence) to the Laveen series include the Toltec, Valencia, Rillito, and Coolidge soil series. Finally, Category 4 marks areas where relict indurated soil horizons are situated within 100–150 cm of the modern surface. These primarily occur along the arc of relict uplifted landforms above the Luke Salt Body. These soils were not identified near the Last Ditch site.

Analysis of county soil-survey data and geomorphic surface features visible in aerial imagery point to an abrupt shift in landform type and age in the vicinity of LAFB. This shift is directly related to a north–south trending arc of uplifted relict basin fills situated between LAFB and the Agua Fria River (Eaton et al. 1972) (see Figure 137). Along the western edge of this zone, alluvial-fan drainages flowing eastward toward the Agua Fria River either converge into narrow incised channels that continue through the uplifted landforms or are diverted to the south. One of these diverted drainages can be traced from just south of the Luke Solar project area all the way to the Gila River (Figure 139). Many of the soils along the western edge of the uplifted basin fills contain indurated/cemented horizons and retain some evidence for perched water tables (see Figure 137). Seasonally perched groundwater and probably ponded surface water along the western side of the uplifted arc very likely supported mesquite bosques and other culturally important plant communities. These communities would have expanded and contracted over time in response to long-term changes in

Figure 139. Historical aerial photograph of eastern White Tank Mountains bajada south of LAFB showing diverted southward-flowing paleochannel.

seasonal precipitation levels, which over the last 5,000–6,000 years appear to have been strongly controlled by ENSO climatic patterns (see Chapter 2).

At the Last Ditch site, uplifted landforms related to the rise of the Luke Salt Body are not present; however, relict calcium carbonate–cemented (petrocalcic) soil horizons are situated within a few meters of the modern surface (Phillips et al. 2001). Similar to the uplifted petrocalcic and duripan (cemented with silica) horizons in the vicinity of Luke Solar, these horizons are impermeable (or have very slow permeability) and have the potential to perch local groundwater. Also similar to the Luke Solar vicinity, this area of the McDowell Mountains piedmont was actively aggrading during the Middle to Late Archaic. The Gilman soil series Torrifluvent at Last Ditch contained C horizons dating to the Middle Archaic, and it is expected that other areas mapped as the Gilman series in the immediate vicinity contain deposits of similar age.

The geochronology of Luke Solar project area and Last Ditch site indicate a significant period of alluvial-fan aggradation beginning around 3000 cal B.C. on the distal piedmonts surrounding the Phoenix Basin. Many of these fan deposits are mapped as Torrifluvents of the Antho, Avondale, Brios, Estrella, Glenbar, and Gilman soil series, and as Haplocalcids or Haplocambids of the Laveen, Rillito, Toltec, Valencia, and Coolidge series (see Table 105). Because actively aggrading alluvial fans appear to have been attractive locations for Archaic period settlement, buried Archaic period occupations (or older) are a distinct possibility in distal-*bajada* settings that contain these soil types. Torrifluvents with gravelly parent materials (some Rillito and Momoli series soils), however, are less likely to contain buried cultural resources because they represent higher-energy depositional environments that are not favorable for preservation (see Table 105). In areas mapped as Haplocambids or Haplocalcids, buried occupations will likely be restricted to the upper 0.5–1.0 m (similar to Luke Solar); however, some Torrifluvents could contain buried archaeology at depths exceeding 2 m.

In summary, widespread late Holocene fan aggradation has very likely had a strong influence on the visibility of Middle to Late Archaic period sites in the Phoenix Basin. In the vicinity of the Luke Solar project area, Category 1 and 2 soils, along with areas mapped as the Coolidge, Laveen, Rillito, Toltec, and Valencia series, are considered to have a high to very high potential for buried archaeological resources (see Figure 137). This is particularly true where these soils abut Category 4 soil types (soils with indurated/cemented horizons). The diverted channel that ultimately flows into the Gila River 11 km (6.8 miles) south of Luke Solar (see Figures 137 and 139) is also considered to be a very likely location for buried archaeological resources.

Conclusion

The analysis and interpretations presented above highlight the importance of the Luke Solar project. The largest site investigated as part of the Luke Solar project, Falcon Landing, represents the most extensive Middle and Late Archaic period site known to date in the Phoenix Basin. Thousands of features identified at Falcon Landing point to a continuum of occupation, beginning around 3300 B.C. and lasting for nearly 5,000 years. Falcon Landing represents a palimpsest of prehistoric occupation in a lower-*bajada* environment. Normally considered an undesirable location for occupation in the Sonoran Desert, the lower *bajada* is generally considered a poor resource zone. The lower-*bajada* landscape surrounding Falcon Landing, however, has a unique geologic setting that attracted prehistoric people for millennia. The presence of a perched water table and possible mesquite bosque immediately south of the site would have drawn foraging groups to this location for the abundant mesquite pods during the summer months. Also during the summer, monsoonal rains periodically deposited fine-grained sediments on the site that would have encouraged wild, edible seed-bearing plants such as cheno-ams and grasses. Traces of cottonwood and a possible cattail grain recovered from ground stone artifacts indicate groups maintained a close connection to a well-watered setting, but it is not clear whether this location was the mesquite bosque located immediately south of LAFB or the Agua Fria River, located approximately 5 km east of Falcon Landing. The Agua Fria River was also the primary source of raw lithic material, an important resource for the inhabitants of Falcon Landing. Groups provisioned and cached grinding and pounding tools for long-term use, while mobile flake blanks, bifacial cores, and finished tools were manufactured on-site in anticipation of upland artiodactyl hunting. Residential groups during the Middle and Late Archaic periods likely occupied the site sporadically or occasionally as different plants matured on the landscape and opportunistically hunted leporids at or near the site while engaged in plant procurement and processing. These activities are known to have been established at Falcon Landing by 3300 B.C. and show a remarkable stability over time. The record of occupation at Falcon Landing persists during several fundamental changes to subsistence, settlement, and technology witnessed elsewhere in the Phoenix Basin and the U.S. Southwest. For instance, the earliest evidence of the use of maize agriculture, around 2100 B.C., did not correspond to a measureable impact on the subsistence and technological patterns observed at Falcon Landing. Furthermore, the advent of the Hohokam archaeological culture, the adoption of a ceramic-container technology, the construction of a vast network of irrigation canals, and the change to settled village life throughout the Phoenix Basin resulted in no substantial changes to on-site activities. The economically important traditions observed at Falcon Landing indicate a tremendously successful aspect of a much larger and elaborate Native American land-use strategy that continues to be an integral aspect of Sonoran Desert cultures.

REFERENCES CITED

Adams, Jenny L.

1997 *Manual for a Technological Approach to Ground Stone Analysis*. Center for Desert Archaeology, Tucson.

2002 *Ground Stone Analysis: A Technological Approach*. University of Utah Press, Salt Lake City.

2005 Early Agricultural Period Grinding Technology. In *Material Cultures and Lifeways of Early Agricultural Communities in Southern Arizona*, edited by R. Jane Sliva, pp. 99–119. Anthropological Papers No. 35. Center for Desert Archaeology, Tucson.

Adams, Jenny L., and Mark D. Elson

1995 Personal Ornaments, Pigments, Rocks, and Mineral Specimens. In *Stone and Shell Artifacts*, edited by Mark D. Elson and Jeffery J. Clark, pp. 115–149. The Roosevelt Community Development Study, vol. 1. Anthropological Papers No. 14. Center for Desert Archaeology, Tucson.

Adams, Karen R.

1988 The Ethnobotany and Phenology of Plants in and Adjacent to Two Riparian Habitats in Southeastern Arizona. Unpublished Ph.D. dissertation, University of Arizona, Tucson.

1997 Chapter 8. Macrobotanical Analysis. In *Agricultural, Subsistence and Environmental Studies*, edited by Jeffrey A. Homburg and Richard Ciolek-Torrello, pp. 149–178. *Vanishing River: Landscapes and Lives of the Lower Verde Valley: The Lower Verde Archaeological Project,* vol. 2. CD-ROM. SRI Press, Tucson. Accompanied by Appendix H: Criteria for Identification of Archaeological Plant Specimens from Lower Verde Sites, with text descriptions of plant parts, measurement data (Tables H1.1, H1.2, H1.3), and flotation (Table H.1) and macrofossil (Table H.2) databases.

2003 Chapter 7. Plant Remains. In *Analyses of Prehistoric Remains*, edited by Eric Eugene Klucas, Richard Ciolek-Torrello, and Rein Vanderpot, pp. 223–246. From the Desert to the Mountains: Archaeology of the Transition Zone: The State Route 87–Sycamore Creek Project, vol. 2. Technical Series 73. Statistical Research, Tucson. Accompanied by Appendix I: Criteria for Identification of Archaeological Plant Specimens, including tables of archaeobotanical data.

Adams, Karen R., and Vorsila L. Bohrer

1998 Archaeobotanical Indicators of Seasonality: Examples from Arid Southwestern United States. In *Seasonality and Sedentism: Archaeological Perspectives from Old and New World Sites*, edited by Thomas R. Rocek and Ofer Bar-Yosef, pp. 129–141. Bulletin No. 6. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

Adams, Karen R., and Suzanne K. Fish

2006 Southwest Plants. In *Environment, Origins, and Population*, edited by Douglas H. Ubelaker, pp. 292–312. Handbook of North American Indians, vol. 3, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

2011 Subsistence through Time in the Greater Southwest. In *The Subsistence Economies of Indigenous North American Societies: A Handbook*, edited by Bruce D. Smith, pp. 147–183. Smithsonian Institution Scholarly Press, Washington, D.C.

Adams, Karen R., and Susan J. Smith

2011 Reconstructing Past Life-Ways with Plants I: Subsistence and Other Daily Needs. In *Ethnobiology*, edited by E. N. Anderson, Deborah M. Pearsall, Eugene S. Hunn, and Nancy J. Turner, pp. 149–171. Wiley-Blackwell, Hoboken, New Jersey.

Adams, Kim

1991 *Archaeological Assessment of a Parcel near Luke Air Force Base, Maricopa County, Arizona*. Archaeological Consulting Services, Tempe, Arizona. Submitted to Geraghty and Miller, Phoenix.

Adams, Kim, Holly DeMaagd, Shereen Lerner, and Larolyn Jackman Jensen

1996 *Archaeological Testing for AZ T:8:58, T:8:61, and U:5:34 (ASM), and Archival Documentation for the Rio Verde Canal (AZ T:8:65(ASM)) located in the Pima Freeway Project, Beardsley Corridor*. Archaeological Consulting Services, Tempe, Arizona.

Adovasio, James M.

1970 The Origin, Development, and Distribution of Western Archaic Textiles. *Tebiwa: Journal of the Idaho State University Museum* 13(2):1–50.

1986 Prehistoric Basketry. In *Great Basin*, edited by Warren L. d'Azevedo, pp. 194–214. Handbook of North American Indians, vol. 11, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Adovasio, James M., R. L. Andrews, D. C. Hyland, and J. S. Illingworth

2001 Perishable Industries from the Windover Bog: An Unexpected Window into the Florida Archaic. In *North American Archaeologist* 22(1):1–90.

Adovasio, James M., Edward Schumacher, and Joel Gunn

1974 Prehistoric North American Basketry. In *Collected Papers on Aboriginal Basketry*, edited by Jane G. Gigli, Donald R. Tuohy, Phil C. Orr, Charles E. Rozaire, and James M. Adovasio, pp. 98–148. Anthropological Papers No. 16. Nevada State Museum, Carson City.

Agenbroad, Larry D.

1970 Cultural Implications from the Statistical Analysis of a Prehistoric Lithic Site in Arizona. Unpublished Master's thesis, Department of Anthropology, University of Arizona, Tucson.

Ahler, Stanley A., and Phil R. Geib

2000 Why Flute? Folsom Point Design and Adaptation. *Journal of Archaeological Science* 27:799–820.

Aikens, C. Melvin

1970 *Hogup Cave*. Anthropological Papers No. 93. University of Utah Press, Salt Lake City.

Albush, Cassandra J.

2009 Features and Artifacts. In *Excavations within the State Route 101L/64th Street Locus of the Last Ditch Site, AZ U:5:33 (ASM), Phoenix, Arizona*, edited by A. E. Rogge, pp. 31–46. URS Corporation, Phoenix.

Alexander, Robert K.

1974 *The Archaeology of Conejo Shelter: A Study of Cultural Stability at an Archaic Rockshelter Site in Southwestern Texas.* Ph.D. dissertation, University of Texas, Austin. University Microfilms, Ann Arbor, Michigan.

Allan, William C.

1973 General Description of the Basketry from Fresnal Shelter. In *Technical Manual: 1973 Survey of the Tularosa Basin, the Research Design*, pp. 402–405. Human Systems Research, Tularosa, New Mexico.

Alley, R. B., P. A. Mayewski, T. Sowers, M. Stuiver, K. C. Taylor, and P. U. Clark

1997 Holocene Climatic Instability: A Prominent Widespread Event 8,200 Years Ago. *Geology* 25(6):483–486.

Allison, Peter A., and David J. Bottjer

2011 Taphonomy: Bias and Process through Time. In *Taphonomy: Process and Bias through Time*, edited by Peter A. Allison and David A. Bottjer, pp. 1–17. 2nd ed. Topics in Geobiology, vol. 32. Springer, Dordrecht.

Alvarez de Williams, Anita

1983 Cocopa. In *Southwest*, edited by Alfonso Ortiz, pp. 99–112. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Amsden, Charles A.

1937 The Lake Mohave Artifacts. In *The Archaeology of Pleistocene Lake Mohave*, by Elizabeth W. C. Campbell, William H. Campbell, Joseph A. Barbieri, and Francis D. Bode, pp. 50–97. Papers No. 11. Southwest Museum, Los Angeles.

Anderson, M. Kat, and Michael J. Moratto

1996 Native American Land-Use Practices and Ecological Impacts. In *Assessment and Scientific Basis for Management Options*, pp. 187–206. Sierra Nevada Ecosystem Project, vol. 2. Centers for Water and Wildland Resources, University of California, Davis.

Anderson, Thomas W.

1968 *Electrical Analog Analysis of Groundwater Depletion in Central Arizona*. Water Supply Paper 1860. U.S. Geological Survey, U.S. Government Printing Office, Washington, D.C.

Andrade, Edward R., and William D. Sellers

1988 El Niño and Its Effect on Precipitation in Arizona and Western New Mexico. *Journal of Climatology* 8:403–410.

Andrefsky, William, Jr.

1994 Raw Material Availability and the Organization of Technology. *American Antiquity* 59:21–34.

2005 *Lithics: Macroscopic Approaches to Analysis*. 2nd ed. Cambridge University Press, Cambridge, England.

Andrews, Peter

1990 *Owls, Caves and Fossils: Predation, Preservation, and Accumulation of Small Mammal Bones in Caves, with an Analysis of the Pleistocene Cave Faunas from Westbury-sub-Mendip, Somerset, UK*. University of Chicago Press, Chicago.

Andrews, Ron L., James M. Adovasio, and Ronald C. Carlisle

1986 *Perishable Industries from Dirty Shame Rockshelter, Malheur County, Oregon*. Ethnology Monographs No. 9. Department of Anthropology, University of Pittsburgh, Pennsylvania. Anthropological Papers No. 34. University of Oregon, Eugene.

Antevs, Ernst

1948 The Great Basin, with Emphasis on Glacial and Post-Glacial Times. *University of Utah, Bulletin* 38(20):168–191.

1955 Geologic-Climatic Dating in the West. *American Antiquity* 20:317–335.

Arizona Bird Committee

2012 Checklist of the Birds of Arizona. Electronic document, http://www.azfo.org/arizonabirdcommittee/az_statelist.html, accessed Feb. 28, 2014.

Arizona Daily Star [Tucson, Arizona]

1909 Killing Rabbits by Wholesale. 12 January: 3. Tucson, Arizona.

2013 When Jackrabbit was the Other White Meat. Electronic document, http://azstarnet.com/special-section/az-at-100/100-years-ago/when-jack-rabbit-was-the-other-white-meat/article_f445b073-07dd-5ff6-b403-c7a4247e4cd4.html, accessed February 28, 2014.

Asmerom, Yemane, Victor Polyak, Stephen Burns, and Jessica Rassmussen

2007 Solar Forcing of Holocene Climate: New Insights from a Speleothem Record, Southwestern United States. *Geology* 35:1–4.

Austin, Daniel F.

2000 *Baboquivari Mountain Plants: Identification, Ecology, and Ethnobotany*. University of Arizona Press, Tucson.

Bacon, Steven N., Eric V. McDonald, Todd G. Caldwell, and Graham K. Dalldorf

2010 Timing and Distribution of Alluvial Fan Sedimentation in Response to Strengthening of Late Holocene ENSO Variability in the Sonoran Desert, Southwestern Arizona, USA. *Quaternary Research* 73:425–438.

Bahr, Donald M.

1983 Pima and Papago Social Organization. In *Southwest*, edited by Alfonso Ortiz, pp. 178–192. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Bahre, Conrad J.

1991 *A Legacy of Change: Historic Human Impact on Vegetation of the Arizona Borderlands*. University of Arizona Press, Tucson.

Baillie, M. G. L.
1991 Suck-In and Smear: Two Related Chronological Problems for the 90s. *Journal of Theoretical Archaeology* 2:12–16.

Ballenger, Jesse A. M., and John D. Hall
2011 Obsidian Procurement, Technology, and Exchange in the Vicinity of Superior, Arizona. In *Analysis of Prehistoric Materials in the Queen Valley to Queen Creek Area*, edited by Robert M. Wegener, Michael P. Heilen, Richard Ciolek-Torello, and John D. Hall, pp. 137–156. The U.S. 60 Archaeological Project: Early Agricultural, Formative, and Historical-Period Use of the Upper Queen Creek Region, vol. 4. Technical Series 92. Statistical Research, Tucson.

Ballenger, Jesse A. M., John D. Hall, and Beth Ann Camp
2011 Stone Artifacts. In *Analysis of Prehistoric Materials in the Queen Valley to Queen Creek Area*, edited by Robert M. Wegener, Michael P. Heilen, Richard Ciolek-Torello, and John D. Hall, pp. 53–136. The U.S. 60 Archaeological Project: Early Agricultural, Formative, and Historical-Period Use of the Upper Queen Creek Region, vol. 4. Technical Series 92. Statistical Research, Tucson.

Ballenger, Jesse A. M., and Jonathan B. Mabry
2011 Temporal Frequency Distributions of Alluvium in the American Southwest: Taphonomic, Paleohydraulic, and Demographic Implications. *Journal of Archaeological Science* 38:1314–1325.

Bamforth, Douglas B.
1986 Technological Efficiency and Tool Curation. *American Antiquity* 51:38–50.

1991 Technological Organization and Hunter-Gatherer Land Use: A California Example. *American Antiquity* 56:216–234.

2006 The Windy Ridge Quartzite Quarry: Hunter-Gatherer Mining and Hunter-Gatherer Land Use on the North American Continental Divide. *World Archaeology* 38:511–527.

Bandelier, Adolph Francis (editor), and Fanny Bandelier (translator)
1905 *The Journey of Alvar Nuñez Cabeza de Vaca and His Companions from Florida to the Pacific 1528–1536*. A. S. Barnes, New York.

Barber, D. C., A. Dyke, C. Hillaire-Marcel, A. E. Jennings, J. T. Andrews, M. W. Kerwin, G. Bilodeau, R. McNeely, J. Southon, M. D. Morehead, and J. M. Gagnon
1999 Forcing of the Cold Event of 8,200 Years Ago by Catastrophic Drainage of Laurentide Lakes. *Nature* 400:344–348.

Barron, John A., David Bukry, and Walter E. Dean
2005 Paleoceanographic History of the Guaymas Basin, Gulf of California, during the Past 15,000 Years Based on Diatoms, Silicoflagellates, and Biogenic Sediments. *Marine Micropaleontology* 56(3–4):81–102.

Barrows, David Prescott
1900 *The Ethno-Botany of the Coahuilla Indians of Southern California*. University of Chicago Press, Chicago.

Basso, Keith H.

1983 Western Apache. In *Southwest*, edited by Alfonso Ortiz, pp. 462–488. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

1996 *Wisdom Sits in Places: Landscape and Language among the Western Apache*. University of New Mexico Press, Albuquerque.

Bayham, Frank E.

1982 *A Diachronic Analysis of Prehistoric Animal Exploration at Ventana Cave*. Ph.D. dissertation, Department of Anthropology, Arizona State University, Tempe. University Microfilms, Ann Arbor, Michigan.

1986a Projectile Point Classification and Middle Archaic Stratigraphic Relationships in the Picacho Area. In *Prehistoric Hunter-Gatherers of South Central Arizona: The Picacho Reservoir Archaic Project*, edited by Frank E. Bayham, Donald H. Morris, and M. Steven Shackley, pp. 217–246. Anthropological Field Studies No. 13. Arizona State University, Tempe.

1986b Middle Archaic Animal Utilization in South-Central Arizona. In *Prehistoric Hunter-Gatherers of South Central Arizona: The Picacho Reservoir Archaic Project*, edited by Frank E. Bayham, Donald H. Morris, and M. Steven Shackley, pp. 315–340. Anthropological Field Studies No. 13. Office of Cultural Resource Management, Department of Anthropology, Arizona State University, Tempe.

Bayham, Frank E., and Donald H. Morris

1986 Episodic Use of a Marginal Environment: A Synthesis. In *Prehistoric Hunter-Gatherers of South Central Arizona: The Picacho Reservoir Archaic Project*, edited by Frank E. Bayham, Donald H. Morris, and M. Steven Shackley, pp. 359–381. Anthropological Field Studies No. 13. Arizona State University, Tempe.

Bayham, Frank E., Donald H. Morris, and M. Steven Shackley

1986 *Prehistoric Hunter-Gatherers of South Central Arizona: The Picacho Reservoir Archaic Project*. Anthropological Field Studies No. 13. Office of Cultural Resource Management, Department of Anthropology, Arizona State University, Tempe.

Bayman, James M.

2007 Papaguerian Perspectives on Economy and Society in the Sonoran Desert. In *Hinterlands and Regional Dynamics in the Ancient U.S. Southwest*, edited by Allen P. Sullivan III and James M. Bayman, pp. 109–124. University of Arizona Press, Tucson.

Bean, Lowell John, and Katherine S. Saubel

1972 *Temalpakh (From the Earth): Cahuilla Indian Knowledge and Usage of Plants*. Morongo Indian Reservation, Malki Museum Press, Banning, California.

Beck, C., A. K. Taylor, and G. T. Jones

2002 Rocks are Heavy: Transport Costs and Paleoarchaic Quarry Behavior in the Great Basin. *Journal of Anthropological Archaeology* 21:481–507.

Behrensmeyer, Anna K.

1978 Taphonomic and Ecological Information from Bone Weathering. *Paleobiology* 4:150–162.

Bell, Fillman, Keith M. Anderson, and Yvonne G. Stewart

1980 *The Quitobaquito Cemetery and Its History*. U.S. Department of the Interior National Park Service, Western Archeological and Conservation Center, Tucson.

Bell, Willis H., and Edward F. Castetter

1937 *The Utilization of Mesquite and Screwbean by the Aborigines in the American Southwest*. Bulletin No. 314, Biological Series 5(2). University of New Mexico Press, Albuquerque.

Bennyhoff, James A., and Richard E. Hughes

1987 *Shell Bead and Ornament Exchange Networks between California and the Western Great Basin.* Anthropological Papers, vol. 64, pt. 2. American Museum of Natural History, New York.

Best, Troy L., and Marian P. Skupski

1994 Perognathus flavus. *Mammalian Species* 471:1–10.

Betancourt, Julio L.

1990 *Tucson's Santa Cruz River and the Arroyo Legacy*. Ph.D. dissertation, University of Arizona, Tucson.

Betancourt, Julio L., Thomas R. Van Devender, and Paul S. Martin

1990 *Packrat Middens: The Last 40,000 Years of Biotic Change*. University of Arizona Press, Tucson.

Bettinger, Robert L., and Martin A. Baumhoff

1982 The Numic Spread: Great Basin Cultures in Competition. *American Antiquity* 47:485–503.

Binford, Lewis R.

1977 Forty-Seven Trips: A Case Study in the Character of Archaeological Site Formation Processes. In *Stone Tools as Cultural Markers: Change, Evolution, and Complexity*, edited by R. V. S. Wright, pp. 24–36. Australian Institute of Aboriginal Studies, Canberra.

1978 *Nunamiut Ethnoarchaeology*. Academic Press, New York.

1979 Organization and Formation Processes: Looking at Curated Technologies. *Journal of Anthropological Research* 35:255–273.

1980 Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity* 45:4–20.

1991 When the Going Gets Tough, the Tough Get Going: Nunamiut Local Groups, Camping Patterns, and Economic Organization. In *Ethnoarchaeological Approaches to Mobile Campsites: Hunter-Gatherer and Pastoralist Case Studies*, edited by W. A. Boismier and C. W. Gamble, pp. 25–137. International Monographs in Prehistory, Ann Arbor, Michigan.

Binford, Lewis R., and Sally R. Binford

1966 A Preliminary Analysis of Functional Variability in the Mousterian of Levallois Facies. *American Anthropologist* 68:238–295.

Birkeland, Peter W.

1999 *Soils and Geomorphology*. 3rd ed. Oxford University Press, New York.

Bleed, Peter

1986 The Optimal Design of Hunting Weapons: Maintainability or Reliability. *American Antiquity* 51:737–747.

Bliege Bird, Rebecca

1999 Cooperation and Conflict: The Behavioral Ecology of the Sexual Division of Labor. *Evolutionary Anthropology* 8:65–75.

Bodily, Mark K.

2009 Residential Mobility of Paleoarchaic and Early Archaic Occupations at North Creek Shelter (42GA5893): An Analysis of Chipped Stone Artifacts. Unpublished Master's thesis, Department of Anthropology, Brigham Young University, Provo, Utah.

Boggs, Sam

1987 *Principles of Sedimentology and Stratigraphy*. Merrill Publishing, Columbus, Ohio.

Bohrer, Vorsila L.

1970 Ethnobotanical Aspects of Snaketown, a Hohokam Village in Southern Arizona. *American Antiquity* 35:413–430.

1975 The Prehistoric and Historic Role of the Cool-Season Grasses in the Southwest. *Economic Botany* 29(3):199–208.

1987 The Plant Remains from La Ciudad, a Hohokam Site in Phoenix. In *Specialized Studies in the Economy, Environment and Culture of La Ciudad, Part III*, edited by JoAnn Kisselburg, Glen Rice, and Brenda Shears, pp. 67–202. Anthropological Field Studies No. 20. Arizona State Museum, University of Arizona, Tucson.

1991 Recently Recognized Cultivated and Encouraged Plants among the Hohokam. *Kiva* 56:227–235.

2007 *Preceramic Subsistence in Two Rock Shelters in Fresnal Canyon, South Central New Mexico*. Archaeological Series 199. Arizona State Museum, University of Arizona, Tucson.

Bostwick, Todd W. (assembler)

1988 *An Investigation of Archaic Subsistence and Settlement in the Harquahala Valley, Maricopa County, Arizona*. Northland Research, Flagstaff, Arizona.

Bostwick, Todd W., and Pamela C. Hatch

1988 Faunal Material. In *An Investigation of Prehistoric Sites in the Harquahala Valley, Maricopa County, Arizona*, assembled by Todd W. Bostwick, pp. 294–310. Northland Research, Flagstaff, Arizona.

Bourdieu, Pierre

1977 *Outline of a Theory of Practice*. Cambridge University Press, Cambridge, England.

1988 *Homo Academicus*. Stanford University Press, Stanford, California.

Boutton, Thomas W., Steven R. Archer, Andrew J. Midwood, Stephen F. Zitzer, and Roland Bol

1998 $\delta\ ^{13}C$ Values of Soil Organic Carbon and Their Use in Documenting Vegetation Change in a Subtropical Savanna Ecosystem. *Geoderma* 82:5–42.

Bowers, Stephen
1888 *The Conchilla Valley and the Cahuilla Indians*. San Buenaventura, California.

Braidwood, Robert J., and Bruce Howe
1960 *Prehistoric Investigations in Iraqi Kurdistan*. Studies in Ancient Oriental Civilization No. 31. University of Chicago Press, Chicago.

Braun, David P.
1980 Experimental Interpretation of Ceramic Vessel Use on the Basis of Rim and Neck Formal Attributes. In *The Navajo Project: Archaeological Investigations, Page to Phoenix 500 kV Southern Transmission Line*, edited by Donald C. Fiero, Robert W. Munson, Martha T. McClain, Suzanne M. Wilson, and Anne H. Zier Fiero, pp. 171–231. Research Paper No. 11. Museum of Northern Arizona, Flagstaff.

1983 Pots as Tools. In *Archaeological Hammers and Theories*, edited by James A. Moore and Arthur S. Keene, pp. 107–134. Academic Press, New York.

Breazeale, James F.
1923 *The Pima and His Basket*. Arizona Archaeological and Historical Society, Tucson.

Breternitz, Cory D.
2004 Introduction, Project Background, and Testing Methodology. In *Archaeological Testing at 33 Sites at Verrado, a Master Planned Community in the White Tank Mountains, Maricopa County, Arizona*, by Cory D. Breternitz, Christine K. Robinson, Aron J. Adams, Steven R. Copeland, and Rebecca J. Hill, pp. 1.1–1-20. Technical Report No. 01-22. Soil Systems, Phoenix.

Bronk Ramsey, C.
2009 Bayesian Analysis of Radiocarbon Dates. *Radiocarbon* 51:337–360.

2011 *OxCal v.4.1 Manual*. Electronic document, https://c14.arch.ox.ac.uk/oxcal/OxCal.html, accessed September 12, 2013.

2013 *OxCal 4.2 Manual*. Electronic document, https://c14.arch.ox.ac.uk/oxcalhelp/hlp_contents.html, accessed March 2014.

Brott, Clark W.
1966 How Stones Became Tools and Weapons. In *Ancient Hunters of Far West,* by M. J. Rogers, pp. 139–193. Union-Tribune Publishing, San Diego.

Brown, David E.
2008 *Arizona Wildlife: The Territorial Years 1863–1912*. Arizona Game and Fish Department, Phoenix.

Bryan, Kirk, and J. H. Toulouse
1943 The San Jose Non-Ceramic Culture and Its Relation to a Puebloan Culture in New Mexico. *American Antiquity* 8:269–280.

1997 *Archaeological Investigations of the Early Agricultural Period Settlement at the Base of A-Mountain, Tucson, Arizona*. Technical Report 96-21. Center for Desert Archaeology, Tucson.

Buchanan, B., M. Collard, and K. Edinborough

2008 Paleoindian Demography and the Extraterrestrial Impact Hypothesis. *Proceedings of the National Academy of Sciences of the United States of America* 105:11651–11654.

Buck, Brenda J., and H. Curtis Monger

1999 Stable Isotopes and Soil Geomorphology as Indicators of Holocene Climate Change, Northern Chihuahuan Desert. *Journal of Arid Environments* 43(4):357–373.

Buikstra, Jane, and Douglas Ubelaker (editors)

1994 *Standards for Data Collection from Human Skeletal Remains: Proceedings of a Seminar at the Field Museum of Natural History*. Research Series No. 44. Arkansas Archeological Society, Fayetteville.

Bull, William B.

1977 The Alluvial-Fan Environment. *Progress in Physical Geography* 1:222–270.

1984 Alluvial Fans and Pediments of Southern Arizona. In *Landscapes of Arizona—The Geological Story*, edited by Terah L. Smiley, J. Dale Nations, Troy L. Péwé, and John P. Schafer, pp. 229–252. University Press of America, Lanham, Maryland.

1991 *Geomorphic Responses to Climatic Change*. Oxford University Press, New York.

1997 Discontinuous Ephemeral Streams. *Geomorphology* 19(3–4):227–276.

Buol, Stanley W., Randal J. Southard, Robert C. Graham, and Paul A. McDaniel

2003 *Soil Genesis and Classification*. 5th ed. Iowa State University Press, Ames.

Buonasera, Tammy Y.

2012 *Expanding Archaeological Approaches to Ground Stone: Modeling Manufacturing Costs, Analyzing Absorbed Organic Residues, and Exploring Social Dimensions of Milling Tools*. Ph.D. dissertation, Department of Anthropology, University of Arizona, Tucson. ProQuest, UMI Dissertations Publishing No. 3550019. University of Arizona, Tucson.

Burr, Jonathan L.

1992 Early Proterozoic Structural Geology, Metamorphism, and Effects of Pluton Emplacement, Southern Big Bug Tectonic Block, Hieroglyphic Mountains, Central Arizona. Unpublished Ph.D. dissertation, Department of Geology and Geography, University of Massachusetts, Amherst.

Burt, William H., and Richard P. Grossenheider

1980 *A Field Guide to the Mammals: North America North of Mexico*. 3rd ed. Peterson Field Guide Series 5. Houghton Mifflin, Boston.

Butler, B. Robert

1978 *A Guide to Understanding Idaho Archaeology: The Upper Snake and Salmon River Country.* 3rd ed. Idaho State Historic Preservation Office, Boise.

1986 Prehistory of the Snake and Salmon River Area. In *California*, edited by Robert F. Heizer, pp. 127–134. Handbook of North American Indians, vol. 8, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Callahan, Errett

1979 The Basics of Biface Knapping in the Eastern Fluted Point Tradition: A Manual for Flintknappers and Lithic Analysts. *Archaeology of Eastern North America* 7:1–180.

Campbell, E. W. C.

1931 *An Archaeological Survey of the Twenty Nine Palms Region*. Papers No. 7. Southwest Museum, Los Angeles.

Campbell, Elizabeth W. C., and William H. Campbell

1935 *The Pinto Basin Site: An Ancient Aboriginal Camping Ground in the California Desert.* Papers No. 9. Southwest Museum, Los Angeles.

Campbell, Lyle

1997 *American Indian Languages*. Oxford University Press, Oxford, England.

Campbell, Paul D.

2009 *Survival Skills of Native California*. Gibbs-Smith, Salt Lake City.

Campbell, Thomas N., and Tommy J. Campbell

1981 *Historic Indian Groups of the Choke Canyon Reservoir and Surrounding Area, Southern Texas*. Choke Canyon Series, vol. 1. Center for Archaeological Research, University of Texas, San Antonio.

Carpenter, John P., Guadalupe Sánchez, and María Elisa Villalpando C.

2005 The Late Archaic/Early Agricultural Period in Sonora, Mexico. In *The Late Archaic across the Borderlands: From Foraging to Farming*, edited by Bradley J. Vierra, pp. 13–40. Texas Archaeology and Ethnohistory Series. University of Texas Press, Austin.

Carpenter, John P., María Elisa Villalpando C., and Guadalupe Sánchez Miranda

2008 Environmental and Cultural Dynamics on the Southern Papaguería Periphery. In *Fragile Patterns: The Archaeology of the Western Papaguería*, edited by Jeffrey H. Altschul and Adrianne G. Rankin, pp. 287–308. SRI Press, Tucson.

Cashdan, Elizabeth

1983 Territoriality among Human Foragers: Ecological Models and an Application to Four Bushman Groups. *Current Anthropology* 24:47–66.

Castetter, Edward F.

1935 *Uncultivated Native Plants Used as Sources of Food.* Ethnobiological Studies in the American Southwest I. Bulletin Whole No. 266. Biological Series, vol. 4, no. 1. University of New Mexico Press, Albuquerque.

Castetter, Edward F., and Willis H. Bell

1937 *The Aboriginal Utilization of the Tall Cacti in the American Southwest*. Bulletin No. 307. Ethnobiological Studies in the American Southwest 4. Biological Series, vol. 5, no. 1. University of New Mexico Press, Albuquerque.

1942 *Pima and Papago Indian Agriculture*. Inter-Americana Studies 1. University of New Mexico Press, Albuquerque.

1951 *Yuman Indian Agriculture: Primitive Subsistence on the Lower Colorado and Gila Rivers.* University of New Mexico Press, Albuquerque.

Castetter, Edward F., Willis H. Bell, and Alvin R. Grove
1938 *The Early Utilization and Distribution of Agave in the American Southwest*. Bulletin No. 335. Ethnobiological Studies in the American Southwest 6. Biological Series, vol. 5, no. 4. University of New Mexico Press, Albuquerque.

Castetter, Edward F., and Morris E. Opler
1936 *Ethnobiological Studies in the American Southwest, III: The Ethnobiology of the Chiricahua and Mescalero Apache.* Bulletin No. 297. Biological Series, vol. 4, no. 5. University of New Mexico Press, Albuquerque.

Castetter, Edward F., and Ruth M. Underhill
1935 *Ethnobiological Studies in the American Southwest II: The Ethnobiology of the Papago Indians.* Bulletin No. 275. Biological Series, vol. 4, no. 3. University of New Mexico Press, Albuquerque.

Cerling, Thure E., Robert H. Webb, Robert J. Poreda, Alan D. Rigby, and Theodore S. Melis
1999 Cosmogenic ^{3}He Ages and Frequency of Late Holocene Debris Flows from Prospect Canyon, Grand Canyon, USA. *Geomorphology* 27:93–111.

Chapin-Pyritz, Regina L.
2007 Faunal Remains and Worked-Bone Artifacts. In *Recurrent Sedentism and the Making of Place: Archaeological Investigations at Las Capas, a Preceramic Period Farming Community in the Tucson Basin, Southern Arizona*, edited by Stephanie M. Whittlesey, S. Jerome Hesse, and Michael S. Foster, pp. 271–322. Cultural Resources Report No. 07-556. Draft. SWCA Environmental Consultants, Tucson.

Cheatum, Elmer P., and Richard W. Fullington
1971 *Keys to the Families of the Recent Land and Fresh-Water Snails of Texas*. Supplement to The Aquatic and Land Mollusca of Texas. Bulletin No. 1. Dallas Museum of Natural History, Dallas.

Ciolek-Torrello, Richard
2004 Hohokam Household Organization and Irrigation in the Phoenix Basin. In *From the Desert to the Mountains: Archaeology of the Transition Zone, the State Route 87–Sycamore Creek Project, Volume 3, Conclusions and Synthesis,* edited by Richard Ciolek-Torrello, Eric Eugene Klucas, and Rein Vanderpot, pp. 201–226. Technical Series 73. Statistical Research, Tucson.

Ciolek-Torello, Richard, and Robert M. Wegener
2011 Summary and Conclusions. In *Florence Junction Area*. The U.S. 60 Archaeological Project: Early Agricultural, Formative, and Historical-Period Use of the Upper Queen Creek Region, vol. 1, edited by Richard Ciolek-Torello and Robert M. Wegener, pp. 275–290. Technical Series 92. Statistical Research, Inc., Tucson.

Ciolek-Torrello, Richard, Eric E. Klucas, and Stephanie M. Whittlesey
2000 Hohokam Households, Settlement Structure, and Economy in the Lower Verde Valley. In *The Hohokam Village Revisited*, edited by D. E. Doyel, S. K. Fish, and P. R. Fish. South-western and Rocky Mountain Division, American Association for the Advancement of Sci-ence, Glenwood Springs, Colorado.

Clark, Jeffrey J., Gavin H Archer, and Penny Dufoe-Minturn

1998 Las Tortugas (U:3:297/332). In *Tonto Creek Archaeological Project: Archaeological Investigations along Tonto Creek,* vol. 2, edited by Jeffery J. Clark and James M. Vint, pp. 293–420. Anthropological Papers No. 22. Center for Desert Archaeology, Tucson.

Clarke, M. L.

1994 Infra-Red Stimulated Luminescence Ages from Aeolian Sand and Alluvial Fan Deposits from the Eastern Mojave Desert, California. *Quaternary Geochronology* 13:533–538.

Cloud, William A.

2004 *The Arroyo de la Presa Site: A Stratified Late Prehistoric Campsite along the Rio Grande, Presidio County, Trans-Pecos Texas*. Reports in Contract Archeology No. 9. Center for Big Bend Studies, Sul Ross University, Alpine, Texas. Report No. 56. Alpine and Archeological Studies Program, Texas Department of Transportation, Environmental Division, Austin.

Conolly, James, and Mark Lake

2006 *Geographic Information Systems in Archaeology*. Cambridge Manuals in Archaeology. Cambridge University Press, New York.

Cook, Sherburne F.

1972 *Prehistoric Demography*. Modular Publications No. 16. Addison-Wesley, Reading, Massachusetts.

Cordell, Linda S.

1979 Prehistory: Eastern Anasazi. In *Southwest*, edited by Alfonso Ortiz, pp. 131–151. Handbook of North American Indians, vol. 9, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Cosgrove, C. B.

1947 *Caves of the Upper Gila and Hueco Areas in New Mexico and Texas*. Papers No. 24. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

Cotterell, Brian, and Johan Kamminga

1987 The Formation of Flakes. *American Antiquity* 52:675–708.

Craig, Douglas B.

2001 Domestic Architecture. In *The Grewe Archaeological Research Project: Project Background and Feature Descriptions*, vol. 1, edited by Douglas B. Craig, pp. 63–108. Anthropological Papers No. 99-1. Northland Research, Inc., Phoenix.

Cressman, Luther Sheeleigh, Frank Collins Baker, Paul S. Conger, Henry P. Hansen, and Robert F. Heizer

1942 *Archaeological Researches in the Northern Great Basin*. Publication 538. Carnegie Institution, Washington, D.C.

Crosswhite, Frank S.

1981 Desert Plants, Habitat and Agriculture in Relation to the Major Pattern of Cultural Differentiation in the O'odham People of the Sonoran Desert. *Desert Plants* 3(2):47–76.

Curtin, Leonora S. M.

1949 *By the Prophet of the Earth*. San Vicente Foundation, Santa Fe.

1984 *By the Prophet of the Earth: Ethnobotany of the Pima*. San Vicente Foundation, Santa Fe.

Curtis, Edward

1926 *Southern California Shoshoneans. The Diegueños. Plateau Shoshoneans. The Washo.* The North American Indian, vol. 15. Plimpton, Norwood, Massachusetts.

Cushing, Frank H.

1920 *Zuni Breadstuff*. Indian Notes and Monographs 8. Museum of the American Indian, New York.

1979 *Zuni: Select Writings of Frank Hamilton Cushing.* University of Nebraska Press, Lincoln.

Dart, Allen

1986 *Archaeological Investigations at La Paloma: Archaic and Hohokam Occupations at Three Sites in the Northeastern Tucson Basin, Arizona*. Anthropological Papers No. 4. Institute for American Research, Goleta, California.

Davis, Owen K., and David S. Shafer

1992 A Holocene Climatic Record for the Sonoran Desert from Pollen Analysis of Montezuma Well, Arizona, USA. *Palaeogeography, Palaeoclimatology, Palaeoecology* 92:107–119.

Dean, Jeffrey S.

1991 Thoughts on Hohokam Chronology. In *Exploring the Hohokam: Prehistoric Desert Peoples of the American Southwest*, edited by George J. Gumerman, pp. 61–149. Amerind Foundation, Dragoon, Arizona, and University of New Mexico Press, Albuquerque.

Dean, Rebecca Marie

2003 People, Pests, and Prey: The Emergence of Agricultural Economies in the Desert Southwest. Unpublished Ph.D. dissertation, Department of Anthropology, University of Arizona, Tucson.

2007a Subsistence: Vertebrate Faunal Material. In *Archaeological Investigations at the El Taller, AZ AA:12:92 (ASM), and Rillito Fan, AZ AA:12:788 (ASM), Sites along Eastbound I-10 between Sunset and Ruthrauff Roads, Tucson, Pima County, Arizona*, edited by Helga Wöcherl, pp. 131–148. Technical Report 2003-04. Desert Archaeology, Tucson.

2007b The Lagomorph Index: Rethinking Rabbit Ratios in Hohokam Sites. *Kiva* 73:7–30.

Demsey, Karen A.

1988 *Geologic Map of Quaternary and Upper Tertiary Alluvium in the Phoenix North 30' × 60' Quadrangle, Arizona*. Map scale 1:100,000. Open-File Report 88-17. Arizona Geological Survey, Tucson.

deMenocal, Peter, Joseph Ortiz, Tom Guilderson, Jess Adkins, Michael Sarnthein, Linda Baker, and Martha Yarusinsky

2000 Abrupt Onset and Termination of the African Humid Period: Rapid Climate Responses to Gradual Insolation Forcing. *Quaternary Science Reviews* 19:347–361.

Densmore, Frances

1979 *Chippewa Customs*. Reprinted. Minnesota Historical Society Press, St. Paul. Originally published 1929, Bureau of American Ethnology Bulletin No. 86, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Dering, J. Phil

1994 Appendix E: Analysis of Plant Remains from 41GR291 and 41GR559. In *Data Recovery at Lake Alan Henry (Justiceburg Reservoir), Garza and Kent Counties, Texas: Phase III, Season 1*, edited by Douglas K. Boyd, C. Britt Bousman, Steve A. Tomka, Karen M. Gardner, and Martha Doty Freeman, pp. 211–220. Reports of Investigations No. 84. Prewitt and Associates, Austin.

1999 Earth-Oven Plant Processing in Archaic Period Economies: An Example from a Semi-Arid Savannah in South-Central North America. *American Antiquity* 64:659–674.

2001 Botanical Remains from the El Paso Loop 375 Sites. In *The El Paso Loop 375 Archaeological Project: Phase II Testing and Phase III Mitigation*, edited by J. Phil Dering, Harry J. Shafer, and Robyn P. Lyle. Report No. 28. Archeological Studies Program, Texas Department of Transportation, Environmental Affairs Division. Reports of Investigations 3. Center for Ecological Archaeology, Texas A&M University, College Station.

2005 *Plant Remains from Hank's Site, Roberts County, Texas.* Manuscript on file, Prewitt and Associates, Austin.

Dick, Herbert W.

1965 *Bat Cave, Catron County, New Mexico*. Monograph No. 27. School of American Research, Santa Fe.

Diehl, Michael W.

2005 Early Agricultural Period Foraging and Horticulture in Southern Arizona: Implications from Plant Remains. In *Subsistence and Resource Use Strategies of Early Agricultural Communities in Southern Arizona*, edited by Michael W. Diehl, pp. 74–89. Anthropological Papers No. 34. Center for Desert Archaeology, Tucson.

Diehl, Michael W. (editor)

2005 *Subsistence and Resource Use Strategies of Early Agricultural Communities in Southern Arizona*. Anthropological Papers No. 34. Center for Desert Archaeology, Tucson.

Diehl, Michael, and Jennifer A. Waters

2006 Aspects of Optimization and Risk during the Early Agricultural Period in Southeastern Arizona. In *Behavioral Ecology and the Transition to Agriculture*, edited by Douglas J. Kennet and Bruce Winterhalder, pp. 63–86. University of California Press, Berkeley.

DiPeso, Charles

1956 *The Upper Pima of San Cayetano del Tumacacori: An Archaeohistorical Reconstruction of the Ootam of Pimeria Alta*. Publication No. 7. Amerind Foundation, Dragoon, Arizona.

Dittemore, Diane D., Terrol Dew Johnson, and Terri Goode

2012 *Basketry Treasured: The Living Legacy of an Ancient Cultural Art.* Gallery Guide. Arizona State Museum, University of Arizona, Tucson.

Dobyns, Henry F.

1988 Piman Indian Historic Agave Cultivation. *Desert Plants* 9:49–53.

Doebley, John F.

1984 Seeds of Wild Grasses: A Major Food of Southwestern Indians. *Economic Botany* 38(1):52–64.

Doelle, William H.

1976 *Desert Resources and Hohokam Subsistence: The CONOCO-Florence Project*. Archaeological Series No. 103. Cultural Resource Management Section, Arizona State Museum, University of Arizona, Tucson.

1980 *Past Adaptive Patterns in Western Papaguería: An Archaeological Study of Nonriverine Resource Use.* Ph.D. dissertation, University of Arizona, Tucson. University Microfilms, Ann Arbor, Michigan.

Dongoske, Kurt E.

1993 Burial Population and Mortuary Practices. In *Archaic Occupation on the Santa Cruz Flats: The Tator Hills Archaeological Project*, edited by Carl D. Halbirt and T. Kathleen Henderson, pp. 173–181. Northland Research, Flagstaff, Arizona.

Donovan, D. J.

1996 Hydrostratigraphy and Allostratigraphy of the Cenozoic Alluvium in the Northwestern Part of Las Vegas Valley, Clark County, Nevada. Unpublished Ph.D. dissertation, Department of Geosciences, University of Nevada, Las Vegas.

Doolittle, Donald E.

2001 *Cultivated Landscapes of Native North America*. Oxford University Press, Oxford, England.

Douglas, Frederic H.

1935 *Apache Baskets*. Esto, Pasadena, California.

Doyel, David E., and Lorraine Marquez Eiler

2003 *Hia C'ed O'odham Traditional Cultural Properties on the Barry M. Goldwater Range and Southwestern Arizona*. Paper No. 6. Estrella Cultural Research, Phoenix.

Doyel, David E., and Mark D. Elson

1985 Ceramic Analysis. In *Hohokam Settlement and Economic Systems in the Central New River Drainage, Arizona*, edited by David E. Doyel and Mark D. Elson, pp. 437–519. Publications in Archaeology No. 4. Soil Systems, Phoenix.

Drew, Frederic

1873 Alluvial and Lacustrine Deposits and Glacial Records of the Upper Indus Basin. *Quarterly Journal of the Geological Society of London* 29:441–471.

Earle, F., and Q. Jones

1962 Analyses of Seed Samples from 113 Plant Families. *Economic Botany* 16:221–250.

Eaton, Gordon P., Donald L. Peterson, and Herbert H. Schumann

1972 *Geophysical, Geohydrological, and Geochemical Reconnaissance of the Luke Salt Body, Central Arizona*. Professional Paper 753. U.S. Geological Survey, U.S. Government Printing Office, Washington, D.C.

Ebeling, Walter

1986 *Handbook of Indian Foods and Fibers of Arid America*. University of California Press, Berkeley.

Eberly, L. D., and T. B. Stanley, Jr.

1978 Cenozoic Stratigraphy and Geologic History of Southwestern Arizona. *Geological Society of America Bulletin* 89:921–940.

Ehleringer, J. R.

1989 Carbon Isotope Ratios and Physiological Processes in Aridland Plants. *Ecological Studies* 68:41–54.

Ehleringer J. R., and T. A. Cooper

1988 Correlations between Carbon Isotope Ratio and Microhabitat in Desert Plants. *Oecologia* 76:562–566.

Eidt, R. C.

1984 *Advances in Abandoned Settlement Analysis: Application to Prehistoric Anthrosols in Columbia, South America*. Center for Latin America, University of Wisconsin, Milwaukee.

Eiselt, B. Sunday, Rachel S. Popelka-Filcoff, J. Andrew Darling, and Michael Glascock

2011 Hematite Sources and Archaeological Ochres from Hohokam and O'odham Sites in Central Arizona: An Experiment in Type Identification and Characterization. *Journal of Archaeological Science* 38:3019–3028.

Ellis, Linda W.

1997 Hot Rock Technology. In *Hot Rock Cooking on the Greater Edwards Plateau: Four Burned Rock Midden Sites in West Central Texas*, by Stephen L. Black, Linda W. Ellis, Darrell G. Creel, and Glenn T. Goode, pp. 43–76. Report No. 2. Archeological Studies Program, Environmental Affairs Division, Texas Department of Transportation, Austin. Studies in Archeology No. 22. Texas Archeological Research Laboratory, University of Texas, Austin.

Ely, L. L.

1997 Response of Extreme Floods in the Southwestern United States to Climatic Variations in the Late Holocene. *Geomorphology* 19:175–201.

Ember, M.

1973 An Archaeological lndicator of Matrilocal versus Patrilocal Residence. *American Antiquity* 38:177–182.

1978 Myths about Hunter-Gatherers. *Ethnology* 17:439–448.

Ervin, Richard G., and Martyn D. Tagg

1984 Lithic Material Procurement Sites in the Rosemont Area. In *Miscellaneous Archaeological Studies in the ANAMAX-Rosemont Land Exchange Area*, edited by Martyn D. Tagg, Richard G. Ervin, and Bruce B. Huckell, pp. 1–59. Archaeological Series, vol. 4, no. 147. Arizona State Museum, University of Arizona, Tucson.

Evans, William S.

1978 *Ethnographic Notes on the Honey Lake Maidu*. Occasional Papers, no. 3, pt. 2. Nevada Statue Museum, Carson City.

Everitt, J., and M. Alaniz

1981 Nutrient Content of Cactus and Woody Plant Fruits Eaten by Birds and Mammals in South Texas. *Southwestern Naturalist* 26:301–305.

Ezzo, Joseph A., and Mary C. Stiner

2000 A Late Archaic Period Dog Burial from the Tucson Basin, Arizona. *Kiva* 66:291–305.

Fægri, Knut, and Johannes Iversen

1989 *Textbook of Pollen Analysis*. 4th ed. John Wiley & Sons, Chichester, England.

Farrar, Jon

2005 The History and Art of Shotshells. *Nebraskaland* 83:28–39.

Farrer, Claire

1992 Those Who Lived Before. In *Basketmakers: Meaning and Form in Native American Baskets*, edited by Linda Mowat, Howard Morphy, and Penny Dransart, pp. 76–90. Monograph 5. Pitt Rivers Museum, University of Oxford, Oxford, England., pp.76-90.

Faught, Michael K, and Andrea K. L. Freeman

1998 Paleoindian Complexes of the Terminal Wisconsin and Early Holocene. In *Paleoindian and Archaic Sites in Arizona*, edited by Jonathan B. Mabry, pp. 34–52. Technical Report 97-7. Center for Desert Archaeology, Tucson.

Felger, Richard S.

1977 Mesquite in Indian Cultures in Southwestern North America. In *Mesquite, Its Biology in Two Desert Ecosystems*, edited by Beryl B. Simpson, pp. 150–176. U.S. and International Biome Project Synthesis Series 4. Dowden, Hutchinson, and Ross, Stroudsburg, Pennsylvania.

1977 Mesquite in Southwestern Indian Cultures. In *A Tree in Perspective: Prosopis in Desert Shrub Ecosystems*, edited by B. Simpson, pp. 150–176. Dowden, Hutchinson and Ross, Stroudsburg, Pennsylvania.

2007 Living Resources at the Center of the Sonoran Desert: Regional Uses of Plants and Animals by Native Americans. In *Dry Borders: Great Natural Reserves of the Sonoran Desert*, edited by Richard S. Felger and Bill Broyles, pp. 147–192. University of Utah Press, Salt Lake City.

Felger, Richard S., and Mary B. Moser

1971 Seri Use of Mesquite (*Prosopis glandulosa* var. *torreyana*). *The Kiva* 37:53–60.

1985 *People of the Desert and Sea: Ethnobotany of the Seri Indians*. University of Arizona Press, Tucson.

Felger, Richard S., Peter L. Warren, L. Susan Anderson, and Gary P. Nabhan

1992 *Vascular Plants of a Desert Oasis: Flora and Ethnobotany of Quitobaquito, Organ Pipe Cactus National Monument, Arizona*. Proceedings of the San Diego Society of Natural History No. 8. San Diego Natural History Museum, San Diego.

Felker, Peter

2005 Mesquite Flour: New Life for an Old Staple. *Gastronomica: The Journal of Food and Culture* 5(2):85–89.

Felker, P., P. Clark, A. E. Lang, and P. F. Pratt

1981 Salinity Tolerance of the Tree Legumes: Mesquite (*Prosopis glandulosa* var. *Torreyana, P. velutina*, and *P. articulate*), Algarrobo (*P. Chilensis*), Kiawe (*P. Pallida*), and Tamarugo (*P. Tamarugo*) Grown in Sand Culture on Nitrogen Free Media. *Plant and Soil* 61:311–317.

Fenneman, Nevin M.
1931 *Physiography of the Western United States*. McGraw-Hill, New York.

Ferg, Alan
1998 Rare Stone, Fired Clay, Bone, and Shell Artifacts. In *Analysis and Synthesis,* edited by Jonathan B. Mabry, pp. 545–654. Archaeological Investigations of Early Village Sites in the Middle Santa Cruz Valley, pt. 1. Anthropological Papers No. 19. Center for Desert Archaeology, Tucson.

2007 Birds in the Southwest. *Archaeology Southwest* 21(1):1–3.

Ferg, Alan, and Jim I. Mead
1993 *Red Cave—A Prehistoric Cave Shrine in Southeastern Arizona*. The Arizona Archaeologist No. 26. Arizona Archaeological Society, Phoenix.

Field, John J.
2001 Channel Avulsion on Alluvial Fans in Southern Arizona. *Geomorphology* 37:93–104.

Field, John J., and Philip A. Pearthree
1991 *Surficial Geology around the White Tank Mountains, Central Arizona*. Open-File Report 91-08. Arizona Geological Survey, Tucson.

Fish, Paul R., Suzanne K. Fish, John H. Madsen, Charles H. Miksicek, and Christine R. Szuter
1992 The Dairy Site: Occupational Continuity on an Alluvial Fan. In *The Marana Community in the Hohokam World*, edited by Suzanne K. Fish, Paul R. Fish, and John H. Madsen, pp. 64–72. Anthropological Papers 56. University of Arizona, Tucson.

Fontana, Bernard L.
1983 Pima and Papago: Introduction. In *Southwest*, edited by Alfonso Ortiz, pp. 125–136. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Fontana, Bernard L., William J. Robinson, Charles W. Cormack, and Ernest E. Leavitt, Jr.
1962 *Papago Indian Pottery*. Monographs of the American Ethnological Society No. 38. University of Washington Press, Seattle.

Forde, C. Daryll
1931 *Ethnography of the Yuma Indians*. Publications in American Archaeology and Ethnology, vol. 28, no. 4. University of California Press, Berkeley.

Formby, D. E.
1986 Pinto-Gypsum Complex Projectile Points from Arizona and New Mexico. *The Kiva* 51:99–125.

Fortier, Jane, and Jerry Schaefer
2010 *Barry M. Goldwater Range (BMGR) West Cultural Affiliation Study.* ASM Affiliates. Carlsbad, California.

Foster, Luther
1916 *The Feeding Value of the Mesquite Bean*. New Mexican Farm Courier, vol. 4, no. 9. New Mexico College of Agriculture and Mechanic Arts, Santa Fe.

Fowler, Catherine S.

1983 Some Lexical Clues to Uto-Aztecan Prehistory. *International Journal of American Linguistics* 49:224–257.

1995 Some Notes on Ethnographic Subsistence Systems in Mojavean Environments in the Great Basin. *Journal of Ethnobiology* 14(1):99–117.

Fowler, Catherine S., and Sven Liljeblad

1986 Owens Valley Paiute. In *Great Basin*, edited by Warren L. d'Azevedo, pp. 435–465. Handbook of North American Indians, vol. 11, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Freeman, Andrea K. L.

1999 Status of the Middle Archaic in Southern Arizona. In *Excavations in the Santa Cruz River Floodplain: The Middle Archaic Component at Los Pozos*, edited by David A. Gregory, pp. 75–84. Anthropological Papers No. 20. Center for Desert Archaeology, Tucson.

Fresquez, T., and M. Toll

2006 Cordage, Knots, Basketry, Bundles, and Bundle Ties. In *High Rolls Cave: Insectos, Burritos, y Frajos, Archaic Subsistence in Southern New Mexico*. Technical Series 2005-1. Office of Archaeological Studies, Museum of New Mexico, Albuquerque.

Fulkerson, Mary Lee, and Kathleen Curtis

1995 *Weavers of Tradition and Beauty: Basketmakers of the Great Basin*. University of Nevada Press, Reno.

Gamble, C., W. Davies, P. Pettitt, L. Hazelwood, and M. Richards

2005 The Archaeological and Genetic Foundations of the European Population during the Late Glacial: Implications for "Agricultural Thinking." *Cambridge Archaeological Journal* 15:193–223.

Garcia, F.

1917 *Mesquite Beans for Pig Feeding*. Annual Report 28. Agricultural Experiment Station, New Mexico State University, Las Cruces.

Garraty, Christopher P.

2011 The Origins of Pottery as a Practical Domestic Technology: Evidence from the Middle Queen Creek Area, Arizona. *Journal of Anthropological Archaeology* 30:220–234.

Garraty, Christopher P., Robert A. Heckman, and Resha Shenandoah

2011 Ceramic Artifacts. In *Analyses of Prehistoric Materials in the Queen Valley to Queen Creek Area*, edited by Robert M. Wegener, Michael P. Heilen, Richard Ciolek-Torello, and John D. Hall, pp. 327–443. The U.S. 60 Archaeological Project: Early Agricultural, Formative, and Historical-Period Use of the Upper Queen Creek Region, vol. 4. Technical Series 92. Statistical Research, Tucson.

Gasser, Robert E.

1982 Hohokam Use of Desert Plant Foods. *Desert Plants* 3(4):216–234.

Gasser, Robert E., and Scott M. Kwiatkowski

1991a Regional Signatures of Hohokam Plant Use. *Kiva* 56:207–226.

1991b Food for Thought: Recognizing Patterns in Hohokam Subsistence. In *Exploring the Hohokam, Prehistoric Desert Peoples of the American Southwest*, edited by George J. Gumerman, pp. 417–459. New World Studies Series No. 1. Amerind Foundation, Dragoon, Arizona, and University of New Mexico Press, Albuquerque.

Gasser, Robert E., and Charles H. Miksicek

1985 The Specialists: A Reappraisal of Hohokam Exchange and the Archaeobotanical Record. In *Proceedings of the 1983 Hohokam Symposium,* pt. 2, edited by Alfred E. Dittert, Jr., and Donald E. Dove, pp. 483–498. Occasional Paper 2. Arizona Archaeological Society, Phoenix Chapter, Phoenix.

Geib, Phil, and Susan J. Smith

2008 Palynology and Archaeological Inference: Bridging the Gap between Pollen Washes and Past Behavior. *Journal of Archaeological Science* 35:2085–2101.

Gentry, H. S.

1963 *The Warihio Indians of Sonora-Chihuahua: An Ethnographic Survey*. Bureau of American Ethnology Bulletin 186, Anthropological Papers No. 65. Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Gibbon, Guy E., and Kenneth Ames (editors)

1998 *Archaeology of Prehistoric Native America: An Encyclopedia*. Garland, New York.

Giddens, Anthon

1979 *Central Problems in Social Theory: Action, Structure, and Contradiction in Social Analysis.* University of California Press, Berkeley.

1984 *The Constitution of Society: Outline of a Theory of Structuration*. University of California Press, Berkeley.

Gifford, Edward Winslow

1932 *The Southeastern Yavapai*. Publications in American Archaeology and Ethnography, vol. 29, no. 3. University of California Press, Berkeley.

1933 *The Cocopa.* Publications in American Archaeology and Ethnology, vol. 31, no. 5. University of California Press, Berkeley.

1936 *Northeastern and Western Yavapai.* Publications in American Archaeology and Ethnology, vol. 34, no. 4. University of California Press, Berkeley.

Gigli, Jane Green

1974 Dat So La Lee, Queen of the Washo Basketmakers. In *Collected Papers on Aboriginal Basketry*, edited by Jane G. Gigli, Donald R. Tuohy, Phil C. Orr, Charles E. Rozaire, and James M. Adovasio, pp. 1–27. Anthropological Papers No. 16. Nevada State Museum, Carson City.

Gilbert, B. Miles

1980 *Mammalian Osteology*. Missouri Archaeological Society, Columbia.

Gilbert, B. Miles, Larry D. Martin, and Howard G. Savage

1985 *Avian Osteology*. Modern Printing, Laramie, Wyoming.

Gile, Leland H.

1975 Holocene Soils and Soil-Geomorphic Relations in an Arid Region of Southern New Mexico. *Quaternary Research* 5:321–360.

Gile, Leland H., John W. Hawley, and Robert B. Grossman

1981 Soils and Geomorphology in the Basin and Range Area of Southern New Mexico: Guidebook to the Desert Project. Memoir 39. New Mexico Bureau of Mines and Mineral Resources, Socorro.

Gillespie, William B.

1988 Faunal Remains from Four Sites along the Tucson Aqueduct: Prehistoric Exploitation of Jack Rabbits and Other Vertebrates in the Avra Valley. In *Syntheses and Interpretations,* pt. 1, edited by Jon S. Czaplicki and John C. Ravesloot, pp. 171–237. Hohokam Archaeology along Phase B of the Tucson Aqueduct Central Arizona Project, vol. 1. Archaeological Series No. 178. Cultural Resource Management Division, Arizona State Museum, University of Arizona, Tucson.

Gish, Jannifer

1993 Ethnobotany of the Tator Hills Sites. In *Archaic Occupation of the Santa Cruz Flats: The Tator Hills Archaeological Project*, edited by Carl D. Halbirt and Kathleen Henderson, pp. 317–331. Northland Research, Flagstaff, Arizona.

Gladwin, Winifred, and Harold S. Gladwin

1929 *The Red-on-Buff Culture in the Gila Basin*. Medallion Papers No. 3. Pasadena.

1933 *Some Southwestern Pottery Types, Series III*. Medallion Papers No. 13. Gila Pueblo, Globe, Arizona.

Gladwin, Harold S., Emil W. Haury, Edwin B. Sayles, and Nora Gladwin

1965 *Excavations at Snaketown I: Material Culture*. Reprinted. University of Arizona Press, Tucson. Originally published 1937, Medallion Papers No. 25, Gila Pueblo, Globe, Arizona.

Glassow, Michael A.

1996 The Significance to California Prehistory of the Earliest Mortars and Pestles. *Pacific Coast Archaeological Society Quarterly* 32(4):14–26.

Goodyear, Albert C., III

1974 *The Brand Site: A Techno-Functional Study of a Dalton Site in Northeast Arkansas*. Publications on Archaeology, Research Series 7. Arkansas Archeological Survey, Fayetteville.

1975 *Hecla II and III: An Interpretive Study of Archeological Remains from the Lakeshore Project, Papago Reservation, South Central Arizona*. Anthropological Research Paper No. 9. Arizona State University, Tempe.

Gootee, Brian F.

2013 *An Evaluation of Carbon Dioxide Sequestration Potential in the Luke Basin, South-Central Arizona*. Open-File Report 13-05. Arizona Geological Survey, Tucson.

Graves, William M.

2011 Pit Features. In *Analyses of Prehistoric Materials in the Queen Valley to Queen Creek Area*, edited by Robert M. Wegener, Michael P. Heilen, Richard Ciolek-Torello, and John D. Hall, pp. 631–682. The U.S. 60 Archaeological Project: Early Agricultural, Formative, and Historical-Period Use of the Upper Queen Creek Region, vol. 4. Technical Series 92. Statistical Research, Tucson.

Graves, William M., Robert M. Wegener, and Richard Ciolek-Torrello (editors)
2009 *Settlement, Production, and the Floodplain Environment of the Lowermost Salt River: Early Archaic, Hohokam, and Protohistoric Life at AZ T:11:94 (ASM), Phoenix, Arizona*. Technical Report 09-32. Statistical Research, Tucson.

Graves, William M., Robert M. Wegener, Richard Ciolek-Torello, and Gary Huckleberry
2011 Settlement and Production at the Cashion Site Complex: The Early Archaic and Hohokam Periods at AZ T:11:94 (ASM). *Journal of Arizona Archaeology* 1:148–161.

Greenhouse, Ruth, Robert E. Gasser, and Jannifer W. Gish
1981 Cholla Bud Roasting Pits: An Ethnoarchaeological Example. *The Kiva* 46:227–242.

Greenwald, Dawn M., and Bradley J. Vierra
2011 Ground Stone. In *The Mescal Wash Site: A Persistent Place along Cienega Creek, Southeastern Arizona: Archaeological Investigations at the Marsh Station Traffic Interchange and Pantano Railroad Overpass, Interstate 10, Pima County, Arizona. Volume 2, Chronometric, Artifactual, and Ecofactual Analyses*, edited by Rein Vanderpot and Michael Heilen, pp. 263–319. Technical Report No. 10-75 (draft final), Statistical Research, Tucson.

Gregory, David A.
1999 Background, Goals, and Methods. In *Excavations in the Santa Cruz River Floodplain: The Middle Archaic Component at Los Pozos,* edited by David A. Gregory, pp. 1–12. Anthropological Papers No. 20. Center for Desert Archaeology, Tucson.

2001 Architectural Features and Their Characteristics. In *Excavations in the Santa Cruz River Floodplain: The Early Agricultural Period Component at Los Pozos*, edited by David A. Gregory, pp. 29–70. Anthropological Papers No. 21. Center for Desert Archaeology, Tucson.

Gregory, David A. (editor)
1999 *Excavations in the Santa Cruz River Floodplain: The Middle Archaic Component at Los Pozos*. Anthropological Papers No. 20. Center for Desert Archaeology, Tucson.

2001 *Excavations in the Santa Cruz River Floodplain: The Early Agricultural Component at Los Pozos*. Anthropological Papers No. 21. Center for Desert Archaeology, Tucson.

Gregory, David A., and Sam W. Baar IV
1999 Stratigraphy, Chronology, and Characteristics of the Natural and Cultural Deposits. In *Excavations in the Santa Cruz Floodplain: The Middle Archaic Component at Los Pozos*, edited by David A. Gregory, pp. 13–32. Anthropological Papers No. 20. Center for Desert Archaeology, Tucson.

Gregory, David A., Jennifer A. Waters, and Jenny L. Adams
1999 *Other Artifacts in Excavations in the Santa Cruz River Floodplain: The Middle Archaic Component at Los Pozos*, edited by David A. Gregory, pp. 47–48. Anthropological Papers No. 20. Center for Desert Archaeology, Tucson.

Griffitts, Janet L.

2006 Bone Tools and Technological Choice: Change and Stability on the Northern Plains. Unpublished Ph.D. dissertation, Department of Anthropology, University of Arizona, Tucson.

2011a Shell, Bone, and Antler Artifacts. In *Analyses of Prehistoric Materials in the Queen Valley to Queen Creek Area*, edited by Robert M. Wegener, Michael P. Heilen, Richard Ciolek-Torello, and John D. Hall, pp. 285–326. The U.S. 60 Archaeological Project: Early Agricultural, Formative, and Historical-Period Use of the Upper Queen Creek Region, vol. 4. Technical Series 92. Statistical Research, Tucson.

2011b Animal Remains. In *Analyses of Prehistoric Materials in the Queen Valley to Queen Creek Area*, edited by Robert M. Wegener, Michael P. Heilen, Richard Ciolek-Torello, and John D. Hall, pp. 157–284. The U.S. 60 Archaeological Project: Early Agricultural, Formative, and Historical-Period Use of the Upper Queen Creek Region, vol. 4. Technical Series 92. Statistical Research, Tucson.

Griffitts, Janet L., and Jennifer A. Waters

2005 Bone Tool Use in the Early Agricultural Period. In *Material Cultures and Lifeways of Early Agricultural Communities in Southern Arizona*, edited by R. Jane Sliva, pp. 121–152. Anthropological Papers No. 35. Center for Desert Archaeology, Tucson.

Grossman, F. E.

1873 The Pima Indians of Arizona. In *Annual Report, 1871*, pp. 407–419. Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Hackbarth, Mark R.

1998 *Archaic and Hohokam Occupation of the Mayo Boulevard Project Area in Northeast Phoenix, Arizona*. Anthropological Papers No. 8. Pueblo Grande Museum, Phoenix.

2001 Late Archaic and Red Mountain Phase Task Group Size in Paradise Valley, Arizona: Evidence from the Last Ditch Site. *Kiva* 67:81–106.

2010 *Prehistoric Fauna and Shell.* In *Phoenix Convention Center Investigations, Vol. 1: Archaeological Investigations of Pueblo Patricio in Blocks 11, 12, 17, and 18 of the Original Phoenix Townsite, Phoenix Arizona*, edited by Mark R. Hackbarth, pp. 127–135. Technical Report No. 5. Logan Simpson Design, Phoenix. Anthropological Papers No. 16. Pueblo Grande Museum, Phoenix.

Halbirt, Carl D., Kurt E. Dongoske, and T. Kathleen Henderson

1993 Coffee Camp: A Late Archaic Site on the Santa Cruz Flats. In *Archaic Occupation of the Santa Cruz Flats: The Tator Hills Archaeological Project*, edited by Carl D. Halbirt and T. Kathleen Henderson, pp. 55–114. Northland Research, Flagstaff, Arizona.

Halbirt, Carl D., and T. Kathleen Henderson (editors)

1993 *Archaic Occupation of the Santa Cruz Flats: The Tator Hills Archaeological Project*. Northland Research, Flagstaff, Arizona.

Hall, John D., Richard Ciolek-Torello, and Robert M. Wegener

2010 *Archaeological Data Recovery Plan for the Luke Air Force Base Solar Power Array Project, Maricopa County, Arizona*. Technical Report 10-69. Statistical Research, Tucson.

Hall, John D., and Robert M. Wegener

2011 *Archaeological Data Recovery Plan for the Luke Air Force Base Solar Power Array Project, Maricopa County, Arizona*. Addendum. Technical Report 10-69. Statistical Research, Tucson.

Hall, John D., Robert M. Wegener, Jason D. Windingstad, Jesse A. M. Ballenger, and John G. Douglass

2011 *Phase 1 Results and Phase 2 Archaeological Data Recovery Plan for the Luke Air Force Base Solar-Power-Array Project, Maricopa County, Arizona*. Technical Report 11-32. Statistical Research, Tucson.

Hall, John D., Jason D. Windingstad, Joseph T. Hefner, and Robert M. Wegener

2010 *The Removal of Human Remains and Evaluation of Geomorphological Processes at AZ EE:2:577 (ASM) in Lower Matty Wash, Las Cienegas National Conservation Area, Arizona*. Technical Report 10-29. Statistical Research, Tucson.

Hard, Robert J., Raymond P. Mauldin, and Gerry R. Raymond

1996 Mano Size, Stable Carbon Isotope ratios, and Macrobotanical Remains as Multiple Lines of Evidence of Maize Dependence in the American Southwest. *Journal of Archaeological Method and Theory* 3(4):253–318.

Harden, T., M. Macklin, and V. R. Baker

2010 Holocene Flood Histories in South-Western USA. *Earth Surface Processes and Landforms* 35:707–16.

Harrington, Mark R.

1933 *Gypsum Cave, Nevada*. Papers No. 8. Southwest Museum, Los Angeles.

Harrison, Mike, John Williams, and Sigrid Khera

2012 *Oral History of the Yavapai*. Edited by Carolina C. Butler. Acacia Publishing, Gilbert, Arizona.

Harvey, A. M., P. E. Wigand, and Stephen G. Wells

1999 Response of Alluvial Fan Systems to the Late Pleistocene to Holocene Climatic Transition: Contrasts between the Margins of Pluvial Lakes Lahontan and Mojave, Nevada and California, USA. *Catena* 36:255–281.

Harwell, Henry O., and Marsha C. S. Kelly

1983 Maricopa. In *Southwest*, edited by Alfonso Ortiz, pp. 71–85. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Hastings, J. R., and R. M. Turner

1965 *The Changing Mile: An Ecological Study of Vegetation Change with Time in the Lower Mile of an Arid and Semiarid Region*. University of Arizona Press, Tucson.

Hattori, Eugene, and Catherine S. Fowler

2009 Recent Advances in Great Basin Textile Research. In *Past, Present and Future Issues in Great Basin Archaeology: Papers in Honor of Don D. Fowler*. Cultural Resources Series No. 20. U.S. Department of the Interior Bureau of Land Management, Nevada.

Haury, Emil W.

1936 *The Mogollon Culture of Southwestern New Mexico*. Medallion Papers No. 20. Gila Pueblo, Globe, Arizona.

1950 *The Stratigraphy and Archaeology of Ventana Cave*. University of Arizona Press, Tucson, and University of New Mexico Press, Albuquerque.

1957 An Alluvial Site on the San Carlos Indian Reservation, Arizona. *American Antiquity* 23:2–27.

1962 The Greater American Southwest. In *Courses toward Urban Life: Archaeological Considerations of Some Cultural Alternatives*, edited by Robert J. Braidwood and Gordon R. Willey, pp. 106–131. Publications in Anthropology No. 32. Viking Fund, New York.

1965 Pottery Types at Snaketown. In *Excavations at Snaketown I: Material Culture*, by Harold S. Gladwin, Emil W. Haury, Edwin B. Sayles, and Nora Gladwin, pp. 169–229. Reprinted. University of Arizona Press, Tucson. Originally published 1937, Medallion Papers No. 25, Gila Pueblo, Globe, Arizona.

1975 *The Stratigraphy and Archaeology of Ventana Cave*. 2nd ed. University of Arizona Press, Tucson.

1976 *The Hohokam, Desert Farmers and Craftsmen: Excavations at Snaketown, 1964–1965*. University of Arizona Press, Tucson.

1983 Concluding Remarks. In *The Cochise Cultural Sequence in Southeastern Arizona.*, by Edwin B. Sayles, pp. 158–166. Anthropological Papers No. 42. University of Arizona Press, Tucson.

1985 *Mogollon Culture in the Forestdale Valley, East-Central Arizona*. University of Arizona Press, Tucson.

Haury, Emil W., and Edwin B. Sayles

1947 *An Early Pit House Village of the Mogollon Culture, Forestdale Valley, Arizona.* Social Science Bulletin No. 16; Bulletin, vol. 18, no. 4. University of Arizona, Tucson.

Hayden, Julian D.

1967 A Summary Prehistory and History of the Sierra Pinacate, Sonora. *American Antiquity* 32:335–344.

1969 Gyratory Crushers of the Sierra Pinacate, Sonora. *American Antiquity* 34:154–161.

1976 Pre-Altithermal Archaeology in the Sierra Pinacate, Sonora, Mexico. *American Antiquity* 41:274–289.

1985 Food Animal Cremations of the Sierra Pinacate, Sonora, Mexico. *The Kiva* 50:237–249.

Haynes, C. Vance, Jr.

1987 Curry Draw, Cochise County, Arizona: A Late Quaternary Stratigraphic Record of Pleistocene Extinction and Paleo-Indian Activities. In *Centennial Field Guide*, vol. 1, edited by M. L. Hill, pp. 23–28. Cordilleran Section, Geological Society of America, Boulder.

Haynes, C. Vance, Jr., and Bruce B. Huckell (editors)

2007 *Murray Springs: A Clovis Site with Multiple Activity Areas in the San Pedro Valley, Arizona*. Anthropological Papers No. 71. University of Arizona Press, Tucson.

Heckman, Robert A.

2001 Ceramics at El Macayo. In *El Macayo: A Prehistoric Settlement in the Upper Santa Cruz River Valley*, edited by William L. Deaver and Carla R. Van West, pp. 73–94. Technical Series 74. Statistical Research, Tucson.

2002 Culinary Vestiges: Form and Function of Prehistoric Ceramic Containers from Tonto Basin, Arizona. Unpublished Master's thesis, Department of Anthropology, Northern Arizona University, Flagstaff.

Heckman, Robert A., Barbara K. Montgomery, and Stephanie M. Whittlesey

2000 *Prehistoric Painted Pottery of Southeastern Arizona*. Technical Series 77. Statistical Research, Tucson.

Heidke, James M.

1999 Cienega Phase Incipient Plain Ware from Southeastern Arizona. *Kiva* 64:311–348.

2005 Early Agricultural Period Pottery from Las Capas and Los Pozos. In *Material Cultures and Lifeways and Early Agricultural Communities in Southern Arizona*, edited by R. Jane Sliva, pp. 171–205. Anthropological Papers No. 35. Center for Desert Archaeology, Tucson.

2006 Native American Pottery. In *Rio Nuevo Archaeology Program, 2000–2003: Investigations at the San Augustin Mission and Mission Gardens, Tucson Presidio, Tucson Pressed Brick Company, and Clearwater Site*, edited by J. Homer Thiel and Jonathan B. Mabry, pp. 7.1–7.93. Technical Report 2004-11. Center for Desert Archaeology, Tucson.

Heidke, James M., Elizabeth J. Miksa, and Michael K. Wiley

1998 Ceramic Artifacts. In *Analysis and Synthesis*, edited by Jonathan B. Mabry, pp. 471–544. Archaeological Investigations of Early Village Sites in the Middle Santa Cruz Valley, pt. 1. Anthropological Papers No. 19. Center for Desert Archaeology, Tucson.

Heilen, Michael P., and Rein Vanderpot

2013a *Archaeological Research Design and Management Strategy for the Barry M. Goldwater Range East.* Technical Report 13-05. Statistical Research, Tucson.

2013b *Pathways to Preservation: A Research Design and Heritage Management Plan for the Barry M. Goldwater Range East, Arizona* (with Michael Heilen). Barry M. Goldwater Range East Cultural Resource Management Program, Cultural Resource Studies in the Western Papaguería 28. Statis-tical Research, Tucson.

Heinrich, P. V.

1993 Allostratigraphy and Geoarchaeology within the Mississippi River Alluvial Valley. In *Quaternary Geology and Geoarchaeology of the Lower Red River Valley: A Field Trip, Friends of the Pleistocene South Central Cell*, edited by W. J. Autin and C. E. Pearson, pp. 137–142. Louisiana Geological Survey, Baton Rouge.

Heizer, Robert F., and Martin A. Baumhoff

1961 *The Archaeology of Two Sites at Eastgate, Churchill County, Nevada: Wagon Jack Shelter*. Anthropological Records, vol. 20, no. 4, pt. 1. University of California Press, Berkeley.

Hejcman, Michal, Jiří Ondráček, and Zdeněk Smrž

2011 Ancient Waste Pits with Wood Ash Irreversibly Increase Crop Production in Central Europe. *Plant Soil* 339:341–350.

Hejcman, Michal, P. Karlík, Jiří Ondráček, and T. Klír

2013 Short-Term Medieval Settlement Activities Irreversibly Changed Forest Soils and Vegetation in Central Europe. *Ecosystems* 16:652–663.

Hejcman, Michal, Kateřina Součková, and Martin Gojda

2013 Prehistoric Settlement Activities Changed Soil pH, Nutrient Availability, and Growth of Contemporary Crops in Central Europe. *Plant Soil* 369:131–140.

Hesse, S. India

2010 Ground Stone Artifacts. In *Recurrent Sedentism and the Making of Place: Archaeological Investigations at Las Capas, a Preceramic Period Farming Community in the Tucson Basin, Southern Arizona*, edited by Stephanie M. Whittlesey, S. Jerome Hesse, and Michael S. Foster, pp. 223–250. Cultural Resources Report No. 07-556. SWCA Environmental Consultants, Tucson.

Hewitt, James E. and David V. M. Stephen

1981 *Archaeological Investigation in the Tortolita Mountain Region, Southern Arizona*. Archaeological Field Report No. 10. Pima Community College Anthropology Series. Pima Community College, Tucson, Arizona.

Hewitt, Nancy J.

1980 Fiber Artifacts. In *Cowboy Cave,* by Jesse D. Jennings, pp. 49–74. Anthropological Papers 104. University of Utah, Salt Lake City.

Hill, Jane H.

2001 Proto-Uto-Aztecan: A Community of Cultivators in Central Mexico? *American Anthropologist* 103:913–34.

Hiller, Wesley R.

1948 Hidatsa Soft Tanning of Hides as Demonstrated by Uta Wian (Weasel Woman). *The Minnesota Archaeologist* 14(1):4–11.

Hillman, Gordon C.

1984 The Glume Wheats. Traditional Husbandry and Processing of Archaic Cereals in Recent Times: The Operations, Products, and Equipment Which Might Feature in Sumerian Texts, pt. 1. *Bulletin on Sumerian Agriculture* 1:114–151.

Hillson, Simon

1992 *Mammal Bones and Teeth: An Introductory Guide to Methods of Identification.* Institute of Archaeology, University College, London.

2005 *Teeth*. 2nd ed. Cambridge Manuals in Archaeology, Cambridge University Press, Cambridge, England.

Hodgson, Wendy

2001 *Food Plants of the Sonoran Desert*. University of Arizona Press, Tucson.

Hoffmeister, Donald F.
1986 *Mammals of Arizona*. University of Arizona Press, Tucson.

Holdaway, Simon J., Patricia C. Fanning, and Judith Littleton
2009 Assessing the Frequency Distribution of Radiocarbon Determinations from the Archaeological Record of the Late Holocene in Western NSW, Australia. In *New Directions in Archaeological Science*, edited by Andrew S. Fairbairn, Sue O'Connor, and Ben Marwick, pp. 1–11. Terra Australis 28. ANU E Press, Canberra, ACT.

Hole, Frank, Kent V. Flannery, and James A. Neely
1968 *Prehistory and Human Ecology of the Deh Luran Plain: The Early Village Sequence in Khuzistan, Iran*. Smithsonian Contributions to Anthropology. Washington.

Hole, Frank, and Robert F. Heizer
1973 *An Introduction to Prehistoric Archeology.* 3rd ed. Holt, Rinehart and Winston, New York.

Holliday, Vance T.
2004 *Soils in Archaeological Research*. Oxford University Press, New York.

Holliday, Vance T., and William G. Gartner
2007 Methods of Soil P Analysis in Archaeology. *Journal of Archaeological Sciences* 34:301–333.

Holmer, Richard N.
1986 Common Projectile Points of the Intermountain West. In *Anthropology of the Desert West: Essays in Honor of Jesse D. Jennings*, edited by Carol J. Condie and Don D. Fowler, pp. 91–110. Anthropological Papers 110. University of Utah, Salt Lake City.

Holmgren, Camille A., M. Cristina-Penalba, Kate-Aasen Rylander, and Julio L. Betancourt
2003 A 16,000 ^{14}C yr B.P. Packrat Midden Series from the USA-Mexico Borderlands. *Quaternary Research* 60:319–329.

Hough, Walter
1907 *Antiquities of the Upper Gila and Salt River Valleys in Arizona and New Mexico*. Bureau of American Ethnology Bulletin 35. Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Hrdlička, Aleš
1906 Notes on the Pima of Arizona. *American Anthropologist* 8:39–46.

1908 Physiological and Medical Observations among the Indians of the Southwestern United States and Northern Mexico. Bureau of American Ethnology Bulletin No. 34. Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Huber, Edgar K.
2005 Early Maize at the Old Corn Site (LA 137258). In *Synthetic Studies and Summary*, edited by Edgar K. Huber and Carla R. Van West, pp. 36.1–36.33. Archaeological Data Recovery in the New Mexico Transportation Corridor and First Five-Year Permit Area, Fence Lake Coal Mine Project, Catron County, New Mexico, vol. 4. Technical Series 84. Statistical Research, Tucson.

Huckell, Bruce B.
1979 *The Coronet Real Project: Archaeological Investigations on the Luke Range, Southwestern Arizona*. Archaeological Series No. 129. Arizona State Museum, University of Arizona, Tucson.

1984a *The Archaic Occupation of the Rosemont Area, Northern Santa Rita Mountains, Southeastern Arizona*. Archaeological Series, vol. 1, no. 147. Arizona State Museum, University of Arizona, Tucson.

1984b The Paleoindian and Archaic Occupation of the Tucson Basin: An Overview. *The Kiva* 49:133–145.

1988 Late Archaic Archaeology of the Tucson Basin: A Status Report. In *Recent Research of Tucson Basin Prehistory: Proceedings of the Second Tucson Basin Conference*, edited by W. H. Doelle and P. R. Fish, pp. 57–80. Anthropological Papers No. 10. Institute for American Research, Tucson.

1990 Late Preceramic Farmers-Foragers in Southern Arizona: A Cultural and Ecological Consideration of the Spread of Agriculture in the Arid Southwestern United States. Unpublished Ph.D. dissertation, Arid Lands Resource Sciences, Department of Anthropology, University of Arizona, Tucson.

1995 *Of Marshes and Maize: Preceramic Agricultural Settlements in the Cienega Valley, Southeastern Arizona*. Anthropological Papers No. 59. University of Arizona Press, Tucson.

1996 The Archaic Prehistory of the North American Southwest. *Journal of World Prehistory* 10:305–373.

1998 An Analysis of the Flaked Stone Artifacts. In *Early Farmers of the Sonoran Desert, Archaeological Investigations at the Houghton Road Site, Tucson, Arizona*, edited by Richard Ciolek-Torrello, pp. 89–117. Technical Series 72. Statistical Research, Tucson.

Huckell, Bruce B., and C. Vance Haynes, Jr.
2003 The Ventana Complex: New Dates and New Ideas on Its Place in Early Holocene Western Prehistory. *American Antiquity* 68:353–371.

Huckell, Bruce B., Lisa W. Huckell, and Steven M. Shackley
1999 McEwen Cave. *Archaeology Southwest* 13(1):12.

Huckell, Lisa W.
1998 Macrobotanical Remains. In *Analysis and Synthesis*, edited by Jonathan B. Mabry, pp. 57–148. Archaeological Investigations of Early Village Sites in the Middle Santa Cruz Valley, pt. 1. Anthropological Papers No. 19. Center for Desert Archaeology, Tucson.

2006 Ancient Maize in the Southwest: What Does it Look Like and What Can It Tell Us? In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, and Evolution of Maize,* edited by John Staller, Robert Tykot, and Bruce Benz, pp. 97–107. Elsevier Academic, Boston.

Huckell, Lisa W., and Molly Toll
2004 Wild Plant Use in the North American Southwest. In *People and Plants in Ancient Western North America*, edited by Paul E. Minnis, pp. 37–114. Smithsonian Books, Washington, D.C.

Huckleberry, Gary

1997 *Rates of Holocene Soil Formation in South-Central Arizona*. Open-File Report 97-7. Arizona Geological Survey, Tucson.

Huckleberry, Gary, Jill Onken, William M. Graves, and Robert M. Wegener

2013 Climatic, Geomorphic, and Archaeological Implications of a Late Quaternary Alluvial Chronology for the Lower Salt River, Arizona, USA. *Geomorphology* 185:39–53.

Hunt, Alice

1960 *Archaeology of the Death Valley Salt Pan, California*. Anthropological Papers 47. University of Utah, Salt Lake City.

Hunter, Cristi Assad

1998 Faunal Analysis. In *Archaic and Hohokam Occupation of the Mayo Boulevard Project Area in Northeast Phoenix, Arizona,* edited by Mark R. Hackbarth, pp. 113–120. Anthropological Papers No. 8. Pueblo Grande Museum, Phoenix.

Hurlbut, Sharon A.

2000 Human Remains and Mortuary Features. In *Archaeological Investigations at AZ V:13:201, Town of Kearny, Pinal County, Arizona*, compiled by Caven P. Clark, pp. 12.1–12.9. Cultural Resources Report No. 114. Archaeological Consulting Services, Tempe.

Hutson, Scott R., Aline Magnoni, Timothy Beach, Richard E. Terry, Bruce H. Dahlin, Mary Jo Schabel

2009 Phosphate Fractionation and Spatial Patterning in Ancient Ruins: A Case Study from Yucatan. *Catena* 78:260–269.

Hyland, David C., James M. Adovasio, and J. S. Illingsworth

2003 The Perishable Artifacts. In *Pendejo Cave*, edited by Richard S. MacNeish and Jane G. Libby, pp. 297–416. University of New Mexico Press, Albuquerque.

Irving, Robert S.

1966 A Preliminary Analysis of Plant Remains from Six Amistad Reservoir Sites. In *A Preliminary Study of the Paleoecology of the Amistad Reservoir Area*, edited by Dee Ann Story and Vaughan M. Bryant, Jr., pp. 61–90. Final Report GS-667. National Science Foundation, Arlington, Virginia.

Irwin-Williams, Cynthia

1967 Picosa: The Elementary Southwestern Culture. *American Antiquity* 32:441–457.

1973 *The Oshara Tradition: Origins of the Anasazi Culture*. Contributions in Anthropology, vol. 5, no. 1. Eastern New Mexico University, Portales.

1979 Post Pleistocene Archaeology, 7000–2000 B.C. In *Southwest*, edited by Alfonso Ortiz, pp. 31–42. Handbook of North American Indians, vol. 9, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

James, George Wharton

1903 *The Indians of the Painted Desert Region*. Little Brown, Boston.

James, Steven R.
1993 Archaeofaunal Analyses of the Tator Hills Sites, South-Central Arizona. In *Archaic Occupation on the Santa Cruz Flats: The Tator Hills Archaeological Project*, edited by Carl D. Halbirt and T. Kathleen Henderson, pp. 345–372. Northland Research, Flagstaff, Arizona.

Janetski, Joel C., Mark L. Bodily, Bradley A. Newbold, and David T. Yoder
2012 The Paleoarchaic to Early Archaic Transition on the Colorado Plateau: The Archaeology of North Creek Shelter. *American Antiquity* 77:125–159.

Jenkins, Dennis L., Loren G. Davis, Thomas W. Stafford, Jr., Paula F. Campos, Bryan Hockett, George T. Jones, Linda Scott Cummings, Chad Yost, Thomas J. Connolly, Robert M. Yohe II, Summer C. Gibbons, Maanasa Raghavan, Morten Rasmussen, Johanna L. A. Paijmans, Michael Hofreiter, Brian M. Kemp, Jody Lynn Barta, Cara Monroe, M. Thomas P. Gilbert, Eske Willerslev
2012 Clovis Age Western Stemmed Projectile Points and Human Coprolites at the Paisley Caves. *Science* 337:223–228.

Jennings, Jesse David
1957 *Danger Cave*. Anthropological Papers No. 27. University of Utah Press, Salt Lake City.

Jennings, Jesse David (editor)
1956 *The American Southwest: A Problem in Cultural Isolation*. Seminars in Archaeology: 1955. Memoirs No. 11. Society for American Archaeology, Salt Lake City.

Johnson, Alfred E.
1963 *An Appraisal of the Archaeological Resources of Five Regional Parks in Maricopa County, Arizona*. Manuscript on file, Arizona State Museum, University of Arizona, Tucson.

Jones, Terry L.
1996 Mortars, Pestles, and Division of Labor in Prehistoric California: A View from Big Sur. *American Antiquity* 61:243–264.

Jones, Volney H.
1944 Was Tobacco Smoked in the Pueblo Region in Pre-Spanish Times? *American Antiquity* 9:451–456.

Justice, Noel D.
2002 *Stone Age Spear and Arrow Points of the Southwestern United States*. Indiana University Press, Bloomington.

Kapp, Ronald O., Owen K. Davis, and James E. King
2000 *Ronald O. Kapp's Pollen and Spores*. 2nd ed. American Association of Stratigraphic Palynologists Foundation, College Station, Texas.

Kearney, Thomas H., and Robert H. Peebles
1960 *Arizona Flora*. 2nd ed. University of California Press, Berkeley.

Keen, Myra
1971 *Sea Shells of Tropical West America: Marine Mollusks from Baja California to Peru*. 2nd ed. Stanford University Press, Stanford, California.

Keil, David J.
1973 Vegetation and Flora of the White Tank Mountains Regional Park, Maricopa County, Arizona. *Journal of the Arizona Academy of Science* 8(1):35–48.

Kelly, Dorothea S.
1937 *McEuen Cave Report*. Manuscript sent to Harold Gladwin, Gila Pueblo Archaeological Foundation, Globe, Arizona.

Kelly, Isabel T., and Catherine S. Fowler
1986 Southern Paiute. In *Great Basin*, edited by Warren L. d'Azevedo, pp. 368–397. Handbook of North American Indians, vol. 11, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Kelly, Robert L.
1988 The Three Sides of a Biface. *American Antiquity* 53:717–734.

1992 Mobility/Sedentism: Concepts, Archaeological Measures, and Effects. *Annual Reviews in Anthropology* 21:43–66.

1995 *The Foraging Spectrum*. Smithsonian Institution, Washington D.C.

Kelly, Robert L., and Lawrence C. Todd
1988 Coming into the Country: Early Paleoindian Hunting and Mobility. *American Antiquity* 53:231–244.

Kelly, William H.
1977 *Cocopa Ethnography*. Anthropological Papers No. 29. University of Arizona Press, Tucson.

Kerr, Thomas R., and Finbar McCormick
2014 Statistics, Sunspots, and Settlement: Influences on Sum of Probability Curves. *Journal of Archaeological Science* 41:493–501.

Khera, Sigrid, and Patricia S. Mariella
1983 Yavapai. In *Southwest,* edited by Alfonso Ortiz, pp. 38–54. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Kingsolver, John M., C. Johnson, S. Swier, and A. Teran
1977 Prosopis Fruits as a Resource for Invertebrates. In *Mesquite: Its Biology in Two Desert Ecosystems*, edited by B. B. Simpson, pp. 110–114. Dowden, Hutchinson, and Ross Stroudsburg, Pennsylvania.

Kissell, Mary Lois
1916 *Basketry of the Papago and Pima*. Anthropological Papers, vol. 17, no. 4. American Museum of Natural History, New York.

Knecht, Heidi
1997 Projectile Points of Bone, Antler, and Stone: Experimental Explorations of Manufacture and Use. In *Projectile Technology*, edited by Heidi Knecht, pp. 191–212. Plenum, New York.

Koerper, Henry C., Mark Q. Sutton, and Polly A. Peterson

2010 An Unusual Donut-Shaped Artifact from CA-LAN-62. *Pacific Coast Archaeological Society Quarterly* 43(4):75–88.

Kohler, Timothy A., Matt Pier Glaude, Jean-Pierre Bocquet-Appel, Brian M. Kemp

2008 The Neolithic Demographic Transition in the U.S. Southwest. *American Antiquity* 73:645–669.

Korotayev, Andrey

2001 An Apologia of George Peter Murdock. Division of Labor by Gender and Postmarital Residence in Cross-Cultural Perspective: A Reconsideration. *World Cultures* 12(2):179–203.

Krieger, Alex D.

2002 *We Came Naked and Barefoot: The Journey of Cabeza de Vaca across North America*. University of Texas Press, Austin.

Kroeber, Alfred Louis

1925 *Handbook of the Indians of California*. Bureau of American Ethnology Bulletin No. 78. Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

1935 *Walapai Ethnography*. Memoirs No. 42. American Anthropological Association, Menasha, Wisconsin.

1953 *Handbook of the Indians of California*. Reprinted. California Book Company, Berkeley. Originally published 1925, Bureau of American Ethnology Bulletin 78, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Kuhn, Steven L.

1989 Hunter-Gatherer Foraging Organization and Strategies of Artifact Replacement and Discard. In *Experiments in Lithic Technology*, edited by Daniel S. Amick and Raymond P. Mauldin, pp. 33–47. British Archaeological Reports, Oxford, England.

1994 A Formal Approach to the Design and Assembly of Mobile Toolkits. *American Antiquity* 59:426–442.

1995 *Mousterian Lithic Technology*. Princeton University Press, Princeton, New Jersey.

Labelle, Jason M., and Jeffrey L. Eighmy

1997 Additional Archaeomagnetic Data on the South-West USA Master Geomagnetic Pole Curve. *Archaeometry* 39:431–439.

La Croix, S., M. L. Zelditch, J. A. Shivik, B. L. Lundigan, and K. E. Holekamp

2011 Ontogeny of Feeding Performance and Biomechanics in Coyotes. *Journal of Zoology* 285:301–315.

Langer, William H., Ed DeWitt, David T. Adams, and Timothy O'Brien

2010 Geologic Study of Gravels of the Agua Fria River, Phoenix, AZ. *Mining Engineering* 62(2):27–31.

Larson, Mary Lou, and Marcel Kornfeld

1997 Chipped Stone Nodules: Theory, Method, and Examples. *Lithic Technology* 22:4–18.

Lascaux, Annick, Jerry D. Lyon, India S. Hesse, S. Jerome Hesse, and Stephany M. Whittlesey

2010 Nonarchitectural Feature Descriptions. In *Recurrent Sedentism and the Making of Place: Archaeological Investigations at Las Capas, a Preceramic Period Farming Community in the Tucson Basin, Southern Arizona*, edited by Stephanie M. Whittlesey, S. Jerome Hesse, and Michael S. Foster, pp. 135–159. Cultural Resources Report No. 07-556. SWCA Environmental Consultants, Tucson.

Lawrence, Barbara

1951 Post-Cranial Skeletal Characters of Deer, Pronghorn, and Sheep-Goat with Notes on Bos and Bison. *Reports of the Awatovi Expedition Peabody Museum*, pt. 2. Harvard University Report No. 4; Papers, vol. 25, no. 3. Peabody Museum of American Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

Layton, Thomas N.

1979 Archaeology and Paleo-Ecology of Pluvial Lake Parman, Northwestern Great Basin. *Journal of New World Archaeology* 3(3):41–56.

Lee, Richard B.

1979 *The !Kung San: Men, Women, and Work in a Foraging Society*. Cambridge University Press, Cambridge, England.

Lengyel, Stacey

2010 The Pre–A.D. 585 Extension of the U.S. Southwest Archaeomagnetic Reference Curve. *Journal of Archaeological Science* 37:3081–3090.

Leopold, Luna B., M. Gordon Wolman, and John P. Miller

1964 *Fluvial Processes in Geomorphology*. W. H. Freeman, San Francisco.

Lincoln-Babb, Lorrie, Penny Dufoe Minturn, Christopher P. Garraty, and Joseph T. Hefner

2011 A Bioarchaeological Study of Human Remains and Mortuary Behavior in the U.S. 60 Project Area. In *Analyses of Prehistoric Materials in the Queen Valley to Queen Creek Area*, edited by Robert M. Wegener, Michael P. Heilen, Richard Ciolek-Torello, and John D. Hall, pp. 549–592. The U.S. 60 Archaeological Project: Early Agricultural, Formative, and Historical-Period Use of the Upper Queen Creek Region, vol. 4. Technical Series 92. Statistical Research, Tucson.

Lindsay, Alexander Johnston, Jr., Richard Ambler, Mary Anne Stein, and Philip M. Hobler

1968 *Survey and Excavations North and East of Navajo Mountain, Utah, 1959–1962*. Bulletin No. 45. Museum of Northern Arizona, Flagstaff. Glen Canyon Series No. 8. Northern Arizona Society of Science and Art, Flagstaff.

Liu, Beiling, Fred M. Phillips, and Andrew R. Campbell

1996a Stable Carbon and Oxygen Isotopes of Pedogenic Carbonates, Ajo Mountains, Southern Arizona: Implications for Paleoenvironmental Change. *Palaeogeography, Palaeoclimatology, Palaeoecology* 124:233–246.

Liu, Beiling, Fred M. Phillips, Molly M. Pohl, and P. Sharma

1996b An Alluvial Surface Chronology Based on Cosmogenic ^{36}Cl Dating, Ajo Mountains (Organ Pipe Cactus National Monument), Southern Arizona. *Quaternary Research* 45:30–37.

Liu, Zhengyu, J. Kutzbach, and Lixin Wu

2000 Modeling Climate Shift of El Niño Variability in the Holocene. *Geophysical Research Letters* 27:2265–2268.

Loendorf, Chris, and Gleen E. Rice

2004 *Projectile Point Typology Gila River Indian Community, Arizona*. Anthropological Research Papers Number 2. Gila River Indian Community Cultural Resource Management Program, Sacaton, Arizona.

López Varela, Sandra L., and Christopher D. Dore

2010 Social Spaces of Daily Life: A Reflexive Approach to the Analysis of Chemical Residues by Multivariate Spatial Analysis. *Journal of Archaeological Method and Theory* 17:249–278.

Lorentzen, Leon H.

1998 Common Paleoindian and Archaic Projectile Points of Arizona, In *Paleoindian and Archaic Sites in Arizona*, edited by Jonathan B. Mabry, pp. 137–151. Technical Report 97-7. Center for Desert Archaeology, Tucson.

Los Angeles Times [Los Angeles, California]

1920 Rabbits, Horse, Fish Go Into Hen's Diet. 18 January: IX21. Los Angeles, California.

Lumholtz, Carl

1912 *New Trails in Mexico: An Account of One Year's Exploration in North-Western Sonora, Mexico, and South-Western Arizona, 1909–1910*. Charles Scribner's Sons, New York.

Lyman, R. Lee

1994 *Vertebrate Taphonomy*. Manuals in Archaeology. Cambridge University Press, Cambridge, England.

2008 *Quantitative Paleozoology*. Manuals in Archaeology, Cambridge University Press, Cambridge, England.

Lyndon, Michael G.

2005 Projectile Points as Indicators of Preceramic Occupation of the Coconino Plateau. Unpublished Master's thesis, Department of Anthropology, Northern Arizona University, Flagstaff.

Mabry, Jonathan B.

1998a Archaic Complexes of the Middle Holocene. In *Paleoindian and Archaic Sites in Arizona*, edited by Jonathan B. Mabry, pp. 65–72. Technical Report 97-7. Center for Desert Archaeology, Tucson.

1998b Site Patterns and Types. In *Paleoindian and Archaic Sites in Arizona*, edited by Jonathan B. Mabry, pp. 137–151. Technical Report 97-7. Center for Desert Archaeology, Tucson.

2005a Changing Knowledge and Ideas about the First Farmers in Southeastern Arizona. In *The Late Archaic across the Borderlands: From Foraging to Farming*, edited by Bradley J. Vierra, pp. 41–83. Texas Archaeology and Ethnohistory Series. University of Texas Press, Austin.

2005b Reading the Traces of Early Farming Villages. In *Material Cultures and Lifeways of Early Agricultural Communities in Southern Arizona*, edited by R. Jane Sliva, pp. 1–17. Anthropological Papers No. 35. Center for Desert Archaeology, Tucson.

2008 Introduction. In *Las Capas: Early Irrigation and Sedentism in a Southwestern Floodplain*, edited by Jonathan B. Mabry, pp. 1–34. Anthropological Papers No. 28. Center for Desert Archaeology, Tucson.

Mabry, Jonathan B. (editor)

1998a *Archaeological Investigations of Early Village Sites in the Middle Santa Cruz Valley: Analyses and Synthesis*, pt. 1. Anthropological Papers No. 19. Center for Desert Archaeology, Tucson.

1998b *Paleoindian and Archaic Sites in Arizona.* Technical Report 97-7. Center for Desert Archaeology, Tucson.

Mabry, Jonathan B., and Michael K. Faught

1998 Archaic Complexes of the Early Holocene. In *Paleoindian and Archaic Sites in Arizona*, edited by Jonathan B. Mabry, pp. 53–64. Technical Report 97-7. Center for Desert Archaeology, Tucson.

Mabry, Jonathan B., and Michelle N. Stevens

2000 The Archaeology of Archaic Hunter-Gatherers and Early Farmers in Southeastern Arizona. In *The Archaeology of the Land Between: Regional Dynamics and Prehistory of Southeastern Arizona*, edited by Henry D. Wallace and Anne I. Woosley. Draft. Amerind Foundation, Dragoon, Arizona, and University of New Mexico Press, Albuquerque. Manuscript on file, Desert Archaeology, Tucson.

Machette, Michael N.

1985 Calcic Soils of the Southwestern United States. In *Soils and Quaternary Geology of the Southwestern United States*, edited by David L. Weide, pp. 1–21. Special Paper 203. Geological Society of America, Boulder, Colorado.

MacNeish, Richard S., and Jane G. Libby (editors)

2003 *Pendejo Cave*. University of New Mexico Press, Albuquerque.

Madsen, David B., and David Rhode

1990 Early Holocene Pinyon (*Pinus monophylla*) in the Northeastern Great Basin. *Quaternary Research* 33:94–101.

Malhi, Ripian S., Holly M. Mortensen, Jason A. Eshleman, Brian M. Kemp, Joseph G. Lorenz, Frederika A. Kaestle, John R. Johnson, Clara Gorodezky, and David Glenn Smith

2003 Native American mtDNA Prehistory in the American Southwest. *American Journal of Physical Anthropology* 120:108–124.

Mangelsdorf, Paul C., and C. Earle Smith, Jr.

1949 *New Archaeological Evidence on Evolution in Maize.* Botanical Museum Leaflets, vol. 13, no. 8. Harvard University Press, Cambridge, Massachusetts.

Maricopa County Parks and Recreation

n.d. Wildlife of Maricopa County Parks: Mammals. Electronic document, http://www.maricopa.gov/parks/images/brochures/Mammals%20FINAL.pdf, accessed June 13, 2013.

Mark, Albyn K.

1961 Description of and Variables Relating to Ecological Change in the History of the Papago Indian Population. Unpublished Master's thesis, Department of Anthropology, University of Arizona, Tucson.

Martin, Paul S.

1963 *The Last 10,000 Years: A Fossil Pollen Record of the American Southwest*. University of Arizona Press, Tucson.

Martin, Paul S., John B. Rinaldo, and Ernst Antevs

1949 *Cochise and Mogollon Sites, Pine Lawn Valley, Western New Mexico*. Fieldiana: Anthropology, vol. 38, no. 1. Publication 627. Chicago Natural History Museum, Chicago.

Martin, Paul S., John B. Rinaldo, Elaine A. Bluhm, Hugh C. Cutler, and Roger Grange, Jr.

1952 *Mogollon Cultural Continuity and Change: The Stratigraphic Analysis of Tularosa and Cordova Caves*. Fieldiana: Anthropology, vol. 40. Publication 699. Chicago Natural History Museum, Chicago.

Matson, Richard G.

1991 *The Origins of Southwestern Agriculture*. University of Arizona Press, Tucson.

Mauldin, Raymond

1993 The Relationship between Ground Stone and Agricultural Intensification in Western New Mexico. *Kiva* 58(3):317–330.

Mayewski, P. A., E. E. Rohling, J. C. Stager, W. Karlen, K. A. Maasch, L. D. Meeker, E. A. Meyerson, F. Gasse, S. van Kreveld, K. Holmgren, J. Lee-Thorp, G. Rosqvist, F. Rack, M. Staubwasser, R. R. Schneider, E. J. Steig

2004 Holocene Climate Variability. *Quaternary Research* 62:243–255.

McAuliffe, Joseph R., and Thomas R. Van Devender

1998 A 22,000-Year Record of Vegetation Change in the North-Central Sonoran Desert. *Paleogeography, Paleoclimatology, Paleoecology* 141:253–275.

McClelland, John C., Annick Lascaux, Jerry D. Lyon, and Stephanie M. Whittlesey

2007 Burial Features and Mortuary Practices. In *Recurrent Sedentism and the Making of Place: Archaeological Investigations at Las Capas, a Preceramic Period Farming Community in the Tucson Basin, Southern Arizona*, edited by Stephanie M. Whittlesey, S. Jerome Hesse, and Michael S. Foster, pp. 159–172. Cultural Resources Report No. 07-556. SWCA Environmental Consultants, Phoenix.

McDonald, Eric V., Leslie D. McFadden, and Stephen G. Wells

2003 Regional Response of Alluvial Fans to the Pleistocene-Holocene Climatic Transition, Mojave Desert, California. In *Paleoenvironments and Paleohydrology of the Mojave and Southern Great Basin Deserts*, edited by Yehouda Enzel, Stephen G. Wells, and Nicholas Lancaster, N. pp. 189–205. Special Paper 368. Geological Society of America, Boulder, Colorado.

McFadden, Leslie D., and John C. Tinsley

1985 Rate and Depth of Pedogenic-Carbonate Accumulation in Soils: Formulation and Testing of a Compartment Model. In *Soils and Quaternary Geology of the Southwestern United States*, edited by David L. Weide, pp. 1–21. Special Papers No. 203. Geological Society of America, Boulder, Colorado.

McFadden, Leslie D., John B. Ritter, and Stephen G. Wells

1989 Use of Multiparameter Relative-Age Methods for Age Estimation and Correlation of Alluvial Fan Surfaces on a Desert Piedmont Eastern Mojave Desert, California. *Quaternary Research* 32:276–290.

McGuire, Kelly R., and William R. Hildebrandt

1994 The Possibilities of Women and Men: Gender and the California Milling Stone Horizon. *Journal of California and Great Basin Anthropology* 16(1):41–59.

McGuire, Randall H.

1982 Problems in Culture History. In *Hohokam and Patayan: Prehistory of Southwestern Arizona*, edited by Randall H. McGuire and Michael B. Schiffer, pp. 153–222. Academic Press, New York.

1983 Walapai. In *Southwest,* edited by Alfonso Ortiz, pp. 25–37. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

McGuire, Randall H., and Michael B. Schiffer (editors)

1982 *Hohokam and Patayan: Prehistory of Southwestern Arizona*. Academic Press, New York.

McKee, Barbara, Edwin McKee, and Joyce Herold

1975 *Havasupai Baskets and Their Makers: 1930–1940*. Northland, Flagstaff, Arizona.

McKusick, Charmion R.

2007a Domestic Turkeys at Casas Grandes. *Archaeology Southwest* 21(1):4.

2007b Casas Grandes Macaws. *Archaeology Southwest* 21(1):5.

Mehlich, A.

1984 Mehlich No. 3 Soil Test Extractant: A Modification of Mehlich No. 2. *Communications in Soil Science Plant Analysis* 15:1409–1416.

Mehringer, Peter J., Jr., Paul S. Martin, and C. Vance Haynes, Jr.

1967 Murray Springs, a Mid-Postglacial Pollen Record from Southern Arizona. *American Journal of Science* 265:786–797.

Menges, C. M., and Pearthree, Philip A.

1989 Late Cenozoic Tectonism in Arizona and Its Impact on Regional Landscape Evolution. In *Geologic Evolution of Arizona: Tucson*, edited by Judith P. Jenny and Stephen J. Reynolds, pp. 649–680. Digest 17. Arizona Geological Society, Tucson.

Merlin, Pinau, and Peter Siminski

2000 Mammal Accounts. In *A Natural History of the Sonoran Desert,* edited by Steven J. Phillips and Patricia Wentworth Comus, pp. 459–507. Arizona-Sonora Desert Museum, Tucson, and University of California Press, Berkeley.

Merrill, William L., Robert J. Hard, Jonathan B. Mabry, Gayle J. Fritz, Karen R. Adams, John R. Roney, and A. C. MacWilliams

2009 The Diffusion of Maize to the Southwestern United States and Its Impact. *Proceedings of the National Academy of Sciences* 106:21019–21026.

Michczyński, Adam, and Anna Pazdur

2003 The Method of Combining Radiocarbon Dates and Other Information in Application to Study the Chronologies of Archaeological Sites. *Geochronometria* 22:41–46.

Miksicek, Charles H.

1988 Rethinking Hohokam Paleoethnobotanical Assemblages: A Progress Report for the Tucson Basin. In *Recent Research on Tucson Basin Prehistory: Proceedings of the Second Tucson Basin Conference*, edited by William H. Doelle and Paul R. Fish, pp. 47–56. Anthropological Papers No. 10. Institute for American Research, Tucson.

Miller, David M., Kevin M. Schmidt, Shannon A. Mahan, John P. McGeehin, Lewis A. Owen, John A. Barron, Frank Lehmkuhl, and Rene Lohrer

2010 Holocene Landscape Response to Seasonality of Storms in the Mojave Desert. *Quaternary International* 215:45–61.

Miller, W. P., D. E. Radcliffe, and D. M. Miller

1988 An Historical Perspective on the Theory and Practice of Soil Mechanical Analysis. *Journal of Agronomic Education* 17:24–28.

Miller, Wick R.

1983 Uto-Aztecan Languages. In *Southwest*, edited by Alfonso Ortiz, pp. 113–124. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Minckley, Thomas A., Andrea B. Brunelle, and Shawn Blissett

2011 Holocene Sedimentary and Environmental History of an In-Channel Wetland along the Ecotone of the Sonoran and Chihuahuan Desert Grasslands. *Quaternary International* 235:40–47.

Minnis, Paul E.

1985 Domesticating People and Plants in the Greater U.S. Southwest. In *Prehistoric Food Production in North America*, edited by Richard I. Ford, pp. 309–339. Anthropological Papers 75. Museum of Anthropology, University of Michigan, Ann Arbor.

Minturn, Penny Dufoe, and Lorrie Lincoln-Babb

1995 Bioarchaeology of the Donaldson Site and Los Ojitos. In *Of Marshes and Maize: Preceramic Agricultural Settlements in the Cienega Valley, Southeastern Arizona*, compiled by Bruce B. Huckell, pp. 106–116. Anthropological Papers No. 59. University of Arizona Press, Tucson.

2001 Appendix C. Human Osteological Remains. In *Excavations in the Santa Cruz Floodplain: The Early Agricultural Period Component at Los Pozos*, edited by David A. Gregory, pp. 303–304. Draft. Anthropological Papers No. 21. Center for Desert Archaeology, Tucson. Submitted to Pima County Cultural Resources and Historic Preservation Office, Tucson.

Mitchell, David L., Dorothea Ivanova, Robert Rabin, Timothy J. Brown, and Kelly Redmond

2003 Gulf of California Sea Surface Temperatures and the North American Monsoon: Mechanistic Implications from Observations. *Journal of Climate* 15:2261–2281.

Mitchell, Douglas R., and M. Steven Shackley

1995 Classic Period Hohokam Obsidian Studies in Southern Arizona. *Journal of Field Archaeology* 22:291–304.

Miyamoto, S.

2008 *Salt Tolerance of Landscape Plants Common to the Southwest*. Technical Report 316. Texas Agrilife Research Center, El Paso, and Texas A&M University System in cooperation with Texas Water Resource Institute and El Paso Water Utilities.

Moerman, Daniel

1998 *Native American Ethnobotany*. Timber Press, Portland, Oregon.

Monger, H. Curtis

1995 Pedology in Arid Lands Archaeological Research: An Example from Southern New Mexico–Western Texas. In *Pedological Perspectives in Archaeological Research*, edited by Mary E. Collins, Brian J. Carter, Bruce G. Gladfelter, and Randal J. Southard, pp. 35–50. Special Publication No. 44. Soil Science Society of America, Madison, Wisconsin.

Moore, Peter D., J. A. Webb, and Margaret E. Collinson

1991 *Pollen Analysis*. 2nd ed. Blackwell Scientific Publications, Cambridge, England.

Moreno, Teresa K.

2000 Accelerator Mass Spectrometry Dates from McEuen Cave. *Kiva* 65:341–360.

Morris, Donald H.

1969 Red Mountain: An Early Pioneer Period Hohokam Site in the Salt River Valley of Central Arizona. *American Antiquity* 34:40–53.

1986 The Ground Stone Assemblage. In *Prehistoric Hunter-Gatherers of South Central Arizona: The Picacho Reservoir Archaic Project*, edited by Frank E. Bayham, Donald H. Morris, and M. Steven Shackley, pp. 247–263. Anthropological Field Studies No. 13. Arizona State University, Tempe.

Morris, Earl H., and Robert F. Burgh

1941 *Anasazi Basketry: Basketmaker II through Pueblo III: A Study Based on Specimens from the San Juan River Country*. Publication No. 533. Carnegie Institution, Washington, D.C.

Moser, Edward

1963 Seri Bands. *The Kiva* 28:14–27.

Mowat, Linda, Howard Morphy, and Penny Dransart (editors)

1992 *Basketmakers: Meaning and Form in Native American Baskets*. Monograph 5. Pitt Rivers Museum, Oxford, England.

Murdock, George P.

1949 *Social Structure*. The Free Press, New York.

Nabhan, Gary P.

1985 *Gathering the Desert.* University of Arizona Press, Tucson.

1993 *Counting Sheep: Twenty Ways of Seeing Desert Bighorn.* University of Arizona Press, Tucson.

Nabhan, Gary P., and J. M. J. DeWet

1983 *Panicum sonorum* in Sonoran Desert Agriculture. *Economic Botany* 38(1):65–82.

Nabhan, Gary P., Wendy Hodgson, and Frances Fellows

1989 A Meager Living on Lava and Sand? Hia C-ed O'odham Food Resources and Habitat Diversity in Oral and Documentary Records. *Journal of the Southwest* 31:508–533.

Nabhan, Gary P., A. M. Rea, K. Reichardt, E. Mellinck, and C. Hutchinson

1982 Papago Influence on Habitat and Biotic Diversity: Quitovac Oasis Ethnoecology. *Journal of Ethnobiology* 2(2):124–143.

Nabhan, Gary P., C. Weber, and J. Berry

1979 Legumes in Papago-Pima Indian Diet and Ecological Niche. *The Kiva* 44:173–190.

Nelson, David M., Feng Sheng Hu, and Robert H. Michener

2006 Stable-Carbon Isotope Composition of Poaceae Pollen: An Assessment for Reconstructing C_3 and C_4 Grass Abundance. *The Holocene* 16(6):819–825.

Nelson, Margaret C.

1991 The Study of Technological Organization. In *Archaeological Method and Theory*, vol. 3, edited by Michael B. Schiffer, pp. 57–100. University of Arizona Press, Tucson.

Nelson, Richard S.

1991 *Hohokam Marine Shell Exchange and Artifacts.* Archaeological Series 179. Arizona State Museum, University of Arizona, Tucson.

Nentvig, Juan

1980 *Rudo Ensayo: A Description of Sonora and Arizona in 1764*. University of Arizona Press, Tucson.

North American Commission on Stratigraphic Nomenclature (NACOSN)

2005 North American Stratigraphic Code. *American Association of Petroleum Geologists Bulletin* 89:1547–1591.

Nordt, Lee C.

2001 Stable Carbon and Oxygen Isotopes in Soils: Applications for Archaeological Research. In *Earth Sciences and Archaeology*, edited by Paul Goldberg, Vance T. Holliday, and C. Reed Ferring, pp. 419–448. Kluwer Academic/Plenum, New York.

Nordt, Lee C., Thomas W. Boutton, Charles T. Hallmark, and Michael R. Waters

1994 Late Quaternary Vegetation and Climate Changes in Central Texas Based on the Isotopic Composition of Organic Carbon. *Quaternary Research* 41:109–120.

Odell, George H.

2004 *Lithic Analysis.* Manuals in Archaeological Method, Theory, and Technique. Kluwer Academic/Plenum, New York.

O'Laughlin, Thomas C.

1980 *The Keystone Dam Site and Other Archaic and Formative Sites in Northwest El Paso, Texas.* Publications in Anthropology No. 8. Centennial Museum, University of Texas, El Paso.

Olsen, Sandra L.

1989 On Distinguishing Natural from Cultural Damage on Archaeological Antler. *Journal of Archaeological Science* 16:125–135.

Olsen, Stanley J.

1964 *Southeastern and Southwestern United States.* Mammal Remains from Archaeological Sites, pt. 1. Papers, vol. 56, no. 1. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

1968 The Osteology of the Wild Turkey. In *Southeastern and Southwestern United States* by Stanley J. Olsen, Appendix. Fish, Amphibian, and Reptile Remains from Archaeological Sites, pt. 1. Papers, vol. 56, no. 2. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

1979 *Osteology for the Archaeologist*. Papers, vol. 56, nos. 3–5. Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts.

Opler, Morris E.

1968a Chiricahua Apache. In *Southwest,* edited by Alfonso Ortiz, pp. 411–412. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

1968b Mescalero Apache. In *Southwest,* edited by Alfonso Ortiz, pp. 419–439. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

1983 The Apachean Culture Pattern and Its Origins. In *Southwest,* edited by Alfonso Ortiz, pp. 368–392. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

1996 *An Apache Life-way: The Economic, Social, and Religious Institutions of the Chiricahua Indians*. University of Nebraska Press. Reprint. Originally published 1941, University of Chicago Press.

Orr, Phil C.

1974 Notes on the Archaeology of the Winnemucca Caves. In *Collected Papers on Aboriginal Basketry*, edited by Jane G. Gigli, Donald R. Tuohy, Phil C. Orr, Charles E. Rozaire, and James M. Adovasio, pp. 47–59. Anthropological Papers No. 16. Nevada State Museum, Carson City.

Owen, Roger C.

1965 The Patrilocal Band: A Linguistically and Culturally Hybrid Social Unit. *American Anthropologist* 67:675–690.

Packard, Frank A.

1974 The Hydraulic Geometry of a Discontinuous Ephemeral Stream on a *Bajada* near Tucson, Arizona. Unpublished Ph.D. dissertation, University of Arizona, Tucson.

Palmer, Edward

1871 Food Products of the North American Indians. In *Report to the Commissioner of Agriculture for the Year 1870*, pp. 404–428. U.S. Department of Agriculture, U.S. Government Printing Office, Washington, D.C.

Panlaqui, Carol

1974 The Ray Cave Site. In *Excavation of Two Sites in the Coso Mountains of Inyo County, California*, pp. 1–62. Monograph 1. Maturango Museum, China Lake, California.

Parker, Kittie F.

1958 *Arizona Ranch, Farm and Garden Weeds*. Service Circular 265. Agricultural Extension, University of Arizona, Tucson.

Parry, William J., and Robert L. Kelly

1987 Expedient Core Technology and Sedentism. In *The Organization of Core Technology,* edited by Jay K. Johnson and Carol A. Morrow, pp. 285–304. Westview, Boulder, Colorado.

Parsons, Jeffrey R., and Mary H. Parsons

1990 *Maguey Utilization in Highland Central Mexico: An Archaeological Ethnography.* Anthropological Papers No. 82. Museum of Anthropology, University of Michigan, Ann Arbor.

Patterson, Leland W.

1990 Characteristics of Bifacial-Reduction Flake-Size Distribution. *American Antiquity* 55:550–558.

Pearthree, Philip A., J. E. Klawon, and T. W. Lehman

2004 *Geomorphology and Hydrology of an Alluvial Fan Flood on Tiger Wash, Maricopa and La Paz Counties, West-Central Arizona*. Open-File Report 04-02. Arizona Geological Survey, Tucson.

Peirce, H. W.

1984 Some Late Cenozoic Basins and Basin Deposits of Southern and Western Arizona. In *Landscapes of Arizona—The Geological Story*, edited by Terah L. Smiley, J. Dale Nations, Terry L. Péwé, and John P. Schafer, pp. 207–227. University Press of America, Lanham, Maryland.

Pennington, Campbell W.

1969 *The Tepehuan of Chihuahua: Their Material Culture*. University of Utah Press, Salt Lake City.

1980 *The Pima Bajo of Central Sonora, Mexico*, vol. 1. University of Utah Press, Salt Lake City.

Pepper, George

1902 *The Ancient Basket Makers of Southeastern Utah*. American Museum Journal supplement. Guide Leaflet No. 6. American Museum of Natural History, New York.

Peregrine, Peter N.

2001 Matrilocality, Corporate Strategy, and the Organization of Production in the Chacoan World. *American Antiquity* 66:1:36–46.

Pérez-Cruz, Ligia

2006 Climate and Ocean Variability during the Middle and Late Holocene Recorded in Laminated Sediments from Alfonso Basin, Gulf of California, Mexico. *Quaternary Research* 65(3):401–410.

Peros, Matthew C., Samuel E. Munoz, Konrad Gajewski, and André E. Viau

2010 Prehistoric Demography of North America Inferred from Radiocarbon Data. *Journal of Archaeological Science* 37:656–664.

Peterson, Roger Tory

1990 *Western Birds.* Peterson Field Guides. Houghton Mifflin, New York.

Pfefferkorn, Ignaz

1949 *Sonora: A Description of the Province.* Translated and annotated by Theodore E. Treutlein. Coronado Cuarto Centennial Publications, 1540–1940, vol. 12. University of New Mexico Press, Albuquerque.

Phillips, Bruce G., Gregory E. Berg, Lourdes Aguila, and Barbara S. Macnider

2001 *Data Recovery at AZ U:5:33 (ASM) within the Pima Freeway Corridor Phoenix, Maricopa County, Arizona*. Cultural Resources Report No. 116. Archaeological Consulting Services, Tempe, Arizona.

Phillips, Bruce G., Steven Bozarth, and Chad Kirvan

2009 Chapter 6: Paleoenvironmental Reconstruction and Exploitable Resources. In *Excavations within the State Route 101L/64th Street Locus of the Last Ditch Site, AZ U:5:33 (ASM), Phoenix, Arizona*, edited by A. E. Rogge, pp. 60–64. Cultural Resources Report 2008-18(AZ). URS Corporation, Phoenix.

Phillips, David A., Jr., Mark C. Slaughter, and Susan B. Bierer

1993 *Archaeological Studies at Kartchner Caverns State Park, Cochise County, Arizona*. Archaeological Report No. 93-26. SWCA, Tucson, Arizona.

Plog, Fred

1979 Prehistory: Western Anasazi. In *Southwest,* edited by Alfonso Ortiz, pp. 131–151. Handbook of North American Indians, vol. 9, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Polyak, Victor J., and Yemane Asmerom

2001 Late Holocene Climate and Cultural Changes in the Southwestern United States. *Science* 294:148–151.

Potter, James M.

2000 Faunal Remains. In *Tributaries, Terraces, and Tinajas: Prehistoric Cultural Variation on Three Drainages near New River, Maricopa County, Arizona*, edited by James M. Potter and Lynn A. Neal, pp. 149–155. Anthropological Research Papers No 7. SWCA Environmental Consultants, Flagstaff, Arizona.

2002 Peripheral Landscapes: The Anthem and West Valley Projects in Regional Context. In *Phoenix Basin to Perry Mesa: Rethinking the Northern Periphery*, edited by Mark R. Hackbarth, Kelley Hays-Gilpin, and Lynn Neal, pp. 191–201. The Arizona Archaeologist No. 34. Arizona Archaeological Society, Phoenix.

Potter, James M., and Randal R. Fox

2000 Site Descriptions. In *Tributaries, Terraces, and* Tinajas*: Prehistoric Cultural Variation on Three Drainages near New River, Maricopa County, Arizona,* edited by James M. Potter and Lynn A Neal, pp. 23–77. Anthropological Research Paper No. 7. SWCA Environmental Consultants, Flagstaff, Arizona.

Potter, James M., and Joseph Garrotto

2000 *The West Valley Survey: A Cultural Resources Inventory of 3,343 Acres East of and Bordering White Tank Mountain Regional Park, Maricopa County, Arizona*. Archaeological Report No. 00-29. SWCA Environmental Consultants, Flagstaff, Arizona.

Premo, Lucas S., and Jonathan B. Mabry

2003 Modeling Landscape Use by Early Farmer-Collectors in the Tucson Basin. In *Las Capas: Early Irrigation and Sedentism in a Southwestern Floodplain*, edited by Jonathan B. Mabry, pp. 283–292. Anthropological Papers No. 28. Center for Desert Archaeology, Tucson.

Prewitt, Elton R.

1981 A Wooden Mortar from the Stockton Plateau of Texas. *Journal of Field Archaeology* 8:111–121.

Price, John A.

1980 *The Washo Indians: History, Life Cycle, Religion, Technology, Economy, and Modern Life*. Occasional Papers No. 4. Nevada State Museum, Carson City.

Proudfoot, B.

1976 The Analysis and Interpretation of Soil Phosphorus in Archaeological Contexts. In *Geoarchaeology, Earth Science, and the Past*, edited by Donald A. Davison and Myra L. Shakley, pp. 93–113. Westview, Boulder, Colorado.

Rainey, Katherine D., and Karen R. Adams

1994 Plant Use by Native Peoples of the American Southwest: Ethnographic Documentation. Electronic document, http://www.crowcanyon.org/researchreports/archaeobotanical/plant_uses/qry-Ethnobot_Uses.asp, accessed September 9, 2013.

Rankin, Adrianne G.

1989 AZ T:3:20 (ASM). In *Settlement, Subsistence, and Specialization in the Northern Periphery: The Waddell Project,* vol. 1, edited by Margerie Green, pp. 307–394. Cultural Resources Report No. 65. Archaeological Consulting Services, Tempe, Arizona.

Rawls, James J., and Walton Bean

2012 The Original Californians. In *California: An Interpretive History*. 10th ed. McGraw Hill, New York.

Rea, Amadeo

1979 *Velvet Mesquite*. Environment Southwest No. 486. San Diego Society of Natural History, San Diego.

1997 *At the Desert's Green Edge: An Ethnobotany of the Gila River Pima*. University of Arizona Press, Tucson.

1998 *Folk Mammalogy of the Northern Pimans*. University of Arizona, Tucson.

2007 *Wings in the Desert: A Folk Ornithology of the Northern Pimans*. University of Arizona, Tucson.

Reagan, Albert B.

1929 Plants Used by the White Mountain Apache Indians of Arizona. *Wisconsin Archaeologist* 8:143–161.

Reid, Fiona A.

2006 *Mammals of North America*. Peterson Field Guides. Houghton Mifflin, New York.

Reimer, P. J., M. G. L. Baillie, Bard E. Bayliss, K. F. Beck, P. G. Blackwell, C. Bronk Ramsey, C. E. Buck, G. S. Burr, R. L. Edwards, M. Friedrich, P. M. Grootes, T. P. Guilderson, I. Hajdas, T. J. Heaton, A. G. Hogg,

K. A. Hughen, K. F. Kaiser, B. Kromer, F. G. McCormac, S. W. Manning, R. W. Reimer, D. A. Richards, J. R. Southon, S. Talamo, C. S. M. Turney, J. van der Plicht, and C. E. Weyhenmeyer

2009 IntCal09 and Marine09 Radiocarbon Age Calibration Curves, 0–50,000 Years cal B.P. *Radiocarbon* 51:1111–1150.

Republican Herald [Phoenix, Arizona]

1901 Chased Desert Game: A Roundup of Coyotes and Rabbits Near Scottsdale. 3 January: 3. Phoenix, Arizona.

Reynolds, Stephen J.

1985 *Geology of the South Mountains, Central Arizona*. Bulletin 195. Arizona Geological Survey, Tucson.

Reynolds, Stephen J., and R. D. Bartlett

2002 *Subsurface Geology of the Easternmost Phoenix Basin, Arizona: Implications for Groundwater Flow*. Contributed Report CR-02-A. Arizona Geological Survey, Tucson.

Reynolds, Stephen J., Stephen E. Wood, Philip A. Pearthree, John J. Field

2002 *Geological Map of the White Tank Mountains, Central Arizona.* Arizona Geological Survey, Tucson.

Rice, Glen E.

1981 Activity Organization at the Desert Gold Sites. In *Prehistoric Community Patterns in the Western Desert of Arizona,* by Glen E. Rice and Edward Dobbins. pp. 39–67. Anthropological Field Studies No. 2. Office of Cultural Resource Management, Department of Anthropology, Arizona State University, Tempe.

Rice, Glen E. (editor)

1987 *Studies in the Hohokam Community of Marana*. Anthropological Field Studies No. 15. Department of Anthropology, Arizona State University, Tempe.

Rice, Glen E., and Edward A. Dobbins

1981 *Prehistoric Community Patterns in the Western Desert of Arizona*. Anthropological Field Studies No. 2. Office of Cultural Resource Management, Arizona State University, Tempe.

Rice, Prudence M.

1999 On the Origins of Pottery. *Journal of Archaeological Method and Theory* 6:1–54.

Richard, Stephen M., Stephen J. Reynolds, John E. Spencer, and Philip A. Pearthree

2000 *Geologic Map of Arizona: Tucson*. Map 35. Scale 1:1,000,000. Arizona Geological Survey, Tucson.

Riddell, Francis A.

1978 Maidu Genealogies. In *Honey Lake Maidu Ethnography*, by Francis A. Riddell, William S. Evans, and Donald R. Tuohy. Occasional Papers, no. 3, pt. 3. Nevada State Museum, Carson City.

Rinck, Brandy A.

2014 A Geoarchaeological Perspective on Late Holocene Puyallup River Delta History Using Lithostratigraphic Data from Xaxtl'abish 1 on the Hylebos Creek Distributary in Tacoma, WA. *Quaternary International* (in press).

Roberts, Helen Heffron

1972 *Basketry of the San Carlos Apache Indians*. Reprinted. Rio Grande Press, Glorieta, New Mexico. Originally published 1929, Basketry of the San Carlos Apache, Anthropological Papers, vol. 31, pt. 2, American Museum of Natural History, New York.

Rogers, Malcolm J.

1939 *Early Lithic Industries of the Lower Basin of the Colorado River and Adjacent Areas.* Museum Papers No. 3. San Diego Museum of Man, San Diego.

Rogge, A. E. (editor)

2009 *Excavations within the State Route 101L/64th Street Locus of the Last Ditch Site, AZ U:5:33 (ASM), Phoenix, Arizona*. Cultural Resources Report 2008-18(AZ). URS Corporation, Phoenix.

Rogge, A. E., Chad Birvan, and Cassandra J. Albush

2009 Chapter 3: Research Questions and Methods. In *Excavations within the State Route 101L/64th Street Locus of the Last Ditch Site, AZ U:5:33 (ASM), Phoenix, Arizona,* edited by A. E. (Gene) Rogge, pp. 24–31. Cultural Resources Report 2008-18(AZ). URS Corporation, Phoenix.

Rogge, A. E., and Bruce G. Phillips

2009a Chronology and Geomorphology. In *Excavations within the State Route 101L/64th Street Locus of the Last Ditch Site, AZ U:5:33 (ASM), Phoenix, Arizona*, edited by A. E. Rogge, pp. 47–59. Cultural Resources Report 2008-18(AZ). URS Corporation, Phoenix.

2009b Introduction. In *Excavations within the State Route 101L/64th Street Locus of the Last Ditch Site, AZ U:5:33 (ASM), Phoenix, Arizona*, edited by A. E. Rogge, pp. 1–13. URS Corporation, Phoenix.

Rosenthal, Jeff

2006 When is an *Olivella* Bead? *Proceedings of the Society for California Archaeology* 19:128–131. Available online at http://www.scahome.org/publications/proceedings/Proceedings.19Rosenthal.pdf, accessed December 11, 2013.

Roth, Barbara J.

1989 Late Archaic Settlement and Subsistence in the Tucson Basin. Unpublished Ph.D. dissertation, Department of Anthropology, University of Arizona, Tucson.

1995 Late Archaic Occupation of the Upper Bajada: Excavations at AZ AA:12:84 (ASM). Tucson Basin. *Kiva* 61:189–207.

1996 Regional Land Use in the Late Archaic of the Tucson Basin: A View from the Upper *Bajada*. In *Early Formative Adaptations in the U.S. Southwest*, edited by Barbara J. Roth, pp. 37–48. Monographs in World Archaeology 5. Prehistory Press, Madison.

2000 Obsidian Source Characterization and Hunter-Gatherer Mobility: An Example from the Tucson Basin. *Journal of Archaeological Science* 27:305–314.

2001 Early Archaic. In *Encyclopedia of Prehistory*, vol. 6, pp. 45–54. Springer, New York.

2006 The Role of Gender in the Adoption of Agriculture in the Southern Southwest. *Journal of Anthropological Research* 62:513–538.

Roth, Barbara J., and Andrea Freeman
2008 The Middle Archaic and the Transition to Agriculture in the Sonoran Desert of Southern Arizona. *Kiva* 73:321–353.

Roth, Barbara J., and Bruce B. Huckell
1992 Cortaro Points and the Archaic of Southern Arizona. *Kiva* 57:353–370.

Rozaire, Charles E.
1974 *Analysis of Woven Materials from Seven Caves in the Lake Winnemucca Area, Pershing County, Nevada*. Anthropological Papers No. 16, Collected Paper No. 4. Nevada State Museum, Carson City.

Ruble, Ellen C., Helga Wöcherl, Andrew R. Dutt, and John McClelland
2008 Feature Descriptions. In *Las Capas: Early Irrigation and Sedentism in a Southwestern Floodplain,* edited by Jonathan B. Mabry, pp. 95–132. Anthropological Papers No. 28. Center for Desert Archaeology, Tucson.

Russell, Frank
1908 *The Pima Indians*. 26th Annual Report of the Bureau of American Ethnology, U.S. Government Printing Office, Washington, D.C.

Sánchez-Morales, Ismael
2012 *Las Industrias Líticas de Puntas de Projectil y Bifaciales en Los Sitios Arcaicos de Sonora*. Escuela de Antropología e Historia, Mexico City.

Sandweiss, Daniel H., Kirk A. Maasch, Richard L. Burger, James B. Richardson III, Harold B. Rollins, and Amy Clement
2001 Variation in Holocene El Niño Frequencies: Climate Records and Cultural Consequences in Ancient Peru. *Geology* 29:603–606.

Sassaman, Kenneth E.
1998 Lithic Technology and the Hunter-Gatherer Sexual Division of Labor. In *Reader in Gender Archaeology*, edited by Kelley Hays-Gilpin and David S. Whitley, pp. 159–171. Routledge Readers in Archaeology. Routledge, London.

Sayles, Edwin B.
1965 Stone Implements and Bowls. In *Excavations at Snaketown: Material Culture*, edited by Harold S. Gladwin, Emil W. Haury, Edwin B. Sayles, and Nora Gladwin, pp. 101–134. University of Arizona Press, Tucson. Reprinted. Originally published 1938, as Medallion Paper No. 25, Gila Pueblo Archaeological Foundation, Globe, Arizona.

1983 *The Cochise Cultural Sequence in Southeastern Arizona*. Anthropological Papers No. 42. University of Arizona Press, Tucson.

Sayles, Edwin B., and Ernst Antevs
1941 *The Cochise Culture.* Medallion Papers 29. Gila Pueblo, Globe, Arizona.

Schiffer, Michael B.
1987 *Formation Processes of the Archaeological Record.* University of New Mexico Press, Albuquerque.

Schlanger, Sarah H.

1991 On Manos, Metates, and the History of Site Occupation. *American Antiquity* 56:460–474.

Schmid, Elisabeth

1972 *Atlas of Animal Bones for Prehistorians, Archaeologists and Quaternary Geologists [Knochenatlas Für Prähistoriker, Archäologen und Quartärgeologen].* Elsevier, Amsterdam.

Schneider, Joan S.

1996 Quarrying and Production of Milling Implements at Antelope Hill, Arizona. *Journal of Field Archaeology* 23:299–311.

Schneider, Joan S., and Bonnie Bruce

2009 Feasibility of Using Protein Residue Analysis to Determine Materials Processed within Bedrock Milling Features. Electronic document, http://www.scahome.org/publications/proceedings/Proceedings.23Schneider.pdf, accessed March 10, 2014.

Schoeneberger, Philip J., D. A. Wysocki, E. C. Benham, and W. D. Broderson (editors)

2002 *Field Book for Describing and Sampling Soils*. Version 2.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Schumm, S. A., and R. F. Hadley

1957 Arroyos and the Semi-Arid Cycle of Erosion. *American Journal of Science* 255:161–74.

Schuster, J. H.

1990 The Ak-Chin Physical Environment: A Geologic Perspective. In *Archaeology of the Ak-Chin Indian Community West Side Farms Project: The Land and the People*, edited by Robert E. Gasser, Christine K. Robinson, and Cory Dale Breternitz, pp 1–35. Publications in Archaeology No. 9. Soil Systems, Phoenix.

Schwartz, Douglas W.

1983 Havasupai. In *Southwest,* edited by Alfonso Ortiz, pp. 13–24. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Scuderi, Louis A., Christine K. Laudadio, and Peter J. Fawcett

2010 Monitoring Playa Lake Inundation in the Western United States: Modern Analogues to Late-Holocene Lake Level Change. *Quaternary Research* 73:48–58.

Sewell, William H.

1992 A Theory of Structure: Duality, Agency, and Transformation. *The American Journal of Sociology* 98(1):1–29.

Shackley, M. Steven

1986 Obsidian Geochemistry and Lithic Technology: Inferences for Archaic Hunter-Gatherer Procurement Ranges. In *Prehistoric Hunter-Gatherers of South Central Arizona: The Picacho Reservoir Archaic Project*, edited by Frank E. Bayham, Donald H. Morris, and M. Steven Shackley, pp. 171–190. Anthropological Field Studies No. 13. Arizona State University, Tempe.

1990 Early Hunter-Gatherer Procurement Ranges in the U.S. Southwest: Evidence from Obsidian Geochemistry and Lithic Technology. Unpublished Ph.D. dissertation, Arizona State University, Tempe.

1996 Elk or San Pedro? A Quantitative Analysis of Late Archaic Projectile Points from White Tanks, Yuma County, Arizona. *Kiva* 61:413–432.

2005 *Obsidian: Geology and Archaeology in the North American Southwest*. University of Arizona Press, Tucson.

Shepard, Anna O.

1985 *Ceramics for the Archaeologist.* Reprinted. Braun-Brumfield, Ann Arbor. Originally published 1956, Carnegie Institution, Washington, D.C.

Shott, Michael J.

1996 An Exegesis of the Curation Concept. *Journal of Anthropological Research* 52:259–280.

Shott, Michael J., and Jesse A. M. Ballenger

2007 Biface Reduction and the Measurement of Dalton Curation: A Southeastern United States Case Study. *American Antiquity* 72:153–175.

Shreve, Forrest

1964 *Vegetation of the Sonoran Desert*. Vegetation and Flora of the Sonoran Desert, vol. 1. Stanford University Press, Stanford, California.

Slawson, Laurie V., and Ronald P. Maldonado

1990 *An Archaeological Survey of 435 Acres for a Proposed Golf Course Adjacent to Luke Air Force Base in Maricopa County, Arizona*. Cultural and Environmental Systems, Phoenix. Submitted to Malcolm Pirnie, Phoenix.

Sliva, R. Jane

1997 *An Introduction to the Study and Analysis of Flaked Stone Artifacts and Lithic Technology*. Center for Desert Archaeology, Tucson.

1999 Cienega Points and Late Archaic Period Chronology in the U.S. Southwest. *Kiva* 64:339–367.

2001 Flaked Stone Artifacts. In *Excavations in the Santa Cruz River Floodplain: The Early Agricultural Period Component at Los Pozos, e*dited by David A. Gregory, pp. 91–106. Anthropological Papers No. 21. Center for Desert Archaeology, Tucson.

2005 Developments in Flaked Stone Technology during the Transition to Agriculture. In *Material Cultures and Lifeways of Early Agricultural Communities in Southern Arizona, e*dited by R. Jane Sliva, pp. 47–98. Anthropological Papers No. 35. Center for Desert Archaeology, Tucson.

2009 Common Middle Archaic and Early Archaic Points in Southwestern Arizona. Archaeology U.S. Southwest Supplemental Information 23. Center for Desert Archaeology, Tucson. Electronic resource, http://www.archaeologyU.S. Southwest.org/pdf/09-01_sliva.pdf, accessed March 5, 2014.

Smith, Susan J.

1998 Processing Pollen Samples from Archaeological Sites in the Southwestern United States: an Example of Differential Recovery from Two Heavy Liquid Separation Procedures. In *New Developments in Palynomorph Sampling, Extraction, and Analysis*, edited by Vaughan M. Bryant and John H. Wrenn, pp. 29–34. Contributions Series No. 33. American Association of Stratigraphic Palynologists, Houston.

Soil Survey Staff

1993 *Soil Survey Manual*. Handbook 18. Soil Conservation Service, U.S. Department of Agriculture, U.S. Government Printing Office, Washington, D.C.

2004 *Soil Survey Laboratory Methods Manual*. Soil Survey Investigations Report No. 42, Version 4.0. U.S. Dept of Agriculture Natural Resource Conservation Service, U.S. Government Printing Office, Washington D.C.

2010 *Keys to Soil Taxonomy*. 11th ed. U.S. Department of Agriculture Natural Resource Conservation Service, U.S. Government Printing Office, Washington, D.C.

2013 Web Soil Survey of Maricopa County, Arizona. United States Department of Agriculture, Natural Resources Conservation Service, Washington, D.C. Electronic document, http://websoilsurvey.nrcs.usda.gov/, accessed August 2013.

Spaulding, W. Geoffrey

1985 *Vegetation and Climates of the Last 45,000 yr in the Vicinity of the Nevada Test Site, South-Central Nevada*. Professional Paper 1329. U.S. Geological Survey, Reston, Virginia.

Spaulding, W. Geoffrey, and L. J. Graumlich

1986 The Last Pluvial Episodes in the Deserts of Southwestern North America. *Nature* 320:441–444.

Spier, Leslie

1928 *Havasupai Ethnography*. Anthropological Papers, vol. 29, pt. 3. American Museum of Natural History, New York.

1933 *Yuman Tribes of the Gila Rive*r. University of Chicago Press, Chicago.

1978 *Yuman Tribes of the Gila River*. Dover Publications, New York. Reprint 1978, original publication 1933 University of Chicago Press, Chicago.

Stekelis, M., and T. Yizraely

1963 Excavations at Nahal Oren: Preliminary Report. *Israel Exploration Journal*, Vol. 13, No. 1, pp. 1–12.

Steinbring, Jack

1966 The Manufacture and Use of Bone Defleshing Tools. *American Antiquity* 31:575–581.

Stevens, Michelle N., and Jane R. Sliva

2002 Empire Points: An Addition to the San Pedro Phase Lithic Assemblage. *Kiva* 67:297–326.

Stevenson, Matilda C.

1915 *Ethnobotany of the Zuni*. Bureau of American Ethnology 30th Annual Report (1908–1909). Smithsonian Institution, Washington, D.C.

Stewart, Kenneth M.

1965 Mohave Indian Gathering of Wild Plants. *The Kiva* 31:46–53.

1983 Yumans: Introduction. In *Southwest,* edited by Alfonso Ortiz, pp. 1–3. Handbook of North American Indians, vol. 10, William C. Sturtevant, general editor, Smithsonian Institution, U.S. Government Printing Office, Washington, D.C.

Stiner, Mary C.

1994 *Honor among Thieves: A Zooarchaeological Study of Neandertal Ecology.* Princeton University Press, Princeton, New Jersey.

Strand, Jennifer G.

1999 Faunal Remains. In *Archaeological Data Recovery at the Home Depot Site, AZ AA:12:352 (ASM), in Marana, Pima County, Arizona*, prepared by David P. Doak, pp. 67–80. Cultural Resources Report No. 99-146. SWCA Environmental Consultants, Tucson.

Stulik, R. S., and Floyd R. Twenter

1964 *Geology and Ground Water of the Luke Area Maricopa County, Arizona*. Water Supply Paper 1779. U.S. Geological Survey, Reston, Virginia.

Surovell, Todd A.

2009 *Toward a Behavioral Ecology of Lithic Technology: Cases from Paleoindian Archaeology.* University of Arizona Press, Tucson.

Surovell, Todd A., Judson Byrd Finley, Geoffrey M. Smith, P. Jeffrey Brantingham, and Robert Kelly

2009 Correcting Temporal Frequency Distributions for Taphonomic Bias. *Journal of Archaeological Science* 36:1715–1724.

Swank, George

1932 The Ethnobotany of Acoma and Laguna. Unpublished Master's thesis, Department of Biology, University of New Mexico, Albuquerque.

Szuter, Christine R.

1984 Faunal Exploitation and the Reliance on Small Animals among the Hohokam. In *Environment and Subsistence*, edited by Lynn S. Teague and Patricia L. Crown, pp. 139–170. Hohokam Archaeology along the Salt Gila Aqueduct Central Arizona Project, vol. 7. Archaeological Series No. 150. Cultural Resource Management Section, Arizona State Museum, University of Arizona, Tucson.

1989 Hunting by Prehistoric Horticulturalists in the American Southwest. Unpublished Ph.D. dissertation, Department of Anthropology, University of Arizona, Tucson.

1991 *Hunting by Prehistoric Horticulturalists in the American Southwest*. Garland, New York.

Szuter, Christine R., and Frank E. Bayham

1989 Sedentism and Prehistoric Animal Procurement among Desert Horticulturalists of the North American Southwest. In *Farmers and Hunters: The Implications of Sedentism*, edited by Susan Kent, pp. 80–95. Cambridge University Press, Cambridge, England.

1996 Faunal Exploitation during the Late Archaic and Early Ceramic/Pioneer Periods in South-Central Arizona. In *Early Formative Adaptations in the Southern Southwest*, edited by Barbara J. Roth, Chapter 7. Monographs in World Archaeology No. 25. Prehistory Press, Madison, Wisconsin.

Tagg, Martyn D.

1996 Early Cultigens from Fresnal Shelter, Southeastern New Mexico. *American Antiquity* 61(2):311–324.

2008 *MSA II: Intensive Archaeological Survey of 262 Acres Adjacent to the Munitions Storage Area, Luke Air Force Base, Arizona.* Technical Report 07-49. Statistical Research, Tucson.

Tagg, Martyn D., Christopher J. Doolittle, Scott Thompson, and Gabrielle Duff

2007 *Intensive Archaeological Survey of 275 Acres Adjacent to the Munitions Storage Area, Luke AFB, Arizona.* Technical Report 04-12. Statistical Research, Tucson.

Tagg, Martyn D., Richard G. Ervin, and Bruce B. Huckell

1984 *Miscellaneous Archaeological Studies in the ANAMAX-Rosemont Land Exchange Area*. Archaeological Series, vol. 4, no. 147. Arizona State Museum, University of Arizona, Tucson.

Tagg, Martyn D., and Bruce B. Huckell

1984 The Sycamore Canyon Sites. In *Miscellaneous Archaeological Studies in the ANAMAX-Rosemont Land Exchange Area*, edited by Martyn D. Tagg, Richard G. Ervin, and Bruce B. Huckell, pp. 61–106. Archaeological Series, vol. 4, no. 147. Arizona State Museum, University of Arizona, Tucson.

Tanner, Clara Lee

1982 *Apache Indian Baskets*. University of Arizona Press, Tucson.

1983 *Indian Baskets of the Southwest*. University of Arizona Press, Tucson.

Terry, Richard E., Sheldon D. Nelson, Jared Carr, Jacob Parnell, Perry J. Hardin, Mark W. Jackson, and Stephen D. Houston

2000 Quantitative Phosphorus Measurement: A Field Test Procedure for Archaeological Site Analysis at Piedras Negras, Guatemala. *Geoarchaeology: An International Journal* 15:151–166.

Thackery, Frank A., and A. R. Leding

1929 The Giant Cactus of Arizona: The Use of Its Fruit and Other Cactus Fruits by the Indians. *Journal of Heredity* 20:401–414.

Thiel, J. Homer

1998 Faunal Remains. In *Analysis and Synthesis*, edited by Jonathan B. Mabry, pp. 165–208. Archaeological Investigations of Early Village Sites in the Middle Santa Cruz Valley, pt. 1. Anthropological Papers No. 19. Center for Desert Archaeology, Tucson.

1998 Worked Bone Artifacts. In *Analysis and Synthesis*, edited by Jonathan B. Mabry, pp. 423–435. Archaeological Investigations of Early Village Sites in the Middle Santa Cruz Valley, pt. 1. Anthropological Papers No. 19. Center for Desert Archaeology, Tucson.

Thomas, David H.

1969 Great Basin Hunting Patterns: A Quantitative Method for Treating Faunal Remains. *American Antiquity* 34:392–400.

1981 How to Classify the Projectile Points from Monitor Valley, Nevada. *Journal of California and Great Basin Anthropology* 3:7–43.

1986 *Refiguring Anthropology: First Principles of Probability & Statistics*. Waveland, Prospect Heights, Illinois.

Thompson, Raymond H.

1983 Introduction. In *The Cochise Cultural Chronology*, edited by Edwin B. Sayles, pp. 1–5. University of Arizona Press, Tucson.

Thomson, Matthew

2001 *Callipepla gambelii*: Gambel's Quail. Animal Diversity Web. Electronic document, http://animaldiversity.ummz.umich.edu/accounts/Callipepla_gambelii/, accessed June 12, 2013.

Torrence, Robin

1983 Time Budgeting and Hunter-Gatherer Technology. In *Hunter-Gatherer Economy in Prehistory: A European Perspective*, edited by G. N. Bailey, pp. 11–22. Cambridge University Press, Cambridge, England.

1989 *Time, Energy, and Stone Tools*. Cambridge University Press, Cambridge, England.

Towner, Ronald H., and Miranda Warburton

1990 Projectile Point Rejuvenation: A Technological Analysis. *Journal of Field Archaeology* 17:311–321.

Tucson Citizen [Tucson, Arizona]

1905 The City News in Paragraphs. 22 August:3. Tucson, Arizona.

1912 List Says Hotels Buy his Arizona Jackrabbits, Serve for Belgian Hares. 29 March 29:3.

1920 Plague of Rabbits Threaten Crops of Pima County. 8 July:3. Tucson, Arizona.

1920 Jack Rabbit Drive in this Country is Promised Shortly. 24 December 24:3. Tucson, Arizona.

Tuohy, Donald R.

1974 *A Cache of Pine Coiled, Feathered and Decorated Baskets from Western Nevada*. Anthropological Papers No. 16, Collected Paper No. 2. Nevada State Museum, Carson City.

Turner, Raymond M., Janice E. Bowers, and Tony L. Burgess

1995 *Sonoran Desert Plants: An Ecological Atlas*. University of Arizona Press, Tucson.

Turner, Raymond M., and David E. Brown

1982 Sonoran Desertscub. In Biotic Communities of the American Southwest—United States and Mexico, edited by David Brown, special issue, *Desert Plants* 4(1–4):181–221.

Underhill, Ruth Murray

1938 *A Papago Calendar Record.* Bulletin No. 322. Anthropological Series, vol. 2, no. 5. University of New Mexico Press, Albuquerque.

1979 *Papago Woman*. Waveland, Prospect Heights, Illinois.

Urban, Sharon F., and Stephanie M. Whittlesey

2010 Shell Artifacts. In *Recurrent Sedentism and the Making of Place: Archaeological Investigations at Las Capas, a Preceramic Period Farming Community in the Tucson Basin, Southern Arizona*, edited by Stephanie M. Whittlesey, S. Jerome Hesse, and Michael S. Foster, pp. 265–270. Cultural Resources Report No. 07-556. SWCA Environmental Consultants, Tucson.

Vanderpot, Rein

1997 From Foraging to Farming: Prehistoric Settlement and Subsistence Dynamics in the San Pedro Valley. In *Prehistory of the Borderlands: Recent Research in the Archaeology of Northern Mexico and the Southern Southwest*, edited by John Carpenter and Guadalupe Sanchez, pp. 33–45. Archaeological Series No. 186. Arizona State Museum, University of Arizona, Tucson.

Van Loon, Maurits N.

1966 First Results of the 1965 Excavations of Tell Mureybat near Meskene. *Annales Archéologiques Arabes Syriennes* 16:211–217.

Van Devender, Thomas R.

1990 Late Quaternary Vegetation and Climate of the Sonoran Desert, United States and Mexico. In *Packrat Middens: The Last 40,000 years of Biotic Change*, edited by Julio L. Betancourt, Thomas R. Van Devender, and Paul S. Martin, pp. 134–165. University of Arizona Press, Tucson.

Van Devender, Thomas R., J. I. Mead, and A. M. Rea

1991 Late Quaternary Plants and Vertebrates from Picacho Peak, Arizona. *The Southwestern Naturalist* 36:302–314.

Van Devender, Thomas R., and W. Geoffrey Spaulding

1979 Development of Vegetation and Climate in the Southwestern United States. *Science* 204:701–710.

Van Devender, Thomas R., R. S. Thompson, and Julio L. Betancourt

1987 Vegetation History of the Deserts of Southwestern North America: The Nature and Timing of the Late Wisconsin–Holocene Transition. In *North America and Adjacent Oceans during the Last Deglaciation*, edited by W. F. Ruddiman and H. E. Wright, Jr., pp. 323–352. Geology of North America, vol. K-3. Geological Society of America, Boulder, Colorado.

Varien, Mark D., and James M. Potter

2008 The Social Production of Communities: Structure, Agency, and Identity. In *The Social Construction of Communities. Agency, Structure, and Identity in the Prehispanic Southwest,* edited by Mark D. Varien and James M. Potter, pp. 1–18. Altamira, Lanham, Maryland.

Vaughn, Catherine S.

2009 Human Remains. In *Archaeological Investigations of Pueblo Patricio in Blocks 11, 12, 17, and 18 of the Original Phoenix Townsite, Phoenix, Arizona*, edited by Mark R. Hackbarth, pp. 163–174. The Phoenix Convention Center Excavations, vol. 1. Draft. Technical Reports in Prehistory No. 5. Logan Simpson Design, Tempe. Anthropological Papers No. 16. Pueblo Grande Museum, Phoenix.

Vehik, Susan C.

1977 Bone Fragments and Bone Grease Manufacturing: A Review of Their Archaeological Use and Potential. *Plains Anthropologist* 22:169–182.

Vincent, Kirk R., Philip A. Pearthree, P. Kyle House, and Karen A. Demsey

2004 *Inundation Mapping and Hydraulic Reconstructions of an Extreme Alluvial Fan Flood, Wild Burro Wash, Pima County, Southern Arizona.* Open-File Report 04-04. Arizona Geological Survey, Tucson.

Vierra, Bradley J.

1994 Archaic Hunter-Gatherer Mobility Strategies in Northwestern New Mexico. In *Archaic Hunter-Gatherer Archeology in the American Southwest*, edited by Bradley J. Vierra, pp. 121–154. Contributions to Anthropology 13(1). Eastern New Mexico University, Portales.

2009 *Keystone in Context: A Significant Archaic Period Site in El Paso, Texas.* SRI Press, Tucson.

2014 Archaic and Basketmaker II Period Foragers in the Southern Chuska Valley. In *Synthesis*, edited by Monica L. Murrell and Bradley J. Vierra, pp. 1.1–1.13. Bridging the Basin: Land Use and Social History in the Southern Chuska Valley, vol. 2, pt. 2. Technical Report 14-20. Draft. Statistical Research, Albuquerque.

Vierra, Bradley J. (editor)

2005 *The Late Archaic across the Borderlands: From Foraging to Farming*. Texas Archaeology and Ethnohistory Series. University of Texas Press, Austin.

Vokes, Arthur W.

1998 Shell Artifacts. In *Analysis and Synthesis*, edited by Jonathan B. Mabry, pp. 437–470. Archaeological Investigations of Early Village Sites in the Middle Santa Cruz Valley, pt. 1. Anthropological Papers No. 19. Center for Desert Archaeology, Tucson.

2001a The Shell Ornament Assemblage. In *Tonto Creek Archaeological Project: Life and Death along Tonto Creek*, edited by Jeffery J. Clark and Penny Dufoe Minturn, pp. 353–420. Anthropological Papers No. 24. Center for Desert Archaeology, Tucson.

2001b The Stone and Clay Jewelry Assemblages. In *Tonto Creek Archaeological Project: Life and Death along Tonto Creek*, edited by Jeffery J. Clark and Penny Dufoe Minturn, pp. 421–457. Anthropological Papers No. 24. Center for Desert Archaeology, Tucson.

2001c Shell Artifacts. In *Excavations in the Santa Cruz Phase Floodplain: The Early Agricultural Period Component at Los Pozos*, edited by David A. Gregory, pp. 135–152. Anthropological Papers No. 21. Center for Desert Archaeology, Tucson.

2003 Personal Ornaments of Shell and Stone from Valencia Vieja. In *Roots of Sedentism: Archaeological Excavations at Valencia Vieja, a Founding Village in the Tucson Basin of Southern Arizona*, edited by Henry D. Wallace, pp. 253–268. Anthropological Papers No. 29. Center for Desert Archaeology, Tucson.

2005 Early Agricultural Period Shell Use. In *Material Cultures and Lifeways of Early Agricultural Communities in Southern Arizona*, edited by R. Jane Sliva, pp. 153–170. Anthropological Papers No. 35. Center for Desert Archaeology, Tucson.

2006 Shell Artifacts. In *Rio Nuevo Archaeology Program 2000–2003: Investigations at the San Agustín Mission and Mission Gardens, Tucson Presidio, Tucson Pressed Brick Company, and Clearwater Site*, edited by J. Homer Thiel and Jonathan B. Mabry, pp. 11.1–11.8. Technical Report 2004-11. Center for Desert Archaeology, Tucson.

2007 Shell. In *Archaeological Investigations at the El Taller, AZ AA:12:92(ASM), and Rillito Fan, AZ AA:12:788 (ASM), Sites along Eastbound I-10 between Sunset to Ruthrauff Roads*, edited by Helga Wöcherl, pp. 149–157. Technical, Report 2003-08. Desert Archaeology, Tucson.

Vokes, Arthur W., and Charles H. Miksicek

1987 Snails, Clams, and Canals: An Analysis of Nonmarine Molluscan Remains. In *Archaeological Investigations of Portions of the Las Acequias–Los Muertos Irrigation System, Testing and Partial Data Recovery within the Tempe Section of the Outer Loop Freeway System, Maricopa County, Arizona*, edited by W. Bruce Masse, pp. 177–187. Archaeological Series No. 176. Arizona State Museum, University of Arizona, Tucson.

Vorhies, Charles T., and Walter P. Taylor

1933 *The Life Histories and Ecology of Jack Rabbits,* Lepus Alleni *and* Lepus Californicus *ssp., in Relation to Grazing in Arizona*. Technical Bulletin No. 49. College of Agriculture, Agricultural Experiment Station, University of Arizona, Tucson.

Wagner, Jennifer D. M.

2006 Speleothem Record of the Southern Arizona Paleoclimate 54 to 3.5 ka. Unpublished Ph.D. dissertation, University of Arizona, Tucson.

Waguespack, Nicole M., Todd A. Surovell, Allen Denoyer, Alace Dallow, Adam Savage, Jamie Hyneman, Dan Tapster

2009 Making a Point: Wood-Versus Stone-Tipped Projectiles. *Antiquity* 83:786–800.

Wallace, William James, and Edith S. Taylor

1955 Archaeology of Wildrose Canyon, Death Valley National Monument. *American Antiquity* 20:355–367.

Wallmo, Charles O.

1972 The Fort Huachuca Wildlife Area Survey. *The Artifact* 10:24–33.

Walton, George P.

1923 *A Chemical and Structural Study of Mesquite, Carob, and Honey Locust Beans*. Bulletin No. 1194. U.S. Department of Agriculture, U.S. Government Printing Office, Washington, D.C.

Wandsnider, LuAnn

1997 The Roasted and the Boiled: Food Composition and Heat Treatment, with Special Emphasis on Pit-Hearth Cooking. *Journal of Anthropological Archaeology* 16:1–48.

Ward, Graeme K., and Sue R. Wilson

1978 Procedures for Comparing and Combining Radiocarbon Age Determinations: A Critique. *Archaeometry* 20:19–31.

Warren, Claude N.

1967 The San Dieguito Complex: A Review and Hypothesis. *American Antiquity* 32:168–185.

1980 Pinto Points and Problems in Mojave Desert Archaeology. In *Anthropological Papers in Memory of Earl H. Swanson, Jr.*, edited by Lucille B. Hasten, Claude N. Warren, and Donald R. Tuohy, pp. 67–76. Special Publication of the Idaho Museum of Natural History, Pocatello.

Waters, Jennifer A.

1998 Vertebrate Faunal Remains from the Wetlands Site. In *Archaeological Investigations at the Wetlands Site, AZ AA:12:90 (ASM)*, edited by Andrea K. L. Freeman, pp. 205–247. Technical Report 97-5. Center for Desert Archaeology, Tucson.

2002 Hunting Patterns along Tonto Creek. In *Stone Tool and Subsistence Studies*, edited by Jefferey J. Clark, pp. 735–767. Tonto Creek Archaeological Project Artifact and Environmental Analyses, vol. 2. Anthropological Papers No. 23. Center for Desert Archaeology, Tucson.

2005a Canid Remains from Special Contexts at Las Capas and Los Pozos. In *Material Cultures and Lifeways of Early Agricultural Communities in Southern Arizona*, edited by R. Jane Sliva, pp. 271–279. Anthropological Papers No. 35. Center for Desert Archaeology, Tucson.

2005b Vertebrate Faunal Remains and Hunting Patterns during the Early Agricultural Period in Southern Arizona. In *Subsistence and Resource Use Strategies of Early Agricultural Communities in Southern Arizona*, edited by Michael W. Diehl, pp. 91–111. Anthropological Papers No. 34. Center for Desert Archaeology, Tucson.

Waters, Michael R.

1985 Early Holocene Occupation along Whitewater Draw, Southeastern Arizona: The Sulphur Spring Stage. *Current Research in the Pleistocene* 2:31–33.

1986 *The Geoarchaeology of Whitewater Draw, Arizona*. Anthropological Papers No. 45. University of Arizona Press, Tucson.

1987 Geomorphic Analysis of Hohokam Settlement Patterns on Alluvial Fans along the Western Flank of the Tortolita Mountains, Arizona. In *Studies in the Hohokam Community of Marana*, edited by Glen E. Rice, pp. 31–48. Anthropological Field Studies No. 15. Office of Cultural Resource Management, Department of Anthropology, Arizona State University, Tempe.

1989 Late Quaternary Lacustrine History and Paleoclimatic Significance of Pluvial Lake Cochise, Southeastern Arizona. *Quaternary Research* 32:1–11.

1992 *Principles of Geoarchaeology*. University of Arizona Press, Tucson.

1998 The Effect of Landscape and Hydrologic Variables on the Prehistoric Salado: Geoarchaeological Investigations in the Tonto Basin, Arizona. *Geoarchaeology* 13:105–160.

2008 Alluvial Chronologies and Archaeology of the Gila River Drainage Basin, Arizona. *Geomorphology* 101:332–341.

Waters, Michael R., and John J. Field

1986 Geomorphic Analysis of Hohokam Settlement Patterns on Alluvial Fans along the Western Flank of the Tortolita Mountains, Arizona. *Geoarchaeology* 1:329–345.

Waters, Michael R., and C. Vance Haynes, Jr.

2001 Late Quaternary Arroyo Formation and Climate Change in the American Southwest. *Geology* 29:399–402.

Waters, Michael R., and David D. Kuehn

1996 The Geoarchaeology of Place: The Effect of Geological Processes on the Preservation and Interpretation of the Archaeological Record. *American Antiquity* 61:483–498.

Webb, George

1959 *A Pima Remembers*. University of Arizona, Tucson.

Webster, Laurie

2007 Mogollon and Zuni Perishable Traditions and the Question of Zuni Origins. In *Zuni Origins: Toward a New Synthesis of Southwestern Archaeology*, edited by David A. Gregory and David R. Wilcox, pp. 250–317. University of Arizona Press, Tucson.

Wegener, Robert M.

2009 Vertebrate Faunal Analysis. In *Analyses of Prehistoric Remains*, edited by Eric Eugene Klucas, Richard Ciolek-Torrello, and Holly Warner, pp. 195–250. The State Route 188–Cottonwood Creek Project: The Sedentary to Classic Period Transition in Tonto Basin, vol. 2, Richard Ciolek-Torrello, general editor. Statistical Research, Tucson.

Wegener, Robert M., Michael P. Heilen, Richard Ciolek-Torello, and John D. Hall (editors)

2011 *Analysis of Prehistoric Materials in the Queen Valley to Queen Creek Area*. The U.S. 60 Archaeological Project: Early Agricultural, Formative, and Historical-Period Use of the Upper Queen Creek Region, vol. 4. Technical Series 92. Statistical Research, Tucson, Arizona.

Wells, Stephen G., Leslie D. McFadden, and J. C. Dohrenwend

1987 Influence of Late Quaternary Climatic Changes on Geomorphic and Pedogenic Processes on a Desert Piedmont, Eastern Mojave Desert, California. *Quaternary Research* 27:130–146.

Wells, Stephen G., Leslie D. McFadden, and J. Harden

1990 Preliminary Results of Age Estimations and Regional Correlations of Quaternary Alluvial Fans within the Mojave Desert in Southern California. In *At the End of the Mojave—Quaternary Studies in the Eastern Mojave Desert*, edited by R. E. Reynolds, Stephen G. Wells, and R. H. Brady, pp. 45–54. San Bernardino County Museum Association, Redlands, California.

Whalen, Norman B.

1971 Cochise Culture Sites in the Central San Pedro Drainage, Arizona. Unpublished Ph.D. dissertation, Department of Anthropology, University of Arizona, Tucson.

1975 Cochise Site Distribution in the San Pedro Valley. *The Kiva* 40:203–211.

Wheat, Joe Ben

1955 Mogollon Culture Prior to A.D. 1000. *Memoirs of the American Anthropological Association, No. 82*.

Wheat, Margaret M.

1990 *Survival Arts of the Primitive Paiutes*. 2nd ed. University of Nevada Press, Reno.

Whitaker, John O.

1980 *The Audubon Society Field Guide to North American Mammals*. Alfred A. Knopf, New York.

White, Tim D., and Pieter A. Folkens

2005 *The Human Bone Manual.* Academic Press, Burlington, Massachusetts.

Whittlesey, Stephanie M., S. Jerome Hesse, and Michael S. Foster

2010 *Recurrent Sedentism and the Making of Place: Archaeological Investigations at Las Capas, a Preceramic Period Farming Community in the Tucson Basin, Southern Arizona.* Cultural Resources Report No. 07-556. Draft. SWCA Environmental Consultants, Tucson.

Wichmann, Søren, André Müller, and Viveka Velupillai
2010 Homelands of the World's Language Families: A Quantitative Approach. *Diachronica* 27(2):247–276.

Wiener, Malcolm H.
2012 Problems in the Measurement, Calibration, Analysis, and Communication of Radiocarbon Dates (with Special Reference to the Prehistory of the Aegean World). *Radiocarbon* 54:423–434.

Wiens, Ruth W.
1994 The Early Archaic in Northwestern New Mexico: A Re-Evaluation Based on Data from Gellegos Mesa. In *Archaic Hunter-Gatherer Archaeology in the American Southwest*, edited by Bradley J. Vierra, pp. 62–75. Contributions to Anthropology 13(1). Eastern New Mexico University, Portales.

Wilcox, David R.
1979 The Hohokam Regional System. In *An Archaeological Test of Sites of the Gila Butte–Santan Region, South-Central Arizona*, edited by Glen E. Rice, David R. Wilcox, Kevin Rafferty, and James Schoenwetter, pp. 77–116. Technical Paper No. 3, Anthropological Research Paper No. 18. Arizona State University, Tempe.

Willey, Gordon R., and Philip Phillips
1958 *Method and Theory in American Archaeology.* University of Chicago Press, Chicago.

Williams, Alan N.
2012 The Use of Summed Radiocarbon Probability Distributions in Archaeology: A Review of Methods. *Journal of Archaeological Science* 39:578–589.

Williams-Dean, Glenna
1978 *Ethnobotany and Cultural Ecology of Prehistoric Man in Southwest Texas*. Anthropology Research Laboratory. Texas A&M University. College Station.

Willig, Judith A., and C. Melvin Aikens
1988 The Clovis-Archaic Interface in Far Western North America. In *Early Human Occupation in Far Western North America: The Clovis-Archaic Interface,* edited by Judith A. Willig, C. Melvin Aikens, John Lee Fagan, pp. 1–40. Anthropological Papers 21. Nevada State Museum, Carson City.

Wills, Wirt H.
1988 *Early Prehistoric Agriculture in the American Southwest.* School of American Research Press, Santa Fe.

Windingstad, Jason D., and Jesse A. M. Ballenger
2010 Christiansen Wash Geomorphology. In *Data Recovery at Christiansen Border Village: Nonriverine Late Archaic/Early Agricultural and Formative Period Archaeology in the Borderlands of Southeastern Arizona*, edited by Robert M. Wegener, Karry L. Blake, and Richard Ciolek-Torrello, pp. 91–123. Technical Report 09-31. Statistical Research, Tucson.

Windmiller, Ric
1973 The Late Cochise Culture in the Sulphur Spring Valley, Southeastern Arizona: Archaeology of the Fairchild Site. *The Kiva* 39:131–169.

Wöcherl, Helga

1999 Faunal Remains. In *Excavations in the Santa Cruz River Floodplain: The Middle Archaic Component at Los Pozos*, edited by David A. Gregory, pp. 63–73. Anthropological Papers No. 20. Center for Desert Archaeology, Tucson.

2001 Faunal Remains. In *Excavations in the Santa Cruz River Floodplain: The Early Agricultural Period Component at Los Pozos,* edited by David A. Gregory, pp. 209–236. Anthropological Papers No. 21. Center for Desert Archaeology, Tucson.

Woodburn, James

1982 Egalitarian Societies. *Man* 17: 431–451.

Wright, David K., Michael R. Waters, Chris Loendorf, M. Kyle Woodson, Wesley D. Miles, and J. Andrew Darling

2013 Late Archaic Wells on the Gila River Indian Community, Arizona. *Journal of Archaeological Science* 40:45–57.

Yanovsky, Elias

1936 *Food Plants of the North American Indians*. Miscellaneous Publication 237. U.S. Department of Agriculture, U.S. Government Printing Office, Washington, D.C.

Zedeño, M. Nieves, Jesse A. M. Ballenger, and John R. Murray

2014 Landscape Engineering and Organizational Complexity among Late Prehistoric Bison Hunters of the Northwestern Plains. *Current Anthropology* 55(1):23–58.

Zepeda, Ofelia

1985 *The Sand Papago Oral History Project*. U.S. Department of the Interior National Park Service, Western Archeological and Conservation Center, Tucson.

Zeveloff, Samuel I.

1988 *Mammals of the Intermountain West*. University of Utah Press, Salt Lake City.

Zolfaghari, R., M. Harden, and L. Huffman

1985 Some Physical and Chemical Properties of Honey Mesquite (*Prosopis glandulosa*) and Applications in Food Products. *Cereal Chemistry* 63(2):104–108.

Zweifel, Matthew Karl

1994 A Guide to the Identification of the Molariform Teeth of Rodents and Lagomorphs of the Columbia Basin. Unpublished Master's thesis, Department of Anthropology, Washington State University.