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 3: Synthetic Studies and Conclusions

Edited by
Rein Vanderpot

Technical Series 96
Statistical Research, Inc.
Tucson, Arizona

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With contributions by

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ABSTRACT

Report Title: 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 3: Synthetic Studies and Conclusions

Report Date: 2016

Project Sponsor: Arizona Department of Transportation and Federal Highway Administration

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Agencies: Arizona State Land Department, Arizona State Historic Preservation Office, Arizona State Museum, Arizona Department of Transportation, and Federal Highway Administration

Project Title: The Marsh Station Archaeological Project (MSAP)

Archaeological Consultants: Statistical Research, Inc. (SRI), 6099 E. Speedway Blvd., Tucson, AZ 85712; (520) 721-4309

Principal Investigator: Jeffrey H. Altschul, Ph.D. (2000–2005); Stephanie M. Whittlesey, Ph.D. (2006); Rein Vanderpot, M.A. (2007–2016)
Project Director: Rein Vanderpot, M.A. (2000–2006)
Field Director: William L. Deaver, M.A., and Robert Wegener, M.A. (2000–2001)

Project Description: In 2000 and 2001, SRI, completed phased archaeological data recovery at the Mescal Wash site (AZ EE:2:51 [ASM]), located at the Marsh Station Traffic Interchange and Pantano Railroad Overpass, Interstate 10, Pima County, Arizona. Phase 1 fieldwork was conducted between June 19 and July 27, 2000; Phase 2 fieldwork was conducted between January 16 and June 15, 2001. A total of 1,197 field person-days was expended during these periods. This work was conducted in support of the reconstruction of the existing interchange and overpass by the Arizona Department of Transportation. During the investigations, SRI identified 2,314 archaeological features, of which 474 features (not counting intramural subfeatures) were excavated. The excavated features included 97 structures and 377 extramural features (48 of which were burials).

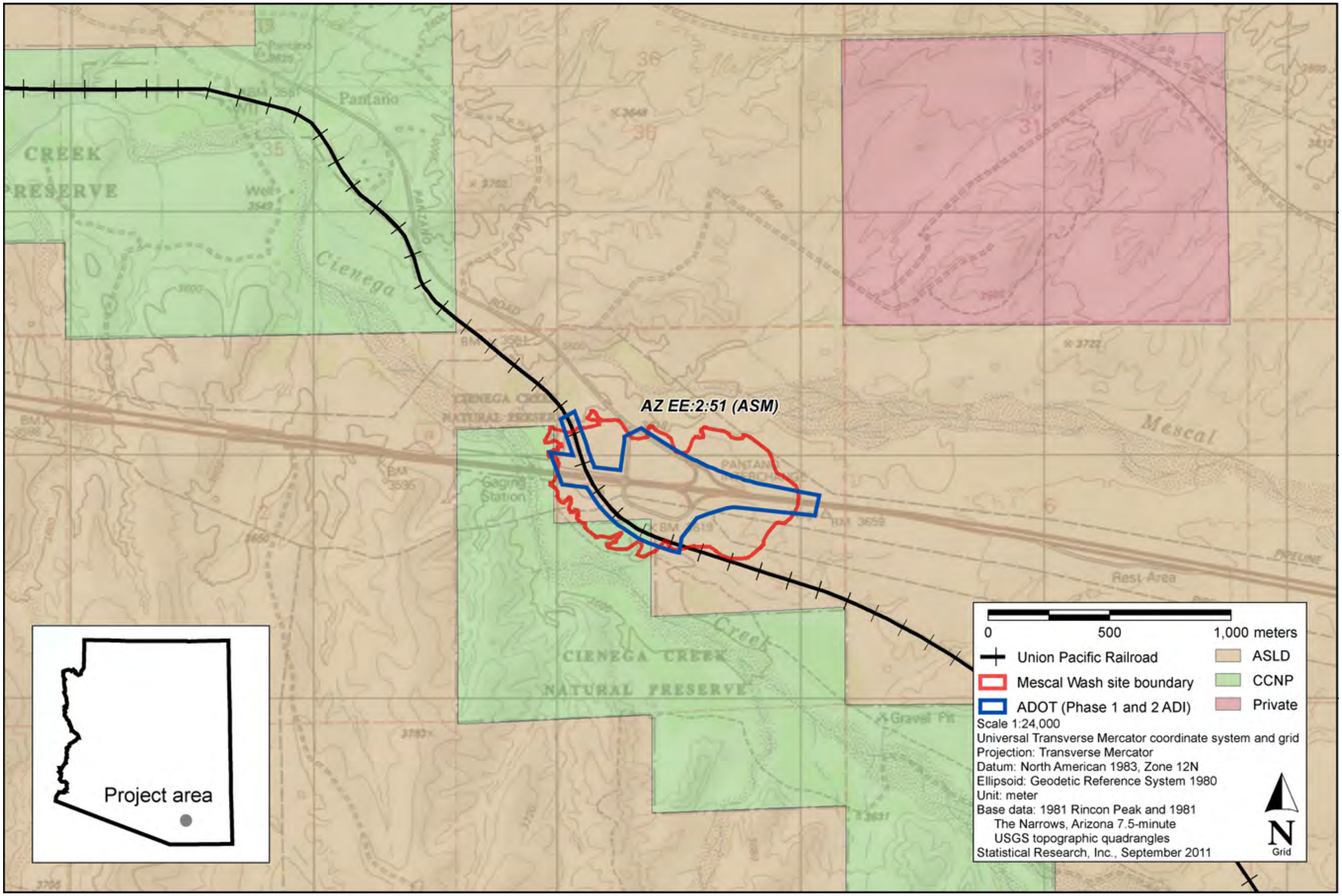
Land Status: Arizona State Land Department, Union Pacific Railroad, Arizona Department of Transportation, and private (including Cienega Creek Natural Preserve [Map 1])

Location: Township 17 South, Range 17 East, Section 1, on the 1981 The Narrows, Arizona, 7.5-minute U.S. Geological Survey topographic quadrangle (Map 1)

NRHP-Eligible Properties: Mescal Wash site (AZ EE:2:51 [ASM]), Criterion d, 1996

Recommendations: SRI recommends that the investigated portions of the Mescal Wash site have been effectively mitigated, and no further research potential exists for the portion of the site within the existing Arizona Department of Transportation right-of-way. Enough of the site remains intact in noninvestigated areas to retain its NRHP eligibility status. Any future ground-disturbing activities within site boundaries outside of the Arizona Department of Transportation right-of-way should be preceded by an appropriate plan of work in consultation with the appropriate agencies and stakeholders.

Curation Facility: Arizona State Museum, University of Arizona, Tucson



Map 1. The Mescal Wash site (AZ EE:2:51 [ASM]) and surrounding area, showing landownership (Arizona State Land Department [ASLD], Cienega Creek Natural Preserve [CCNP], and other, private ownership) and right-of-way areas (Arizona Department of Transportation [ADOT] Area of Direct Impact and Union Pacific Railroad [UPRR]).

CHAPTER 1

Introduction

Rein Vanderpot

This document is the final of three volumes presenting the results of a two-phase data recovery program conducted by Statistical Research, Inc. (SRI), at the Mescal Wash site, AZ EE:2:51 (Arizona State Museum [ASM]), in Pima County, southeastern Arizona (Figure 1). The site is located in Section 1, Township 17 South, Range 17 East (The Narrows 1981 7.5-minute U.S. Geological Survey [USGS] quadrangle), on land managed by the Arizona Department of Transportation (ADOT), the Union Pacific Railroad (UPRR), the Cienega Creek Natural Preserve, and the Arizona State Land Department (ASLD). The archaeological site covered an area of nearly 1 km^2 at the confluence of Mescal Wash and Cienega Creek, traversed by Interstate 10 (I-10) and the UPRR line. ADOT's proposed reconstruction of the existing Pantano Railroad Overpass and the Marsh Station traffic interchange at I-10 would impact large portions of the site. The construction project was funded by the Federal Highway Administration (FHWA). Hence, it was considered an undertaking as defined by Section 106 of the National Historic Preservation Act of 1966, as amended. To comply with the law, a Memorandum of Agreement was executed among the FHWA, ADOT, the ASLD, the ASM, the Hopi Tribe, the Tohono O'odham Nation, the U.S. Army Corps of Engineers, the Arizona State Historic Preservation Office, and the Advisory Council on Historic Preservation. To fulfill its obligations under the pertinent state and federal historic-preservation laws, ADOT contracted with SRI to mitigate the adverse effects resulting from the construction efforts. SRI conducted phased data recovery in 2000 and 2001 (the Marsh Station Archaeological Project [MSAP]) sponsored by ADOT, under Engineering Consultants Section Contract No. 00-64 (Temporary Restriction and Closure System Permit No. H2390 01E), and under the terms and conditions of State Highway Right-of-Way (ROW) Permit No. 78066; State Land Permit No. 2000-92ps; the *Arizona Revised Statutes*, Section 41-844 (Case No. 00-21), Burial Agreement; ASM Repository Agreement No. 865; and UPRR Contract Folder No. 01904-64.

During the investigations, SRI identified eight loci (Loci A–H) (Figure 2), of which all but Locus H were completely or partially within ADOT's proposed area of direct impact. Phase 1 testing included all or portions of six loci (Loci A–F); Loci G and H were mapped but were not subjected to testing or surface collection. Over 1,500 m of backhoe trenches and about 1,150 m^2 of stripping units were excavated. During Phase 2, the backhoe stripped overburden from large areas in Loci A–D that, together, measured about 3.3 acres. The excavations focused on the southern half of Locus A, most of Locus B, all of Locus C, and most of Locus D. At the end of fieldwork, the total feature inventory numbered 2,314 archaeological features, of which 474 features (not counting intramural subfeatures) were excavated. The excavated features included 97 structures and 377 extramural features (48 of which were burials).

Volume 1 in this series presented the results of the field investigations, including an overview of the various feature types and in-depth descriptions of each locus; detailed discussions of the site's recording history, project environment, and excavation methods compose the first part of the volume. Volume 2 presented the results of the analyses of the various artifacts and other remains and samples that were collected during our excavations. In this final volume, we synthesize the results of the field investigations and the analyses of prehistoric remains and environmental materials, in order to address research issues considered important to the prehistory of southeastern Arizona and the Mescal Wash site, itself.

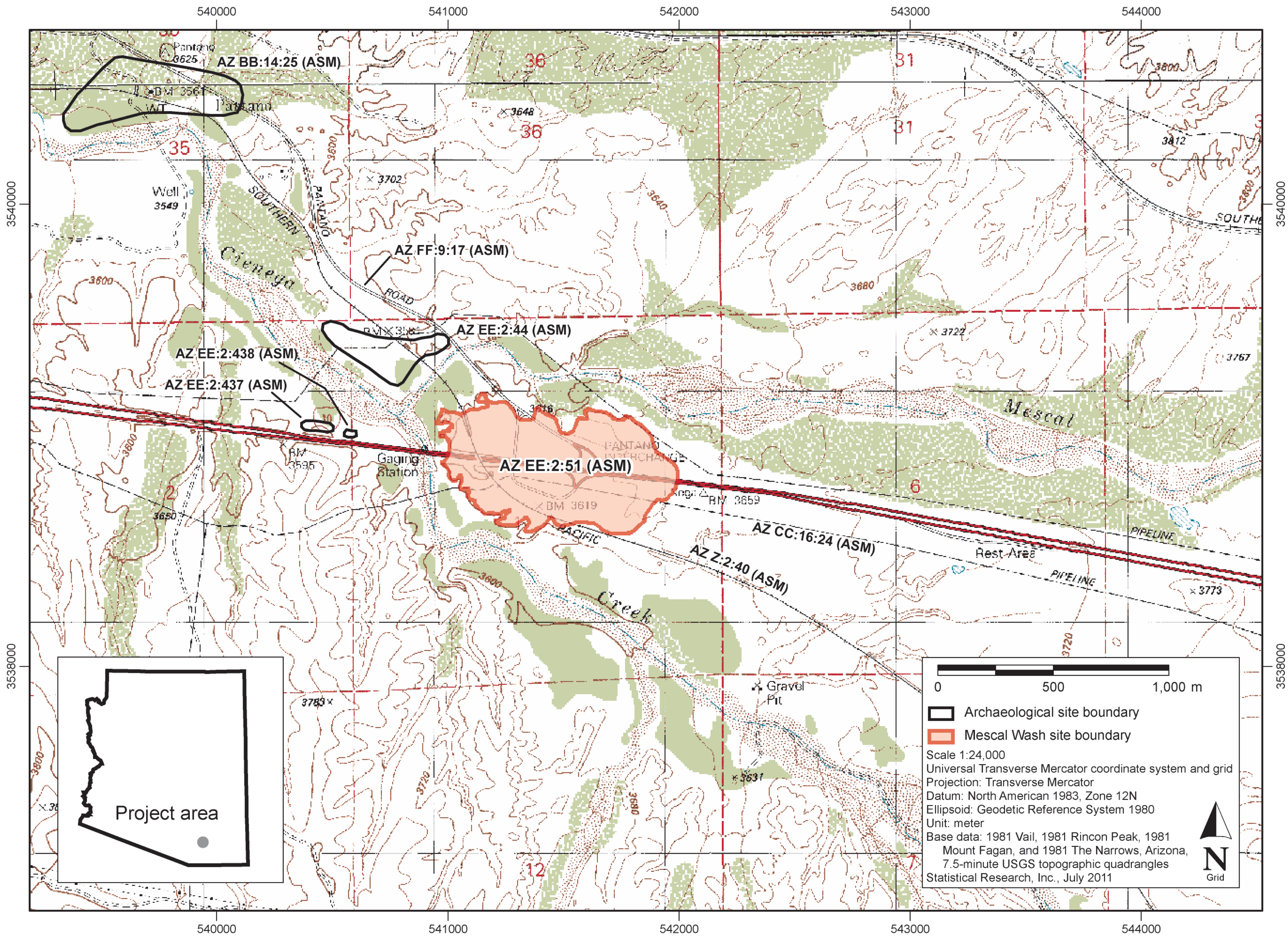


Figure 1. Map showing the locations of Mescal Wash and adjacent sites along Cienega Creek.

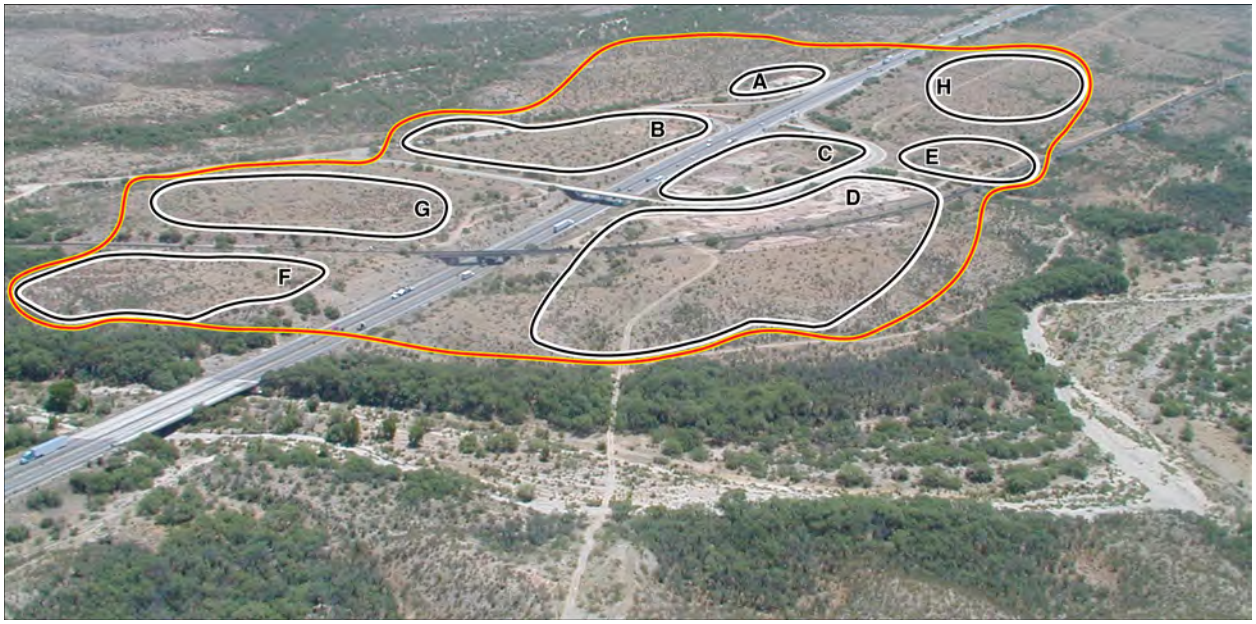


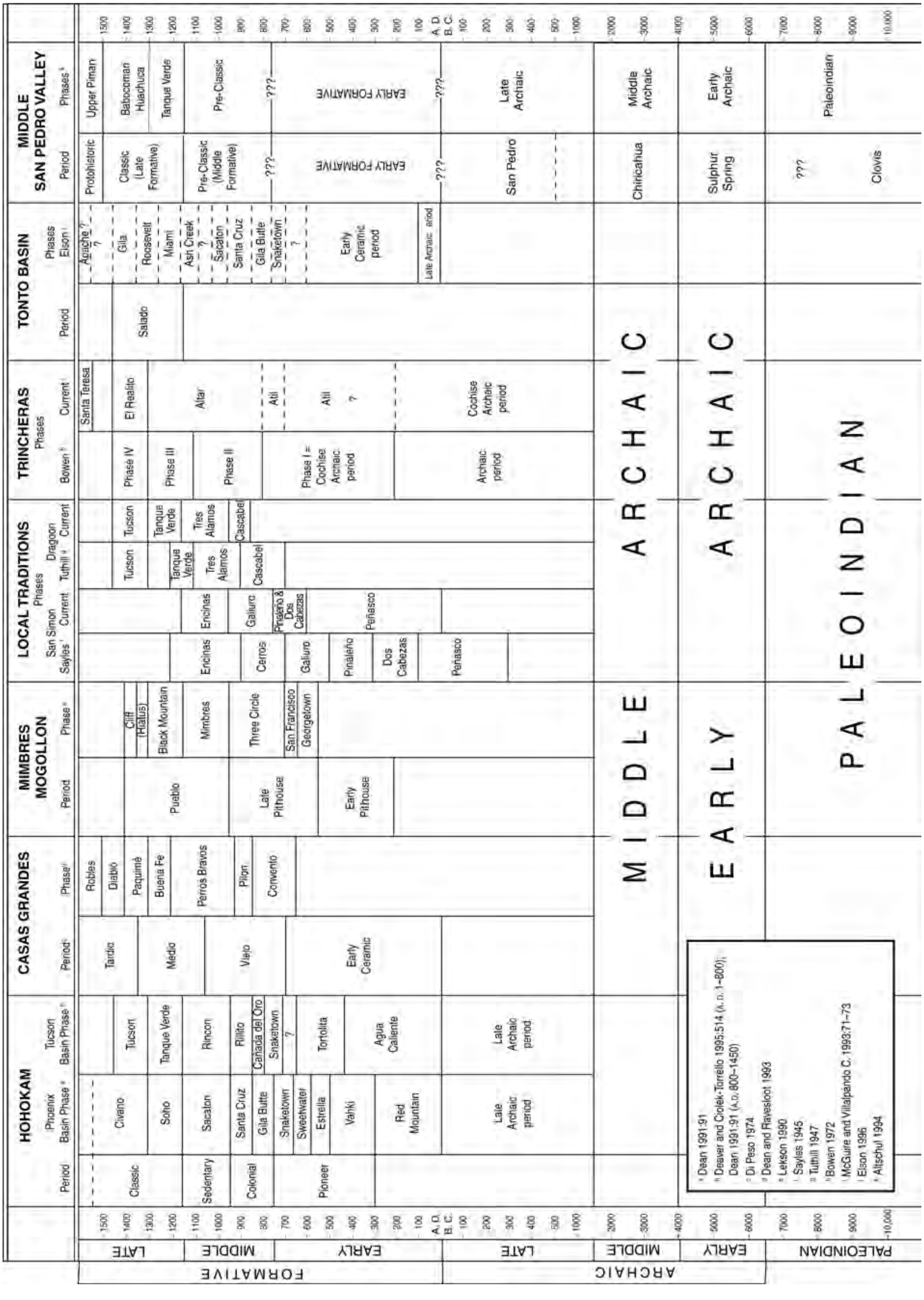
Figure 2. Aerial map of the Mescal Wash site, showing Loci A–H.

Site Context and Chronology

The Mescal Wash site is located in Empire Valley, on a broad terrace at the confluence of Mescal Wash and Cienega Creek (see Figures 1 and 2). Situated in an area of upland hills and grassland approximately halfway between the Tucson Basin and the San Pedro River, the site lies in an ecological transition zone between the Sonoran Desert and the Chihuahuan Desert grasslands. Perennial water flows through most of the lower half of Cienega Creek, and along much of its course are large areas of slowly flowing, ponded water flanked by lush riparian vegetation. At its confluence with the creek, Mescal Wash—an ephemeral drainage holding water only during summer rainstorms—flows through a broad, flat channel. An important feature of the valley is the presence, within a small area, of three major plant communities: riparian, grassland, and oak woodland. Conifer forest is present a few kilometers away, higher up in the mountains, and Sonoran Desertscrub vegetation is within easy reach, to the northwest. Significantly, site location on a flat ridge at the confluence of two major drainages would have provided a number of attractive features for prehistoric populations. Principal among these would have been immediate access to arable land on the floodplains and the water resources of the drainages themselves.

The combination of resource diversity, abundance, and accessibility probably was a major reason for the longevity of the Mescal Wash site. The investigations showed that the site had witnessed habitation spanning nearly 3,000 years; the excavated loci evidenced an episodic rhythm to the occupation. Travelers, hunters, gatherers, farmers, pioneers, and colonists—in different configurations and at different times—all made their mark on and contributed to the local landscape in distinctive ways. As determined from radiocarbon and archaeomagnetic dates, the Mescal Wash site was intermittently occupied between about 1200 B.C. and A.D. 1450, a time span corresponding to the Late Archaic and Formative periods. Middle Archaic period dart points recovered from the site suggested even earlier use, but no protohistoric artifacts or features were identified. Several undated rock-lined roasting pits in Locus D found at or just below the modern ground surface, however, might have been late prehistoric or protohistoric. Historical documents showed that by the 1800s, the greater site area was known as the Ciénega de los Pimas and was used regularly as a camping and watering stop for soldiers, settlers, and Apaches alike (Albright 1921; Dobyns 1981:18; Officer 1987:15; Wagoner 1975:151). Wagon roads and the Butterfield Overland Mail Company line followed. No artifacts or features dating to that time were found, and the only evidence of historical-period use was limited to subsequent roads, the railroad, and a scatter of artifacts from the 1950s or later in Locus B.

For our purposes, we have divided the Formative period into the Early (A.D. 1–750), Middle (A.D. 750–1150), and Late (A.D. 1150–1450) Formative period (Figure 3; Table 1). We use this unconventional designation instead of the better-known sequence used for the Hohokam and their predecessors because the latter implies a cultural affiliation. Because one of our research goals is to investigate cultural affiliation, it is best not to make assumptions at the outset. On the basis of ceramic evidence, the



[a] Dean 1991:91
[b] Deaver and Ciolek-Torrello 1995:514 (A.D. 1–800); Dean 1991:91 (A.D. 800–1450)
[c] Di Peso 1974
[d] Dean and Ravesloot 1993
[e] Lekson 1990
[f] Sayles 1945
[g] Tuthill 1947
[h] Bowen 1972
[i] McGuire and Villalpando C. 1993:71–73
[j] Elson 1996
[k] Altschul 1994

Figure 3. Chronological chart for southeastern Arizona.

Table 1. Chronology for the Mescal Wash Site

Period	Date Range
Paleoindian[a]	11,500–8500 B.C.
Archaic	8500 B.C.–A.D. 1
Early Archaic[a]	8500–4800 B.C.
Middle Archaic	4800–1500 B.C.
Late Archaic	1500 B.C.–A.D. 1
Formative	A.D. 1–1450
Early Formative	A.D. 1–750
Middle Formative	A.D. 750–1150
Middle Formative A	A.D. 750–950
Middle Formative B	A.D. 950–1150
Late Formative	A.D. 1150–1450
Late Formative A[a]	A.D. 1150–1300
Late Formative B	A.D. 1300–1450

[a] There was no direct evidence of this period at the Mescal Wash site.

Middle Formative period at the Mescal Wash site can be subdivided into two parts: Middle Formative A (A.D. 750–950) and Middle Formative B (A.D. 950–1150). Although we do not want to use Hohokam terms in discussing the site, it is convenient to say that these two spans of time correspond to the Colonial and Sedentary periods in the Hohokam cultural sequence and also mirror similar periods in the Mogollon and San Simon sequences (see Figure 3). Similarly, the Late Formative period can be divided into Late Formative A (A.D. 1150–1300) and Late Formative B (A.D. 1300–1450), roughly corresponding to the conventional Early and Late Classic period divisions.

The earliest and also the latest features were found in Locus D. In that locus, SRI excavated a series of small, circular pole-and-brush structures and associated bell-shaped storage pits dating to the Late Archaic and Early Formative periods. The focus of the settlement was clearly on the farmland along Cienega Creek. Only a small portion of the early component was located within the project area; additional early features probably were located in the western portion of the locus, closer to Cienega Creek.

The site reached its population peak in the Middle Formative A period, when Locus D was developed to such a degree that clustering and superimposition of structures were the norm. The structures varied in size, shape, and orientation, but most were reminiscent of Hohokam houses-in-pits. The dense feature clusters and conglomerates of superimposed houses signified either continuous, long-term habitation or repeated, short-term occupation over several centuries. The dramatic overbuilding suggested a densely occupied, discrete hamlet or perhaps a village.

In the Middle Formative B period, the occupation shifted away from Locus D to portions of the site farther north and east along Mescal Wash. Instead of being contained in a single village, the population was dispersed across several discrete hamlets. Locus D showed little evidence of occupation during this period; in contrast, Locus A and most of Locus C were solely occupied during this time. In Locus A, houses were found isolated, rather than in clusters. In Locus C, they were clustered, but not as densely as in Locus D. As in the previous period, many of the houses were identical to Hohokam houses found in the Tucson Basin and elsewhere. However, six examples of what appeared to be local architecture were found—pit structures, each characterized by a large, circular, recessed area in the floor adjoining the entrance. The hearth was located in the center of the sunken area, and postholes suggested that the recess had its own special roof. One of the recessed-hearth structures contained a series of parallel grooves in the floor outside the recessed area, suggesting a raised floor. Given that it was the largest excavated structure at the site and the only one with an east-facing entryway, it may have had a communal function.

No evidence of occupation during the Late Formative A period was found, perhaps because a lack of sufficient water flow in the adjacent creek bed forced the local farmers to a more favorable setting downstream. Possibly, they moved to AZ BB:14:25 (ASM) (the Pantano Town site) (see Figure 1), the prehistoric component of which was a large habitation site occupied predominantly during the Late Formative A period. Four Late Formative B period adobe-walled houses with raised floors and narrow, stepped entryways were found in Locus D. Two additional Late Formative B period houses were identified at the site; one was excavated in Locus C, and another was found (but not excavated) in Locus E during Phase 1. Thus, with its focus once more on the arable land along Cienega Creek, the occupational cycle of the site was completed.

Research Themes and Goals

Southeastern Arizona in prehistory was a meeting ground for diverse peoples and distinctive cultures. Its unique environmental and cultural setting has attracted people since Paleoindian period times. Situated on two important frontiers, the Mescal Wash site was a particularly notable place. Importantly, it was located on the divide between the Tucson Basin, the scene of a unique regional variant of Hohokam culture (Doelle and Wallace 1991; Whittlesey 1998a), and the San Pedro Valley, an important corridor linking northern and central Arizona with people and cultures of Mexico (Fish and Fish 1999; Masse et al. 1997).

The site's position between the Tucson Basin and the San Pedro Valley placed it in an ecological transition between Sonoran Desertscrub vegetation to the west and Chihuahuan Desert grasslands to the east. As discussed above, it also was in a cultural transition zone between prehistoric agriculturists to the west (considered part of the Hohokam culture) and those to the north and east (recognized as Mogollon). Southeastern Arizona is one of the most intriguing regions, archaeologically, in the U.S. Southwest yet is one of the least understood. It was a crossroads for diverse cultures, including the Tucson Basin Hohokam, a local Mogollon group named the San Simon Branch (Sayles 1945), and others (e.g., "Dragoon") yet to be named and fully investigated, all characterized by unique ceramic styles and architecture (see Altschul et al. 1999; Di Peso 1951; Fulton 1940; Fulton and Tuthill 1940). The region's prehistoric "hinterland" populations appear to have been overshadowed by major cultural developments in the surrounding "heartland" areas. The excavations at the long-lived Mescal Wash site have provided a much-needed opportunity to study the complex interplay among these various cultures and to evaluate the prevalent concept of southeastern Arizona as a hinterland between heartlands.

The Mescal Wash site witnessed a nearly continuous occupation from the Late Archaic period through the Formative period, interrupted only for a century and a half in late prehistory. Artifacts and architectural styles indicate that, over time, Mescal Wash was indeed visited, settled, and influenced by people of many surrounding cultures and groups. Some occupations were transient and left few or no marks, such as the hunter-gatherers of the Archaic period and the equally mobile Apache or Sobaipuri. The Late Archaic and Formative period occupations were more permanent—as indicated by the presence of architecture and storage pits—and probably included an indigenous core population. Between A.D. 750 and 950, the site may have reached village size on one or more occasions, possibly with as many as 100 permanent inhabitants. During A.D. 950–1150, the population decreased, and the site consisted of a series of dispersed farmsteads. In the Late Formative B period, a few farmers reoccupied the site, establishing a small number of widely spaced adobe houses among the earlier ruins. It is interesting to note that site layout always remained informal, lacking a ball court or platform mound, and none of the structures were arranged in courtyards or enclosed by compound walls. The only evidence of shared symbolism may be the recessed-hearth-style pit structures.

Identifying longevity as a key attribute of the site, the project's research design (Altschul et al. 2000:5–14) centered on investigating the characteristics of the ancient community at Mescal Wash. In essence, we wanted to understand the factors and processes that repeatedly drew people from diverse backgrounds to the locale. Broadly considered, this historic context might be considered "an archaeology of place," defining the factors that promoted community development and change. It is a nested concept, ranging from single settlements to regions, and similarly, the research themes range from the Mescal Wash community to its environment, its economy, its demography, and, finally, its regional landscape. These themes are intertwined, and they overlap with each other, rather than forming stand-alone topics.

Community and Locale: Mescal Wash as a Persistent Place

Community is broadly understood as a residential group whose members interact with each other regularly (Wills and Leonard 1994). Mescal Wash was the scene of repeated occupation over a period of several-thousand years by several different cultures. Thus, the site provides an ideal setting to examine processes of community development, particularly the concept of persistent places. Some locales in southern Arizona experienced repeated, intensive occupation, often by several different populations, creating an impression of deep sedentism that persisted for centuries. These favored locales may correspond to what Schlanger (1992) has labeled "persistent places" in Anasazi history. Schlanger (1992:97) defined "persistent places" as "places that were repeatedly used during long-term occupations of regions. A "persistent place" is marked by cultural features that attract and orient reoccupation. They are neither strictly sites (that is, concentrations of cultural materials) nor simply features of a landscape. Instead, they represent the conjunction of particular human behaviors on a particular landscape." Schlanger's argument suggests that persistent places emerge as the result of the particular qualities or characteristics intrinsic to particular places. Qualities promoting the formation of persistent places are of three modes: (1) environmental, (2) cultural facilities or features, and (3) artifactual materials. People are attracted to reused places because of their intrinsic environmental or ecological attributes, pre-existing cultural features, or exploitable tools and raw materials. To Schlanger (1992:105), "[M]ulticomponent assemblages are the clearest indicators of persistent places that can be identified from the archaeological record preserved on the modern ground surface."

Our basic task is to determine whether the Mescal Wash site represents such a persistent place and whether similar changes occurred there. What was the role of Mescal Wash in the overall settlement system? Rather than labeling the site as one of several types (e.g., farmstead, hamlet, or village), we need to think in terms of occupation duration, intensity, and continuity and apply or develop metrics that can be used to monitor and compare these factors. Developing a detailed site chronology is the first step in beginning to answer these questions. A spatial analysis of the site, including a detailed study of the architectural and extramural feature, is a second step.

Environment and Subsistence

Before seeking to investigate social, ideological, and other aspects influencing change in ancient communities, we need to look at the physical and biological environments to explain site location and type. We have many questions about the ancient environment and the site's subsistence base, their relationship, and how each changed over time. Situated at an ecological crossroads along a riparian zone (*cienegas*) between grassland and desert, the Mescal Wash site offered its occupants access to highly diverse economic resources. After simple beginnings as a hunter-gatherer base camp, the site appears to have functioned as a mixed, forager-farmer *ranchería* during much of its long history. Among the factors we must consider are the amount and productivity of arable land, including characteristics of soils; the type and predictability of water sources; and the influence of paleoenvironmental factors, such as fluctuations in average precipitation, susceptibility to erosion and headcutting, and so on. We ask the question: How fertile were the soils for particular farming technologies? As a first step, we need to reconstruct the geomorphic history of Cienega Creek and Mescal Wash, as well as the local climatic history. Assessing agricultural productivity will also involve determining the mix of crops cultivated (or encouraged) and how it changed through time. Although agriculture must have played a significant role since Late Archaic period times, wild-plant and animal resources always remained important. Wild-plant and animal resources must be cataloged, because few if any southwestern populations were solely dependent on cultivated foodstuffs. What resources were available in the immediate vicinity and at increasingly larger distances? What was the mix of wild plants that were collected, and how did that mix change through time?

Numerous fire-cracked rock (FCR) clusters—often associated with metates and manos—found during surveys in the grassland environment of the San Pedro Valley have been interpreted as hearths used in the processing of native plants, particularly the parching of the grains of grasses and other hard-seed-bearing plants (Vanderpot 1997). FCR was commonly found in pit features excavated at Mescal Wash, and we suspect that a similar wild-cereal-focused economy was prevalent at the site.

In addition, we need to understand the past environment. Did the past environment differ from the present one, and in what ways? Can paleoclimatic and paleoenvironmental data be correlated with demographic, subsistence, and settlement information? We must also be concerned with the culturally modified or anthropogenic environment. Interaction between people and their environment is culturally conditioned and mutually reinforcing. Human activities alter and transform the physical and biological environments, often to the point of degradation. Thus, we need to model human and environmental interactions through time, which involves a synthesis of many factors, including food, building materials, fuel, water, landscape changes, and sustainability. We must determine whether local plant foods were depleted. Through faunal analysis, we need to evaluate temporal changes in the use and availability of faunal resources. We can use the vertebrate-faunal remains to assess changes in the paleoenvironment by focusing on environmentally sensitive taxa, such as rodents, amphibians, and riparian-dwelling animals. Temporal changes can also be assessed in terms of cultural processes, taxonomic processes, and environmental change. We need to examine how changes in agricultural investment correlated with prey selection, hunting methods, and animal-food-processing technology.

Economy: Resource Extraction and Technology

This broad category of variables seeks to understand how people extract and use energy from their environments and how they develop, refine, and use technologies to accomplish these undertakings. Technological organization, subsistence and economy, foraging scheduling, agricultural technology, and processes of agricultural intensification are among the primary factors. Extracted resources include stone (for tool manufacture), wild plants (for food and fiber), and animals (for food, clothing, and tools). Sourcing raw lithic materials, identifying plant remains, and faunal analysis will allow us to quantify these data. Environmental studies may provide information about agricultural techniques. The questions we ask concerning technology can be correlated with historic contexts developed for irrigation farming (Dart 1989) and non-irrigation farming (Doyel 1993) in Arizona. The difference in the reliability and productivity of different farming systems has been a traditional pursuit in understanding regional differences in the Hohokam culture. Haury's (1950) classic dichotomy between the River Hohokam, with their dense communities, complicated ritual system and ideology, and craft production, and the less-populous and more-impoverished Desert Hohokam was based rather simply upon the irrigation agriculture of the former and the floodwater farming of the latter. Although we have increased our level of sophistication in investigating variability in agricultural technology (Van West and Altschul 1994), the distinction remains an important one to consider. The topic of technology specific to Mescal Wash includes the study of flaked stone, ground stone, ceramic, bone, and shell artifacts, as well as the array of food-processing and storage features found at the site.

Demography: Population and Sustainability

Demographic variables are traditionally viewed in relation to economic variables. Agricultural strategies and population size are closely linked. For example, Adler (1994) hypothesized that aggregation among late-twelfth- and early-thirteenth-century Anasazi communities was centered on the availability of perennial water supplies. We are particularly interested in knowing the size of the population at Mescal Wash at different points in time. What was the optimal population size, based on a sustainable economy? Can we estimate the maximum population that could be supported for brief periods of time by a more-intensive economy? Among the variables to explore are population size and composition, occupational duration and intensity, size and composition of domestic groups, activity organization, and stages in domestic-group cycling. Mobility and site reoccupation must also be considered. We are especially interested in knowing whether the people living at Mescal Wash represented a largely isolated, independent group or seasonal visitors from larger, more-permanent communities based elsewhere. We also want to know whether the demographic composition changed through time. Demography and community organization may undergo a cyclical sequence that is necessary to understand if we are to reconstruct community histories, particularly at persistent places. For example, did communities fission as population reached the maximum carrying capacity, creating daughter communities that remained linked to the mother village, which continued to serve integrative and ideological functions, as Gregory (1995) observed in the Meddler Wash community in Tonto Basin? Or were existing communities completely abandoned and new settlements established elsewhere? We will also want to compile information about abandonment processes at Mescal Wash, determining whether abandonment was gradual, sudden, or catastrophic.

The Social and Cultural Landscape

Finally, we are interested in relating the Mescal Wash population to the larger, regional community. Southeastern Arizona remains one of the most archaeologically intriguing but also least-understood parts of the U.S. Southwest. By Late Archaic period times, settlement of southern Arizona had expanded into rich, moist river valleys, such as the Santa Cruz and San Pedro Valleys (Mabry et al. 1997); along secondary streams, such as Cienega Creek (Eddy and Cooley 1983; Huckell 1995); and to canyon mouths in the larger mountain ranges (Vanderpot 1997). *Bajada* and piedmont settings were used, as well (Altschul and Jones 1990: Huckell 1984; Roth 1996; Vanderpot 1997; Whalen 1971), prompting some to speculate that a dual-*bajada* settlement system existed (Fish, Fish, and Madsen 1992).

In Formative period times, the Hohokam and Mogollon and local cultures emerged from the Archaic period population base. Southeastern Arizona, in particular, became a crossroads for diverse cultures. These included a local Mogollon group named the San Simon Branch (Sayles 1945), the Tucson Basin Hohokam, and local cultures characterized by unique ceramic styles and architecture (see Altschul et al. 1999, 2014; Di Peso 1951; Fulton 1940; Fulton and Tuthill 1940). Late in prehistory, the region experienced the sweeping demographic shifts and unsettled economic and social conditions that characterized much of the southern Southwest. Influences from Chihuahua (Casas Grandes) to the southeast, the enigmatic Salado culture to the north, and western New Mexico (Mogollon) all filtered into southern Arizona at the same time that small family groups (Anasazi) were fleeing the Colorado Plateau southward along the San Pedro River (Altschul et al. 1999; Di Peso 1958; Fish and Fish 1999; Whittlesey and Heckman 2000; Woodson 1995). Remains of all these cultures intermingled and overlapped within southern Arizona, often at the same sites. The region's populations appear to have taken second stage to major cultural developments elsewhere. To various degrees, local communities interacted with their better-known neighbors, often accommodating immigrants and at times outnumbered by colonists. That these communities persisted in the face of more-dominant neighbors is interesting, but what is more intriguing is that they seem to have retained their unique identity.

The location of Mescal Wash itself also suggests a cultural crossroads. The great variability in cultural traits such as architectural styles, ceramics, and burial practices suggests that people borrowed cultural concepts from other groups in surrounding areas. Or perhaps it was the other way around, and the other groups actually moved to the site. If so, what were the factors and the processes that repeatedly drew people from diverse cultural backgrounds to this locale? By asking specific questions, such as "From where does the recessed hearth architectural style originate?" we might be able to address more general problems, such as "What constitutes cultural identity, and how can we avoid imposing poorly defined archaeological concepts (i.e., Hohokam) on groups living along cultural boundaries?"

Volume Organization

In this volume, we present the synthetic studies conducted for the project. Following this introduction are two chapters on the geoarchaeology of the Cienega Creek–Mescal Wash confluence area. Chapter 2, prepared by Philip Pearthree, Jeffrey Homburg, and Steve DeLong, reconstructs the alluvial history of the confluence area. A timeline of downcutting and aggradation events aids archaeological interpretations of land use, particularly when floodwater agriculture was possible near the site. Chapter 3, by Jeffrey Homburg, Francis Casey, and Michael Heilen, provides a model of agricultural land use and assesses the soil quality of possible agricultural fields near the site. To place agricultural land use near the Mescal Wash site into a broader regional context, the study also includes the results of geographic information systems (GIS) analysis of soil surveys conducted for a large part of southeastern Arizona. Chapter 4, by Richard Ciolek-Torello, looks at the Mescal Wash site structure to evaluate the use of space, community activities, and domestic organization. Chapter 5, by Chris Garraty and William Graves, provides an analysis of the site's intramural and extramural pit features to infer function and make meaningful assertions about food preparation, storage, and the social construction of space and how these changed over time. Chapter 6, by Rein Vanderpot, focuses on the unique position of the site at an ecological crossroads, exploring the degree to which the site's plant-resource abundance supplemented agricultural pursuits. The chapter also looks at the specific functions of the site's food-processing features, comparing ethnographic evidence with the site's archaeology. In Chapter 7, Jesse Ballenger discusses hunting strategies along Cienega Creek, tracing animal use through time. In Chapter 8, Michael Heilen investigates the formation of persistent places in southeastern Arizona, finding that persistent places on a multiscale level, such as Mescal Wash, are extremely rare. Finally, Chapter 9, by Jeffrey Altschul and Rein Vanderpot, recaps the project results, emphasizing the unique place of the Mescal Wash site within the region. Appendixes A–D, respectively, provide soil-pedon descriptions, soil-stratigraphic descriptions, geologic-unit descriptions, and soil-series descriptions for the project area.

CHAPTER 2

Alluvial Geomorphology and Geoarchaeology of the Cienega Creek–Mescal Wash Confluence Area

Philip A. Pearthree, Jeffrey A. Homburg, and Steve DeLong

The purpose of this chapter is to describe the geologic and geomorphic setting of the Mescal Wash site. The Arizona Geological Survey (AZGS) recently completed 1:24,000-scale geologic mapping in the area encompassing the site. Therefore, it seemed appropriate that the AZGS and SRI collaborate on the geoarchaeological investigations of the Mescal Wash site area, which are reported herein. The site is located on a relatively planar Pleistocene alluvial terrace above the confluence of two sizable watercourses—Cienega Creek and Mescal Wash—in a landscape dominated by eroded ridges and narrow valleys (Figure 4). In this chapter, supplementing overviews provided in Volume 1, Chapter 2, we discuss the geologic and geomorphic setting of the Mescal Wash site, focusing on the geomorphology, Quaternary geology, and soils of the immediate area and the late Holocene evolution of Cienega Creek and Mescal Wash near the site.

Geologic Setting

The study area is located ca. 30 miles (50 km) southeast of downtown Tucson, in a valley informally known as Empire Valley or Cienega Valley (see Eddy and Cooley 1983). This broad, dissected valley is bounded by the Rincon Mountains on the north, the Empire Mountains on the southwest, and the Whetstone Mountains on the southeast (see Volume 1, Chapter 2). To the northeast, the valley provides access through a relatively low pass into San Pedro Valley and southward into the grasslands of the Sonoita Creek valley.

The geology of this area is complex and includes several sets of rock units (see also Volume 1, Chapter 2): (1) mylonitic granitic and gneissic bedrock, which forms most of the Rincon Mountains to the north; (2) complexly deformed Paleozoic sedimentary rocks and Proterozoic granitoids and diabase that are exposed at the southwestern foot of the Rincon Mountains; (3) the Oligocene-Miocene Pantano Formation, which consists of variably tilted conglomerate, sandstone, mudstone, and andesitic lava flows and underlies much of Cienega Valley; (4) structurally complex Proterozoic and Paleozoic rocks of diverse composition in the Empire Mountains to the south; (5) deformed, regionally southeast-dipping Mesozoic siliciclastic sedimentary rocks at the northern end of the Empire Mountains; and (6) Precambrian granite and Paleozoic sedimentary rocks in the Whetstone Mountains. Much of the area between the mountain ranges, including the entire area around the Mescal Wash site, consists of eroded, unconsolidated to poorly consolidated clastic sedimentary deposits that are mantled by colluvium, as well as Quaternary terrace and alluvial-fan deposits (Figure 5).

The modern landscape of Cienega Valley began to form as a result of major normal displacement along the Catalina detachment fault in the Oligocene and early Miocene (20–30 million years ago [ma]). The Catalina detachment fault is a gently to moderately southwest-dipping normal fault with at least 27 km of displacement of rocks above the detachment to the southwest (Dickinson 1991). That displacement, combined with uplift of the rocks below the detachment, gradually uncovered the mid-crustal gneissic and granitic rocks that form the Rincon Mountains and resulted in deposition and deformation of the sediments of the Pantano Formation in Cienega Valley. The lower part of the Pantano Formation consists of faulted and tilted conglomerate, sandstone, siltstone, and clay, with interbedded porphyritic andesite that is approximately 27 ma in age. The degree of tilting and faulting in the Pantano Formation dies out dramatically upward within the fine-grained upper part of the formation. Younger Miocene conglomerate and sandstone represented by the Wakefield Canyon unit are typically only slightly faulted and deformed.

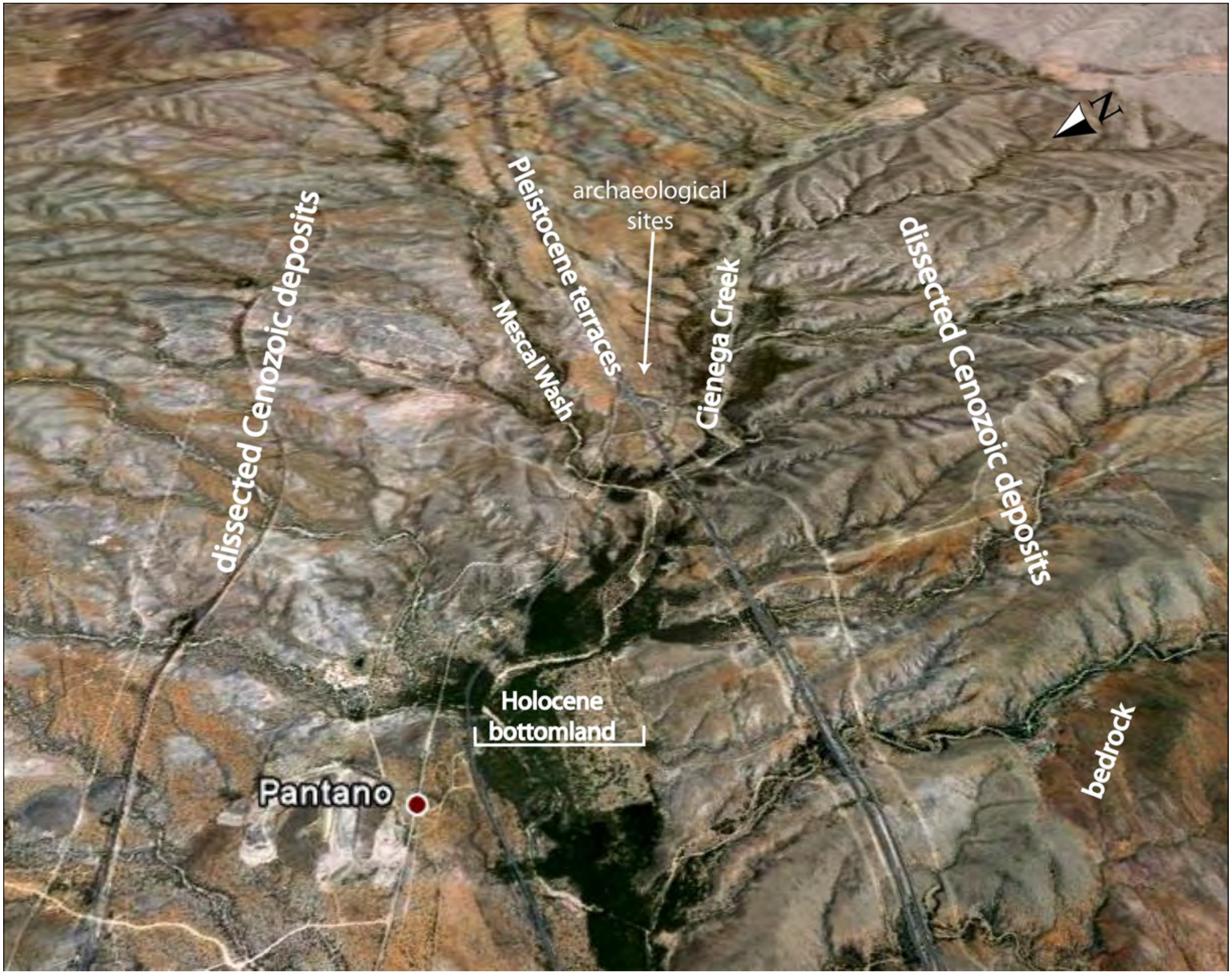


Figure 4. Perspective photograph of the Cienega Creek valley, view to the southeast. Archaeological sites at the Marsh Station interchange are on a planar Pleistocene terrace remnant above the confluence of Cienega Creek and Mescal Wash. Most of the terrain to the north and south is much more rugged; so, the watercourses or the Pleistocene terraces may have been convenient pathways between the Tucson Basin to the west and San Pedro Valley to the east.

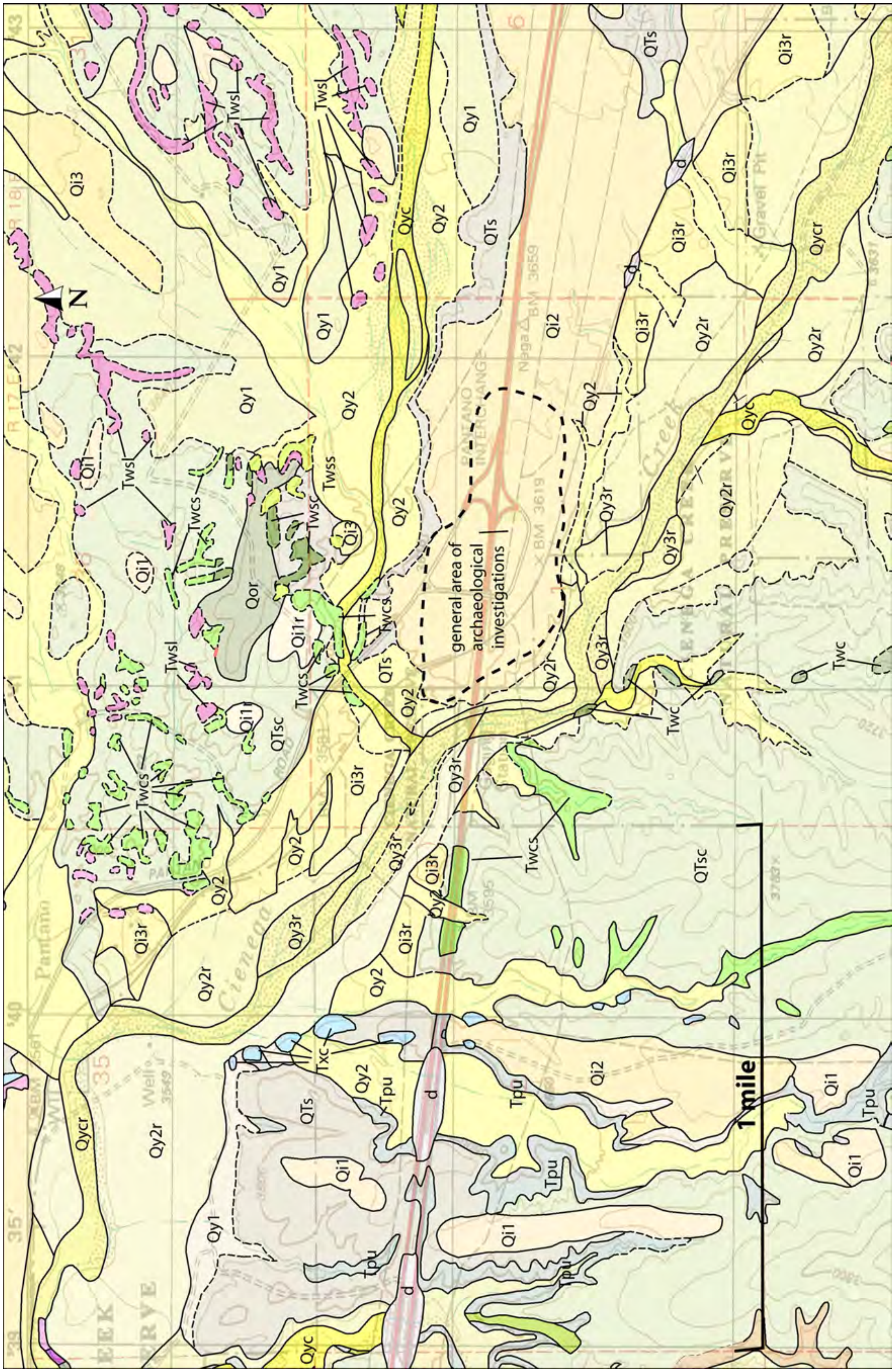


Figure 5. Location geologic map (1:16,000 scale), showing the general outline of the Marsh Station archaeological investigations on the Pleistocene Qi2 terrace (*Note*: The geologic units are described in Appendix C).

However, Wakefield Canyon strata are locally tilted up to 50° in a northeast-striking, northwest-facing monocline located several kilometers southeast of the Mescal Wash site. Relatively thin Pliocene to early Quaternary deposits (mapped as QTs) are poorly exposed beneath Quaternary fan and terrace deposits and slope colluvium. There is no evidence of tectonic deformation of QTs or any Quaternary deposits in this area (Spencer et al. 2002).

Quaternary Geology of Cienega Valley

Cienega Valley is located along the eastern edge of the Sonoran Desert subprovince of the Basin and Range physiographic province. The landscape of the Tucson area consists of a broad alluvial basin between large, high mountain ranges to the east and north and small, low-lying mountain ranges to the west. Along the eastern margin of the Tucson area, high mountain ranges and adjacent piedmont areas are deeply dissected. In those areas, erosion has dominated landscape evolution at least through the Quaternary. Periods of aggradation have punctuated the long-term trend toward downcutting along the major streams, such as Cienega Creek, resulting in the formation of terraces along those watercourses.

The highest levels of alluvial deposits in Cienega Valley (high ridgelines on unit QTs and sparse Qo surfaces) certainly were deposited prior to significant incision by Cienega Creek. It is likely that in the late Pliocene, Cienega Valley was a broad, minimally dissected, northwest-facing valley that graded to a large alluvial-fan complex that emanates from this area westward, across the Tucson Basin (Spencer et al. 2002). During the past several-million years, Cienega Creek and its tributaries have downcut substantially into the Quaternary and Tertiary deposits of Cienega Valley, leaving high ridges and deep valleys characteristic of much of the valley. Episodes of downcutting of Cienega Creek caused erosion of the toes of alluvial fans and older deposits on both sides of the valley and resulted in long-term downcutting of the tributary streams that feed into Cienega Creek. The ultimate cause of the downcutting by the larger streams in southeastern Arizona is uncertain, but it may have occurred as a delayed response during integration of the Tucson Basin streams into the larger regional drainage system.

Whether fluvial systems aggrade or degrade is a function of sediment supply and their ability to transport sediment. Most of Cienega Valley consists of hillslopes, where sediment is generated from weathering and erosion of bedrock or Cenozoic deposits and transported downslope to the stream system. If hillslopes are stable, then weathering dominates, and the sediment supply to streams is relatively low. These conditions may have existed in this region during glacial intervals, when vegetation density on hillslopes was greater as a result of increased annual precipitation and/or decreased summer temperatures in the region. Hillslopes have probably been unstable during changes between glacial and interglacial conditions, as vegetation responded to changing climate and the character of runoff varied in response to changes in the nature and frequency of thunderstorm activity (see Bull 1991). As a result of these climate-induced changes, large fluxes of sediment may have been introduced into the fluvial systems, causing periods of aggradation along the valley axis. The fans and terraces of the Cienega Valley may record climate changes of this kind.

Modern Climate

The climate of the study area (described in more detail in Volume 1, Chapter 2) is semiarid to subhumid, with a warm-weather rainy season (monsoon) and a cool winter season. Most of the annual precipitation in Cienega Valley falls during the summer monsoon from June to September, when moist air sweeps northward from the Gulf of California and the Gulf of Mexico, and much of that rainfall occurs as thunderstorms. Occasional intense late-summer to early-fall precipitation occurs in this region because of incursions of moist air derived from dissipating tropical storms in the Pacific Ocean. All of the larger historical floods on Cienega Creek have occurred in the summer or early fall. Winter precipitation generally results from cyclonic storms originating in the Pacific Ocean. It is usually less intense and may be more prolonged and therefore infiltrates into the soil more deeply than summer rainfall (Sellers and Hill 1974).

Several weather stations surrounding the study area that have operated for substantial intervals over the past century give a reasonable approximation of the annual climate. The Tucson Weather Service Office at Tucson International Airport (about 25 miles west of the study area; 2,500 feet above mean sea level [AMSL]) has records from 1930 to the present, a weather station at the Helvetia Santa Rita Ranch (about 15 miles southeast of the study area; 4,200 feet AMSL) has records from 1916 to 1950, and a weather station at Benson (about 15 miles east of the study area; 3,500 feet AMSL) was maintained from 1894 to 1975. Climate records from Tucson and Benson are quite similar, although Benson is somewhat cooler, especially in winter (Western Regional Climate Center 2009) (Table 2). The temperatures of the study area are probably similar to those of Benson, because their altitudes are very similar (3,600 and 3,500 feet AMSL, respectively). Freezing morning temperatures are common in December and January, and light snowfall is not unusual. Because of the study site's proximity to mountain ranges, annual precipitation

Table 2. Some Climate Parameters from Weather Stations Surrounding the Cienega Valley

Weather Station	Tucson	Helvetia	Benson
Length of the record (years A.D.)	1930–2008	1916–1950	1894–1975
Average temperature (°F) (maximum/minimum)	83/55	76/52	80/45
Monthly average temperature (°F) (July maximum/January minimum)	100/39	91/36	97/29
Annual precipitation (average in inches/summer percentage of total)	11.5/53	19.7/56	11.3/63

there is likely significantly greater than either Tucson or Benson, and is probably closer to the Helvetia average. The combination of cool winter temperatures and late summer rains is significant archaeologically because it implies that the relatively moist summer season is very important for agricultural production in the study area.

Geology and Geomorphology of the Cienega Creek–Mescal Wash Confluence Area

The area surrounding the Mescal Wash site consists primarily of Cenozoic deposits that have been deeply eroded into high ridges and steep-sided valleys. The more spatially limited Pleistocene terraces and Holocene bottomlands associated with Cienega Creek and Mescal Wash are more favorable for human settlement and land use, however, because of the abundance of riparian food resources and the availability of land suitable for agriculture.

Most of the Mescal Wash site is located on a Pleistocene terrace above and just upstream from the confluence of Cienega Creek and Mescal Wash. Several soil profiles described on this Pleistocene terrace have moderately well-developed, loam to clay loam argillic or calcic horizons in the upper meter (see Appendix A). All soils have some calcium-carbonate accumulation, but the amount of calcium carbonate and the depth to accumulation vary substantially. By comparison with other Pleistocene soils that have been documented in the region (e.g., Pearthree and Calvo 1987), the moderately well-developed soils associated with the terrace suggest that it is of late Pleistocene age, perhaps 50,000–100,000 years old. Because the terrace is between Cienega Creek and Mescal Wash, it is likely that it was deposited by a combination of these drainages during a late Pleistocene aggradation period. The sloping sides of the Pleistocene terrace surface are mantled by younger colluvium derived from the terrace deposits and underlying older basin deposits.

The Pleistocene terrace of the Mescal Wash site is flanked on both the north and south by fairly extensive Holocene deposits of Cienega Creek and Mescal Wash (Figure 6). In the modern environment, the channels, bars, and low terraces of Cienega Creek are lined with mature riparian trees and are about 5 m below adjacent terraces. Gravel deposits are common, although finer-grained overbank deposits also occupy much of the active drainage system. The terraces that are approximately 5 m above the active floodplain are not subjected to inundation and typically are covered with dense stands of mesquite. Historical accounts and photographs indicate that the geomorphology of the bottomland was dramatically different before the late 1800s, when the valley bottomland was unincised and supported grasses and few riparian trees (Figure 7). Through-going channel development and entrenchment that began in the 1880s (Dobyns 1981; Myrick 1975) resulted in dramatic changes in the fluvial system and the vegetation assemblages of the valley bottomland. The railroad track that was emplaced in the late 1870s was moved out of the valley bottomland by 1890 because of flooding and erosion. As will be considered in more detail below, the large, complex, incised channel system of Cienega Creek is anomalous in the late Holocene.

Incision and lateral erosion of Cienega Creek and Mescal Wash have provided numerous relatively fresh stratigraphic exposures. We described soils and stratigraphic units exposed at several locations near the Mescal Wash site in order to document the late Holocene alluvial history of Cienega Creek and Mescal Wash. We chose to describe 4+-m-high exposures along Mescal Wash about 100 m above the confluence, Cienega Creek at the confluence, and Cienega Creek about 650 m upstream of the confluence (see Appendix B; see Figure 6 for locations). At each site, we found relatively plentiful charcoal that was amenable to radiocarbon dating, and we report 20 new radiocarbon dates (Tables 3 and 4).

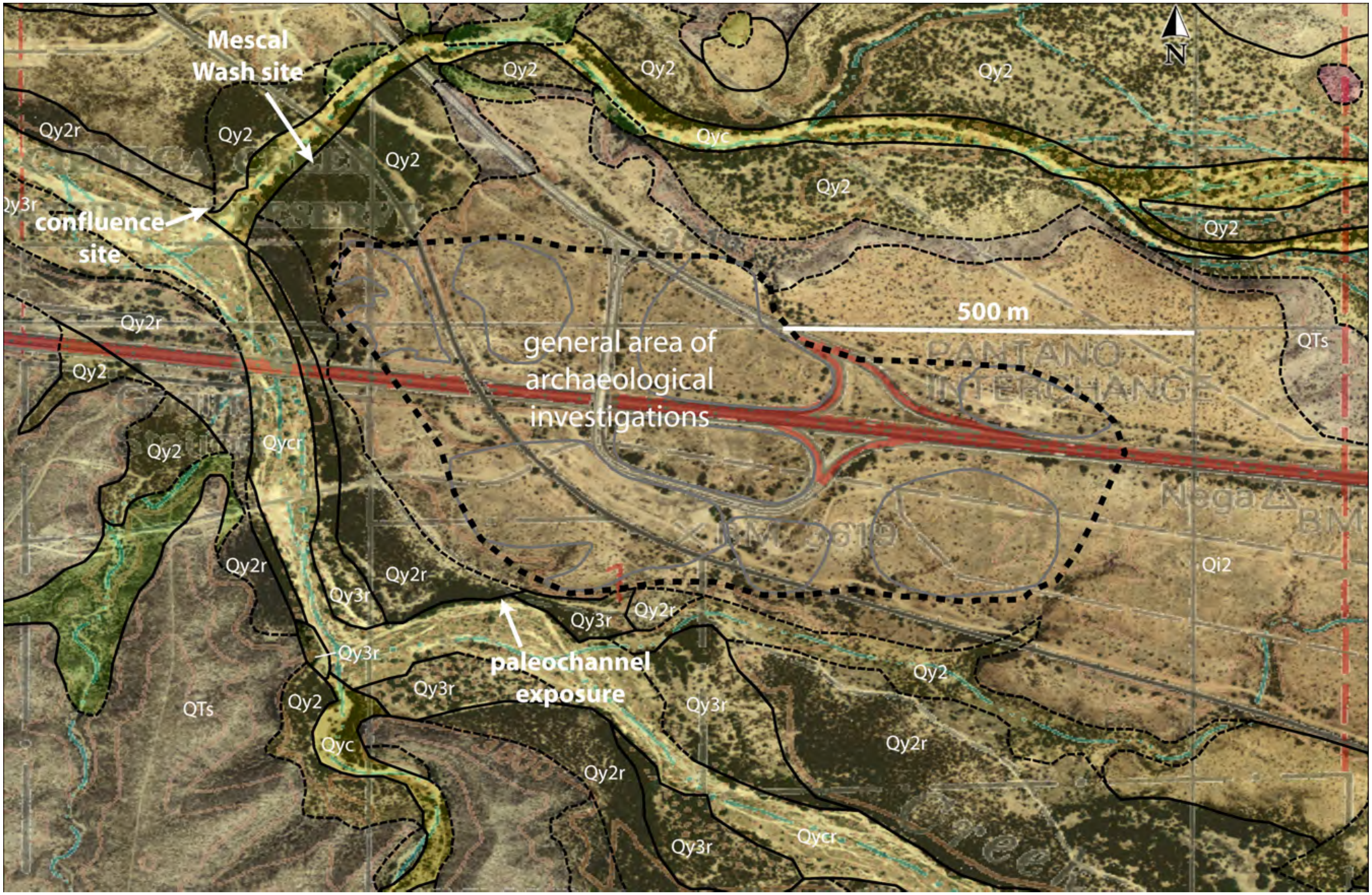


Figure 6. Close-up geologic map over a color orthophotograph (1:6,000 scale), showing the locations of field sites and stratigraphic sections.

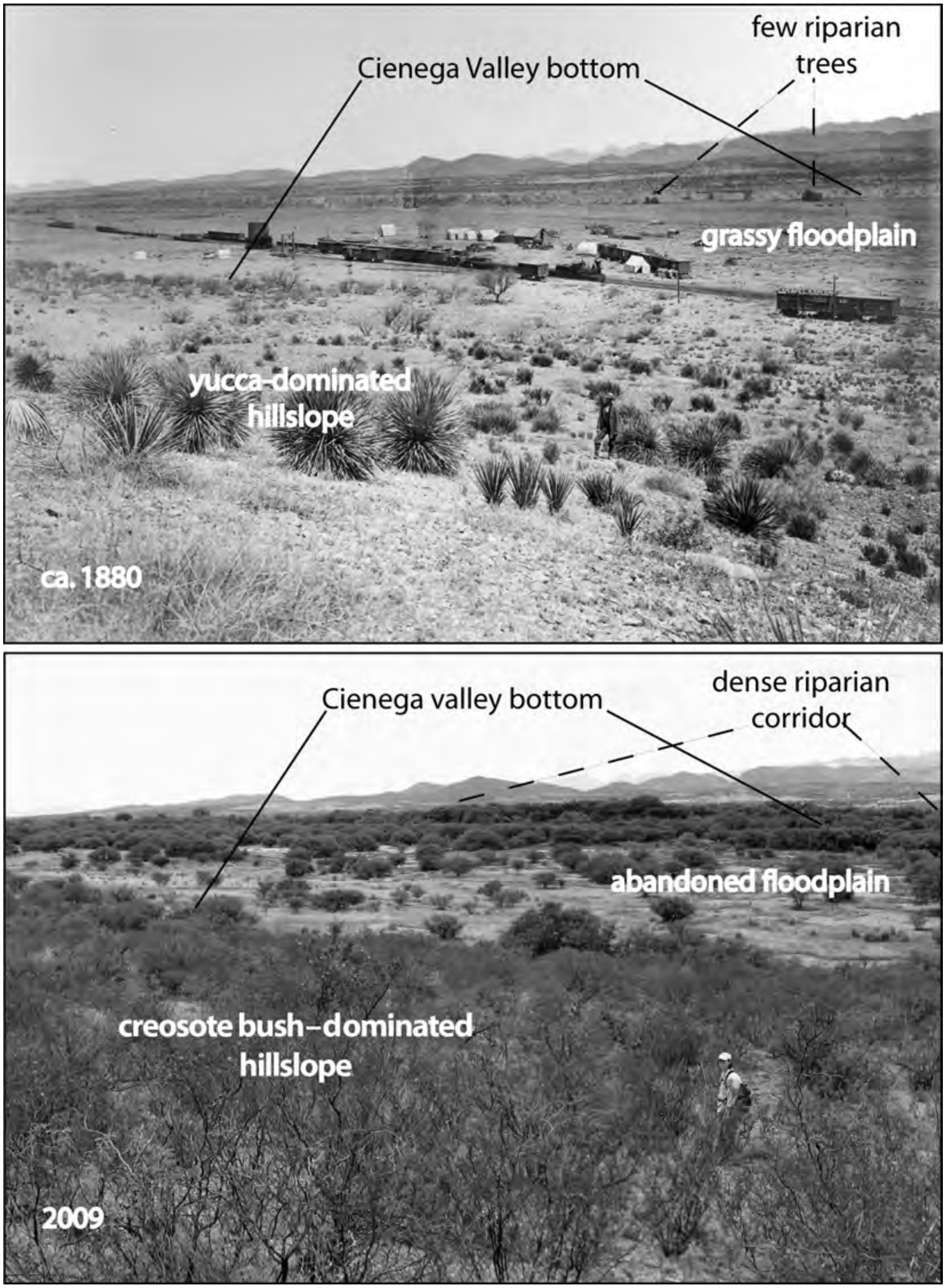


Figure 7. Repeat photograph of the Cienega Creek valley bottom at Pantano station. The upper photograph was taken in 1880, soon after the railroad was completed in this area. The tracks were moved north of the valley bottomland because of erosion and flood damage by 1890. The valley bottom at that time was an unincised, grass-covered floodplain with few riparian trees. The modern photograph shows the dense riparian tree corridor along the incised Cienega Creek on the northern side of the valley. The abandoned floodplain has numerous mesquite trees. In fact, the relatively open area in the middle of the photograph was probably cleared for agricultural activity during the twentieth century, because other abandoned floodplain terraces along Cienega Creek are covered with dense mesquite stands.

Table 3. Analytical Data and Radiocarbon Dates from Stratigraphic Sections of the Mescal Wash–Cienega Creek Confluence

SRI PD No.	University of Waikato Laboratory No.	Soil Horizon	Depth (cmbs)	Dated Material	δ^{13}C (‰)	Radiocarbon Age (Years B.P. ± 1σ)[a]	Calibrated Age(s) Obtained from Intercepts (cal A.D. Ranges for 2σ)[a]	Calibrated Age Ranges from the Probability Distribution (cal A.D. Ranges for 2σ)[a]
				Profile 6				
10880	10568	2Ab	42–52	Gramineae-stem fragment	–12.8 ± 0.2	273 ± 57	A.D. 1476 (1644) 1947	A.D. 1471–1681 (0.842)
				Gramineae-stem fragment				A.D. 1735–1806 (0.134)
				Gramineae-stem fragment				A.D. 1932–1947 (0.023)
10882	10570	4A	125–135	Gramineae-stem fragment	–12.0 ± 0.2	412 ± 57	A.D. 1412 (1452) 1638	A.D. 1417–1531 (0.667)
				Gramineae-stem fragment				A.D. 1543–1635 (0.333)
10884	10571	4A	143–153	Gramineae-stem fragment	–14.1 ± 0.2	722 ± 57	A.D. 1215 (1284) 1391	A.D. 1194–1196 (0.002)
				Gramineae-stem fragment				A.D. 1210–1329 (0.789)
				Gramineae-stem fragment				A.D. 1343–1395 (0.209)
10881	10569	6Ab	235–245	Gramineae-stem fragment	–11.3 ± 0.2	641 ± 63	A.D. 1269 (1302, 1370, 1381) 1420	A.D. 1275–1418 (1.000)
10885	10572	6Ab	275–285	*Celtis*-seed fragment	–9.9 ± 0.2	1451 ± 58	A.D. 441 (619, 634, 635) 675	A.D. 439–452 (0.017)
								A.D. 462–518 (0.068)
								A.D. 528–678 (0.915)
				Profile 7				
10895	10574	2Ab4	76–87	Gramineae-stem fragment	–12.4 ± 0.2	512 ± 57	A.D. 1304 (1420) 1474	A.D. 1302–1370) (0.271)
								A.D. 1381–1481 (0.729)
10897	10576	5ACb	194–203	monocotyledon tissue	–13.4 ± 0.2	786 ± 66	A.D. 1062 (1261) 1378	A.D. 1041–1096 (0,069)
								A.D. 1116–1141 (0.034)
								A.D. 1152–13-3 (0.879)
								A.D. 1368–1383 (0.018)
10898	10577	6ACb1	250–265	unidentified charcoal	–18.7 ± 0.2	569 ± 72	A.D. 1285 (1334, 1336, 1401) 1447	A.D. 1287–1445 (1.000)
10899	10578	6ACb2	265–280	*Prosopis*-pod fragment	–26.9 ± 0.2	modern (<200 B.P.)		
10900	10579	7ACb	290–300	unidentified charcoal	–23.5 ± 0.2	636 ± 60	A.D. 1276 (1303, 1368, 1383) 1420	A.D. 1279–1414 (1.000)

[a] Radiocarbon ages were calibrated using the CALIB 4.3 program, based on Stuiver and Reimer (1993). Calibrated age ranges were obtained from intercepts (Method A, with one or more intercepts between the conventional radiocarbon age and the dendrocalibrated calendar time-scale curve, placed in parentheses between the 2σ age range) and from the probability distribution (Method B, with the probability in parentheses after each range).

Key: cmbs = centimeters below surface; PD = provenience designation; SRI = Statistical Research, Inc.

Table 4. Radiocarbon Dates from the Cienega Creek–Paleochannel Section

AZGS No.	UA Sample No.	^{14}C years B.P. (1σ)	Calibrated Age Ranges from Probability Distribution (cal A.D. Ranges for 2σ)	Calendar Age Range (2σ)	Geologic Setting
040604.2	AA64499	369 ± 43	A.D. 1446–1532 (0.516) A.D. 1537–1635 (0.484)	A.D. 1446–1635	pre-paleochannel, must be introduced
040604.3	AA64500	1915 ± 39	A.D. 3–181 (0.955) A.D. 187–214 (0.045)	A.D. 3–214	high in pre-paleochannel deposits
040604.4	AA64501	582 ± 37	A.D. 1298–1372 (0.664) A.D. 1378–1419 (0.336)	A.D. 1298–1419	base of paleochannel
040604.6	AA64503	649 ± 37	A.D. 1279–1330 (0.461) A.D. 1338–1397 (0.539)	A.D. 1287–1397	fine deposits, essentially above paleochannel fill
040604.5	AA64509	1228 ± 51	A.D. 669–895 (0.987) A.D. 925–937 (0.013)	A.D. 669–937	low in pre-paleochannel deposits
040604.7	AA64504	662 ± 37	A.D. 1274–1327 (0.507) A.D. 1342–1395 (0.493)	A.D. 1274–1395	just above paleochannel gravel, fairly low in section
040604.8	AA64505	582 ± 41	A.D. 1297–1420 (1.000)	A.D. 1297–1420	fine deposits above paleochannel fill
040704.1	AA64506	683 ± 62	A.D. 1226–1403 (1.000)	A.D. 1226–1403	base of paleochannel
040704.2	AA64507	736 ± 37	A.D. 1218–1298 (0.977) A.D. 1370–1379 (0.023)	A.D. 1218–1379	fine deposits just above paleochannel fill
041304.1	AA64508	718 ± 37	A.D. 1223–1306 (0.890) A.D. 1363–1385 (0.110)	A.D. 1223–1385	within thick paleochannel gravel unit

Note: Radiocarbon ages were calibrated using CALIB REV5.0.2, after Stuiver and Reimer (1993).

Key: AZGS = Arizona Geological Survey; UA = University of Arizona.

Mescal Wash Section

The thickest section of Holocene alluvium was found along Mescal Wash, just upstream of the confluence. At this site, about 5 m of predominantly fine-grained deposits are exposed. Most of the deposits are grayish brown (Figure 8), but detailed description of the section revealed about 10 depositional units, most of which are marked by distinct, weak to moderate soil development (see Appendix C). The deposits consist of sand, silt, and clay and vary from sandy loam to silt loam in texture, with very minor quantities of fine gravel. Other exposures along Mescal Wash in this vicinity have some gravel beds, but in all exposures, fine-grained deposits predominate. Soil development associated with the surface deposits is very weak, but we recognized 7 buried weak to moderately developed soils. Dates obtained from the section indicate that at least the upper 3 m of the exposure are less than 1,600 years old, and the upper 2.5 m are less than 800 years old (Figure 9; see Table 3). The combination of substantially different dates obtained from within and on top of a moderately well-developed soil suggests that there is a substantial unconformity at about 240 cm in depth in the section. Several buried soils higher in the section also are indicative of times of decreased sedimentation and greater soil development, but the rate of aggradation does not appear to have varied dramatically between A.D. 1200 and 1880.

Cienega Creek–Mescal Wash–Confluence Section

We described a 4.5+-m section of predominantly fine-grained deposits near the confluence of Cienega Creek and Mescal Wash (Figure 10). In general, the deposits of this section are somewhat coarser than those of the Mescal Wash section, and soil textures range from sand to silt loam and a few fine gravel layers. Soils in the section are less well developed than in the Mescal Wash section. The surface soil is weakly developed, two moderately developed buried soils were recognized, and several other horizons in the section exhibited very weak soil development (see Table 3; Figure 9). It is clear from exposures in the immediate vicinity of the confluence that late Holocene aggradation lapped onto topography formed on older Quaternary and probably Miocene-age deposits (see Figure 10). Although there is some scatter in the dates, the upper 3 m of the section were probably deposited after about A.D. 1200. The stratigraphically lowest radiocarbon date (A.D. 1276–1420) was obtained from just above a thin but obvious buried soil, and that buried soil may correlate to the thicker soil at a depth of 240 cm in the Mescal Wash section. It is possible that all but the upper 25 cm of sediment in the Cienega Creek–Mescal Wash–confluence section was deposited by A.D. 1500, allowing the development of a moderate soil that was subsequently buried prior to channel incision in the late 1800s.

Cienega Creek–Paleochannel Section

We described several stratigraphic sections and mapped the channel bank at a location about 650 m upstream of the Cienega Creek–Mescal Wash confluence, where there is evidence of a Cienega Creek paleochannel (Figure 11). The paleochannel is about 40 m wide and was filled primarily with cobbly, pebbly gravel. The gravelly channel fill grades laterally into finer-grained floodplain deposits; the contacts between these facies are complex and are generalized in Figure 12. All of the upper 0.5 m is made up of fine-grained floodplain deposits with very minor fine gravel. At the western margin of the paleochannel, the exposed section is primarily fine-grained deposits with minor gravel, and below about 90 cm, these deposits predate erosion of the paleochannel. Three radiocarbon dates that were obtained from these older deposits did not yield a straightforward interpretation (see Table 4; Figure 12). One date (040604.2) was clearly too young, and the dated material was probably introduced during paleochannel aggradation. The two older dates were stratigraphically reversed, with the older date (040604.3) from higher in the section. Therefore, we can only conclude that the pre-paleochannel deposits are probably less than 2,000 years old.

Radiocarbon dates from material in the paleochannel units were consistent with relatively rapid filling of the channel after A.D. 1200. Two dates obtained from charcoal that was essentially at the base of the channel were between A.D. 1200 and 1400. Four dates that were obtained from different stratigraphically higher levels in the paleochannel overlapped with the lowest dates. There was also little evidence of buried soils or other depositional hiatuses in this section. The combination of coarse channel deposits, the absence of soil-profile development, and the overlapping dates all argue for rapid aggradation and filling of the paleochannel within a couple-hundred years. Although the radiocarbon dates from the pre-paleochannel deposits do not closely constrain the age of incision, it is likely that the channel cut very quickly around A.D. 1200 and filled quite rapidly thereafter.

Conclusions

This study of the local geology and geomorphology has important implications for interpreting the utilization of floodplain resources by humans in prehistory. It is very

Figure 8. Photographs showing 4+ m of mostly fine-grained deposits on the left bank of Mescal Wash, about 200 m above the Cienega Creek confluence. Nearly all of the deposits are of late Holocene age.

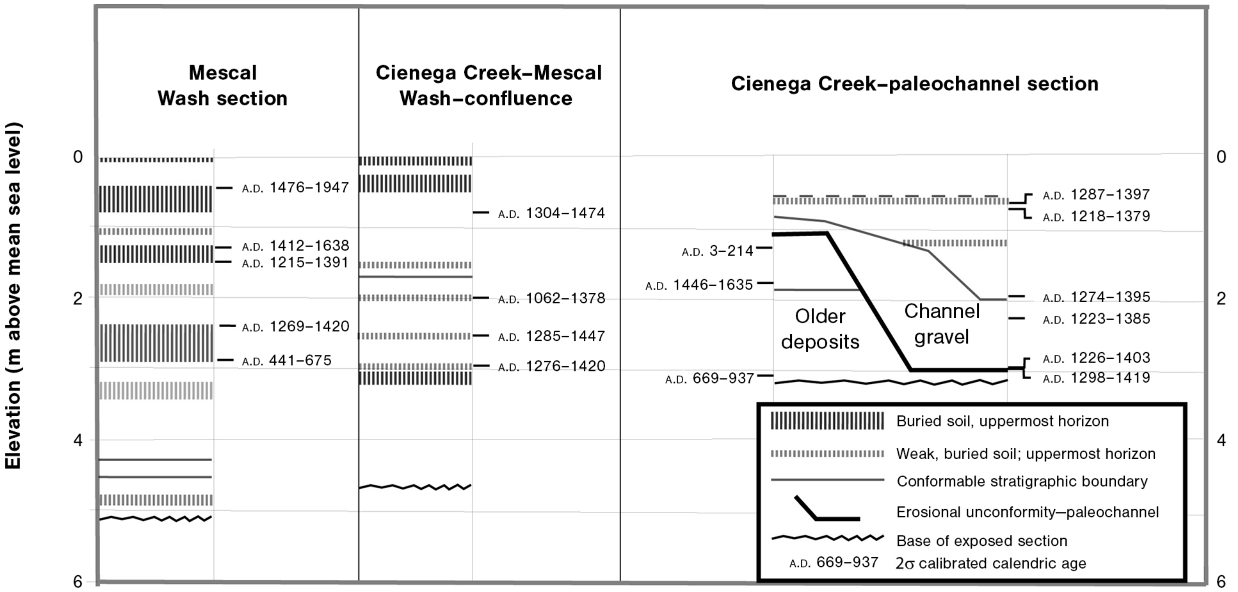


Figure 9. Correlation diagram of stratigraphic sections from Mescal Wash, the Cienega Creek–Mescal Wash confluence, and the Cienega Creek paleochannel upstream. Nearly all of the Mescal Wash and confluence sections are quite fine-grained and have minor gravel. The paleochannel is mainly filled with gravel, but the gravel beds grade laterally into finer-grained deposits, and the upper 1 m are generally fine-grained. The Cienega Creek–paleochannel section implies that the period of channel incision or arroyo cutting occurred about A.D. 1200. Dates from all sites are consistent with relatively rapid aggradation after A.D. 1200.

Figure 10. Photograph of the Cienega Creek–Mescal Wash confluence, showing about 3 m of late Holocene deposits onlapping older, indurated deposits over an erosional unconformity. The erosional unconformity is at the feet of the geologist.

Figure 11. Photograph of the western margin and central parts of the 3-m-deep, gravel-filled Cienega Creek paleochannel.

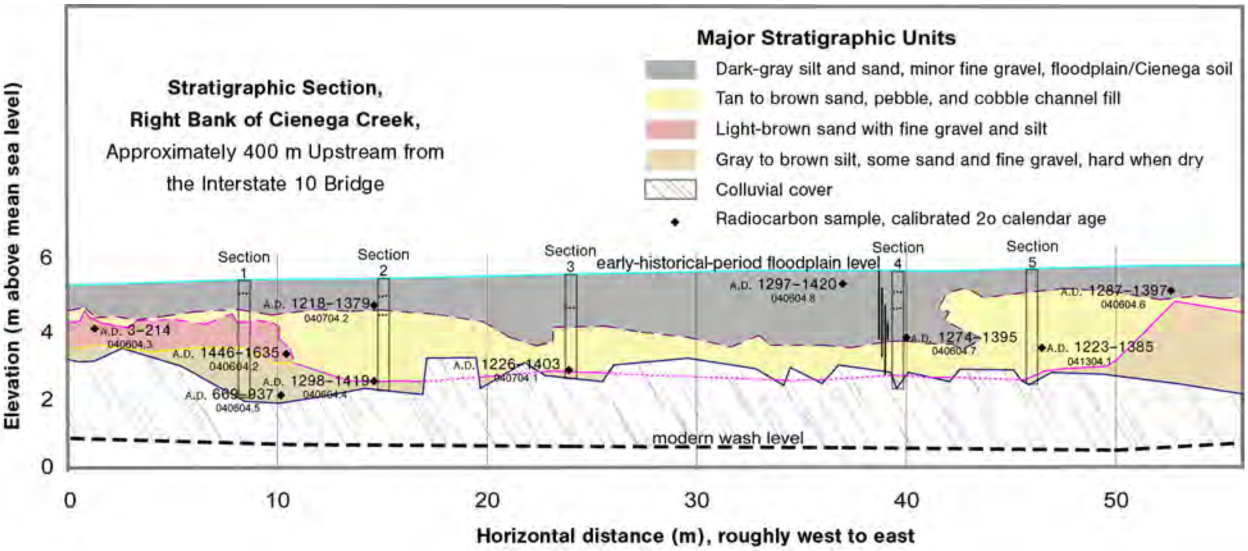


Figure 12. Stratigraphic section of the Cienega Creek paleochannel, on the right bank of Cienega Creek, about 400 m upstream from the Interstate 10 bridge (see Figure 5 for the location).

likely that the modern Cienega Creek and Mescal Wash environments are not representative of the character of the valley bottomland during most of the late Holocene. Historical-period evidence of unincised, grassy bottomlands with limited riparian trees is clear. The fine-grained sediments exposed in the banks along Cienega Creek and Mescal Wash were deposited in a floodplain environment with shallow, relatively low-velocity flood flows. Thus, the early-historical-period bottomland environment is a reasonable model for the environment during most of the late Holocene.

Substantial sediment accumulation between A.D. 1200 and 1500 may have occurred in the wake of a significant disturbance of the valley bottomland around A.D. 1200. Although age constraints on the timing of incision of the Cienega Creek paleochannel are not great, evidence that the channel filled very quickly is quite clear. Given the historical model of rapid arroyo development on many streams in Arizona, it is likely that the A.D. 1200 paleochannel formed quite rapidly, as well. The timing of the incision is consistent with the chronology developed for the Matty Wash–Cienega Creek confluence area, about 10 miles south of our study site. In that area, there is evidence of arroyo development and erosion between A.D. 1100 and 1300 (Eddy and Cooley 1983). It appears that floodplain aggradation diminished after A.D. 1400–1500 along Cienega Creek, although dates from the Mescal Wash section are consistent with more-uniform aggradation from ca. A.D. 1200 to the early historical period. Thus, for most of the late Holocene, the valley bottomland of Cienega Creek was probably reasonably well watered and stable. It was, however, likely subjected to at least shallow inundation, and that was probably an important factor in the choice to occupy a Pleistocene terrace that was far above the level of flood inundation.

This alluvial reconstruction has important implications for interpreting possible agricultural use of the floodplain during the Holocene. Aggrading conditions prior to A.D. 1100 and between about A.D. 1300 and 1400–1500 were well suited to floodwater farming, and possibly even irrigation agriculture, although no canals have been identified in the alluvium of Cienega Creek. Small pockets of Holocene alluvium next to the Mescal Wash site may have been farmed, but a large expanse of Holocene bottomland is located nearby, about 2–3 km south of the site, where the Empirita Ranch is now located (see Homburg and Sterner 2004). Arroyo development and erosion from about A.D. 1100 to 1300 likely made floodwater/irrigation farming impractical on the Cienega Creek floodplain. Diminished aggradation after ca. A.D. 1400–1500 (but prior to the late-1800s channel incision) would have made floodwater/irrigation farming less productive than the previous periods of aggradation, but limited or sporadic farming may have occurred along Cienega Creek during that interval. Because Mescal Wash appears to have experienced more-uniform aggradation between A.D. 1200 and the late 1800s, floodwater farming may have been practiced there at times when it could not be practiced along Cienega Creek, but the lack of perennial flow in Mescal Wash would have limited its suitability for agricultural production.

Except for the period from about A.D. 1100 to 1300, the geomorphic conditions (e.g., the perennial flow, aggrading conditions, and availability of pockets of land suitable for farming) along Cienega Creek were well suited for agricultural production, and that was especially true prior to A.D. 1100. The presence of such a reliable water source and the availability of agricultural land that could be easily watered throughout much of prehistory are critical factors that help explain the placement, intensity, and temporal span of occupation at the Mescal Wash site.

CHAPTER 3

Agricultural Soil Productivity and Hydraulic Properties in the Cienega Creek–Mescal Wash Confluence Area

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Introduction

The MSAP provides an important opportunity for documenting and evaluating soil quality and agricultural suitability in the Cienega Creek–Mescal Wash confluence area. Ancient farmers of the Mescal Wash site (AZ EE:2:51 [ASM]) and other communities throughout the U.S. Southwest used a variety of agricultural strategies (irrigation, floodwater, runoff, and rock mulch) to cope with environmental vagaries. Fields in bottomlands are better watered and more fertile than higher-elevated landscape positions but can be prone to salinization and damaging floods, whereas fields on higher terraces in valley margins and those placed in ephemeral drainageways are more drought-prone but avoid the effects of flooding and cold-air drainage. Ancient farmers managed agricultural risk by using a variety of soil- and water-conservation measures and by spreading their fields across many different landscape positions. Few such fields in the confluence area of Cienega Creek and Mescal Wash, however, have archaeological traces of agriculture, such as agricultural terraces, rock alignments, and rock piles. Not all ancient fields leave lasting physical remains of agriculture, especially floodwater farming, which was likely the dominant agricultural system practiced along Cienega Creek. That is not surprising, given that Cienega Creek must have been a perennial drainage in prehistory. Small-scale irrigation systems may have been established along Cienega Creek, although no such evidence has been identified. If present, canals have probably been buried in the alluvial record or erased by erosion associated with lateral stream migration and cut and fill processes. To assess and model soil quality and agricultural suitability for different soils and landforms in the study area, we integrated field data on soil fertility and hydraulic soil properties, such as water infiltration and retention, with soil data and maps from the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS).

Agricultural land-use practices, both in prehistory and modern times, are largely determined by the limiting resources of an area, especially water and soils. Water in semiarid environments, such as the study area, is the limiting resource. The spatial and temporal availability of water constrains the kinds of agricultural management practices that are possible. Analysis of soil quality and soil hydraulic properties can provide unique insights for evaluating ancient agricultural soil productivity. Water redistribution within soil is largely determined by the soil pore-size distribution, which is largely a function of soil texture and structure. Soils formed in stream alluvium tend to be well sorted, with coarser soil textures near the river channel and finer ones away from the river. Alluvial soils formed from mixed parent materials, such as those of the Cienega Creek and Mescal Wash floodplains and terraces, have highly variable fertility and hydraulic properties, depending on their proximity to the creek. Furthermore, morphological features within a single soil profile can have subsurface soil horizons that vary in soil quality and hydraulic properties, relative to the surrounding matrix. Depending on landscape positions, diagnostic subsurface argillic or calcic horizons form from illuvial accumulations of translocated of clay or carbonates, respectively, and may result in layers that restrict water transfer. Previous studies have shown that the presence of argillic horizons can dominate the water-transfer regime in the landscape, leading to perched water tables (Boersma et al. 1972; Simonson and Boersma 1972), lateral transfer of water (Cox and McFarlane 1995; McDaniel and Falen 1994) and solute (Mallawatantri et al. 1996; Reuter et al. 1998), and lower hydraulic conductivities (McDaniel et al. 2001). Furthermore, the higher clay content of an argillic horizon causes greater adsorption of water, thereby retaining water in the root zone for periods long after rain fall events.

In the process of plant transpiration, there is a continuum of water transfer from the soil to the roots, through the plant, and into the atmosphere in the form of water vapor. That process is driven by variability in energy potentials, whereby water moves from areas of high potential, the soil, to areas of low potential, the atmosphere. Soil-water relations are integral in that continuum of water transfer and strongly affect vegetation and agricultural productivity. Measuring soil hydraulic properties and modeling water transfer and water uptake by roots can provide unique insights into agricultural potential.

The objective of this research was to suggest possible historical-period land-use practices in two soils that have archaeological significance. Unique approaches were used to characterize these soils for their hydraulic properties and to make model predictions. In situ and laboratory methods were used to measure soil hydraulic properties, and a two-dimensional water-transfer model was used to simulate water movement and root water uptake. These methods should provide a deeper understanding of the water transfer in these soil profiles and help make deductions about past land-use practices.

Macrobotanical analysis has shown that occupants of the Mescal Wash site practiced maize agriculture, in addition to cultivating a variety of other crops and harvesting wild-plant foods. In addition, the presence of certain ground stone artifacts, especially trough metates and two-handed manos, has shown that maize processing was an important activity on-site. Although no agricultural features such as rock alignments, rock piles, or terraces were found at or near the Mescal Wash site, the recovery of carbonized maize in excavations and the concentration of cooking and storage features leave little doubt that agriculture was practiced at or near the site in prehistory. It is noteworthy that many modern Native American runoff systems in the Southwest, such as those of the Zuni and Navajo, commonly lack lasting features that would persist in the archaeological record. Earthen berms and brush structures—materials that are rarely preserved archaeologically—were commonly used to control erosion and spread runoff across fields for crops to use.

Background Discussion

Overcoming low water availability is usually viewed as the major hurdle to agricultural sustainability in the semiarid Southwest, which contrasts sharply with humid regions, where soil-fertility maintenance is the main limiting factor (Dregne 1963:219; Sanders 1992:283). Soil fertility, however, is still an important aspect of the agroecology of farming systems in areas of the Southwest where productivity is not limited by water alone (Ludwig 1987). Nitrogen deficiency, in fact, is so common in desert soils that its effect in limiting agricultural production is almost as great as water availability (Nabhan 1983, 1984). Cultivation of crops with high nutrient requirements, such as maize, can heighten that problem by depleting already-low nitrogen stores (Doolittle 1984; Loomis and Connor 1992:Figure 12.1; Stevenson 1982). Water availability was undoubtedly the most limiting factor in agricultural production in the study area; so, it is important that water hydraulic properties are included in this soil study.

Archaeologists and soil scientists began studying soil quality in ancient farming systems of the semiarid Southwest in the early 1960s, and this type of research has accelerated during the last two decades. Ancient agricultural soils in the Southwest are well suited for geoarchaeological research, because soil-formation processes (e.g., weathering, leaching, and illuviation) proceed much more slowly in deserts than in more-humid climates. Consequently, soil changes caused by cultivation practices tend to persist and to be detectable for long periods after fields are abandoned, on time scales of a millennium or longer. A common outcome of long-term agriculture in deserts is soil degradation, whereby changes in soil properties reduce agricultural productivity (Hillel 1991). Common forms of soil degradation caused by agriculture include reduced nitrogen and phosphorus levels, compaction, accelerated erosion, decreased A-horizon thickness, and salinization (Table 5). A few soil studies in the Southwest have found that ancient farming systems degraded the nutrient status of agricultural soils. For example, long-term cultivation significantly lowered the fertility of terraced fields in the Mimbres area of southwestern New Mexico (Sandor 1983; Sandor et al. 1986, 1990). Farming practices in prehistoric fields near Flagstaff and Santa Fe and at Mesa Verde lowered phosphate and other nutrients severely enough that some fields became unproductive and were abandoned (Arrhenius 1963). Other studies in central Arizona, especially those associated with rock-mulch agricultural systems, however, have found that agricultural soils were enhanced, not degraded (Homburg 1994; Homburg and Sandor 1997, 2002, 2011; Homburg et al. 2004; Sandor and Homburg 2011). Soil studies conducted thus far in the Southwest have indicated that the consequences of cultivation are highly variable in terms of soil quality and possible degradation, because of many interacting environmental and cultural factors.

No universally accepted method exists for assessing potential degradation in all agricultural soils. There is no consensus on how soil quality should be defined and measured and what soil tests should provide a minimal data set. The usefulness of the soil-quality concept itself has even come under attack (Sojka and Upchurch 1999). As noted by Mausbach and Seybold (1998:33), soil-quality definitions range from simply “the capacity of a soil to function” (Pierce and Larson 1993) to more-inclusive ones, including “the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air

Table 5. Soil Properties that May Indicate Soil Degradation Caused by Cultivation

Soil Property	Criteria for Recognizing Degradation: Typical Causes and Consequences
A-horizon thickness	Decreased thickness caused by water or wind erosion. Reduces important organic-matter-enriched surface layer that can be exploited by plants for water, nutrients, and oxygen. Shallower depth to possible root-limiting subsurface layers, such as strongly developed argillic horizons.
Soil structure	Macromorphology: lowered grade of granular or subangular blocky structure and trend toward massive state, especially in surface horizons. Commonly results from compaction and organic-matter decline.
Bulk density	Compaction (increase in bulk density above that of natural condition) associated with soil structure degradation. Compaction and structure degradation commonly retard seed germination and root growth; reduce root access to water, oxygen, and nutrients; reduce diffusion of gases; and decrease water infiltration and available water capacity.
Organic carbon	Decrease in organic carbon (C) is common under conventional cultivation. Results from accelerated microbial oxidation of organic matter in disrupted, exposed soil aggregates and other effects of agriculture. Numerous benefits of organic matter for soil physical, chemical, and biological properties important to plant growth are well documented.
Nitrogen	Decrease in total nitrogen (N) accompanies declining organic matter in agricultural soils, although the C:N ratio tends to decrease. N and ammonium are plant-available forms of N, which is commonly a key limiting factor for plant growth in all regions, including arid regions.
Phosphorus	Phosphorus (P), both total and available, is another macronutrient that has been shown to decrease as a result of cultivation in some cases. P is a key ecological and soil indicator because of its low mobility, its low availability to plants, and the long-term stability of its forms in soils.
pH	Very high soil pH can indicate salt accumulation (which is measured by electrical conductivity). Sodic soil conditions (recognized by high exchangeable sodium) can be prevalent in agricultural soils of arid and semiarid regions. Detrimental effects on many plants, including crop species, occur through both direct chemical effects and soil structural deterioration. pH is also an indicator of the availability of nutrients to crops.

Note: Adapted from Homburg et al. (2005).

quality, and support human health and habitation" (Karlen et al. 1997). In selecting a suite of soil tests, it is necessary to consider such local factors as climate, topography, hydrology, soil type, native vegetation, crop type and variety, agricultural technology, and the duration and intensity of cultivation. Many of the soil properties analyzed in this study area are summarized in Table 5. Each of these is a key indicator of soil quality and agricultural sustainability (Arshad and Coen 1992; Larson and Pierce 1991, 1994; Papendick and Parr 1992).

Two kinds of soil investigations have been conducted in the Southwest, paired and unpaired studies. Paired studies aim to compare cultivated and uncultivated soils in order to measure anthropogenic effects on soil quality, such as studies in the Mimbres and Hohokam culture areas (e.g., Homburg 1992; Homburg and Sandor 1997; Homburg et al. 2004; Homburg et al. 2005; Sandor and Gersper 1988; Sandor et al. 1986, 1990). This type of study is done when there is a basis for differentiating cultivated soils, indicated by ancient agricultural features such as rock alignments, rock piles, terraces, and buried earthen berms used in irrigation systems (examples of buried earthen berms have been documented at the Las Capas site in the Tucson Basin), and control soils from similar soil and landform settings that lack evidence of cultivation. By contrast, unpaired studies are done when cultivated and uncultivated soils cannot be differentiated, such as cases in which no agricultural soils can be identified (e.g., Homburg 1994, 2000, 2003, 2005; Homburg and Casey 2007). Unpaired studies focus on general assessments of soil productivity rather than measuring anthropogenic effects on soil quality.

Methods

Field Methods

Field methods included excavating backhoe trenches, describing soil profiles, collecting soil samples, and collecting soil hydraulic data. Two backhoe trenches were excavated, one on a Pleistocene terrace in Locus B of the Marsh Station site (Trench 1) and one on a Holocene terrace near Cienega Creek (Trench 2). Both of the trenches are in possible agricultural settings; Trench 1 was excavated in a place where runoff or rock-mulch agriculture is possible (although no agricultural features were found), and Trench 2 was excavated in a place where floodwater or possibly even irrigation could have been practiced. Each trench was excavated in steps to a depth of 1 m, and the steps were excavated in 25-cm intervals. Soil hydraulic tests were conducted on the surface, in each step, and at the bottom of the trench, and soil samples were collected near where each soil hydraulic test was conducted.

Two additional soil samples were collected from potential agricultural soils near Mescal Wash. In all, 13 soil samples were collected: 5 from Profile 2 in Trench 1, 6 from Profile 8 in Trench 2, and 2 surface samples from potential agricultural fields along Mescal Wash. In all, 6 profile descriptions were made at and near the Mescal Wash site (Appendix A). Soil morphological properties (e.g., depth and thickness of soil horizons, color, texture, and structure) were described for all profiles in accordance with procedures of soil-survey manuals (Soil Survey Division Staff 1993; Soil Survey Staff 1999).

Laboratory Methods

Organic matter, available-phosphorus (P), pH, electrical-conductivity, particle-size, specific-surface, and exchangeable-calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K) analyses were completed by Mary Jo Schabel at the Milwaukee Soil Laboratory. Subsamples for each laboratory test were taken from bulk samples collected from profiles or using augers. Initial sample preparation involved air drying and sifting samples through a 2-mm sieve to remove gravel, roots, and other coarse, undecomposed, organic debris. Organic matter, available P, and exchangeable-Ca, Mg, Na, and K analyses were done on 10-g subsamples that were mechanically ground to pass through a No. 100 sieve. Particle-size distributions were determined using the sieve-and-pipette method (Gee and Or 2002:Methods 2.4.3.2 and 2.4.3.4); samples were pretreated with 30 percent hydrogen peroxide for organic-matter digestion and a sodium-hexametaphosphate solution for clay dispersion. Specific surface area was determined based on retention of ethylene glycol monoethyl ether (EGME), a polar liquid that leaves a monomolecular layer coating on all particle surfaces after volatilization under vacuum (Kennell 2002:Method 2.5.4.3.b). Soil pH was measured electrometrically using a 1:1 (by weight) suspension of soil and distilled/deionized water (Thomas 1996). Organic matter and calcium carbonate were determined by dry combustion, based on loss on ignition (Nelson and Sommers 1982 [high-temperature induction furnace method]). Available P was measured in a buffered alkaline solution using the Olsen extraction method (Olsen and Sommers 1982:Method 24-5.5.20), which uses an extract of 0.5 M $NaHCO_3$ at pH 8. Salinity was determined using an electrical-conductivity meter (Rhoades 1996). Exchangeable bases (Ca, Mg, Na, and K) were measured using a leaching solution of 1N ammonium acetate (Nh_4OAc) buffered at pH 7.0 (Jackson 1958; Leitel et al. 1980; Metson 1956). Cation-exchange capacity (CEC) was estimated using a formula based on the measured exchangeable Ca, Mg, and K:

$$\mathrm{CEC} = (\mathrm{Ca}/200) + (\mathrm{Mg}/121.5) + (\mathrm{K}/390)$$

A multiplier of 0.75 was used to estimate CEC for sandy soils.

Soil Hydrology Methods

The soil hydrology study included in situ infiltration measurements in the field, laboratory analysis to prepare soil water-retention curves, and modeling of two-dimensional water transfer and root water uptake. Automated tension infiltrometers (Casey and Derby 2002) with base-plate diameters of 80 mm were used to measure unsaturated infiltration rates at 25-cm intervals from the surface to 100 cm in the soil trenches. The five 25-cm sampling intervals (at 0, 25, 50, 75, and 100 cm) facilitated obtaining measurements for all major soil horizons. At each soil horizon, two infiltration-rate measurements were made for the following sequence of pressure heads (ψ): –50, –100, and –150 mm. The surface of the soil was leveled to ensure good hydraulic contact between the infiltrometer disk and the soil surface. Infiltration was observed for at least 25 min at each ψ, or until steady-state infiltration was reached, and the infiltration volumes were automatically recorded every 20 seconds.

Hydraulic conductivity (K) was determined from a method proposed by Logsdon and Jaynes (1993), where Gardner's (1958) expression for the exponential relation between K and ψ was substituted into Wooding's (1968) solution for unconfined steady-state infiltration from a disk. The exponential relation between K and ψ is as follows (Gardner 1958):

Equation 1:

$$K(\psi) = K_{sat} e^{\alpha\psi}$$

where $K(\psi)$ is the unsaturated hydraulic conductivity (cm min^{-1}) at the specified pressure head (ψ), K_{sat} is the saturated hydraulic conductivity, and α is a constant (cm^{-1}) that reflects the slope of the exponential function (White and Sully 1987). Logsdon and Jaynes (1993) assumed α to be constant for $\psi \leq 0$ and derived a method to estimate α and K_{sat} using a nonlinear regression technique to fit the following expression to measured data:

Equation 2:

$$\frac{q(\psi)}{(\pi R^2)} = K_{sat}\ e^{\alpha\psi} + \frac{4K_{sat}\ e^{\alpha\psi}}{\pi R\alpha}$$

In Equation 2, q is the measured steady-state infiltration rate (cm min^{-1}), and R is the base radius (4 cm) of the infiltrometer. Experimental parameters of α and K_{sat} were estimated using a nonlinear regression technique by plotting steady-state fluxes ($= q/\pi R^2$) versus the pressure-head values at which they were measured (i.e., ψ = –2, –10, and –15 cm). The α and K_{sat} values were iteratively changed so that an optimized fit of Equation 2 to the measured data was achieved. The optimized *Ksat* and α values were then substituted into Equation 1 to calculate *K* at any unsaturated ψ (Logsdon and Jaynes 1993).

Soil samples for analysis of soil water-retention curves were obtained soil cores. Soil cores were sampled in brass cylinders (diameter = 55 mm; height = 30 mm) by using a Ulen core. The Ulen core apparatus reduces compaction of soil cores resulting from percussion of the slide hammer during sampling. The brass cylinders were adapted to fit into standard manufactured Tempe cells, which were used to obtain soil moisture-release curves for ψ values between 0 and 1,000 cm of water (Gardner et al. 1991). Moisture-release data for ψ values between 1,000 and 1 × 105 cm of water were obtained using a Decagon WP4 Dewpoint PotentiaMeter. The PotentiaMeter uses chilled mirror and thermocouple psychrometer technology to obtain accurate water-potential readings to as low as –40 MPa (Decagon 2001).

Measured volumetric soil water contents versus ψ were plotted to create soil water-retention curves. The soil water-retention curves were then fit with the following van Genuchten (1980) equation:

Equation 3:

$$\theta = \theta_r + \frac{(\theta_s - \theta_r)}{\left[1 + (\alpha^* \psi)^j\right]^n}$$

where θ is the volumetric water content (cm^3 cm^3); subscripts r and s are the saturated and residual water contents, respectively; α^* (cm^1), j (unitless), and m (unitless) are constants controlling the shape of the function; and ψ is the pressure head (cm), which is understood to be positive in this equation. The inverse of α^* is generally taken as an estimate for air-entry potential. The constant m is related to j in the following expression:

Equation 4:

$$m = 1 - \frac{1}{j}$$

Equation 3 was fit to the measured data using a least-squares optimizing routine where an objective function containing the unknown adjustable parameters of the α* and *n* was minimized. The optimization routine was a simplification of the nonlinear least-squares curve-fitting program of Meeter (1966). A detailed description of the method was given by Press et al. (1992). The minimization of the objective function was achieved by iteratively changing α and *n* values until the best fit of Equation 3 to the data was achieved. The coefficient of determination (r^2) of the measured data versus the model data was used to estimate the goodness of fit, where a value of unity is best.

The HYDRUS-2D model (Šimůnek et al. 1998) was used to simulate two-dimensional water transfer and root water uptake. HYDRUS-2D uses a Galerkin finite element scheme to solve Richards's equation for variably saturated flow and incorporates a sink term to account for water uptake by plant roots. The following form of Richard's equation governs the vertical transfer of water:

Equation 5:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left[K\left(\frac{\partial \psi}{\partial t} + 1\right)\right] - S(\psi)$$

where *t* is time (t) and S is the root water-uptake sink (L t^{-1}). The water-uptake model is an S-shaped function that was developed by van Genuchten (1987).

Equation 6:

$$S(\psi) = \frac{S_p}{1 \left(\frac{\psi}{\psi_{50}}\right)^3}$$

The optimized parameters of Equation 3 fit to the measured soil water-retention data were used to model variably saturated water transfer through the soil profile.

The boundary and initial conditions that were used to solve the two-dimensional water transfer simulated infiltration from a constant water source and calculated the progression of a wetting front in the soil profile through time. These boundary and initial conditions would simulate water transfer under conditions such as flood irrigation or a runoff event where there is overland flow of water on the surface. The initial condition of the soil was uniformly dry (ψ = –10,000 cm of water). The upper boundary condition was 0 cm of water pressure, and the lower boundary condition was free drainage.

The optimized parameters of Equation 3 fit to the measured soil water-retention data were used to model variably saturated water transfer through the soil profile. Furthermore, the root water-uptake parameters of Equation 6 were estimated using published data of observed and predicted root water uptake from *Agave deserti* (Alm and Nobel 1991). Estimates of *Sp* (0.4 cm d^{-1}) and ψ 50 were calculated for *A. deserti* and were assumed to be similar to *A. murpheyi*. *A. deserti* and *A. murpheyi* are similar, although *A. murpheyi* tends to have a slightly deeper rooting depth (personal communication, Dr. Park S. Nobel, Plant Physiologist, University of California, Los Angeles 2010). Rooting depth (Figure 13) was estimated to be 0.008–0.134 m with a mean of 0.069 m (Nobel 1996). The water uptake was modeled for a medium-sized *A. murpheyi* plant that was 30 cm tall and had 27 leaves (Smith et al. 1987). Simulation of root water

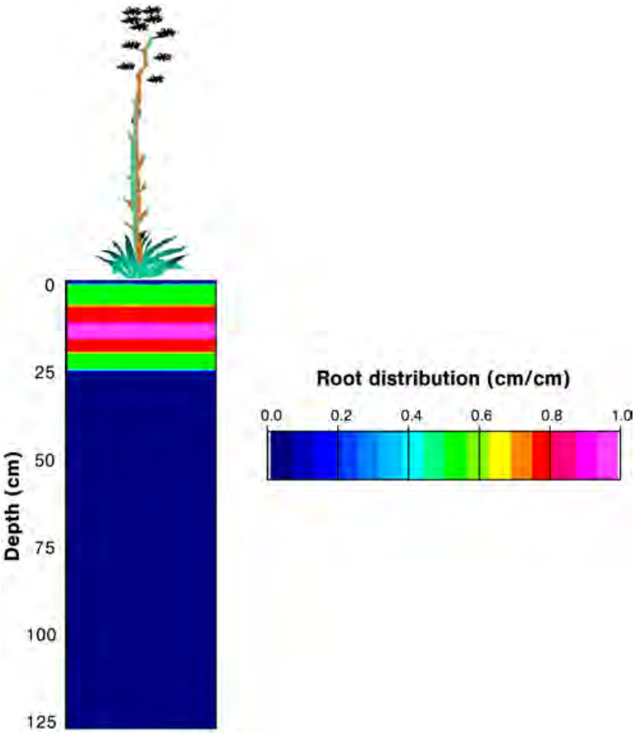


Figure 13. Model of agave-root-density distribution, by depth.

uptake did not take into consideration diurnal fluctuations in atmospheric conditions and the plant-respiration responses. Rather, the transpiration rate was a mean between the high and low rates. The average transpiration rate was used because of a lack of atmospheric and plant physiological data; nonetheless, the average transpiration rate was useful for comparing the two soil horizons for Trenches 1 and 2.

Two-dimensional water transfer was modeled under two sets of boundary and initial conditions in which (1) water infiltration and percolation was considered and (2) root water uptake was considered. The first set of boundary and initial conditions was specified to simulate saturated infiltration and percolation that may occur under flooded conditions (e.g., flood irrigation). The initial condition of the soil was uniformly dry ($\psi = -100{,}000$ cm of water). The upper boundary condition was 5 cm of water ponded on the soil surface, and the lower boundary condition was free drainage. The second set of boundary and initial conditions was used to model water uptake of *A. murpheyi*. Initially, the soil profiles were uniformly wet ($\psi = -5$cm), and a steady transpiration rate was considered (4 cm per day). The upper boundary condition was atmospheric pressure, and the lower boundary condition was free drainage.

GIS Analysis

GIS analysis was used to create a spatial model of soil quality for the area around the Mescal Wash site and for a large section of southeastern Arizona. The analysis was conducted based on soil-survey data for nine soil surveys in southeastern Arizona that were obtained from the Soil Survey Geographic (SSURGO) database of the NRCS (available online at http://soils.usda.gov/survey/geography/ssurgo/, accessed April 2006). These data were integrated with data from archaeological sites, obtained from the Arizona Archaeological Site and Survey Database (AZSITE) (available online at http://www.statemuseum.arizona.edu/crservices/azsite/index.shtml, accessed October 2005), which is based on records archived at the Arizona State Museum. Locational data on sites with agricultural features (canals, check dams, terraces, and rock piles) were integrated in a GIS so that their relationships to soil properties could be cross tabulated. Soil data from the SSURGO database used for assessing soil quality included the following soil properties: A-horizon thickness, available water capacity, bulk density, calcium carbonate, CEC, depth to the Bt horizon (a horizon where translocated clay accumulates), depth to a restrictive layer (e.g., bedrock or a petrocalcic horizon), electrical conductivity, organic matter, pH, sodium-adsorption ratio (SAR, defined as the proportion of sodium to calcium + magnesium ions), texture, and percentage of rock fragments. Each of these soil properties was divided into different ranges important for assessing soil quality, and the spatial distributions of these properties were mapped and integrated, to produce a model of soil quality. Digital elevation model (DEM) data were obtained from the USGS, to facilitate spatial analysis of slope aspects and gradients for the study area in a GIS. Spatial distributions of different soil and physiographic properties were used to model agricultural soil quality and suitability for different types of farming systems. The distributions of ancient agricultural fields and other types of archaeological sites were then evaluated in relation to a spatial model of agricultural soil quality.

Results and Discussion

Soil Distributions, Morphological Properties, and Agricultural Capability

The Mescal Wash site is situated on a stable Pleistocene stream terrace sandwiched between Cienega Creek to the south and Mescal Wash to the north. Appendix A presents the profile descriptions for six soil profiles documented at the Mescal Wash site. All soils at the Mescal Wash site are classified as Aridisols, soils that are dry more than half the year and moist less than 90 consecutive days per year. Soils were differentiated based on the following diagnostic subsurface horizons: (1) calcic horizons (soils enriched with significant illuvial accumulations of calcium carbonate), (2) argillic horizons (soils enriched by illuvial clay), and (3) cambic horizons (soils with structural development or color changes). Calcic horizons are widespread throughout most of the Mescal Wash site, and they are most prominent in Locus A, as indicated by areas where creosote bush grows. Calcic development is weak to moderate, as indicated by whitish filaments and masses of calcium carbonate and coatings on rock fragments and artifacts. Argillic horizons are also widespread at the site, often co-occurring with calcic horizons. Argillic horizons are marked by the presence of thin, reddish brown clay coatings on the faces of subangular blocks or prisms. The most strongly developed argillic horizons are located in the western part of Locus B, where calcic carbonate is absent. Cambic horizons indicate areas with the least soil development, especially areas where colluvium accumulated during the late Holocene. Cambic horizons were mainly noted in Locus E and the western part of Locus C.

Soil-map units within 10 km of the Mescal Wash site are shown in Figure 14 and summarized in Table 6, which shows the acreage for each soil-map unit within 1 km (776 acres), 5 km (19,408 acres), and 10 km (77,630 acres) of the site. Units 5 (Arizo-Riverwash complex), 19 (Comoro sandy loam), and 68 (Riveroad and Comoro soils), all of which are located in Holocene alluvium that could have been used for floodwater farming, are among the best agricultural soils in the area, and they are concentrated along Cienega Creek and Mescal Wash, near the Mescal Wash site. Soils farther from the site include high percentages of exposed bedrock and older Pleistocene soils that have more-limited agricultural potential than the soils nearer to the Mescal Wash site.

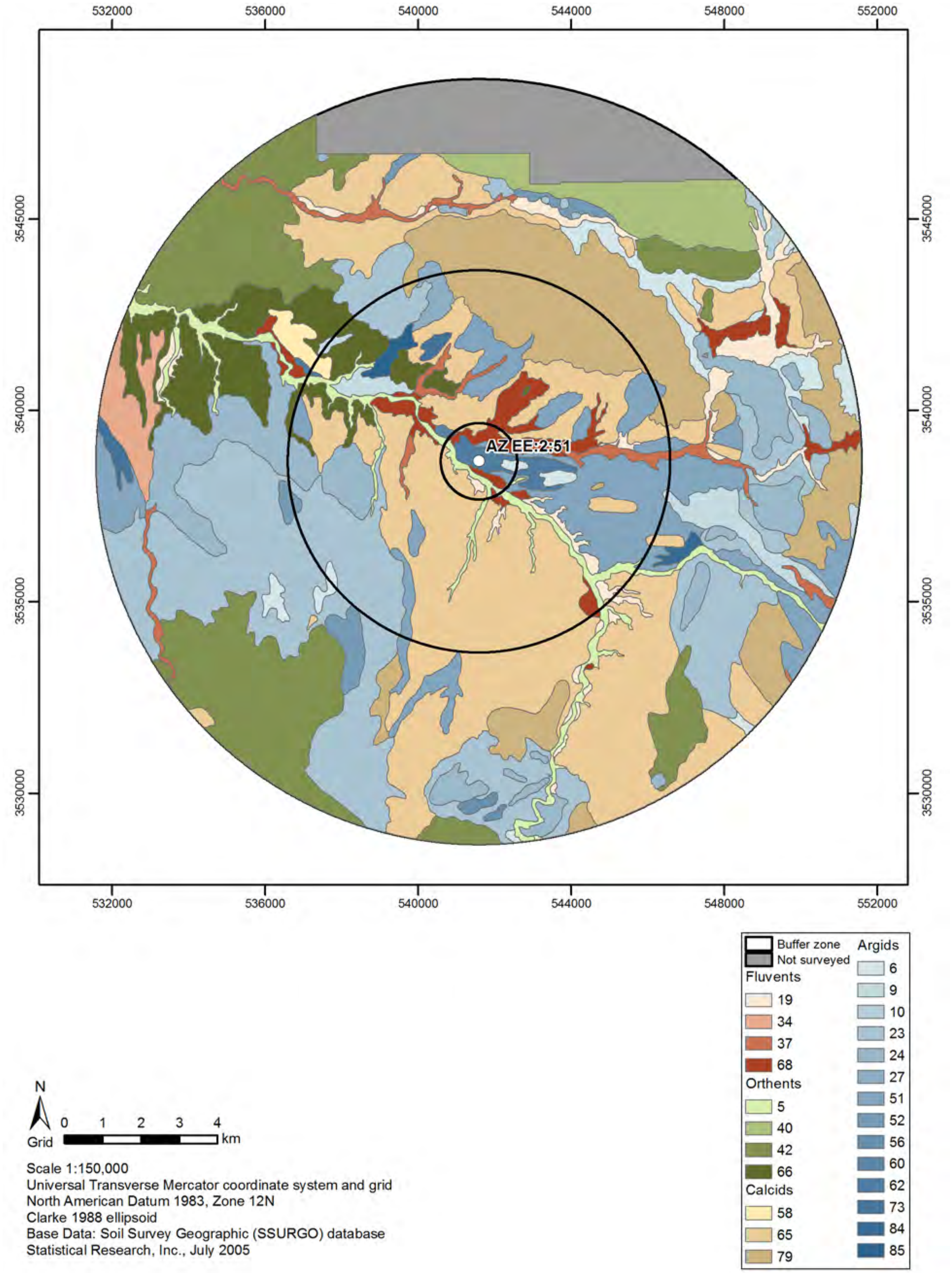
Detailed information on the soil series that make up the soil-map units within 10 km of the Mescal Wash site are presented in Appendix D. The soil classification, landform and geological associations, percent slope, and texture are summarized in Table 7 for each soil series. These soils are dominated by the Aridisols soil order (Argids, Calcids, and Cambids suborders) and Entisols soil order (Fluvents and Orthents suborders). The Fluvents of floodplains, alluvial fans, and lower stream terraces generally have the best agricultural potential.

Table 8 shows an NRCS land-capability classification prepared for modern agriculture. The classification is divided into eight classes and four subclasses that indicate limitations for agriculture. Although the classification is designed to classify land in terms of potential for modern commercial agriculture, it is also pertinent to the potential for ancient agricultural production in the study area.

Table 9 shows how the soil series in the soil-map units within 10 km of the Mescal Wash site are classified according to the NRCS land capability classification, divided by irrigated and non-irrigated systems. The classification for irrigated systems can be considered analogous to floodwater agriculture, the type of agriculture assumed to have been dominant in prehistory in the project area. From best to least for floodwater farming, soils near the Mescal Wash site are ranked as follows: Riveroad>Comoro/Diaspar>Hantz. Soils in Class VI are not considered suitable for modern agriculture; small parcels within some of them, however, could have been used for non-irrigated farming, such as runoff or rock-mulch agriculture, especially those with lower slope gradients and small watersheds. Table 10 summarizes the agricultural suitability of all soil series, with information on a number of properties that are important for agriculture (e.g., permeability, available water capacity, runoff, water-erosion hazard, and rooting depth).

Chemical and Physical Soil Properties

Laboratory soil data for Trenches 1 and 2 (Profiles 2 and 8, respectively) and for the upper surfaces of potential agricultural soils along Mescal Wash are summarized in Table 11. Soils in Trench 1 are Haplargids, soils characterized by a shallow argillic horizon. Soil development in Trench 1 is much stronger than that of Trench 2, which is not surprising, given that Trench 1 is on a Pleistocene terrace, and Trench 2, located on a Holocene terrace, is much younger. Overall, Trench 1 has a higher sand content and lower silt and clay contents, although it has an increase in clay content at about 50 cm, a clay bulge that indicates that the clay is illuvial (that is, clay translocated from above) (Figure 15). The textural properties of the different soil horizons in Trench 2 are functions of natural flood deposition on the floodplain rather than soil formation. Ranges of textures are represented in the two profiles: sandy loam, sandy clay loam, loam, and sand in Trench 1 and silt loam, loam, silty clay, and silty clay loam in Trench 2. This kind of textural variability with depth is favorable for agriculture, because these changes



Scale 1:150,000
Universal Transverse Mercator coordinate system and grid
North American Datum 1983, Zone 12N
Clarke 1988 ellipsoid
Base Data: Soil Survey Geographic (SSURGO) database
Statistical Research, Inc., July 2005

Figure 14. Map showing the soil-map units within 1, 5, and 10 km of the Mescal Wash site.

Table 6. Distribution of Soil-Map Units around the Mescal Wash Site

Unit No.	Soil-Map Unit	10-km Buffer Zone			5-km Buffer Zone			1-km Buffer Zone		
		Acreage	Polygons	%	Acreage	Polygons	%	Acreage	Polygons	%
5	Arizo-Riverwash complex, 1–8 percent slopes	1,696	1	2.3	738	1	3.8	96	1	12.5
6	Bernardino-Tombstone association, 5–16 percent slopes	1,508	10	2.1	146	3	0.8	24	1	3.2
9	Caralampi very gravelly sandy loam, 5–15 percent slopes	956	4	1.3	252	3	1.3	—	—	
10	Caralampi extremely gravelly sandy loam, 15–45 percent slopes	129	1	0.2	—	—		—	—	
19	Comoro sandy loam, 0–2 percent slopes	1,565	24	2.1	279	5	1.4	24	1	3.1
23	Deloro-Andrada complex, 5–35 percent slopes	12,139	15	16.6	1,947	2	10.0	—	—	
24	Deloro–Rock outcrop complex, 15–60 percent	4,470	15	6.1	653	1	3.4	—	—	
27	Diaspar sandy loam, 1–5 percent slopes	249	1	0.3	200	1	1.0	—	—	
34	Hantz loam, 0–1 percent slopes	841	1	1.2	—	—		—	—	
37	Keysto extremely gravelly fine sandy loam, 2–8 percent slopes	1,057	7	1.4	371	3	1.9	—	—	
40	Lampshire-Romero–Rock outcrop complex, 10–65 percent slopes	2,045	1	2.8	—	—		—	—	
42	Mabray-Deloro–Rock outcrop complex, 20–65 percent slopes	8,745	8	12.0	—	—		—	—	
51	Nolam-Tombstone complex, 8–30 percent slopes	5,405	14	7.4	3,003	10	15.5	57	1	7.3
52	Oracle-Romero–Rock outcrop complex, 5–35 percent slopes	644	4	0.9	26	2	0.1	—	—	
56	Pantak-Deloro complex, 8–35 percent slopes	105	2	0.1	—	—		—	—	
58	Pantano-Granolite complex, 5–25 percent slopes	302	1	0.4	55	1	0.3	—	—	
60	Pinaleno-Stagecoach complex, 5–16 percent slopes	30	1	0.0	30	1	0.2	3	1	0.4
62	Pinaleno very cobbly sandy loam, 1–8 percent slopes	399	2	0.5	381	2	2.0	195	1	25.3
65	Powerline-Kimrose family complex, 10–35 percent slopes	17,080	19	23.4	7,278	9	37.5	194	2	25.1
66	Redington very gravelly fine sand, 3–50 percent slopes	3,362	8	4.6	850	5	4.4	—	—	
68	Riveroad and Comoro soils, 0–2 percent slopes	1,527	14	2.1	1,010	9	5.2	182	3	23.6
73	Sasabe-Caralampi complex, 1–15 percent slopes	228	2	0.3	80	1	0.4	—	—	
79	Tombstone very gravelly loam, 15–50 percent slopes	8,288	9	11.3	1,949	2	10.0	—	—	
84	White House–Caralampi complex, 5–25 percent slopes	104	1	0.1	—	—		—	—	
85	White House gravelly loam, 1–8 percent slopes	160	1	0.2	160	1	0.8	—	—	
87	reservoirs	3	1	0.0	—	—		—	—	
No data		4,592	1		—	—		—	—	
Total area		77,630			19,408			776		

Table 7. Soil Classification and Landform and Geologic Associations of Soil Series in the Mescal Wash–Cienega Creek Area, by Soil Order

Soil Series, by Suborder	Soil Family	Landform(s)	Slope (%)	Geologic Parent Material	Soil Texture
			Entisols		
Fluvents					
Comoro	coarse-loamy, mixed, superactive, calcareous thermic Ustic Torrifluvents	floodplains and alluvial fans	0–8	stratified alluvium mainly from granite and rhyolite	sandy loam
Hantz	fine, mixed, superactive, calcareous, thermic Vertic Torrifluvents	floodplains, stream terraces, and alluvial fans	0–5	stratified, mixed alluvium	silty clay
Keysto	loamy-skeletal, mixed, superactive, nonacid, thermic Ustic Torrifluvents	alluvial fans and stream terraces	0–8	mixed fan and stream alluvium	very gravelly sandy loam
Riveroad	fine-silty, mixed, superactive, calcareous, thermic Ustic Torrifluvents	floodplains and alluvial fans	0–5	mixed stream alluvium from igneous, metamorphic, and sedimentary rocks	clay loam
Orthents					
Arizo	sandy-skeletal, mixed, thermic Typic Torriorthents	channels, bars, alluvial fans, and floodplains	0–15	mixed alluvium	very gravelly fine sand
Lampshire	loamy-skeletal, mixed, superactive, nonacid, thermic Lithic Ustic Torriorthents	hills and mountains	3–90	alluvium and colluvium from metamorphic and igneous rocks	very cobbly loam
Mabray	loamy-skeletal, carbonatic, thermic Lithic Ustic Torriorthents	hills and mountains	3–70	slope alluvium from limestone	very gravelly loam
Redington	sandy, mixed, thermic Typic Torriorthents	hills and dissected relict lakebeds	3–60	mixed stream and fan alluvium	very gravelly fine sand
Romero	loamy-skeletal, mixed, superactive, nonacid, thermic, shallow Ustic Torriorthents	pediments, hills, and mountains	10–65	slope alluvium from granite, gneiss, granodiorite, and schist or pegmatite	very gravelly sandy loam
			Aridisols		
Argids					
Bernardino	fine, mixed, superactive, thermic Ustic Calciargids	fan terraces	0–30	fan alluvium from igneous and sedimentary rock	gravelly clay loam
Caralampi	loamy-skeletal, mixed, superactive, thermic Ustic Haplargids	fan terraces and hills	1–50	fan and slope alluvium from granitic and volcanic rock	very gravelly sandy loam
Deloro	clay-skeletal, mixed, superactive, thermic, shallow Ustic Haplargids	pediments, hills, and mountains	1–45	mixed alluvium from shale, schist, phyllite, or sandstone	extremely channery loam
Diaspar	coarse-loamy, mixed, superactive, thermic Ustic Haplargids	fan terraces	0–8	mixed alluvium from granitic and volcanic rocks	sandy loam
Granolite	clayey-skeletal, mixed, superactive, thermic, shallow Typic Haplargids	hills, mountains, and pediments	2–65	slope alluvium from volcanic and metamorphic rocks	extremely gravelly sandy loam

Soil Series, by Suborder	Soil Family	Landform(s)	Slope (%)	Geologic Parent Material	Soil Texture
Mohave	fine-loamy, mixed, superactive, thermic Typic Calciargids	fan terraces, basin floors, and stream terraces	0–8	mixed alluvium from acid and basic igneous rocks	sandy loam
Nolam	loamy-skeletal, mixed, superactive, thermic Ustic Calciargids	fan terraces and piedmonts	2–15	alluvium from rhyolite and andesite	very gravelly sandy loam
Oracle	loamy, mixed, superactive, thermic, shallow Ustic Haplargids	hills and pediments	5–45	granitic residuum	very gravelly loam
Pantak	loamy-skeletal, mixed, superactive, thermic Lithic Ustic Haplargids	pediments, hills, and mountains	8–60	mixed slope alluvium, colluvium, and residuum	very gravelly sandy loam
Pinaleno	loamy-skeletal, mixed, superactive, thermic Typic Calciargids	fan terraces and stream terraces	0–45	mixed fan and steam alluvium	very gravelly clay loam
Sasabe	fine, mixed, superactive, thermic Ustic Paleargids	fan terraces	0–20	mixed fan alluvium	sandy loam
White House	fine, mixed, superactive, thermic Ustic Haplargids	fan terraces	0–35	mixed fan alluvium	gravelly loam
Calcids					
Andrada	loamy-skeletal over fragmental, mixed, superactive, thermic Ustic Haplocalcids	hills and pediments	3–45	alluvium and residuum from shale, sandstone, diorite, and conglomerate	extremely gravelly loam
Kimrose	loamy-skeletal, mixed, superactive, thermic shallow Ustic Petrocalcids	fan piedmonts and fan terraces	1–20	mixed alluvium from gneiss, schist, and granite	very gravelly sandy loam
Pantano	loamy-skeletal, mixed, superactive, thermic, shallow Typic Haplocalcids	hills, pediments, and mountains	5–50	slope alluvium/colluvium from metamorphic rocks and limestone	extremely gravelly loam
Powerline	loamy-skeletal, mixed, superactive, thermic Ustic Haplocalcids	hills	2–40	mixed slope alluvium from calcareous sandy fanglomerate	very gravelly sandy loam
Stagecoach	loamy-skeletal, mixed, superactive, thermic Typic Haplocalcids	fan terraces	0–55	mixed fan or stream alluvium	very gravelly sandy loam
Tombstone	loamy-skeletal, mixed, superactive, thermic Ustic Haplocalcids	fan and stream terraces	1–50	mixed fan or stream alluvium	very gravelly fine sandy loam
Cambids					
Sahuarita	coarse-loamy, mixed, superactive, thermic Typic Haplocambids	fan terraces and basin floors	0–8	mixed alluvium from limestone, schist, phyllite, and granitic rocks	very gravelly fine sandy loam

Table 8. Land-Capability Classification

Class/Subclass	Definition
Class	
I	Soils have few limitations that restrict their use.
II	Soils have moderate limitations that reduce the choice of plants or that require moderate conservation practices.
III	Soils have severe limitations that reduce the choice of plants or that require special conservation practices, or both.
IV	Soils have very severe limitations that reduce the choice of plants or that require very careful management, or both.
V	Soils are not likely to erode but have other limitations, impractical to remove, that limit their use.
VI	Soils have severe limitations that make them generally unsuitable for cultivation.
VII	Soils have very severe limitations that make them generally unsuitable for cultivation.
VIII	Soils and miscellaneous areas that have limitations that nearly preclude their use for commercial crop production.
Subclass	
e	Main hazard is the risk of erosion unless close-growing plant cover is maintained
w	Water in or on the soil interferes with plant growth or cultivation
s	Soil is limited mainly because it is shallow.
c	Chief limitation is climate that is very dry.

Note: After Cochran and Richardson (2003).

Table 9. Distribution of Soil-Map Units around the Mescal Wash Site

Unit No.	Soil-Map Unit	Soil Series	Land-Capability Classification*	
			Non-Irrigated	Irrigated
5	Arizo-Riverwash complex, 1–8 percent slopes	Arizo	VIw	IVw
		Riverwash	VIII	
6	Bernardino-Tombstone association, 5–16 percent slopes	Bernardino	VIs	
		Tombstone	VIs	
9	Caralampi very gravelly sandy loam, 5–15 percent slopes		VIs	
10	Caralampi extremely gravelly sandy loam, 15–45 percent slopes		VIIe	
19	Comoro sandy loam, 0–2 percent slopes		VIs	IIs
23	Deloro-Andrada complex, 5–35 percent slopes	Deloro	VIs	
		Andrada	VIs	
24	Deloro–Rock outcrop complex, 15–60 percent	Deloro	VIIe	
		rock outcrop	VIII	
27	Diaspar sandy loam, 1–5 percent slopes		VIs	IIe
34	Hantz loam, 0–1 percent slopes		VIIw	IIIw
37	Keysto extremely gravelly fine sandy loam, 2–8 percent slopes		VIs	
40	Lampshire-Romero–Rock outcrop complex, 10–65 percent slopes	Lampshire	VIIe	
		Romero	VIIe	
		rock outcrop	VIII	
42	Mabray-Deloro–Rock outcrop complex, 20–65 percent slopes	Mabray	VIIe	
		Deloro	VIIe	
		rock outcrop	VIII	
51	Nolam-Tombstone complex, 8–30 percent slopes	Nolam	VIs	
		Tombstone	VIs	
52	Oracle-Romero–Rock outcrop complex, 5–35 percent slopes	Oracle	VIs	
		Romero	VIs	
		rock outcrop	VIII	
56	Pantak-Deloro complex, 8–35 percent slopes	Pantak	VIs	
		Deloro	VIs	
58	Pantano-Granolite complex, 5–25 percent slopes	Pantano	VIIs	
		Granolite	VIIs	
60	Pinaleno-Stagecoach complex, 5–16 percent slopes	Pinaleno	VIIs	
		Stagecoach	VIIs	
62	Pinaleno very cobbly sandy loam, 1–8 percent slopes		VIIs	
65	Powerline-Kimrose family complex, 10–35 percent slopes	Powerline	VIs	
		Kimrose	VIs	
66	Redington very gravelly fine sand, 3–50 percent slopes		VIIe	
68	Riveroad and Comoro soils, 0–2 percent slopes	Riveroad	VIc	I
		Comoro	VIs	IIs
73	Sasabe-Caralampi complex, 1–15 percent slopes	Sahuarita	VIe	
		Caralampi	VIs	
79	Tombstone very gravelly loam, 15–50 percent slopes		VIIe	
84	White House-Caralampi complex, 5–25 percent slopes	White House	VIc	
		Caralampi	VIs	
85	White House gravelly loam, 1–8 percent slopes		VIc	

Table 10. Agricultural Suitability of Soils near Marsh Station

Soil Series, by Order	Permeability	Available-Water Capacity	Water-Erosion Hazard	Runoff	Rooting Depth (cm)	Agricultural Suitability	Irrigated Land Capability	Non-Irrigated Land Capability
Entisols								
Arizo	very rapid	low	very high	very slow	>150	Poorly suited for farming. Subjected to frequent flooding, is moderately alkaline, and has low water availability.	IVw	VIw
Comoro	moderately rapid	moderate	slight	medium	>150	Well suited for floodwater and irrigation farming.	IIs	VIs
Hantz	slow	high	slight	slow to medium	>150	Moderately suited for farming. Cracks develop during the dry season that can damage crop roots.	IIIw	VIIw
Keysto	moderately rapid	low	slight to moderate	medium	>150	Moderately to poorly suited for farming. Has 50–80 percent gravel and cobbles and low water availability.		VIs
Lampshire	moderate to moderately rapid	low	moderate to high	medium to rapid	<20	Poorly suited for farming. Has 35–80 percent gravel and cobbles; shallow depth, low water availability, and steep slopes are common.		VIIe
Mabray	moderate	low	slight to moderate	medium to rapid	10–50	Poorly suited for farming. Has 35–85 percent gravel and shallow depth; slightly to moderately alkaline; steep slopes are common.		VIIe
Redington	rapid to moderately rapid	low	moderate to high	medium	>150	Poorly suited for farming. Root restrictive when dry. Has 20–45 percent gravel, cobbles, and petronodes and 5–10 percent gypsum.		VIIe
Riveroad	moderate to moderately slow	high	slight	slow	>150	Poorly to moderately to well suited for floodwater and irrigation farming.	I	VIc
Romero	rapid to moderately rapid	low	moderate to high	medium	<50	Poorly suited for farming. Has about 40 percent fine gravel and shallow depth; steep slopes are common		VIs, VIIe
Aridisols								
Andrada	moderately slow	very low	slight to moderate	medium to rapid	25–50	Very poorly suited for farming. Has 35–85 percent gravel and cobbles, shallow depth, and very low water availability; steep slopes are common; slightly to moderately alkaline.		VIs
Bernardino	slow	moderate	slight to moderate	slow to medium	>150	Poorly suited for farming. Has up to 35 percent fine gravel and is moderately alkaline.		VIs
Caralampi	moderately slow	moderate	moderate to high	medium to rapid	>150	Poorly suited for farming. Has 35–80 percent gravel, and steep slopes are common.		VIs, VIIe, VIIs
Deloro	slow	low	slight to moderate	rapid	25–50	Poorly suited for farming. Has 35–85 percent gravel or channers, shallow depth, very low water availability, and steep slopes.		VIs

Soil Series, by Order	Permeability	Available-Water Capacity	Water-Erosion Hazard	Runoff	Rooting Depth (cm)	Agricultural Suitability	Irrigated Land Capability	Non-Irrigated Land Capability
Diaspar	moderately rapid to moderate	moderate	slight	medium	>150	Moderately suited for farming. This soil is used for modern irrigation to cultivate cotton, corn, small grains, and alfalfa	IIe	VIs, VIIe
Granolite	slow	very low	slight to moderate	rapid	25–50	Poorly suited for farming. Has 35–85 percent gravel, shallow depth, and very low water availability.		VIIs
Kimrose	moderate	low	slight	slow to medium	20–50	Poorly suited for farming. Has shallow depth and is neutral to moderately alkaline.		VIs
Mohave	moderately slow	moderate	slight to moderate	slow	>150	Moderately to poorly suited for runoff farming.		VIIe
Nolam	moderate to moderately slow	moderate	moderate	medium	>150	Poorly suited for farming. Has up to 35 percent gravel and is moderately alkaline.		VIs
Oracle	moderately slow	low	moderate	medium to rapid	25–50	Poorly suited for farming. Has up to 65 percent gravel on the surface, shallow depth, and low water availability; steep slopes are common.		VIs
Pantano	moderate	low	slight to moderate	medium to very rapid	25–50	Poorly suited for farming. Has a 65–70 percent gravel cover, shallow depth, steep slopes, and low water availability.		VIIs
Pantak	moderate	moderate	moderate to high	medium to rapid	25–50	Poorly suited for farming. Has 35–65 percent gravel, shallow depth, and steep slopes.		VIs
Pinaleno	moderately slow	moderate	slight to moderate	slow to medium	>150	Poorly suited for all but possibly runoff or rock-mulch farming.		VIIs
Powerline	moderate	moderate	slight	medium to rapid	50–100	Poorly suited for all but possibly runoff or rock-mulch farming.		VIIs
Sahuarita	moderate to moderately rapid	low	slight to moderate	slow to medium	>150	Moderately suited for runoff farming.		VIe
Sasabe	slow to moderate	moderate	slight	slow to medium	>150	Moderately to poorly suited for runoff farming.		VIs
Stagecoach	moderately rapid	moderate	slight	medium	25–50	Poorly suited for farming. Has a shallow depth, is calcareous throughout, and has 35–85 percent gravel; steep slopes are common.		VIIs
Tombstone	moderately rapid	moderate	slight	slow	>150	Poorly suited for farming. Has 35–70 percent gravel and is moderately alkaline; steep slopes are common.		VIs, VIIe
White House	slow to very slow	moderate	slight	slow to medium	>150	Poorly suited for farming. Has up to 35 percent gravel and is moderately alkaline; steep slopes are common.		VIc

Table 11. Soil Analysis for the Marsh Station Archaeological Project, by Sample Location

Provenience Designation No./Site No.	Depth (cm)	Horizon	Particle-Size Distribution			Textural Class	Surface Area (m^2/g)	pH	Soluble Salts dS/m	Organic Matter (%)	Total Carbonates (%)	Exchangeable Elements (mg/kg)				Available P (mg/kg)	Estimated Cation Exchange Capacity (meq)
			Sand (0.005–2 mm)	Silt (2–50 µm)	Clay (<2 µm)							Ca	Mg	Na	K		
Trench 1 (Pleistocene Terrace), Profile 2																	
10847	0–5	A	68	25	8	sandy loam	40	6.8	0.07	1.0	2.9	912	135	0.0	227	13.1	5
10848	25–30	Bt1	59	22	19	sandy loam	88	8.2	0.16	1.1	4.1	2,042	204	2.4	378	0.9	10
10849	50–55	Bt1	50	20	30	sandy clay loam	105	8.1	0.17	1.2	4.8	2,692	320	13.4	216	0.4	12
10850	75–80	Bk	48	30	22	loam	74	8.5	0.17	0.9	37.8	4,470	259	13.0	107	4.5	25
10851	100–105	2C	92	4	5	sand	31	8.9	0.12	0.5	4.2	3,650	153	6.6	95	2.1	15
Trench 2 (Holocene Terrace), Profile 8																	
10852	0–5	O	23	50	26	silt loam		7.3	0.57	37.5	14.7	7,062	253	0.4	444	57.6	39
10853	5–10	A	40	40	19	loam	83	7.8	0.31	8.4	11.8	5,180	195	0.0	432	26.6	29
10854	25–30	C	8	70	21	silt loam	111	8.3	0.28	4.4	11.0	6,184	260	2.0	1140	4.2	36
10855	50–55	2Ab1	3	44	53	silty clay	177	8.0	0.48	3.6	14.0	6,982	435	16.4	887	2.5	41
10856	75–80	2Ab3	1	60	39	silty clay loam	151	7.8	0.78	5.1	22.7	7,712	442	46.8	377	3.9	43
10857	100–105	2Ab3	1	61	38	silty clay loam	157	7.9	0.60	3.2	29.4	7,188	411	29.2	332	4.7	40
Potential Agricultural Soil, Soil Sample 1 (near Unrecorded Lithic Scatter)																	
	0–15	A	78	15	7	sandy loam		8.2	0.23	1.5	13.7	3,910	196	0.0	172	10.6	16
Potential Agricultural Soil, Soil Sample 2 (Comoro Series)																	
SRI-4	0–15	A	17	54	29	silty clay loam		8.4	0.24	2.1	16.3	6612	316	22.8	660	7.1	37

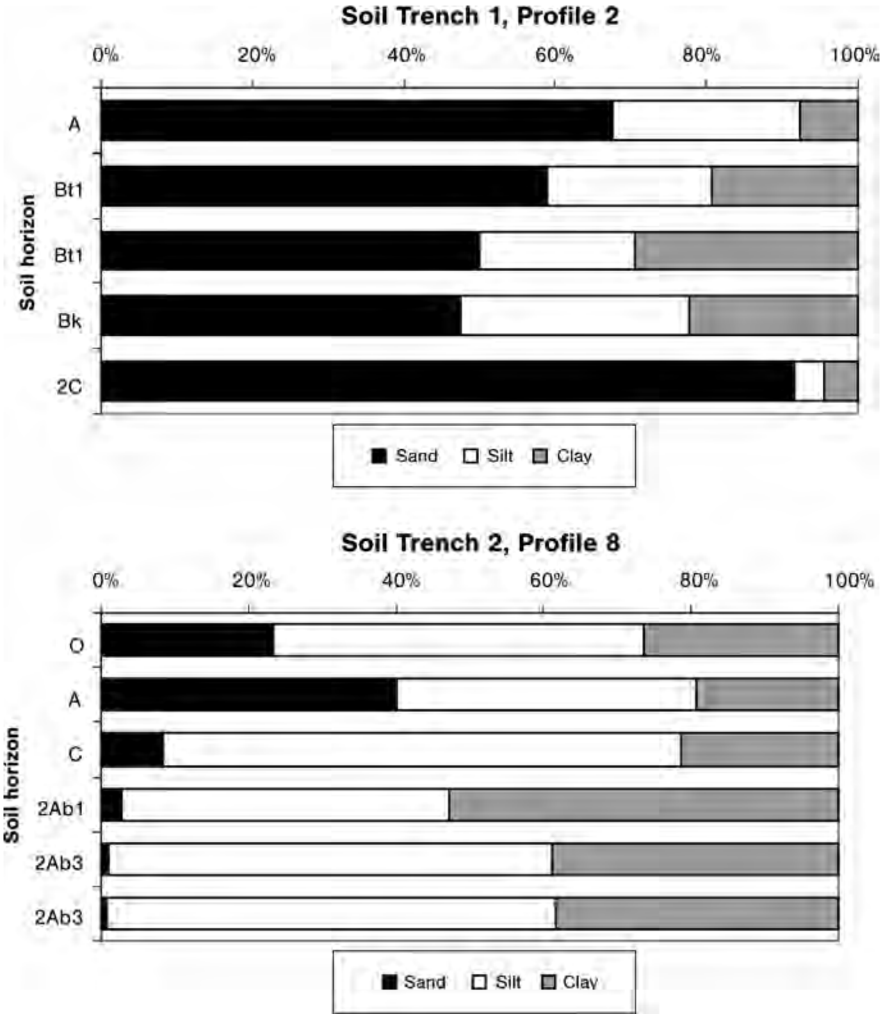


Figure 15. Charts of particle-size distributions for Trenches 1 (top) and 2 (bottom).

tend to slow water infiltration and help conserve moisture in the root zone. Because of the finer texture in Trench 2, it has significantly more plant-available water, as shown in Figure 16. The data summarized in Figure 16 are based on regression coefficients provided by Saxton et al. (1986) for the particle-size data in Table 11. A model of the amount of water held at the permanent wilting point, field capacity, and saturation is summarized in Table 12. Plant-available water is determined by the difference in the amount of water held at the permanent wilting point and the field capacity. Table 12 shows that saturated hydraulic conductivity tends to be higher in Trench 1, which is expected, given its higher sand content.

Surface area is an excellent overall indicator of soil fertility and texture. Soils with finer textures have higher surface areas, measured in square meters per gram of soil. Higher surface areas are usually associated with higher CECs, because roots are more likely to come into contact with nutrients in the soil solution around soil particles. Figure 17shows that Trench 2 has a high surface area, and thus, there is clearly a higher overall soil fertility on the Holocene floodplain. This assessment is consistent with the finding that Trench 2 has significantly more organic matter, available phosphorus, and exchangeable bases than Trench 1. The most fertile agricultural soils typically have organic matter in excess of 3 percent, as was found at Trench 2. Still, there are numerous examples of sustainable ancient agricultural systems in the Southwest that have about 1 percent soil organic matter, or even less, such as at Hopi and Zuni (Homburg et al. 2005). Exchangeable bases are sufficient in both Trenches 1 and 2, but it is important to note that they are rarely found deficient in Arizona soils. Soluble salt levels are higher in Trench 1, but the levels are far below levels that could have a detrimental effect on crop productivity.

Available phosphorus levels appear to be sufficient in Trench 2, and they are very high in the upper 10 cm of this trench. The Bt horizon in Trench 2 appears to be deficient in available phosphorus. Phosphorus deficiencies

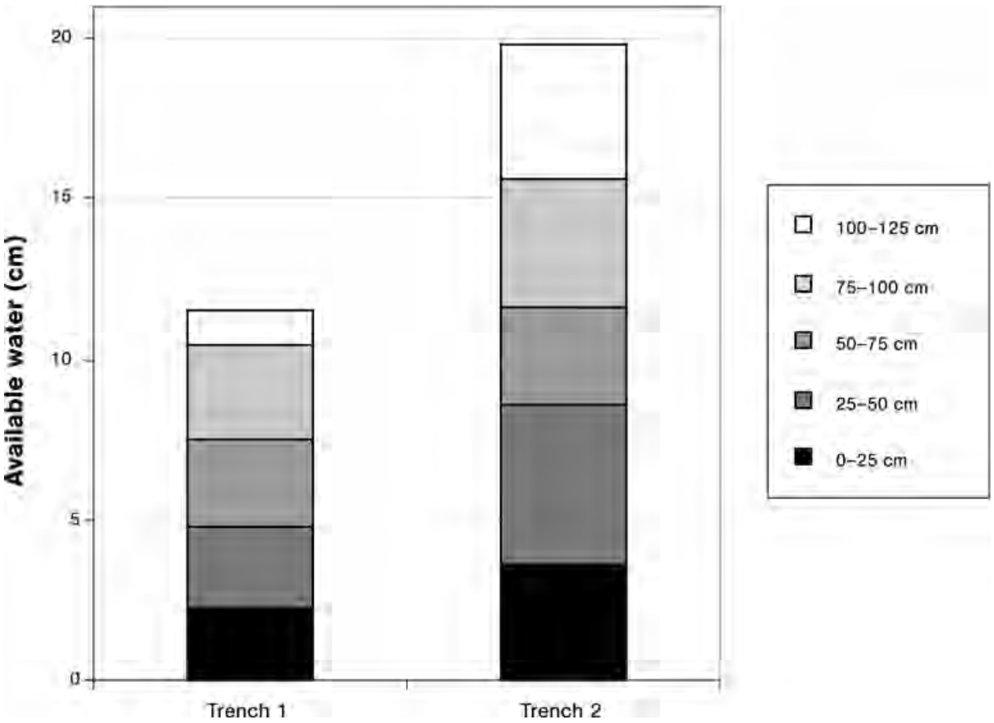


Figure 16. Model of plant-available water for Trenches 1 and 2.

Table 12. Model of Soil Hydraulic Properties

Depth (cm Below Surface)	Horizon	Soil Hydraulic Properties						Available Water at Field Capacity (cm)		
		Wilting Point (%, 1500 kPa)	Field Capacity (%, 33 kPa)	Saturation (%, 0 kPa)	Available Water (%)	Saturated Hydraulic Conductivity (mm/hour)	Bulk Density (g/cm^3)	Depth (cm)	Trench 1	Trench 2
	Trench 1 (Pleistocene Terrace), Profile 2									
0–5	A	5.5	14.1	41.3	0.09	53.7	1.55	0–25	2.3	3.6
25–30	Bt1	12.1	22.0	40.8	0.10	16.8	1.57	25–50	2.5	5.0
50–55	Bt1	18.6	29.7	42.2	0.11	4.8	1.53	50–75	2.8	3.0
75–80	Bk	13.8	25.6	41.4	0.12	13.2	1.55	75–100	3.0	4.0
100–105	2C	2.7	6.6	42.1	0.04	109.9	1.54	100–125	1.0	4.3
	Trench 2 (Holocene Terrace), Profile 8									
0–5	O	16.2	32.2	44.2	0.16	4.8	1.48	0–25		3.6
5–10	A	12.2	25.8	41.7	0.14	11.2	1.55	25–50		5.0
25–30	C	13.5	33.5	44.5	0.20	4.4	1.47	50–75		3.0
50–55	2Ab1	30.7	42.5	55.6	0.12	5.2	1.18	75–100		4.0
75–80	2Ab3	23.8	40.3	58.0	0.16	13.7	1.11	100–125		4.3
100–105	2Ab3	23.6	40.1	54.4	0.17	7.5	1.21			
	Soil Sample 1 (near Unrecorded Lithic Scatter)									
0–15	A	5.3	12.1	43.0	0.07	73.9	1.51	0–25		1.8
	Soil Sample 2 (Comoro Series, Eroded Slope East of SRI-4)									
0–15	A	18.3	35.2	48.3	0.17	6.1	1.37	0–25		4.3
~200	C									

Note: Based on calculations of Saxton et al. (1986).

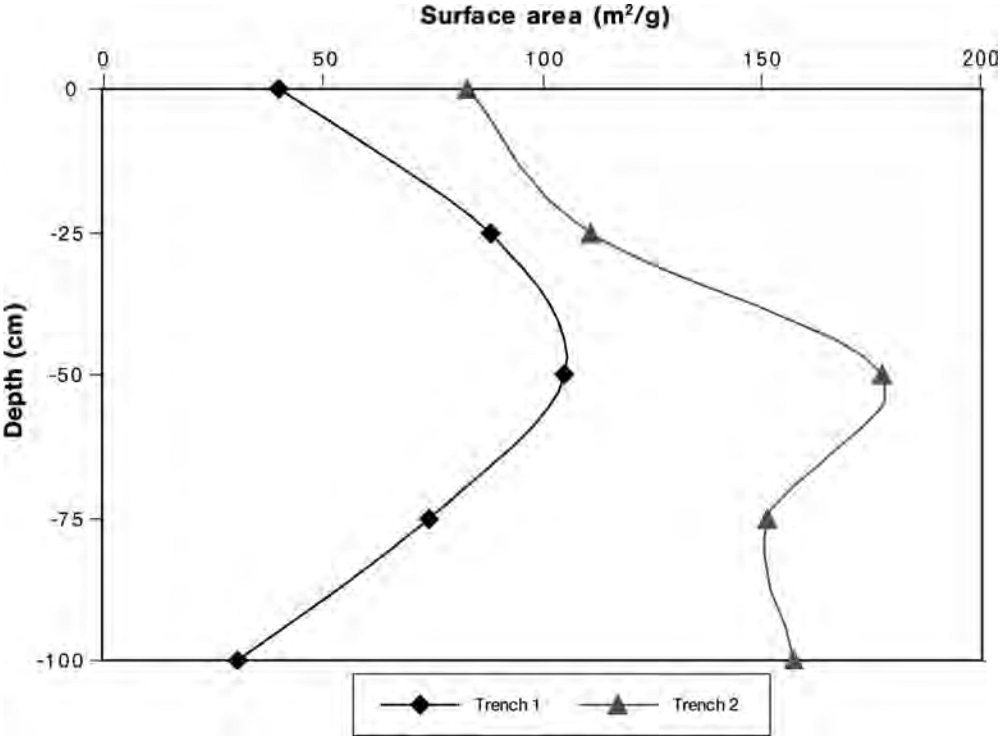


Figure 17. Chart of surface areas of soils in Trenches 1 and 2.

have been found throughout Arizona for a variety of crops. The precise levels needed for crop production are poorly known, but levels below 2 mg/kg are considered deficient, and levels above 5 mg/kg are usually considered sufficient (Doerge 1985). The exceedingly high levels of available P in Trench 2 appear to be chiefly due to high amounts of apatite ($(Ca_5(PO_4)_3(OH, F, Cl))$) in soils weathered from volcanic parent rock.

Soil pH is generally lower in Trench 2, which means that soil nutrients are more readily available to crops in this trench. Soil pH in the range of 6–7 is ideal for maize agriculture, but maize can be cultivated successfully up to about pH 8.2. Soil pH levels in Trench 1 range up to 8.5 and 8.9, which indicates that salts are present that would be detrimental to maize agriculture on the Pleistocene terrace. Agave is probably better adapted to the soil conditions of Trench 1 than those of Trench 2.

The surface textures of potential agricultural soils along Mescal Wash range from sandy loams to silty clay loams. The overall soil fertility of soils along Mescal Wash are generally intermediate between the fertility of Trenches 1 and 2.

Soil Hydraulic Properties

Infiltration Measurements

The two infiltrometers used in the field are shown in Figures 18 and 19, as infiltrometer measurements were collected from Trenches 1 and 2 during the field investigation. Results from the tension infiltration experiments are presented in Figure 20 and Table 13. The saturated-hydraulic-conductivity values are similar for the two trenches. There was a zone between 50 and 75 cm in Trench 1 (see Figure 20) where the measured infiltration rates and calculated saturated- and unsaturated-hydraulic-conductivity (*K*) values were lower than in adjacent horizons. The soil horizons in Trench 2 had relatively uniform *K* values throughout the soil profile.

The lower hydraulic conductivities present in the subsurface horizons (about 50 cm in depth) in Trench 1 appear to represent a hydraulically restrictive soil horizon. This depth in the soil profile corresponded to an argillic horizon that has a higher clay content than the adjacent horizons. Argillic horizons have been shown by McDaniel et al. (2001) to have lower *K* values, which are primarily attributed to the absence of a continuous macropore network (Hammel et al. 1994; Reuter et al. 1998).

The absence of a continuous macropore network would strongly impact the hydraulic properties of the soil, especially when soil is near saturation. The in situ tension infiltrometer experiments were done at pressure-head (ψ) values that were close to saturation ($-5 \text{ cm} \geq \psi \geq -15 \text{ cm}$). The near-saturated hydraulic functions (Figure 21) of *q* measured at $\psi = -5, -10$, and -15 cm can provide information about the in situ soil macropore network. In Trench 1, the shape of the q-ψ functions at 0-, 25-, and 100-cm soil depths were noticeably different than the shape of the steady-state

Figure 18. Photograph of tension infiltrometers testing the 25-cm-depth level of Trench 2.

Figure 19. Photograph of tension infiltrometers at the 25-cm-depth level of Trench 1, as the 75-cm-depth interval is being leveled in preparation for infiltrometer tests.

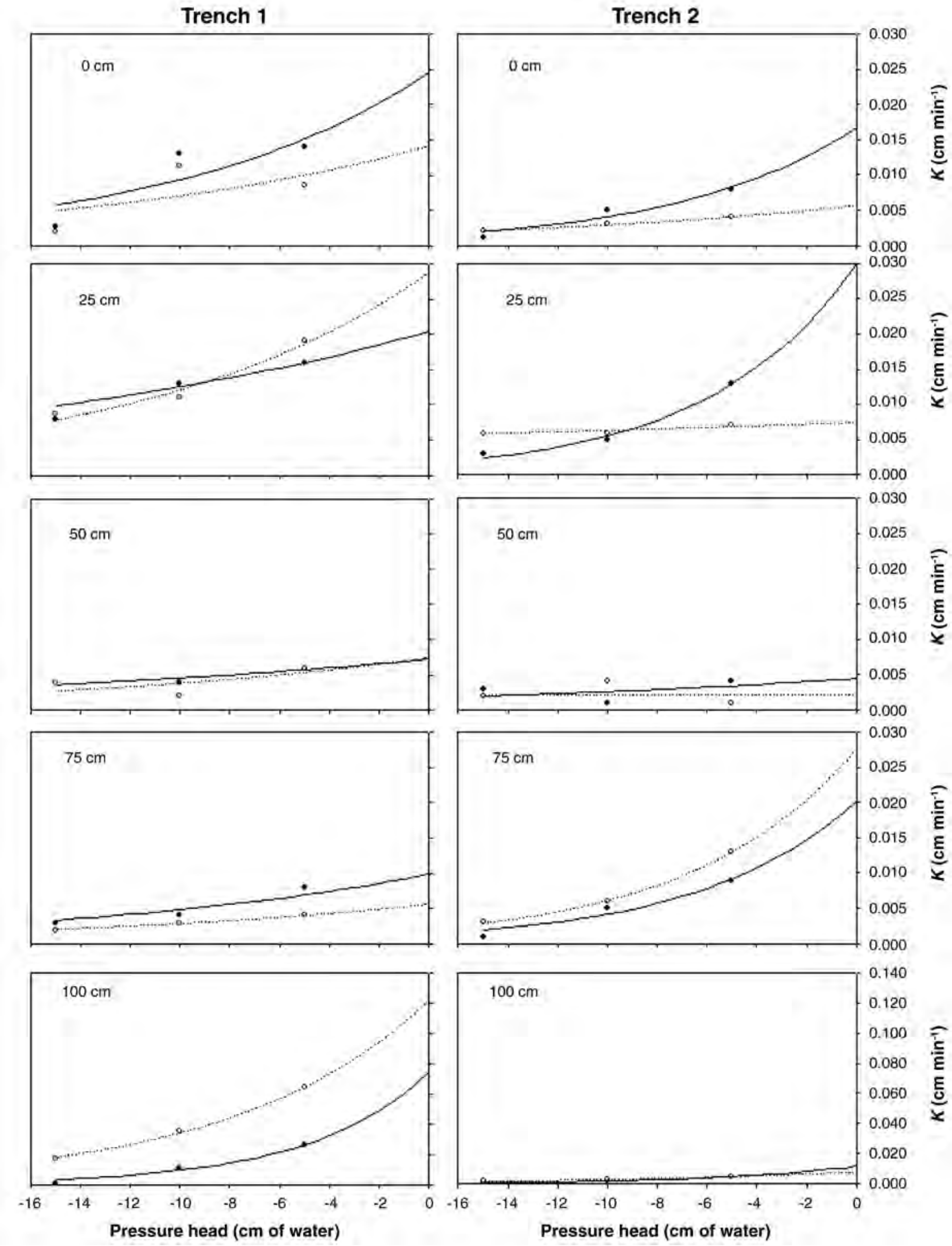


Figure 20. Charts of the infiltration function for Trenches 1 and 2 for five depths at 25-cm intervals.

Table 13. The Measured Steady-State Infiltration Rate at Each Soil Depth of Trenches 1 and 2, with Best-Fit K_{sat} and α Values from Equation 2

Soil Depth (cm)	Measured Steady-State Infiltration Rate (cm min^{-1})			Ksat (cm min^{-1})	α (cm min^{-1})
	$\psi = -15$ cm	$\psi = -10$ cm	$\psi = -5$ cm		
Trench 1					
0	0.034/0.041	0.097/0.086	0.023/0.017	0.003/0.007	0.015/0.036
25	0.060/0.065	0.097/0.085	0.102/0.138	0.016/0.041	0.047/0.081
50	0.032/0.032	0.031/0.013	0.046/0.046	0.006/0.010	0.040/0.066
75	0.059/0.027	0.027/0.022	0.021/0.012	0.029/0.007	0.121/0.072
100	0.192/0.474	0.079/0.263	0.006/0.127	0.224/0.253	0.212/0.126
Trench 2					
0	0.057/0.027	0.035/0.025	0.004/0.017	0.041/0.004	0.151/0.041
25	0.098/0.049	0.036/0.042	0.025/0.042	0.078/0.002	0.168/0.015
50	0.028/0.028	0.010/0.031	0.024/.014	0.002/0.006	0.028/0.052
75	0.068/0.095	0.033/0.041	0.006/0.025	0.061/0.063	0.180/0.149
100	0.037/0.040	0.014/0.021	0.008/0.014	0.031/0.018	0.174/0.112

Note: Values in the table are given in the format, Measurement Replication 1/Measurement Replication 2.

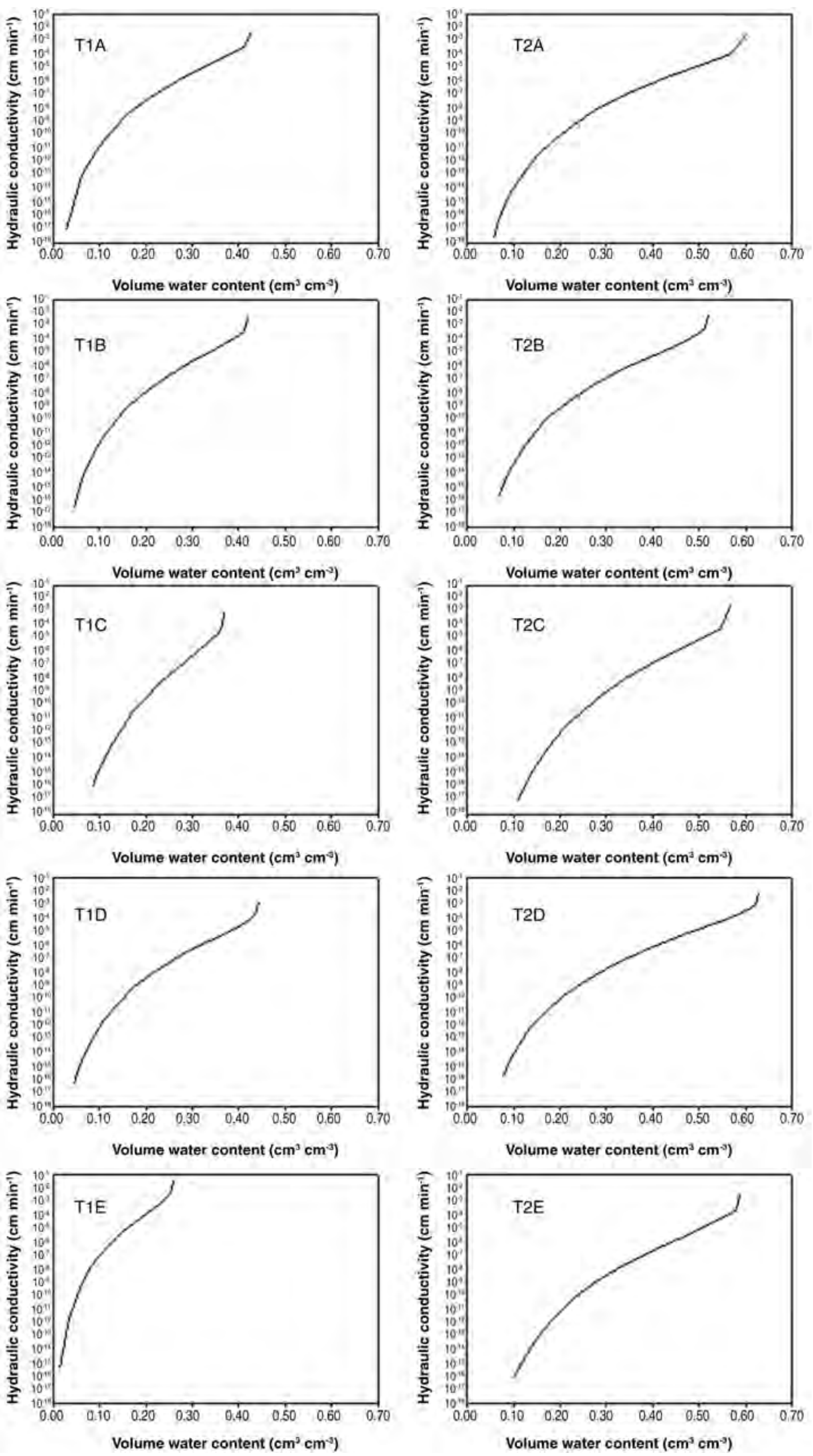


Figure 21. Charts of the hydraulic function for Trench 1 (T1) and Trench 2 (T2) for five depths at 25-cm intervals

infiltration-rate/pressure-head (q-ψ) functions at 50 and 75 cm in depth (Figure 22). The difference in the q-ψ functions was indicated by the inflections between ψ values at –5 and 0 cm, where the slope of the q-ψ functions at 50 and 75 cm in depth were less steep. Scotter and Ross (1994) attributed this inflection to a separation between the macropore and mesopore regions of water-flow domains. The lower inflection of the q-ψ functions at the soil depths of 50 and 75 cm (see Figure 22) may indicate the lack of a continuous macropore network, which is attributed to low K values in argillic horizons (Hammel et al. 1994; Reuter et al. 1998).

Laboratory Soil Water-Retention Curves

Results from the laboratory moisture-release experiments are shown in Table 14, and the soil water-retention curves with the fitted model (Equation 3) are shown in Figure 23. The high value of (residual) volumetric water content (θr) at 50 cm in depth in Trench 1 is the result of high amounts of strongly adsorbed water, which corresponds to the argillic horizon. The high clay content of the argillic horizon likely caused greater amounts of water retention at these high pressure potentials. Another obvious distinction of the water-retention data was the low saturated volumetric water-content (θs) value at 100 cm in depth in Trench 1 (see Table 14). This low θs value may indicate either compaction caused by the overlying soil mass or a decrease in macropore structure. The formation of macropores results from various biotic (e.g., root growth, worm holes, or animal burrows) and abiotic (e.g., freeze/thaw or desiccation) processes, which are common at the soil surface and decrease with depth. The decrease in soil macropores with depth would result in decreased θ values at low pressure potential and could explain the low θs at 100 cm in depth in Trench 1.

The θ values of Trench 2, at each tension, were higher than the Trench 1 θ values for all soil horizons (see Figure 23). That indicated that there were differences in pore-size distributions of each horizon in the two trenches. The bulk-density values (see Table 14) of each horizon in Trench 1 were higher than the corresponding bulk-density values of Trench 2. The higher bulk densities result in less pore space (on a volumetric basis) and significantly different water-retention curves. The differences in bulk densities may be caused by different particle-size distributions of the soils present in Trenches 1 and 2. Soils that are heterogeneous tend to have lower bulk densities, because the smaller size-particle fractions can fill between larger particles, allowing for a closer packing arrangement, whereas a more homogeneous particle-size distribution would have fewer small particles filling spaces between larger particles. The soil in Trench 2 was formed in alluvium where the suspended transport of river material could have sorted the particles, which would have resulted in a more-homogeneous particle-size distribution and lower bulk densities.

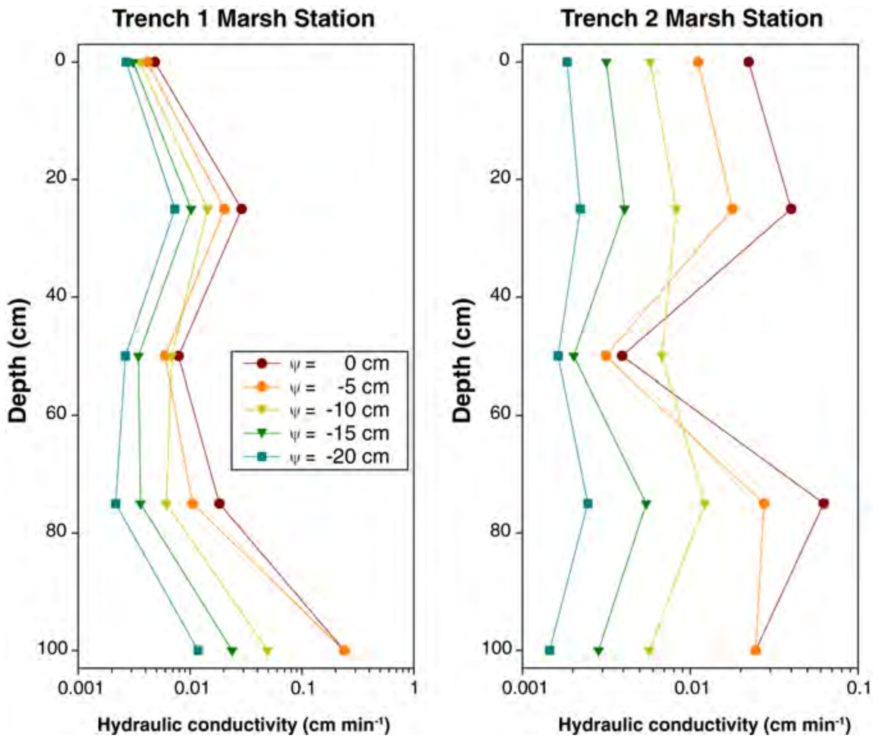


Figure 22. Charts of the unsaturated hydraulic conductivity at five different tension levels for Trenches 1 and 2.

Table 14. The Best-Fit Parameter Estimates of Equations 3 and 5 Used to Describe Soil-Water-Characteristics Curves through the Soil Profiles of Trenches 1 and 2

Depth (cm)	Bulk Density (g cm^{-3})	α (cm^{-1})	m	n	r^2	θs (cm^3 cm^{-3})	θr (cm^3 cm^{-3})
Trench 1							
0	1.469	0.159	0.195	1.242	0.985	0.431	0.012
25	1.435	0.128	0.173	1.209	0.996	0.431	0.019
50	1.572	0.075	0.127	1.145	0.979	0.391	0.036
75	1.389	0.069	0.179	1.218	0.975	0.448	0.011
100	1.651	0.067	0.210	1.266	0.986	0.264	0.005
Trench 2							
0	1.047	0.293	0.177	1.215	0.978	0.612	0.026
25	1.195	0.071	0.172	1.207	0.985	0.532	0.029
50	1.082	0.289	0.133	1.153	0.972	0.590	0.049
75	0.944	0.084	0.170	1.206	0.964	0.637	0.022
100	1.036	0.101	0.148	1.174	0.958	0.604	0.037

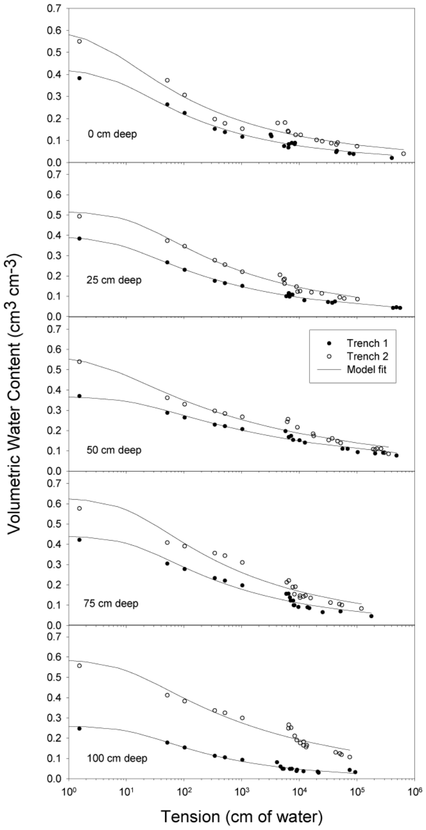


Figure 23. Charts of the water-retention curves for Trenches 1 and 2 for five depths at 25-cm intervals.

Two-Dimensional Water Transfer and Root Water Uptake

Ponded Infiltration

The simulation of water redistribution from a step input of 5 cm of water ponded on the soil surface is presented in Figures 24 and 25. The wetting front advanced much faster in Trench 1 than in Trench 2. The entire soil profile of Trench 1 was nearly saturated after only 10 days; however, only a quarter of the soil profile of Trench 2 was saturated in twice that time. The difference in the wetting-front advancement of the two soil profiles was likely caused by a difference in pore water velocity (v). Also, the air-entry potential of the C horizon in Trench 2 may have contributed to the slow advancement of the wetting front. Low v values and a high air-entry potential would result in slow wetting advancement. The θs values of each horizon in Trench 1 were less than the corresponding values in Trench 2 (see Table 14), which would result in higher v, because v is inversely proportional to θs ($v=q/\theta$). Additionally, the air-entry potential of the C horizon in Trench 2 would be relatively high, which may result in slower penetration of water into the soil profile. The air-entry potential is the pressure potential that is required for water to enter into a pore and is generally taken to be $1/\alpha^*$ in Equation 3. The air-entry potential of the C horizon in Trench 2 was approximately 14 cm of water, which was greater than the imposed boundary condition of 5 cm of water. Comparatively, the top two horizons in Trench 1 had air-entry potentials of 7.8 and 6.3 cm, respectively, which were closer to the imposed boundary condition and required less energy to penetrate the soil. The argillic horizon (approximately 50 cm in depth) in Trench 1 appeared to have little influence on wetting-front movement through the soil profile.

Root Water Uptake

The simulation of root water uptake of *Agave murpheyi* from Trench 1 is presented in Figure 26. The pattern of water uptake from Trench 2 was similar, but it had more available water for plant transpiration. The greater availability of water in Trench 2 could sustain plant growth for a longer period of time, assuming the soil was initially wet. There is a strong advantage of agricultural production at Trench 2, on the Holocene floodplain, if the soil was initially wet, such as after a flooding event. However, the infiltration of the water into the Trench 2 soil would be slow if the soil was initially very dry. The Pleistocene terrace where Trench 1 was placed may have an advantage for runoff farming, because it is capable of responding rapidly to water input, such as that from small runoff events that would characterize this setting. The lower water-filled pore space of Trench 1, however, would make this soil less beneficial than the Trench 2 soil over long periods of aridity. The argillic horizon (approximately 50 cm) in Trench 1 would retain more water than the rest of the horizon and limit water loss, but its lower porosity would result in less available water for plant uptake. Consequently, Trench 2,

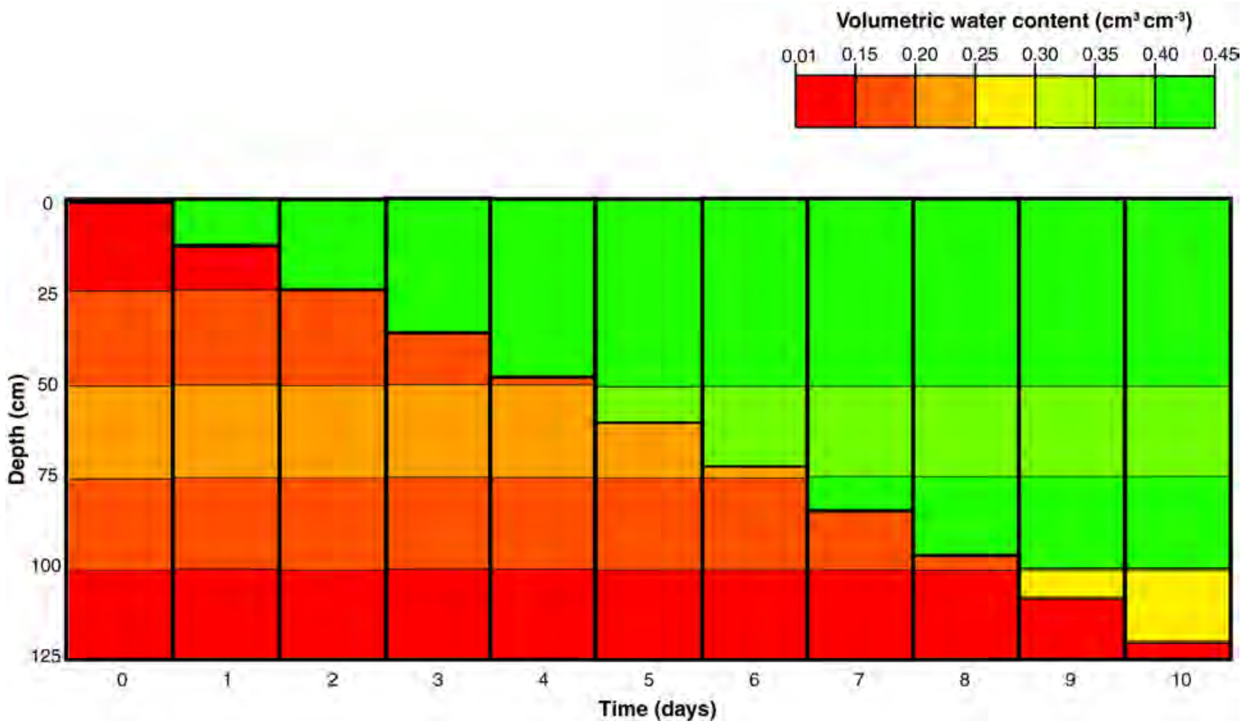


Figure 24. Model of wetting front, based on infiltration rates for Trench 1.

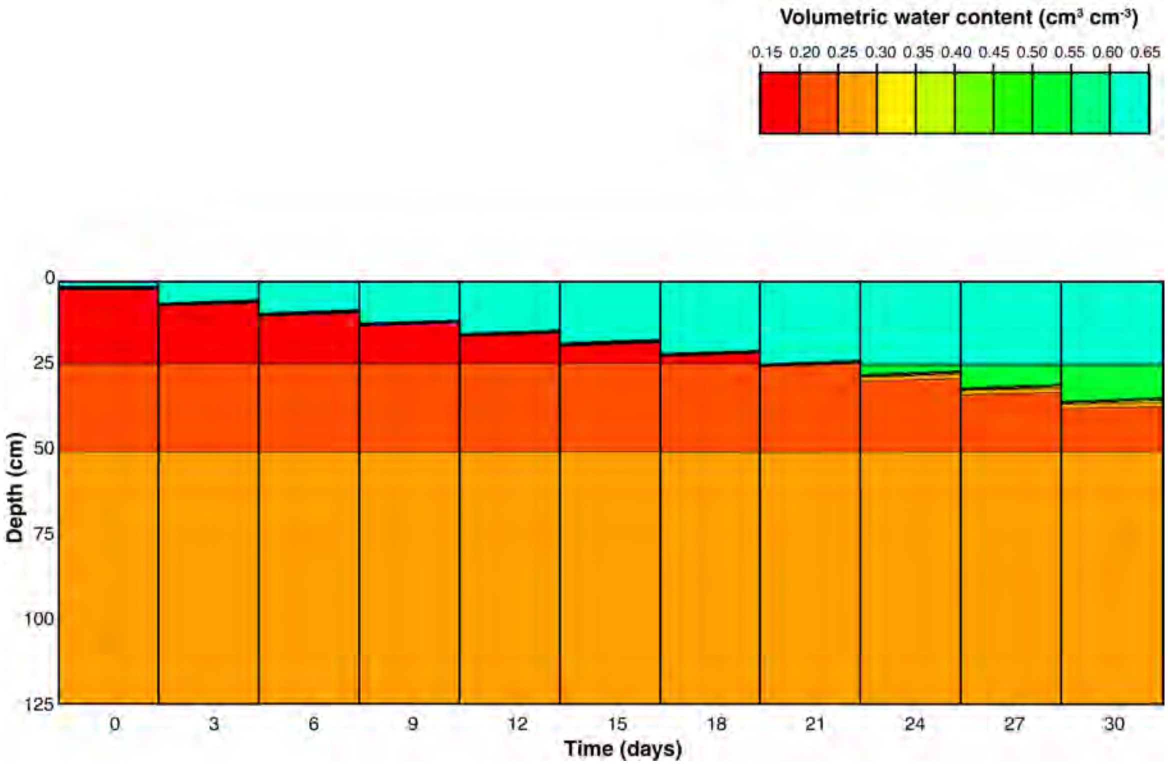


Figure 25. Model of wetting front, based on infiltration rates for Trench 2.

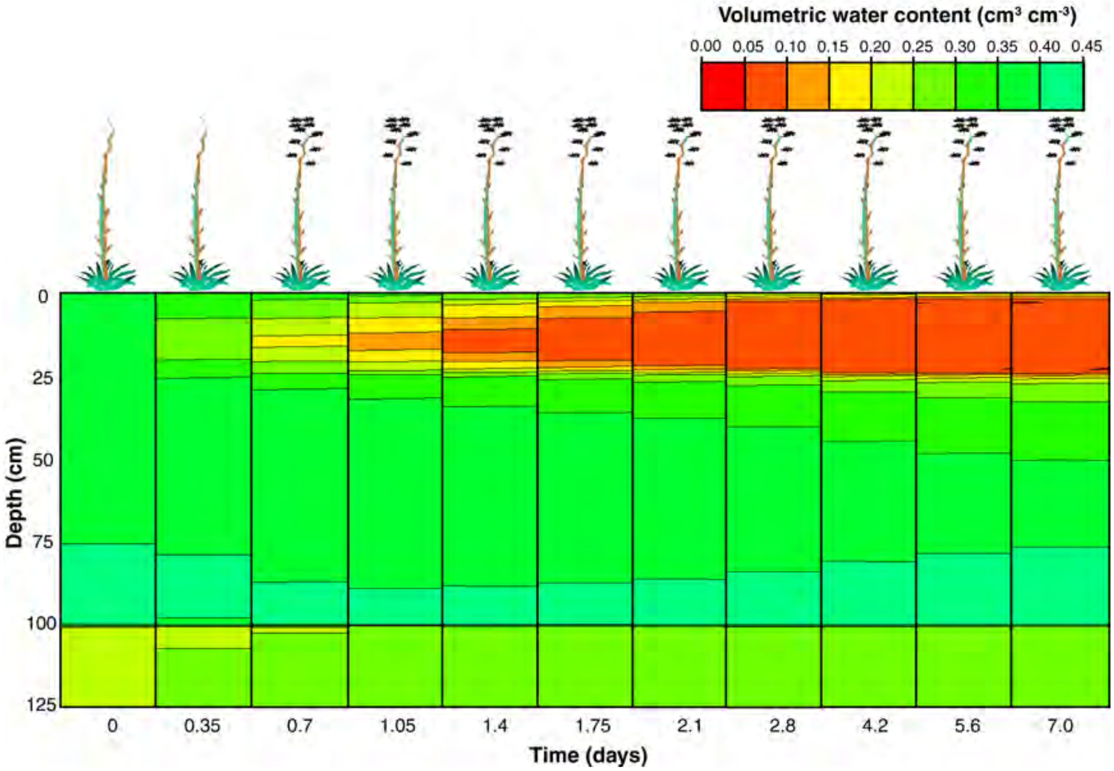


Figure 26. Model of water uptake by agave roots.

on the Holocene floodplain, is in a more-advantageous setting for water availability than the Trench 1 setting on the Pleistocene terrace.

Model of Agricultural Soil Quality

Soil-quality map Figure 27 integrates properties in the model of agricultural landscapes. Lands identified as prime farmland by the NRCS (see the red areas in Figure 27) are concentrated in well-watered, fertile soils along perennial drainages, where irrigation agriculture is best suited, and in smaller pockets of land flanking those drainages. Rock-pile fields are strongly associated with very to extremely gravelly and cobbly soils on the terraces of alluvial fans and streams. Areas best suited to runoff farming include landforms with 2–8 percent slopes. Most rugged and mountainous terrain is unsuited for agriculture.

Some areas of prime farmland occur in the immediate vicinity of the Mescal Wash site (see Figure 27). Prime farmland (the red areas in Figure 27) is likely where floodwater farming, and possibly even irrigation, was practiced. If irrigation systems were established, they would have to be small-scale systems, given the relatively small size of the areas of prime farmland along Cienega Creek. The presence of this prime farmland, combined with a perennial potable water source, likely explains the location of the intense archaeological occupations at the Mescal Wash site. Prime farmland occurs in pockets of alluvium along Cienega Creek near the Mescal Wash site and in larger expanses in the Mescal Wash drainage system to the north and northwest. Because Cienega Creek was a perennial drainage in prehistory along that reach, it likely supplied floodwater-agricultural fields with a more reliable water source than did Mescal Wash, even though the pockets of prime agricultural land are smaller and more dispersed along Cienega Creek than along Mescal Wash.

Large expanses of very gravelly or very cobbly soils (areas with more than 35 percent rock fragments, the yellow areas in Figure 27) are located near the Mescal Wash site. Rock-mulch- and runoff-agricultural fields could have been placed in pockets of rocky areas, with the rocks used to build rock alignments and rock piles, especially areas where runoff water is naturally concentrated. There has been so little archaeological survey in these very gravelly to very cobbly, rocky areas, however, that the true extent of non-irrigated agriculture in these rocky areas is unknown. Areas with greater than 8 percent slopes (the green areas in Figure 27) are unlikely to have been used for any type of agriculture, although a variety of wild-plant foods are available in those areas.

Figure 28 presents a model of agricultural soil quality for much of southeast Arizona, extending from the Tucson Basin eastward to the Wilcox Playa and southward to near the Mexican border. Areas in the north-central part of the map were not modeled, because of the lack of digital soil-survey data at the time when we initiated this study (these areas have since been digitized, and so, it is possible to add these areas and extend this model). It is clear in Figure 28 that large expanses of prime farmland exist along the Santa Cruz River in and adjacent to the Tucson Basin. These large expanses of prime farmland undoubtedly explain the relatively high concentrations of archaeological sites, including many villages and other kinds of settlements, along the Santa Cruz River. Large areas of prime farmland flank the Wilcox Playa and the Sulphur Springs valley to the north and south of the playa, areas that have been used extensively for agriculture, in prehistory as well as today. It is interesting to note that at the scale depicted in Figure 28, the pockets of prime farmland in the Cienega Creek–Mescal Wash confluence area near the Mescal Wash site are barely visible. Even though pockets of prime farmland do exist near the Mescal Wash site, their relatively small size suggests that inhabitants of the site relied on more of a mixed subsistence economy that included wild-plant and animal foods, in all likelihood to a greater degree than farming communities along the Santa Cruz River and in the Sulphur Springs Valley. It is interesting that relatively little prime farmland was identified along the San Pedro River, although digital soil-survey data were missing from this model for much of the San Pedro; if soil-survey data for this reach were added, then it would undoubtedly add some pockets of the floodplain that would be classified as prime farmland.

Archaeological site data obtained from the AZSITE database indicated that the area shown in Figure 28 had 56 sites with canals (or “ditches”), 66 sites with check-dams, 69 sites with agricultural terraces, and 780 sites with rock piles. Many of these agricultural features are concentrated along the Santa Cruz River and, to a lesser degree, along tributaries of the Santa Cruz River, such as the Rillito River and Pantano Wash, and drainages, such as the San Pedro River. Not surprisingly, many of the canals are associated with prime farmland in alluvial areas. Rock piles are concentrated on alluvial fans that flank the larger drainage systems.

All agricultural systems are concentrated on gently sloping terrain where water could be controlled and conserved. Most agricultural features were built on slopes of less than about 8 percent. Irrigated and floodwater fields were mainly established on floodplains (areas with low slope gradients, typically below 1 or 2 percent), runoff fields in and at the mouths of ephemeral drainageways on alluvial fans, and rock-pile fields on cobbly ridges and fan terraces.

The soil-quality model presented in Figure 27 is based on a number of soil properties, slope aspects, and slope gradients that were analyzed using the SSURGO database and the USGS DEM. The soil properties and the range for each soil and gradient property used in this analysis are listed in Table 15. Prime farmland tends to have the best

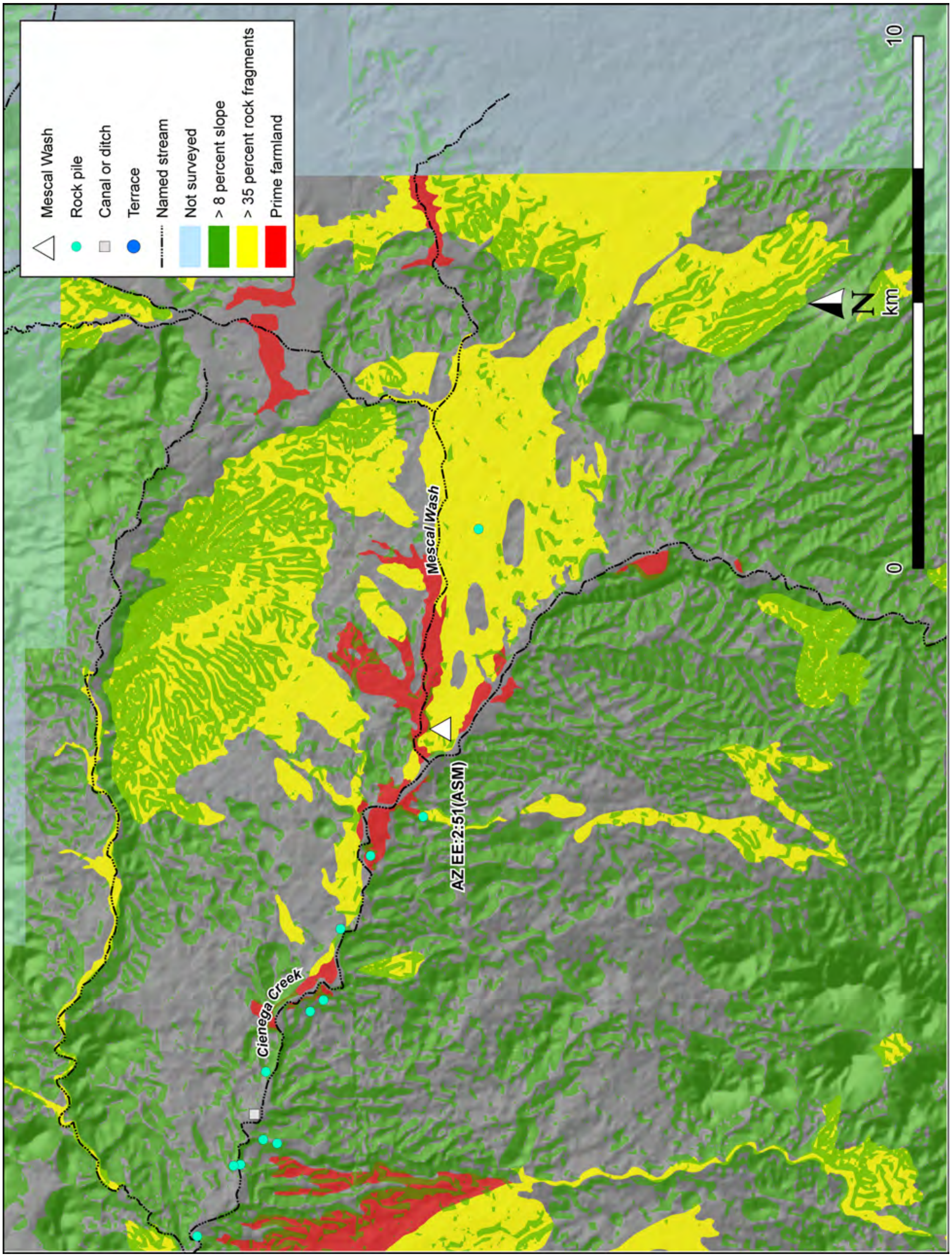


Figure 27. Model of agricultural soil quality in the vicinity of Mescal Wash site.

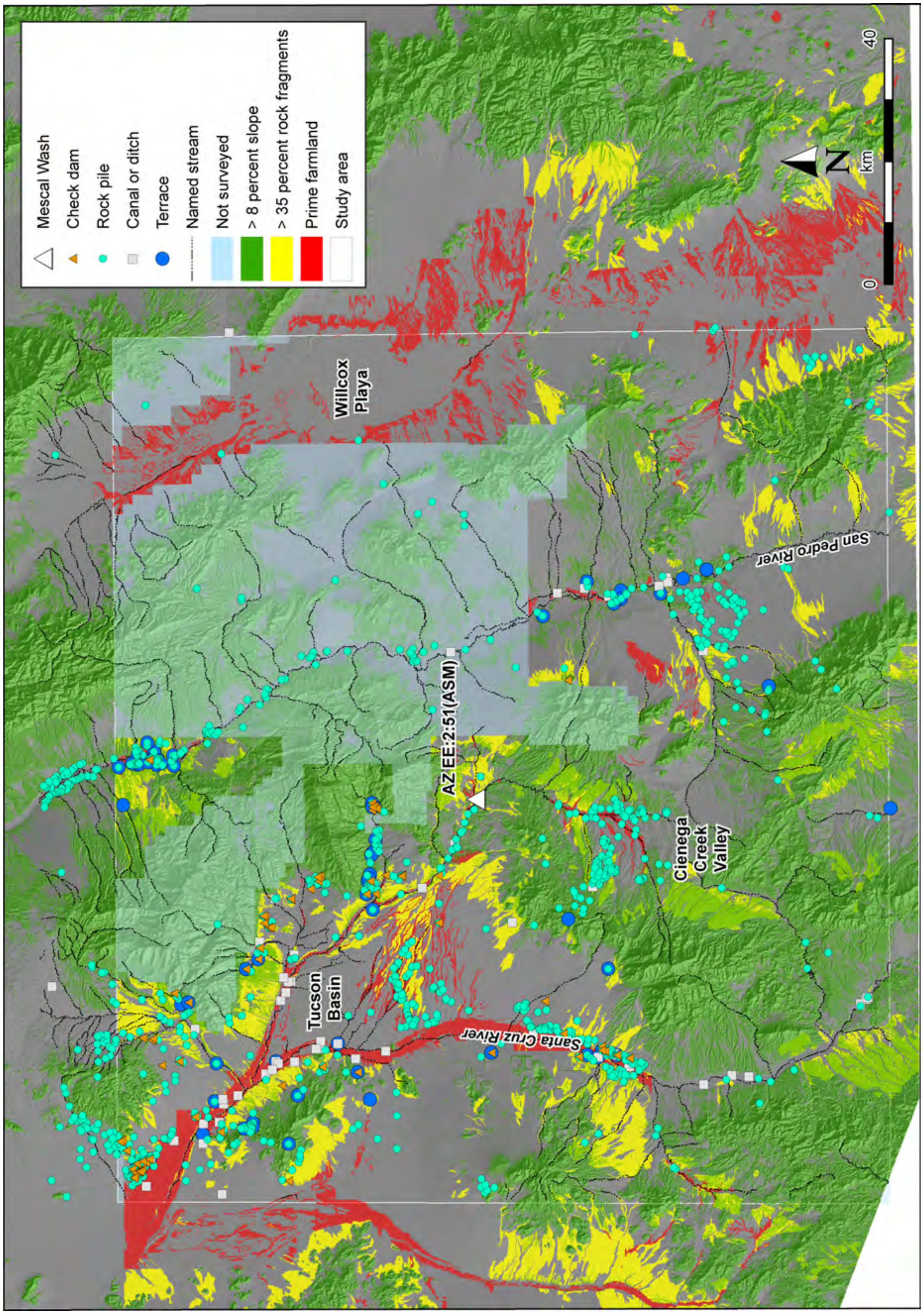


Figure 28. Model of agricultural soil quality in southeastern Arizona.

Table 15. Soil Properties Used in the Soil-Quality Model in Relation to Ancient Agricultural Features in Southeastern Arizona

Description, by Soil Property	Range	Relative Area (%)	Sites with Agricultural Features (%)			
			Canals	Checkdams	Terraces	Rock Piles
A horizon (cm)						
Thin	0–25	77	46	71	78	86
Medium	25–50	15	34	8	9	8
Thick	>50	8	20	21	13	6
Available water capacity (AWC) (cm^3/cm^3)						
Very low	0–0.05	32	4	21	43	26
Low	0.05–0.10	23	38	38	23	32
Medium	0.1–0.15	29	16	36	29	32
High	0.15–0.20	16	43	5	4	11
Total AWC						
Very low	0–8	34	4	33	51	31
Low	8–16	25	45	32	23	32
Medium	16–24	28	32	33	23	32
High	24–32	13	20	2	3	4
Bulk density (g/cm^3)						
Restricted	depends on texture	41	4	36	28	34
Somewhat restricted	depends on texture	44	70	38	41	49
Unrestricted	depends on texture	15	27	26	32	17
Calcium carbonate (%)						
Very calcareous	>10	25	14	32	14	27
Calcareous	5–10	19	18	26	42	22
Slightly calcareous	2–5	22	41	17	22	25
Slightly calcareous	1–2	8	16	8	3	17
Very slightly calcareous	0.5–1	8	9	6	1	4
Noncalcareous	<0.5	18	2	12	17	5
Cation-exchange capacity (meq/100g)						
Low	0–10	53	59	42	65	39
Medium	10–20	34	41	50	33	51
High	> 20	13	0	8	1	9
Depth to Bt horizon (cm)						
Very shallow	0–15	54	0	73	0	58
Shallow	15–50	10	18	14	51	11
Deep	50–150	4	5	0	3	1
Very deep	>150/absent	31	77	14	46	29
Depth to restrictive layer (cm)						
Very shallow	0–15	55	14	68	51	48
Shallow	15–50	24	11	23	3	30
Deep	50–150	3	2	0	0	2
Very deep	>150	18	73	9	46	21
Electrical conductivity (dS/m)						
Strongly saline	≥16	1	0	0	0	0
Moderately saline	8–16	0	0	2	4	3
Slightly saline	4–8	1	0	17	7	1
Very slightly saline	2–4	4	13	2	6	7
Non saline	0–2	93	88	80	83	90
Organic matter (%)						

Description, by Soil Property	Range	Relative Area (%)	Sites with Agricultural Features (%)			
			Canals	Checkdams	Terraces	Rock Piles
Low	0–0.5	35	32	62	64	60
Medium	0.5–1.0	30	18	21	19	20
High	>1.0	29	27	12	9	6
Undetermined	—	5	23	5	9	15
pH						
Poor	<6.0/>8.4	3	0	0	0	0
Fair	7.9–8.4	43	80	62	62	56
Good	7.4–7.8	33	16	29	28	35
Optimal	6.1–7.3	21	4	9	10	9
Sodium-adsorption ratio (proportion of Na to Ca+K+ Mg)						
Very high	>12	2	0	0	0	1
High	6–12	5	54	68	17	8
Medium	3–6	5	0	23	0	4
Low	0–3	87	46	0	83	87
Texture						
Poor	sand, loamy sand	4	5	11	22	11
Fair	non-loamy and non-sandy	46	29	47	54	33
Good	loamy	51	66	42	25	56
Rock fragments (%)						
Not rocky	0–15	56	61	33	42	31
Rocky	15–35	31	27	42	26	36
Very rocky	35–60	8	9	9	14	18
Extremely rocky	>60 percent	5	4	15	17	15
Aspect (degrees)						
North	337.5–22.5	19	29	10	17	18
Northeast	22.5–67.5	13	7	3	9	6
East	67.5–112.5	12	5	10	10	12
Southeast	112.5–157. 5	10	4	13	22	10
South	157-5–202.5	10	2	16	12	12
Southwest	202.5–247.5	11	11	23	14	11
West	247.5–292.5	11	18	12	7	15
Northwest	292.5–337.5	14	25	13	9	16
Slope (%)						
Flat	0	8	18	1	1	4
Very low	0–2	23	41	29	13	24
Low	2–5	23	30	39	22	39
Medium	5–8	10	9	20	16	16
High	8–11	6	0	0	19	8
Very high	>11	30	2	10	29	9

mix of these properties—for example, greater A-horizon thickness, high available-water capacity, bulk densities that do not restrict root elongation (that is, are not compacted), high CECs, shallow depth to the Bt horizon (at least for nonriverine agriculture), deep rooting depth (that is, not restricted by shallow bedrock or petrocalcic horizons), low electrical-conductivity levels, high organic-matter levels, optimal pH levels (especially between pH **6** and 7), low SARs, intermediate textures (especially loamy textures, such as loams, silt loams, clay loams, silty clay loams, and sandy loams), low percentage of rock fragments (except for runoff- and rock-mulch-agricultural systems), and low slope gradients (but not flat; slopes between about 2 and 8 percent, which is sufficient to generate runoff but not rapid enough for runoff to cause gully and sheetwash erosion and to reduce infiltration). Each of these soil properties was divided into different ranges important for assessing soil quality and spatial distributions. These properties were mapped and integrated to produce a model of soil quality, including indication of areas of prime farmland.

Separate maps were produced for many of the properties listed in Table 15, but only some of the most critical ones are briefly discussed in this section, including available water capacity, organic matter, depth to restrictive layer, and SAR.

As discussed in the previous section on soil hydraulic properties, available water capacity is a crucial variable, and that is especially true for agricultural sustainability in desert settings. Although floodplains along the major rivers are the best-watered locales, the loamy soils of alluvial fans tend to have the highest available water capacities. Because the floodplains are better watered, however, these are areas where prime farmland is concentrated. Upland soils tend to have the lowest available water capacities, because of shallow bedrock or petrocalcic horizons.

Soils with higher organic-matter contents are the most productive agricultural soils. Organic-matter content is typically low in the study area, because of high oxidation rates and relatively low rates of biomass production. Soils with the highest organic-matter contents are mainly along the Santa Cruz River floodplain and the floodplains of other perennial drainage systems, in *bajadas* flanking the uplands, and in the mountains at elevations too high for agriculture.

The depth to restrictive layers is shallowest in soils that occur in upland settings and deepest in bottomlands. The depth to restrictive layers, especially bedrock and petrocalcic horizons, limits the volume available to plants for water and nutrient uptake. Shallow soils are advantageous to shallow-rooting crops, such as agave, because moisture is conserved in the root zone. Most crops, however, are more productive in deeper soils, such as alluvial bottomlands.

SAR is a measure of the proportion of sodium ions to the concentration of calcium and magnesium ions. High to very high SAR levels cause soils to become hard and cloddy when dry, to develop crusts, and to take in water very slowly. They limit the ability of plants to absorb water. High to very high SAR levels occur in 7 percent of the study area, mainly in low-elevation landscape positions around the Wilcox Playa and along the Santa Cruz River. SAR hazards can be managed by flushing salts below the root zone in irrigated soils.

Conclusions

The Mescal Wash site is located on an important frontier that served as a meeting ground in prehistory for diverse cultures and peoples, intermediate between those who lived in the Tucson Basin to the west and those who lived along the San Pedro River to the east. Hilly and mountainous terrain to the north and south of the Mescal Wash site has constrained transportation routes between the Tucson Basin and the San Pedro River to a corridor that crosses the Mescal Wash site, even today, where I-10 was constructed to avoid rugged terrain to the north and south. The location of the Mescal Wash site is noteworthy, because its location provided ready access to food resources along Cienega Creek, on the *bajada* flanking the Rincon Mountains to the north, and in the mountains. A mixed economy based on floodwater farming, gathering of wild foods, and hunting was the primary pursuit at the Mescal Wash site.

Soil productivity was assessed in this study based on soil maps, laboratory data on soil properties useful for measuring soil quality, and field and laboratory investigations of hydraulic soil properties.

Digitized soil maps and databases were useful for modeling soil quality in ancient agricultural landscapes for much of southeastern Arizona. The model is the most significant result of this study, because it can be used to evaluate archaeological site locations and site types, especially settlements associated with agricultural land, for a vast part of Arizona. Because of the high resolution of this spatial model, it is possible to focus on small areas by enlarging specific parcels and cropping out the rest of the map, as was done for the area immediately around the Mescal Wash site. That exercise indicated that small pockets of prime farmland exist in the Cienega Creek–Mescal Wash area, but they pale in comparison to the large expanses of prime farmland along the Santa Cruz River to the west and in the Sulphur Springs Valley to the east. That finding indicated that occupants of the Mescal Wash site likely relied on a mixed subsistence economy that included agriculture, collection of wild-plant foods, and hunting. The location of the Mescal Wash site is well positioned to take advantage of both local riparian resources and nearby upland settings, including those of the Rincon Mountains to the north.

The model of soil quality presented in Figure 28 generally conforms well to locations where archaeological traces of agriculture have been identified in association with irrigation, runoff, and rock-mulch systems.

Pedology and soil physics were used to investigate soils properties for two trenches: Trench 1, on the Pleistocene terrace at Locus B of the Mescal Wash site, and Trench 2, on the Holocene floodplain near the Mescal Wash site. Soil properties indicate that the Holocene floodplain is more fertile and has a number of favorable soil hydraulic properties. Infiltration measurements and laboratory experiments indicated that a hydraulically restrictive horizon occurs in the soil profile of Trench 1, which corresponded to an argillic horizon. The presence of that argillic horizon is advantageous in terms of moisture retention, which would be favorable to runoff and rock-mulch agriculture in similar settings. The soils of Trench 2, by contrast, are less compacted and have a greater porosity, which strongly influences water transfer and retention. The higher porosity resulted in slower percolation rates because of slower pore-water velocities, but water content is greater in Trench 2, at near-saturated pressure potentials. The differences in soil properties in Trenches 1 and 2 caused differences in wetting-front advancements, when ponded infiltration was simulated. The soils of Trench 2 had much slower wetting-front advancement than Trench 1. Furthermore, the argillic horizon in Trench 1 had little influence on the wetting-front advancement under saturated movement of water. Model simulation suggested that water would be readily available to *Agave murpheyi* in the soil of Trench 1, as well as in Trench 2, provided the soil was initially wet. Agave or other drought-tolerant crops would most likely have been cultivated in settings similar to Trench 1. Maize and other crops that require more water would have been best adapted to the soils of Trench 2, a setting where floodwater farming, possibly even irrigation, was likely practiced.

Although we were unable to pinpoint the precise locations of agricultural fields near the Mescal Wash site, we designed a useful approach for modeling soil quality near the site, using soil-map data combined with measurements of a variety of chemical and physical soil properties and soil water-transfer measurements and simulations. Our GIS study permitted us to effectively model agricultural soil quality for much of southeastern Arizona. We recommend that future investigations expand this model to include the San Pedro River area, which lacked digitized soil data when we started this investigation. We also recommend that archaeologists use this model to help model agricultural soil quality and the mix of subsistence at other sites, especially agricultural settlements, in other parts of southeastern Arizona.

CHAPTER 4

Household and Community Structure

Richard Ciolek-Torello

Introduction

As stated in the original research design (Altschul et al. 2000), the Mescal Wash site was seen as a fascinating archaeological phenomenon located in a poorly understood part of southeastern Arizona. Like many archaeological sites in this region, Mescal Wash is located at the nexus of different environmental zones—the Sonoran and Chihuahuan Deserts—and cultural regions—the Hohokam and Mogollon. People used the site area repeatedly for hundreds, if not thousands, of years. We borrowed the term "persistent places" (Schlanger 1992) to describe such sites. For most of that occupation, social and economic adaptations were stable, and small communities practiced a broad-spectrum subsistence strategy focused on a mix of domesticates and native resources. We applied a farmer-forager and village-farmer model developed by SRI for the upland "Transition Zone" of central Arizona (Ciolek-Torrello et al. 1994) to the settlement-subsistence strategy at Mescal Wash. In its broadest terms, the model contrasts long-term occupation by people who practiced a mixed agricultural economy and lived in small, dispersed communities—farmer-foragers in *rancherías*—with a briefer occupation by larger, more densely settled people with a greater dependence on farming—village farmers. Throughout much of central and southern Arizona, village farmers replaced farmer-foragers for a relatively brief period late in prehistory, before much of the region was abandoned (Ciolek-Torrello et al. 1994; Elson et al. 1995; Rice et al. 1998; Whittlesey et al. 1998).

Preliminary investigations suggested that late in prehistory, Mescal Wash experienced a more intensive and aggregated occupation, like many other persistent places in the neighboring San Pedro Valley and Tucson Basin. According to the forager-farming model, these aggregated settlements represented a shift by farmer-foragers to a more intensive agricultural strategy, a shift that we believed could not be sustained in the Chihuahuan Desert. Thus, we believed Mescal Wash to be a suitable case to test the farmer-forager and village-farming model, as well as the concept of persistent places.

The study of household and community organization, the primary line of inquiry for this chapter, can provide important insights into evaluating the model. Domestic-group size and organization are closely related to agricultural production and land tenure. In an attempt to explain the relationships among group size, domestic organization, and food production in central Arizona, Ciolek-Torrello (2012) recast Flannery's (1972) hypothesis, which proposed that large but loosely structured residential groups are associated with communal ownership of land and resources in economies with a relatively low investment in food production. As food production is intensified along with labor investment, ownership of land and resources at the household level becomes more important. These changes are associated with the emergence of more nucleated and structured arrangements of households as the primary residential groups. Like much of central and southern Arizona, these more nucleated settlements are evidenced in southeastern Arizona by compact settlements of aboveground adobe rooms, often surrounded by compound walls, as found at Babocomari Village, the Garden Canyon site, the Second Canyon Ruin, and Villa Verde (Altschul et al. 1999; Franklin 1980; Heckman 2000). Research in the Lower Verde Valley has suggested strong relationships among a reduction in household size, more structured communities, and the intensification of food production (Ciolek-Torello 2012; Ciolek-Torrello et al. 2000; Klucas et al. 1998). Taking a slightly different perspective, Huntington (1986) argued that large residential groups, such as extended households in the Tucson Basin, were better able to manage food production and collection where agricultural land and other food resources were widely dispersed, whereas smaller households were more efficient where land and resources were concentrated.

Among the variables to explore in evaluating the model are domestic-group size and composition, activity organization, occupational duration and intensity, and stages in the cycle of domestic groups. Mobility and site reoccupation must also be considered. Did the residents of Mescal Wash represent a largely independent and isolated group, or were they seasonal visitors from larger, more permanent communities in surrounding regions? Of particular importance is determining whether there was a change in domestic-group composition over the course of the site's occupation.

A second line of inquiry focuses on Mescal Wash's borderland location at the crossroads of major southwestern cultures, such as the Hohokam, Mogollon, Salado, Mimbres, and Chihuahuan. The basic issues are who the people that lived at Mescal Wash were and whether they changed over time. To address these questions, we must understand the cultural character of the population over time and compare it with neighboring populations. Can the residents of Mescal Wash be identified as Hohokam or Mogollon, or did they represent a distinctive indigenous population or a mixed community with coresident members of different cultural groups? Finally, did the cultural composition of the community change over time? Past research has demonstrated that architecture, activity organization, and domestic arrangements can provide important clues regarding the cultural composition of a community (Ciolek-Torrello 1998; Clark 1995, 2004; Gregory 1995; Wheat 1955).

A Theoretical and Methodological Perspective on Households and Domestic Groups

The household is viewed here as the fundamental and elemental social and economic unit in preindustrial societies. It is isomorphic with the basic unit of consumption and is distinguished from the reproductive unit commonly known as the family (Ciolek-Torrello and Reid 1974; Goody 1972; Wilk and Rathje 1982). The family as a set of individuals and the household to which those individuals may belong are not necessarily the same (Buchler and Selby 1968:21–23). As Wilk and Rathje (1982:618) have pointed out in their classic work on household studies, *household* can be defined as

> the most common social component of subsistence, the smallest and most abundant activity group. This household is composed of three elements: (1) social: the demographic unit, including number and relationship of the members; (2) material: the dwelling, activity areas and possessions; and (3) behavioral: the activities it performs. This total household is the product of a domestic strategy to meet the productive, distributive, and reproductive needs of its members.

In addition to these definitions of *household*, it is important to consider the fundamental functions of households. Douglass and Gonlin (2012:3-5) have recently summarized and expanded upon Netting et al.'s (1984) classic definition of the five primary functions of households, discussing the five functions below:

1. *Production* is "human activity that procures or increases value of resources" (Wilk and Netting 1984:6). This activity can range from farming the land or grinding maize to raising a house or fetching water.

2. *Distribution* is another widely recognized activity of the household and involves moving material from producers to consumers. The exchanges and transactions within and among households fall into this domain, as does the consumption of food and goods.

3. *Transmission* of material wealth and non-material items, such as titles or positions within a sociopolitical system, is colloquially referred to as inheritance. Inheritance is affected by such variables as amounts of land, degree of agricultural intensification, population density, family preferences, and a host of other criteria.

4. *Reproduction* encompasses the generation of new family members by birth. Although this activity is common to most households, it does not have to occur within the domains of the household, nor does it occur between most members of a household.

5. *Coresidence* is not necessary for many functions of the household, although it has previously been assumed to be a criterion of households. Definitions of *family* are explicitly characterized by coresidence (Murdock 1966:1), although there are many exceptions.

It is also important to note that households are not equated with families. Families are social units with fictive or actual kin relationships, whereas households are defined based on behavior, and members may or may not be related (see Buchler and Selby 1968:21–23; Ciolek-Torrello and Reid 1974; Lightfoot 1994:12; Netting et al. 1984:xix–xxi).

Households are not static but are constantly changing, in terms of both their composition and the activities they perform. Some of these changes can be viewed from the perspective of the developmental cycle of domestic groups. According to this model, the domestic group, of which the household is a part, goes through a cycle of normal development analogous to the growth of a living organism: "The group as a unit retains the same form, but its members or the activities which unite them, go through a regular sequence of changes during the cycle, which culminates in the dissolution of the original unit and its replacement by one or more units of the same kind" (Fortes 1971:2).

Fortes (1971:4–5) divided the cycle into four developmental phases. The first phase involves the establishment of the domestic group. The domestic group then goes through an expansion phase as parents have offspring and unattached adults (e.g., grandparents, widowed aunts or uncles, or other relatives) join the group. The third phase involves the dispersion or fission of the domestic group as children marry and either move out or establish their own households adjacent to the parent household. The fourth phase, replacement, involves the death or dispersion of the parent household and its replacement in the social structure and settlement by the families of its offspring. This developmental cycle provides an "ideal" model of expected change against which other changes in domestic groups can be measured. Under ideal conditions, a domestic group should proceed through the normal phases of establishment, expansion, fission, and replacement.

Finally, households are not isolated occurrences on a landscape but are components of larger communities, whether they are individual households, clusters of households, or something else. Kolb and Snead (1997:611) have defined *community* as a "spatially defined locus of human activity that incorporates social reproduction, subsistence production, and self identification." That is, communities are the settings for households and their activities (see Mobley-Tanaka 2010:34).

With this conceptualization of households in mind, how does one define households in the Southwest through time and space? Generally, households are defined by the physical remains left behind. Although artifact distributions can play a key part in defining households, preservation of in situ artifacts representing domestic activities are rare at most southwestern desert sites, and Mescal Wash is no exception. There, as at most archaeological sites, the architectural elements are the most readily available indicators of households. Although there is wide variability in the architecture associated with households, that variability reflects the diverse activities of household members and temporal change. But in a behavioral approach to household analysis, as used here, the focus remains on the activities that a household conducted rather than only the elements of social organization. From a practical standpoint, households are not equated with individual pit houses in a behavioral approach (see Wills 2012). Rather, the ethnologist, Goody (1972:9) is followed, and he equated what has traditionally been called the household with the unit of consumption (the commensal unit), although he recognized the greater variety of boundary-maintaining units in the broader rubric of the domestic group.

In this approach, the focus is placed on the distribution of intramural hearths as representative of commensal cooking activity, storage features, food-processing technology, subsistence remains, and burials, in addition to architecture. Wills (2012:188–189; see also Wills 2001:494) emphasized the importance of the formal hearth as the focal point of households and the "tremendously strong symbolic connection between" the female members of a household and the hearth. Similarly, Whittlesey (2010a:73) wrote, "The household hearth may have been a deeply layered symbol of femaleness, with connotations of food, fertility, nurturing, warmth, and shelter. . . . So pervasive is this symbolism that among some ethnographically described peoples, certain domestic units are equated with the hearth. . . ." Equating the hearth with the household is not a novel notion; it has a long tradition in anthropology (Beaglehole 1935:42; Kroeber 1917). Wills (2012:190) also asserted that hearths "establish commensal rights. People who cook and eat at the same hearth share food and rights to that food. . . . Formality marks the relative importance of the hearth in centering the group. The more formal (and therefore expensive) the hearth, the more likely it is that the hearth group is durable . . . and the more likely it is symbolic of group identity." Similarly, Weismantel (1989:57) wrote, "The existence of a household is defined by the presence of a kitchen. . . . [Although] other buildings are storage rooms and sleeping places; only the kitchen is home." Wills (2012:189) recognized, however, that "individual hearths cannot be assumed a priori to correspond to single households; they may, but this is a correspondence that has to be established contextually in every case."

Thus, not all hearths are equal. Cooking activities are represented at prehistoric sites in southern Arizona by different types of hearths: formal, clay-lined hearths and slab-lined fireboxes; informal firepits and oxidized pits; and roasting pits and *hornos* or pit ovens. The last, however, are not found in intramural contexts. We identify domestic hearths—those most closely associated with the kitchen and the commensal unit—as formal, prepared cooking features, such as clay-lined firepits and slab-lined fireboxes (the latter are restricted to the latest phase of occupation in the region [see Tuthill 1947:Plate 7a] and won't be considered further here). The formal hearth is considered here to represent the cooking hearth associated with the household as a commensal unit. The energy invested in constructing these types of hearths and their standardized placement in the house meets Wills' (2012:188–190) criteria for the "focal point" and for symbolic representation of the household (see also Whittlesey 2010a; Wills 2001). Formal hearths are each invariably located in a central location, aligned with the house entry, whereas informal firepits are often located on the peripheries of house floors (Ciolek-Torrello and Greenwald 1988; Klucas et al. 1998). Unprepared firepits and oxidized pits may also have been used in food-preparation activities but were not the primary facilities employed by a household for that purpose;

the lack of preparation and the light oxidation that distinguishes these features suggest that they were not used routinely and were probably ancillary cooking features or were used for other purposes. Thus, houses lacking formal hearths or with only simpler, unlined firepits should not be equated with households (see Whittlesey 2010a; Wills 2001, 2012).

Other domestic activities can also inform on the identification of households. Food-preparation activities are represented by manos and metates, although both have been rarely found in Mescal Wash houses. Storage activities are represented by bell-shaped pits; shallow, basin-shaped pits; and small structures lacking interior features. Manufacturing activities are represented by the tools and raw materials used in manufacturing ceramic vessels and other implements. Evidence of these activities has been rarely found on Mescal Wash house floors, and thus, manufacturing activities could not be documented in this study.

The various implements and facilities representing these domestic activities are not randomly distributed among project pit houses and surface rooms. As in the case of other sites in the Southwest, different types of house functions at Mescal Wash can be distinguished on the basis of common associations. Doyel (1981) first applied Hill's Puebloan room-function typology to Hohokam Classic period adobe structures, distinguishing habitation, storage, and ceremonial structures in the Escalante Ruin Group based on house size, architectural and floor features, and associated artifacts. A habitation is a larger structure distinguished by the presence of a formal or domestic hearth as well as a great diversity of the implements and facilities employed in domestic activities. It may also contain firepits and storage pits and vessels, as well as the remains of manufacturing and ritual activities. By contrast, storage areas are more specialized and have often been distinguished by the absence of evidence of activities. Using similar characteristics, others have extended this typology to pre-Classic period Hohokam pit houses throughout central and southern Arizona (Ciolek-Torrello and Greenwald 1988; Ciolek-Torrello et al. 2000; Whittlesey 2010a). For example, Ciolek-Torello (2012; Ciolek-Torrello et al. 2000; see also Klucas et al. 1998) distinguished three types of pit houses at Scorpion Point Village in the Lower Verde Valley: (1) large habitation structures with formal, centered, clay-lined hearths aligned with formal entryways; (2) smaller habitation or multifunctional structures with formal, centered, clay-lined hearths or informal firepits, sometimes with entryways; and (3) the smallest structures, lacking hearths and entryways but often containing storage pits, suggesting a primary storage function. Storage structures ranged in size from 6 to 15 m^2, small habitations ranged in size from 8 to 16 m^2, and large habitations ranged in size from 20 to 37 m^2, with a definite break in the size distribution of the two habitations (Ciolek-Torrello et al. 2000:Figure 5). In most cases, a large habitation was paired with a small habitation or storage structure. Similarly, at the West Branch site in the Tucson Basin, Whittlesey (2010a) distinguished standard habitations as larger structures with formal hearths from smaller habitations with informal firepits, and from other small structures, which lacked both types of hearths and served special or indeterminate functions.

Hohokam and Mogollon Architecture and Site Structure

In order to address the issue of the cultural character of the residents of Mescal Wash from the standpoint of household organization, it is necessary to review the nature of contemporaneous Hohokam and Mogollon architecture and site structure. With the exception of the early Pioneer period houses, Hohokam houses usually have been described as houses-in-pits, as opposed to true pit houses (Wheat 1955:196; see also Deaver 2010:3-2–3-3). True pit houses incorporate the pit wall as the lower part of the house wall, and the superstructure is built on the ground surface surrounding the pit. The posts that form the skeleton of the pit-house walls are presumed to be embedded in the ground surface surrounding the pit, although the holes associated with those posts are rarely found. The pit walls, excavated as much as 1 m deep (Wheat 1955:196), were often plastered or covered by a thin clay lining. By contrast, the walls of houses-in-pits are built within the pit excavation itself, and the pit walls are often unfinished or unidentifiable. The posts that compose the wall skeleton of a house-in-pit are embedded around the periphery of the floor area at the base of the pit. The walls are often identified by a series of peripheral posts or a floor groove or narrow trench encircling the floor. The pits in which Hohokam houses were constructed were highly variable, ranging in depth from just below the surface to about 0.5 m (Haury 1976:72). Haury (1976:72) regarded the house-in-pit as the archaeological idiom of the Hohokam. House-in-pit architecture, however, was rare throughout the pre-Classic period in peripheral areas, such as Queen Creek (Sires 1984a:379, 1984b:118) and the Picacho Mountains (Ciolek-Torrello and Greenwald 1988). Both types of architecture also were in use at the Grewe site, a largely Sedentary period settlement in the heart of the Phoenix Basin (Hayden 1931).

Wheat (1955:196) also considered that Hohokam and Mogollon houses differed in terms of entryways. He suggested that lateral entryways were more common in Hohokam houses and that they usually ended in a step. By contrast, Haury (1976) argued that side entrances were equally common in Mogollon and Hohokam pit houses, but Hohokam entryways were considerably shorter and ended with a step because of the shallowness of Hohokam house pits, whereas Mogollon entryways were long, sometimes equaling the width of the house. Wheat also suggested that Hohokam hearths were usually more formal in construction and had plastered basins or clay-coped rims and that the placement of the hearth near the entryway was more consistent. Finally, he suggested that the Mogollon used a greater variety of roofing plans than the Hohokam, who consistently used a quadrangular or peripheral post plan supplemented by random interior posts. Haury (1976:72) suggested that the quadrangular pattern was most common in square Hohokam houses, whereas a two-post pattern with supplemental peripheral posts was more common in rectangular or elliptical houses, resulting in a ridged roof pattern.

Hohokam archaeologists generally consider the courtyard group as the elemental spatial unit associated with what Wilcox et al. (1981) called the "primary social group" in pre-Classic period Hohokam society. The courtyard group was made up of two or more contemporary pit houses with entryways that opened onto a common courtyard area that was the focus of domestic activities. Often pit ovens, trash mounds, and burial areas were located on the periphery of the courtyard group, suggesting that it represented the shared domain of a larger, corporate group. Focusing on coresidence rather than socioeconomic functions, Hohokam archaeologists tend to ignore the internal variability of courtyard groups and equate each with a single household (but see Huntington [1986] for an exception); some even go so far as to dismiss the possibility that a courtyard group may contain more than one household (Lindeman 2000:236; Wallace 2003:346).

However, a focus on the commensal unit and evidence of the locations of different domestic activities indicate much greater complexity in the organizational patterns of Hohokam households. For example, an informal, extended household pattern was evident at Scorpion Point Village, where courtyard groups comprised a variety of structures, including a single large habitation and either a smaller habitation or a storage structure (Ciolek-Torrello et al. 2000; Klucas et al. 1998; see also Ciolek-Torrello 1988). The smaller habitation (with limited storage and food-processing space) may have represented a small household that was dependent on the larger household that occupied the large habitation. By contrast, later Sacaton period courtyard groups were made up of two or more large habitations each, suggesting that each represented multiple independent households associated with a larger domestic group housed within the courtyard group. At the largely Middle Formative period (Rincon phase) West Branch site, Whittlesey (2010b:260–261) identified three types of households. Just under half the households were represented by individual isolated houses not spatially related to any others. The rest of the households were represented by "household clusters"—domestic groups represented by more than one household that shared a parcel of land. Among the vast majority of the household clusters, each cluster consisted of a pair of standard habitations that shared "closely spaced, angled or facing dwellings and associated courtyard space" (Whittlesey 2010a:261). Not surprisingly, the paired structures often differed in size (see also Huntington 1986), although there was not a regular pattern of paired large and small houses or a difference in function. Whittlesey (2010b:262) inferred that these household clusters represented related families or extended families living together. She further speculated that the relationships among paired houses could represent the construction of separate residences by adult children and their spouses next to their parental home (see Sires 1984b), fraternal or sororal associations (see Wilk 1984:228), or even polygamous marriage (although she rejected the latter as unlikely in the Southwest).

Mogollon settlements exhibited a much looser arrangement and generally consisted of 20–30 houses (that might be characterized better as hamlets) (Bullard 1962:109–110). These settlements appeared to have been quite stable, usually inhabited from several-hundred to a thousand years (Wheat 1955:35). Because of the lengthy span of occupation of most settlements, the actual number of contemporaneous houses may have been quite small. One generally recognized characteristic of the early Mogollon settlements is the lack of a plan; houses were built wherever it was convenient, with little regard for village organization (Bullard 1962:109; Wheat 1955:35). Two characteristics suggest that some kind of plan was present, however. A standard feature of Mogollon settlements is the presence of a single large and architecturally distinct pit house that was apparently used for communal or ceremonial purposes (Anyon and LeBlanc 1980; Bullard 1962:109; Wheat 1955:35). Often the communal house was located at the center of the settlement. Although large communal houses have not been found in the San Simon region, a smaller house showing similar distinctive architectural features is present at San Simon Village (Sayles 1945) and may represent what Anyon and LeBlanc (1980) referred to as "protocommunal" houses. The large P-4-type houses found in early Hohokam settlements in the Phoenix (Haury 1976) and Tucson (Wallace 2003) Basins may represent a similar function in early Hohokam villages (Doyel 1991).

Another feature of Mogollon settlements is the parallel arrangement of entryways with a generally eastward orientation for most houses (Gregory 1995; Wheat 1955:42). That arrangement, however, may reflect a culturally specified norm, rather than having organizational implications for the conduct of household activities (Gregory 1995). Alignments of houses with parallel east-facing entryways, however, have sometimes been suggested as evidence of Mogollon affiliation in other regions (Gregory 1995). However, Bernard-Shaw (1990) observed a "linear" arrangement for Tortolita phase (Early Formative period) houses at Lonetree and interpreted it as a product of conforming house arrangements to local landforms rather than a reflection of social structure.

Household Demography and House Size

An examination of the sizes of individual houses and the number of individuals they could have housed is essential to understanding the nature of the resident group. Many previous studies have estimated household size from archaeological data. Most have employed the total floor area or roofed area to estimate the number of individuals that composed a household, although Schlanger (1987) examined the "sleeping area" or "open floor" area—the portion of the house floor that did not contain pits or other facilities and was available for sleeping. A similar "total useable floor area" was calculated for many of the fully excavated houses at Mescal Wash. On the one hand, that calculation did not take into consideration the fact that interior pits could have been covered and used for floor space, and on the other hand, the comparable data were not available for the tested houses. Because of the limited information on "total useable floor area" for Mescal Wash houses, total floor area or roofed area was used to estimate household size. Unfortunately, one shortcoming of this approach is that it did not take into consideration the floor areas of houses-in-pits, which are contained within the smaller areas defined by the floor grooves rather than the pit outlines. Thus, the sizes of most of the Mescal Wash houses, which were based on the pit outlines, were overestimated.

In a worldwide ethnographic study, Brown (1987) calculated a cross-cultural average of 6.2 m^2 of roofed area per person. Brown's sample, however, included households from a wide variety of economic and social circumstances. Roof space per person should increase with greater sedentism, partly because of the greater amount of space devoted to storage and food-processing activities in permanent, long-term residences. Recognizing that factor, Dohm (1990) calculated an average of 9.7 m^2 of roofed area per person in nineteenth- and twentieth-century Navajo settlements and 17.7 m^2 per person in 22 modern Pueblo villages. Lightfoot (1994:149) used a combination of those two estimates to calculate the range in household size at the Duckfoot site. An alternative estimate was provided by Cook's (1972:16; see also Cook and Heizer 1968) formula, which was based on both ethnographic and archaeological data from California. Although most of the data were obtained from hunter-gatherer societies, Cook's formula has been commonly applied to sedentary agricultural Hohokam settlements (sires 1984b; Wilcox et al. 1981:159). For a given house, Cook calculated that 2.3 m^2 was required for each of the first six individuals in a household, and 9.3 m^2 was required for each additional person. This formula, however, may be more appropriate for the Late Archaic and Early Formative period and may actually overestimate the size of households in more-sedentary agricultural settlements of the Middle and Late Formative period.

Ciolek-Torello et al. (2014) used a combination of three formulae to estimate the population of households in Late Archaic, Basketmaker, and Anasazi period sites in northwestern New Mexico. They found that using Brown's and Dohm's constants greatly underestimated most Late Archaic and early Basketmaker period household sizes, suggesting that most houses were insufficient for even a single individual. Estimates using Cook's formula, however, suggested that most Late Archaic and early Basketmaker period houses could have provided residence for 1–3 individuals—a number more suitable for temporary, pre- or early-agricultural settlements. Dohm's and Brown's constants also appeared to underestimate household population in more-permanent agricultural settlements in Basketmaker III and Pueblo I period sites, with most households comprising fewer than 4 persons in the former period and 3 or fewer in the latter. Again, Cook's formula provided much higher estimates of 6–8 individuals—a more reasonable household size for the more-permanent agricultural settlements during those time periods. Greater variability was evident in the estimates of the sizes of Pueblo II and III period households. Once again, however, Cook's formula appeared to provide the most reasonable estimates of household size. Thus, that formula will be used here.

In their ethnographic study, Cook and Heizer (1968:93, 95) not only examined the number of individuals that resided in individual houses but also independently examined the typical number of individuals that composed households. They concluded that 4.5 people was the *absolute minimum* number of people per household in their California sample and that 6 people was the *minimum average* size of a household. Most households consisted of 6–8 people, which they considered a "*conventional*" household size. That is an important consideration in estimating the size of archaeological households. Is a single structure sufficient in size to have housed an absolute minimum- or conventional-sized household? Or would it have been necessary to combine the sizes of two or more adjacent structures to provide sufficient space for one of these households?

Using these calculations of household population size with Cook's formula for estimating household area provided us with estimates of the floor areas required by these basic household types. The minimum-sized household would have required at least 10.4 m^2 of floor area to conduct its household activities, an average-sized household would have required 13.8 m^2 of floor area, and a conventional household would have required from 13.8 m^2 to as much as 37 m^2 of floor area.

Mescal Wash Structures

Houses identified during Phase I and II Data Recovery were distributed among seven discrete loci (Vanderpot

2001a; Vanderpot and Altschul 2000). Only Loci A, C, and D, however, were investigated in detail, and only houses in these three loci were excavated or sampled. Thus, houses in these three loci constituted the basis of this analysis (Table 16). Of these three loci, only Locus A represents a discrete archaeological locality. Loci C and D were most likely connected to each other prior to the construction of I-10. All three loci, however, were excavated and analyzed as separate localities. Therefore, it is appropriate that this analysis, too, will examine each locus separately.

Locus A

Locus A is situated in the northeastern portion of the site (see Figure 2). SRI's investigations in this locus identified 9 structures, along with a trash mound, a single burial, and 38 extramural pits (see Figure 2). Most of the extramural pits were nonthermal, although 1 roasting pit and 1 *horno* were excavated in the northeastern corner of the excavation area. Three of the houses were of the recessed-hearth type (Figure 29), a distinctive house style restricted to southeastern Arizona and presumed to represent a local variant of the raised-wooden-floor house-in-pit style found at Hohokam sites (see Volume 1) (Fulton and Tuthill 1940; Tuthill 1947:32; see also for comparison Ciolek-Torrello 1994:333–335; Haury 1932, 1976:274–275; Henderson 1987:26–27).

All houses but Feature 2198 were completely excavated. Eleven archaeomagnetic (AM) samples were recovered from the eight excavated houses, and dates were obtained for all but Feature 2195 (see Lengyel, Volume 2, Chapter 2). Five tree-ring samples were obtained from Feature 200 but could not be dated. No other chronometric samples were collected from this locus. There was a noticeable absence of stratigraphic relationships between the features in Locus A, suggesting a relatively brief occupation. Only two structures (Features 2157 and 2192) were in stratigraphic relationships with other features; in each case, the structure was intruded by an extramural feature. Features 200 and 207 had been extensively remodeled, suggesting that these structures had a longer use life than the others in the locus. Feature 200, one of the three recessed-hearth structures, had been remodeled into a more traditional Hohokam house-in-pit style. Lengyel (Volume 2, Chapter 2) used the AM-date determinations and temporally diagnostic ceramics to conclude that Locus A represented a discrete Middle Formative period farmstead occupied largely between A.D. 950 and 1150—identified here as the Middle Formative B period. Although no absolute date was obtained from Feature 2195, ceramics suggested that it dated earlier, to the Middle Formative A period (A.D. 860 to 990), and had been abandoned before the other structures.

Additional excavations were conducted in Locus A by WestLand Resources, Inc. (WestLand) (Deaver 2010), less than 20 m north of the SRI excavations (Figure 30). WestLand excavated 12 structures in that area, 5 of which were recessed-hearth structures and 3 of which were Mogollon-style structures similar to a Cerros phase structure at Cave Creek Village (Deaver 2010:3-12). Deaver (2010:3-13) also distinguished two small, shallow structures on the eastern perimeter of the residential area that may have been associated with the use of a large activity area. Both structures were irregularly shaped depressions with large, centrally located postholes. One contained several interior pits. Their irregular shape, informal construction, and lack of observable entryways suggested that they were ancillary domestic structures.

As in the case of the SRI sample from Locus A, stratigraphic relationships between houses in the WestLand sample were rare; only Features 1875 and 1876 were built sequentially in the same pit. Similarly, there was little evidence of remodeling. Deaver dated all the WestLand houses to A.D. 900–1100, which roughly corresponds to the Middle Formative B period. Combining his results with Lengyel's (Volume 2, Chapter 2) for the SRI portion of Locus A, Deaver (2010:Figure 3.4) distinguished 6 discrete occupational episodes among 14 dated features in Locus A.

Deaver (2010:6-2) concluded that the structures excavated by SRI in Locus A and the structures excavated by WestLand in Locus A were not contemporary and that the WestLand structures represent the last of the Middle Formative period occupation at the Mescal Wash site and the culmination of a gradual northward shift in occupation over the course of the Middle Formative period.

Locus C

Locus C is situated at the center of the Mescal Wash site, along the southern side of I-10. Excavation of Locus C was focused on four different areas. Most of the houses were concentrated in the north-central portion of the locus, and two additional houses were located in the northwestern part of the locus (see Figure 2). Houses extended to the limits of the excavation areas; so, it remains unclear what the boundaries of the residential areas were.

Locus C appeared to have had a somewhat longer and more complex occupational history than Locus A. AM dates and artifact information suggested that it was occupied throughout the Formative period and possibly during the Late Archaic period and the transition to the Late Formative period (Lengyel, Volume 2, Chapter 2). Fifteen structures, including 3 with recessed hearths, and 65 extramural features were either partially or completed excavated. AM samples were recovered from 13 structures and 1 extramural thermal feature, and dates were obtained for 11 structures and the thermal pit.

Many of the houses and extramural features exhibited stratigraphic relationships with one another. Four pairs of superimposed houses were found in the largest concentration of houses. Two pairs consisted of houses with recessed

Table 16. Temporal and Architectural Information for All Known Structures at Mescal Wash

Locus	Feature No.	Date Range	Temporal Period	House Type	Shape	Feature Length (m)	Feature Width (m)	Total Usable Floor Area (m^2)	Total Floor Area (m^2)	Entry Orientation	Entry Type	Stratigraphic Associations with Other Structures (Intrusive/Intruded)
A	200	A.D. 935–1040	Middle Formative B	house-in-pit, recessed hearth	subrectangular	6.2	3.8	15.6	21.2	south	rectangular, ramped and stepped	
A	207	A.D. 935–1150	Middle Formative B	house-in-pit	subrectangular	5.1	3.3	15.1	15.2	north	protruding	
A	290	A.D. 1010–1150	Middle Formative B	house-in-pit	subrectangular to oval	4.6	3.7	14.5	17.0	south	bulbous	
A	1189	A.D. 935–1040	Middle Formative B	house-in-pit	subrectangular	5.3	3.8	18.1	17.5	southeast	protruding	
A	2157	A.D. 935–1040	Middle Formative B	house-in-pit	subrectangular	5.0	3.5	10.8	15.8	north?		
A	2160	A.D. 935–1040	Middle Formative B	house-in-pit, recessed hearth	subrectangular	6.2	3.8	15.6	21.2	north	square	
A	2192	A.D. 950–1150	Middle Formative B	house-in-pit, recessed hearth	subrectangular	6.0	3.6	15.7	19.4	north	rectangular	
A	2195	A.D. 860–915, 935–990	Middle Formative A	house-in-pit	subrectangular	5.2	3.9	9.7	18.2	southwest	protruding	
A	2198	not dated			subrectangular?	4.2	3.9		14.7			
A[a]	210	A.D. 900–1100	Middle Formative B	pit house	oval	4.9	4.2		16.5	south	ramp	
A[a]	215	A.D. 900–1100	Middle Formative B	house-in-pit, recessed hearth	oval	3.8	2.8		9.6	north		
A[a]	216	A.D. 900–1100	Middle Formative B	pit house	oval	4.0	3.8		13.7	north	bulbous ramp	
A[a]	298	A.D. 900–1100	Middle Formative B	house-in-pit, recessed hearth	subrectangular	6.4	4.0		23.0	south	stepped	
A[a]	299	A.D. 900–1100	Middle Formative B	house-in-pit, recessed hearth	subrectangular	5.6	4.4		22.2	north	stepped	
A[a]	304	A.D. 900–1100	Middle Formative B	house-in-pit, recessed hearth	subrectangular	5.4	3.7		18.0	north	ramp	
A[a]	311	A.D. 900–1100	Middle Formative B	house-in-pit, recessed hearth	subrectangular	4.8	3.0		13.0	south	ramp	
A[a]	349	A.D. 900–1100	Middle Formative B	house-in-pit	subrectangular	4.7	3.5		14.8	south	stepped	
A[a]	362	A.D. 900–1100	Middle Formative B	pit house	irregular	4.5	3.2		13.0		none	
A[a]	346	A.D. 900–1100	Middle Formative B	pit house	oval	3.9	2.8		8.7		none	
A[a]	1875	A.D. 900–1100	Middle Formative B	house-in-pit	subrectangular	4.8	3.4		16.3			built in the same pit as Feature 1876
A[a]	1876	A.D. 900–1100	Middle Formative B	subrectangular	oval	4.0	2.8		9.0	north	ramp	built in the same pit as Feature 1875
B	245	not dated				4.0	2.7					

Locus	Feature No.	Date Range	Temporal Period	House Type	Shape	Feature Length (m)	Feature Width (m)	Total Usable Floor Area (m²)	Total Floor Area (m²)	Entry Orientation	Entry Type	Stratigraphic Associations with Other Structures (Intrusive/Intruded)
B	364	not dated										
C	231	not dated										
C	235	A.D. 1160–1690	Late Formative	pit structure	ovate or subrectangular	4.0	2.7		9.2	north or west		intrusive to Feature 379
C	241	not dated										
C	276	A.D. 650–1150	Middle Formative	house-in-pit	subrectangular	5.2	3.9	9.7	18.2	southwest	protruding, ramped	
C	376	A.D. 835–1015	Middle Formative	house-in-pit	subrectangular	5.4	2.6		12.6			
C	379	A.D. 1010–1140	Middle Formative B	house-in-pit, recessed hearth	subrectangular	9.8	5.8	34.7	51.2	east	protruding	intruded by Feature 235
C	609	not dated										
C	897	not dated										
C	995	A.D. 935–1100	Middle Formative B	house-in-pit, recessed hearth	subrectangular	6.0	3.3	12.8	17.8	north	bulbous	intruded by Feature 6129
C	6010	A.D. 700–950	Middle Formative A	house-in-pit	subrectangular	6.4	3.0		17.3			
C	6095	A.D. 935–1040	Middle Formative B	house-in-pit	subrectangular	4.9	3.6		14.0	north	protruding	
C	6098	A.D. 935–1015	Middle Formative B	house-in-pit, recessed hearth	subrectangular	8.1	4.8	26.2	35.0	north	protruding?	intruded by Feature 7461
C	6129	A.D. 935–1015	Middle Formative B	house-in-pit	subrectangular	5.5	2.8	8.6	13.9	north	rectangular	abutted Feature 995
C	6138	A.D. 935–1315	Middle/Late Formative	house-in-pit	oval	3.9	2.6		8.1			
C	6139	A.D. 700–1040	Middle Formative	house-in-pit	subrectangular to oval	5.0	3.3		14.0	south	protruding	
C	6153	A.D. 1010–1040	Middle Formative B	house-in-pit	rectangular	5.1	3.7		18.9	north	protruding	
C	6154	A.D. 935–1015	Middle Formative B	house-in-pit	subrectangular	5.8	4.2	15.9	21.9		rectangular	
C	7201	A.D. 935–1015	Middle Formative B	house-in-pit	rectangular	4.8	4.1		19.7	north	square?	
C	7461	A.D. 935–1040	Middle Formative B	house-in-pit	subrectangular	5.9	3.9	14.3	20.7	north	protruding	intrusive to Feature 6098
D	437	not dated										Feature 3582
D	438	A.D. 735–865	Middle Formative A	house-in-pit	subrectangular	7.6	4.4	31.5	30.1	north	protruding, stepped	included in Feature 7697, superimposes Features 5986 and 7978
D	448	post- A.D. 1	Early/Middle Formative	house-in-pit	subrectangular	5.8	4.2		21.9			
D	459	not dated				4.5						

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Locus	Feature No.	Date Range	Temporal Period	House Type	Shape	Feature Length (m)	Feature Width (m)	Total Usable Floor Area (m²)	Total Floor Area (m²)	Entry Orientation	Entry Type	Stratigraphic Associations with Other Structures (Intrusive/Intruded)
D	492	A.D. 735–840	Middle Formative A	house-in-pit	oval	5.6	5.0		22.4	south	protruding	
D	565	A.D. 735–840	Middle Formative A	house-in-pit	oval	4.0	3.0	9.8	9.6	north		
D	575	A.D. 700–1150	Middle Formative	house-in-pit	subrectangular	8.4	4.2		31.8	north	protruding	
D	726	post-200 B.C.	Early/Middle Formative	house-in-pit		6.3	6.4		24.7	north		
D	834	A.D. 685–915	Middle Formative A	house-in-pit	sub-square	5.1	3.9		17.9	north	protruding	
D	1571	A.D. 1–1150	Middle Formative	house-in-pit	subrectangular	3.4	2.1	7.0	7.1	south?	informal?	
D	1575	A.D. 1385–1690	Late Formative to protohistoric	adobe-walled	rectangular	6.7	3.3	22.1	22.1	northwest	rectangular	
D	1815	1500 B.C.–A.D. 700	Late Archaic to Early Formative	pole and brush	circular	2.3	2.2	3.0	3.9			
D	1816	1500 B.C.–A.D. 700	Late Archaic to Early Formative	pole and brush	circular	2.4	2.2	3.4	3.7	north?	informal	
D	3545	A.D. 860–1015	Middle Formative	house-in-pit	subrectangular	5.8	3.7	20.2	19.3	north	protruding, ramped	superimposed on Feature 5518
D	3569	A.D. 935–1015	Middle Formative B	house-in-pit	subrectangular	3.7	2.0		6.7	south?		included in Feature 3544, intrusive to Feature 3869
D	3582	A.D. 700–950	Middle Formative A	house-in-pit	subrectangular	4.5	2.4	7.2	9.7	north	protruding, ramped and stepped	
D	3596	post-A.D.500	Middle Formative	house-in-pit	subrectangular to oval	5.0	3.0		12.8		protruding	
D	3617	A.D. 700–950	Middle Formative A	house-in-pit	subrectangular	5.0	3.0	8.5	13.5	north	protruding	
D	3641	A.D. 1–690	Early Formative B	house-in-pit	subrectangular to oval	4.4	3.6		13.5		protruding	
D	3663	A.D. 935–1040	Middle Formative B	house-in-pit	oval	4.8	2.6	8.8	10.0	north	protruding	
D	3670	A.D. 685–990	Middle Formative A	house-in-pit	subrectangular	4.1	2.2		8.1	north	protruding, ramped	included in Feature 3544
D	3677	post-A.D. 1	indeterminate Formative	house-in-pit	subrectangular to oval	4.6	2.9	12.9	11.3		protruding	
D	3679	A.D. 835–865	Middle Formative A	house-in-pit	subrectangular	7.2	3.8	11.9	24.6	north		included in Feature 3544, superimposed on Feature 3868
D	3680	post-A.D.950	Middle Formative	house-in-pit	subrectangular							included in Feature 437, intruded by Feature 3681

Locus	Feature No.	Date Range	Temporal Period	House Type	Shape	Feature Length (m)	Feature Width (m)	Total Usable Floor Area (m^2)	Total Floor Area (m^2)	Entry Orientation	Entry Type	Stratigraphic Associations with Other Structures (Intrusive/Intruded)
D	3681	A.D. 700–950	Middle Formative A	house-in-pit	subrectangular	4.7	3.8	11.4	16.1	north		included in Feature 437, intruded by Feature 3871, intrusive to Feature 3680
D	3710	A.D. 685–915	Middle Formative A	house-in-pit	subrectangular	4.5	2.7	8.1	10.9	south	bulbous	
D	3817	A.D. 700–1015	Middle Formative	house-in-pit	oval	3.8	2.1	5.4	6.4	north?		
D	3868	A.D. 600–865	Middle Formative A	house-in-pit	oval	7.2	3.8	25.1	21.9	south	protruding	included in Feature 3544, under Feature 3679
D	3869	A.D. 700–1050	Middle Formative	house-in-pit, recessed hearth	subrectangular	4.5	2.9	10.2	11.7	north	protruding, ramped	included in Feature 3544, intruded by Feature 3569
D	3879	A.D. 700–950	Middle Formative A	house-in-pit	subrectangular	4.8	3.3	8.5	14.2	north	vestibule/protruding	
D	3921	not dated	indeterminate Formative	house-in-pit	subrectangular to oval	4.4	2.8		10.5			
D	4003	post-200 B.C.	Late Archaic to Early Formative	house-in-pit	subrectangular to oval	5.8	3.9		19.2			
D	4333	A.D. 685–1015	Middle Formative	house-in-pit	subrectangular to oval	6.9	3.0		17.6			
D	4441	not dated	indeterminate Formative	house-in-pit	subrectangular to oval	5.3	4.2		18.9		protruding	
D	4462	post-200 B.C.	Late Archaic to Early Formative	house-in-pit	subrectangular to oval	4.4	3.0	4.0	11.2	north	protruding	
D	4516	A.D. 700–950	Middle Formative A	house-in-pit	circular	2.0	2.0	2.6	3.2	northwest		within remodeled Feature 3879
D	4642	A.D. 500–915	Early/Middle Formative A	house-in-pit	subrectangular to oval	5.8	3.2		15.8			
D	4682	A.D. 825–1015	Middle Formative	house-in-pit	subrectangular	4.3	2.6	9.1	10.1	northeast	protruding	intruded by Feature 5616
D	4683	A.D. 1385–1690	Late Formative to protohistoric	adobe walled	rectangular	5.4	3.6	13.6	19.4	south	protruding, ramped	
D	4684	A.D. 1310–1690	Late Formative to protohistoric	adobe walled	rectangular	5.9	4.3	25.1	25.4	south	protruding	
D	4729	A.D. 1340–1390	Late Formative	adobe walled	rectangular	6.3	4.0	22.0	25.2	southwest	rectangular	intrusive to Features 5513 and 7943

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Locus	Feature No.	Date Range	Temporal Period	House Type	Shape	Feature Length (m)	Feature Width (m)	Total Usable Floor Area (m^2)	Total Floor Area (m^2)	Entry Orientation	Entry Type	Stratigraphic Associations with Other Structures (Intrusive/Intruded)
D	4733	post-A.D. 500	Middle Formative	house-in-pit	oval	2.3	1.8	2.5	3.3	south?		
D	4768	A.D. 1010–1090	Middle Formative B	house-in-pit	subrectangular	5.5	3.4	15.3	16.8	north	protruding, ramped and stepped	intrusive to Feature 8655
D	4912	200 B.C. to A.D. 700	Late Archaic to Early Formative	house-in-pit	circular	2.0	2.0	2.4	3.2		informal	
D	4935	post-200 B.C.	Late Archaic to Early Formative	pole-and-brush	circular	2.5	2.4	4.2	4.7	southeast?	informal	
D	5513	A.D. 500–1390	Middle/Late Formative	house-in-pit	subrectangular	4.7	3.0		12.7	east		intruded by Feature 4729
D	5518	A.D. 700–1015	Middle Formative	house-in-pit	subrectangular	5.8	3.7	21.0	19.3	south	protruding	under Feature 3545
D	5616	A.D. 500–1310	indeterminate Formative	house-in-pit	round to ovate							intruded by Feature 4684
D	5781	A.D. 660–940	Middle Formative A	house-in-pit	subrectangular to oval	5.6	3.3		14.8			included in Feature 437, intruded by Features 5794 and 5795
D	5794	A.D. 910–1015	Middle Formative	house-in-pit								included in Feature 437, intruded by Features 5794 and 5795
D	5795	A.D. 910–1150	Middle Formative A	house-in-pit	subrectangular to oval	6.0	2.7		13.8			included in Feature 437, intrusive to Features 5781 and 5794
D	5986	A.D. 700–865	Middle Formative A	house-in-pit	subrectangular	5.5	3.2	16.8	15.8	north		included in Feature 7697, superimposed by Feature 438
D	5994	A.D. 650–950	Middle Formative A	house-in-pit	subrectangular	6.3	4.0		22.7	east	parallel-sided vestibule	
D	7558	A.D. 710–740	Middle Formative A	pole-and-brush	subrectangular	2.3	2.1	3.1	4.3			included in Feature 3501
D	7559	A.D. 785–840	Middle Formative A	pole-and-brush	circular	2.3	1.9	2.8	3.5	east?	informal	included in Feature 3501
D	7879	pre-A.D. 865	Early Formative	house-in-pit	subrectangular	5.0	3.5	10.4	15.8	north	ramped, protruding	intruded by Feature 7880
D	7880	A.D. 735–865	Middle Formative A	house-in-pit	subrectangular	5.0	3.5	10.9	15.8	north	ramped, protruding	superimposes Feature 7879
D	7942	A.D. 700–925	Middle Formative A	house-in-pit	subrectangular	2.7	2.6	7.2	8.7	south	protruding	

Locus	Feature No.	Date Range	Temporal Period	House Type	Shape	Feature Length (m)	Feature Width (m)	Total Usable Floor Area (m²)	Total Floor Area (m²)	Entry Orientation	Entry Type	Stratigraphic Associations with Other Structures (Intrusive/Intruded)
D	7943	A.D. 700–925	Middle Formative A	house-in-pit	rectangular	5.4	3.0	15.8	16.2	south	protruding	intruded by Feature 4729, superimposed by Feature 7942
D	7978	A.D. 700–865	Middle Formative A	house-in-pit	subrectangular	6.0	3.6	21.2	19.4	north		included in Feature 7697, superimposed by Feature 438
D	8607	not dated										intruded by Feature 3681, unclear relationship with Feature 3680
D	8643	A.D. 685–915	Middle Formative A	house-in-pit	subrectangular	6.0	3.4		18.4	south	protruding	superimposed by Feature 8644
D	8644	A.D. 685–915	Middle Formative A	house-in-pit	subrectangular	6.0	3.4		18.4	north	protruding	superimposed Feature 8643
D	8655	A.D. 825–1090	Middle Formative A	house-in-pit	subrectangular	5.4	3.7	16.5	18.0	southeast?	informal	intruded by Feature 4768
D	8841	A.D. 835–865	Middle Formative A	house-in-pit	subrectangular	5.8	4.4	22.7	23.0	north	protruding	
D	8842	A.D. 735–840	Middle Formative A	house-in-pit	subrectangular	5.7	4.3	22.7	22.1	north	protruding	
D	9729	A.D. 500–840	Early to Middle Formative	house-in-pit	subrectangular?					south?		included in Feature 4895, intruded by Features 9867 and 11390
D	9867	A.D. 760–840	Middle Formative A	house-in-pit	subrectangular					south	protruding	included in Feature 4895, intrusive to Feature 9729, intruded by Feature 11390
D	10560	A.D. 735–840	Middle Formative A	house-in-pit	subrectangular to oval	5.6	2.7		12.8	south?		intruded by Feature 10561
D	10561	A.D. 835–990	Middle Formative A	house-in-pit	subrectangular to oval	6.0	3.9		19.9	south	protruding	
D	10729	A.D. 935–1015	Middle Formative B	house-in-pit	subrectangular	3.7	3.2	11.2	10.7	north	protruding	
D	10781	A.D. 935–1015	Middle Formative B	house-in-pit, recessed hearth	subrectangular	6.0	3.2		17.3	north	protruding	included in Feature 3595, under Feature 10782

continued on next page

Locus	Feature No.	Date Range	Temporal Period	House Type	Shape	Feature Length (m)	Feature Width (m)	Total Usable Floor Area (m²)	Total Floor Area (m²)	Entry Orientation	Entry Type	Stratigraphic Associations with Other Structures (Intrusive/Intruded)
D	10782	A.D. 935–1015	Middle Formative B	house-in-pit	oval	4.0	3.0		9.6	north	protruding	included in Feature 3595, built over Feature 10781
D	11251	200 B.C.–A.D. 700	Late Archaic to Early Formative	pole-and-brush	circular	2.1	2.1	3.5	3.5	northeast?	informal	
D	11390	post-A.D. 760	Middle to Late Formative	house-in-pit						south?		included in Feature 4895, intrusive to Features 9729 and 9867
E	316	not dated				3.4						
E	318	not dated				4.3						
E	348	not dated				3.22						
E	350	not dated										
E	384	not dated										later than Features 5986 and 7978
E	788	not dated		adobe-lined pit house	subrectangular or rectangular	5.5					protruding	
F	614	not dated				2.15						
F	652	post-A.D. 1	Formative	house-in-pit, recessed hearth		4.8			2.44			
G[a]	257		Middle Formative B	house-in-pit	subrectangular	4.8	3.6		15.6	south	stepped	
G[a]	1122		Middle Formative B	pit house	subrectangular	4.0	3.2		11.5	north	bulbous stepped	
G[a]	1124		Middle Formative B	house-in-pit, recessed hearth	subrectangular	4.8	3.4		14.7			

[a] WestLand Resources, Inc., locus.

Figure 29. Feature 2160, a house-in-pit with a recessed hearth area.

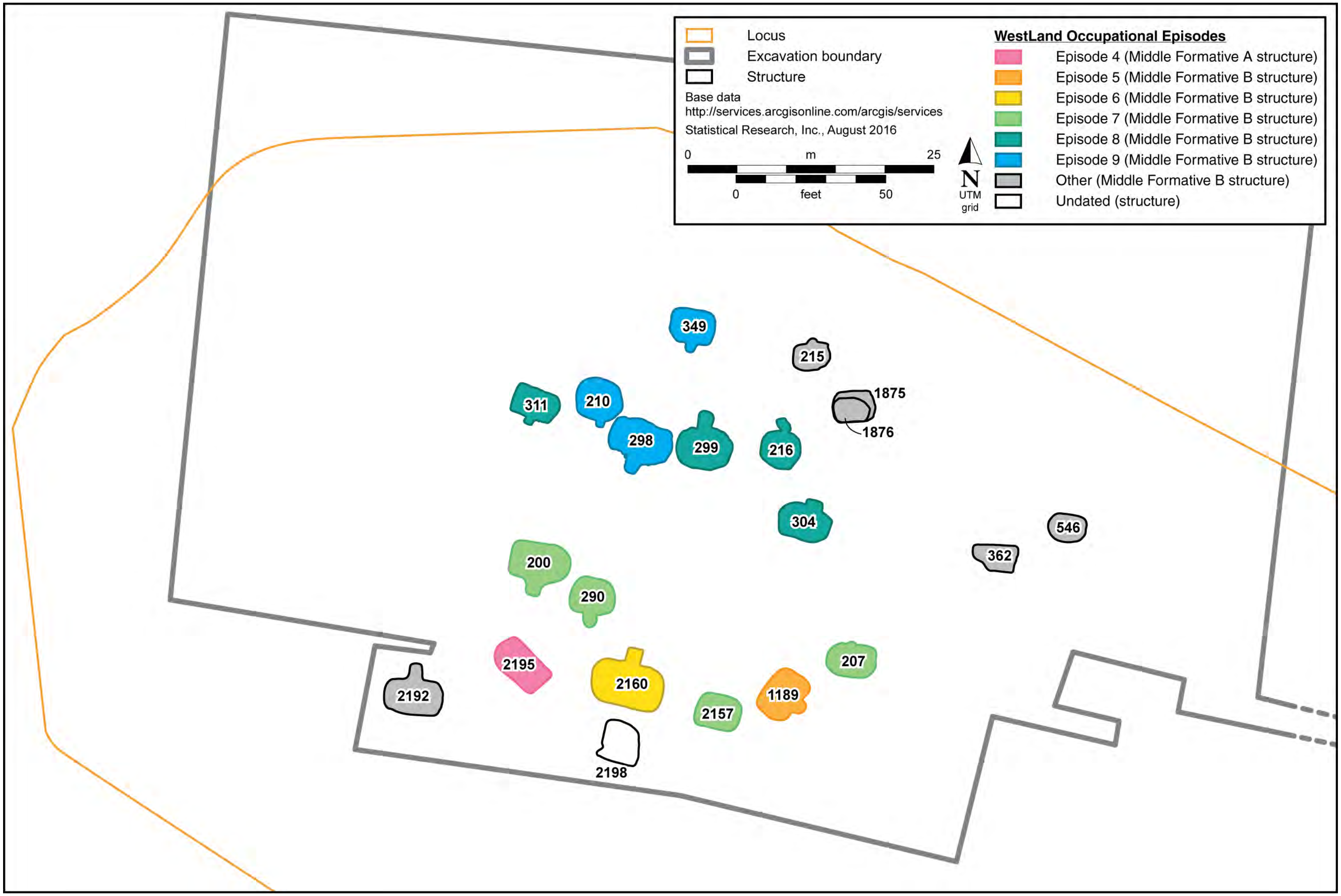

Figure 30. Map of Locus A showing the locations of houses excavated by Statistical Research, Inc., and WestLand Resources, Inc. (adapted from Deaver 2010:Figure 3-1).

hearths that were partially superimposed by Hohokam style houses-in-pits. In both cases, the later house was placed north of the earlier house, covering the entryway area of the latter. A third pair consisted of two slightly superimposed Hohokam-style houses-in-pits. One house faced north, and the other faced south. The fourth pair included the largest house found at Mescal Wash, Feature 379, a massive recessed-hearth structure with a series of parallel grooves cross-cutting the entire raised floor area (Figure 31). The southwestern corner of the house had been superimposed by a much smaller surface structure dated to the Late Formative period, although a Middle Formative B period date was also possible for that feature.

Chronometric and artifact information suggested that most of the structures dated to Middle Formative B period. Features 376 and 6139 could not be so precisely dated and were assigned to the general Middle Formative period. No absolute dates were obtained for Features 276 and 6010, located in the northwestern corner of Locus C. Feature 6010 was assigned to the Middle Formative A period, based on ceramic data, and Feature 276 could not be more specifically dated than to the general Middle Formative period. Lengyel (Volume 2, Chapter 2) distinguished four occupational episodes, based on her AM-contemporaneity study of the locus. Feature 6129 was the oldest, Group 1, although it superimposed the entryway of Feature 995, which was not dated archaeomagnetically. Feature 995, however, was assigned to the Middle Formative B period, based on ceramics. Group 2 consisted of the largest number of structures and included Features 6095, 6098, 6154, and 7201. Group 3 consisted of a single structure, Feature 7461, which was superimposed over the entryway and northeastern corner of Feature 6098. Group 4 included both the largest structure, Feature 379, and the smallest structure, Feature 6138, an informal, oval pit structure, as well as a rectangular house-in-pit, Feature 6153.

Locus D

Locus D is in the southwestern portion of the site, immediately south of Locus C and west of Locus E. Excavation of Locus D focused on a large swath of the area extending north of the railroad ROW, which extends from the northwest to the southeast and splits the locus in half, and the southern boundary of Locus C. Because excavation of Locus C focused on its northern portion, a large uninvestigated gap lies between the house areas of Loci C and D. Additional excavations were undertaken along the southern boundary of the railroad ROW, and some houses and extramural features were found in that area, as well.

Locus D had the longest and most complex occupational history of all the investigated loci at Mescal Wash, as evidenced by its long occupation span, high density of features, and extensive superpositioning and remodeling of houses and extramural features (Figure 32). Chronometric and artifact data suggested that this locus was used more or less continuously from the Late Archaic period to the Late Formative period (Lengyel, Volume 2, Chapter 2). Seventy-four structures and 164 extramural features were either completely or partially excavated. AM samples were obtained from 48 structures (multiple samples were

Figure 31. Photograph of Feature 379, a very large house-in-pit with a recessed hearth area and parallel floor grooves.

Figure 32. Photograph of Feature 7697, an extensively remodeled house-in-pit.

collected from many) and 14 extramural features. However, only 41 of those features could be dated by that method. In addition, 11 botanical samples were dated by accelerator mass spectrometry (AMS) radiocarbon dating.

Stratigraphy contributed greatly to the dating of houses in Locus D. Of the 175 pairs of stratigraphically related features, 38 could be dated only through their stratigraphic relationships to better-dated features (Lengyel, Volume 2, Chapter 2). In addition, 18 clusters of multiple superimposed features were also encountered, indicating intensive reuse of portions of this locus. One such cluster in the southeastern portion of the locus consisted of 5 structures and at least 18 extramural features. In addition, 6 sets of reused house pits were discovered. It could not be determined whether they represented significant remodeling episodes or discrete construction events; so, each structure identified within a house pit was treated separately.

Although the ceramic collection spanned the Middle and Late Formative periods, 65 percent of the collection dated from the end of the Early Formative period to the Middle Formative A period (A.D. 650–950), and only 25 percent of the collection dated to the Middle Formative B period (Lengyel, Volume 2, Chapter 2). Similarly, AM data indicated that Locus D was occupied throughout the Formative period, although it was occupied most intensively during the Middle Formative A period. Forty-five AM samples from 34 structures and 7 thermal features produced magnetic directions that could be dated. The majority of those structures returned date ranges of roughly A.D. 700–900 (Lengyel, Volume 2, Chapter 2).

The radiocarbon dates indicated that this locus was also used during the Late Archaic period. The samples recovered from six bell-shaped pits returned calibrated ages within the early part of the Late Archaic period. Additionally, Late Archaic to Early Formative period occupation was indicated by projectile points. Of the 76 dart points recovered from the locus, 39 came from structures, but only 1 of them was recovered from a probable Late Archaic or Early Formative period structure (Feature 1815), suggesting that the rest had been recycled and redeposited during later occupations (Lengyel, Volume 2, Chapter 2). Twenty Late Archaic period dart points were recovered from extramural pits; significantly, 6 were from 3 of the bell-shaped pits (Features 3976, 3983, and 5505) that were radiocarbon dated to the early part of the Late Archaic period.

Using a combination of chronometric, stratigraphic, and artifact data, Lengyel assigned 30 features, including 24 structures, to temporal groups. One structure (Features 3641) was assigned to the Early Formative period, 20 were assigned to the Middle Formative period, and 3 (Features 1575, 4683, and 4729) were assigned to the Late Formative period. A radiocarbon date obtained from Feature 4729 indicated that this group of structures most likely had been abandoned either between cal A.D. 1270 and 1320 or between cal A.D. 1340 and 1390 (Lengyel, Volume 2, Chapter 2), suggesting a hiatus in occupation between the Middle and Late Formative periods. Lengyel distinguished seven discrete temporal groups among the Middle Formative period features. The oldest consisted of

Feature 3756, an extramural pit in the northeastern part of the locus (Lengyel, Volume 2, Chapter 2, Figure 15). Feature 7558, a small house in the northeastern corner of the locus, was the only structure in Group 2. Group 3 was the largest and included 11 structures scattered across the entire locus. Group 4 included 2 structures: Feature 4682, located near the center of the locus, and Feature 10561, located in the dense concentration of houses and features in the southeastern portion of the locus. Group 5 included 2 structures: Features 3545 and 10781, also located in that dense concentration. Group 6 consisted of 3 structures in that area, and Group 7 consisted of 1 house, Feature 3663, located in that concentration, and another house, Feature 4768, located in the northwestern corner of the locus (Figure 33). Two of the three Late Formative period structures, Features 4683 and 46484, were located at the center of the locus, and the third, Feature 4729, was located in the northwestern extremity, the last in a small cluster of 4 superimposed houses.

Using artifact associations and stratigraphic relationships with these better-dated structures, many more of the houses in Locus D could be given temporal assignments. However, they could only be assigned to general time periods rather than fine temporal groups. Based on this evidence, 13 houses were assigned to the Late Archaic to Early Formative period, the Early Formative period, or the Early to Middle Formative period (see Table 16). These houses were scattered throughout the middle and western portions of Locus D and on both sides of the railroad ROW, although 5 were clustered near the center of the locus (see Figure 2). In total, 31 houses were assigned to the Middle Formative A period, but only 6 were assigned to the Middle Formative B period. In addition, 10 structures could only be assigned to the general Formative period, and 1 could be assigned to the more general Middle to Late Formative period. The latter was superimposed by a Late Formative period house, Feature 4729, in the northwestern corner of the locus. Finally, 1 additional structure was assigned to the Late Formative period, bringing the total to 4. Feature 1575 was located in the southwestern portion of the locus, south of the railroad ROW.

Taken together, this evidence indicates that the original occupants of Mescal Wash in the Late Archaic period settled in the western portion of Locus D, an occupation that extended across the railroad ROW. By the Early Formative period, there appears to have been a gradual movement to the center of the locus. By the Middle Formative period, occupation extended over the entire locus but was most heavily concentrated in the southeastern portion, especially during the Middle Formative A period. Occupation during the Middle Formative B period was greatly reduced but remained concentrated in the southeastern portion of the locus. After a hiatus of at least 100 years, the middle and western portions of the locus were reoccupied in the Late Formative period by a few households.

Other Loci

Houses were also identified in Loci B, E, and F during Phase I investigations (see Figure 2), but none was sampled or excavated; thus, their ages and characteristics

Figure 33. Photograph of Feature 4768, one of the last Middle Formative B period houses occupied in Locus D.

are unknown. Two houses were identified in Locus B (see Table 16), a large area at the center of the site, north of Locus C and I-10. Six structures were identified in Locus E, wedged between the southeastern portion of Locus C and the northeastern portion of Locus D. One of those structures, Feature 788, an adobe-lined pit house, may represent a Late Formative period structure, based on its architecture. Two structures were found in Locus F, at the northwestern extremity of the site. In addition, WestLand excavated three structures and a number of associated extramural features in the northern portion of Locus G (Deaver 2010), east of the railroad tracks from Locus F (Figure 34). Deaver (2010:3-11) characterized one of these structures, Feature 1124, as a Hohokam-style house-in-pit with a traditional raised floor, as indicated by three parallel rows of postholes across the unprepared floor and a plastered apron around the entryway. Deaver suggested that this architectural style was analogous to the recessed-hearth structures found in this region. He also characterized Feature 1122 as another Mogollon-style house. He assigned Feature 1124 to his Episode 8 occupation (see Figure 30), and Feature 1122 was assigned to the final (Episode 9) occupation. Feature 257 was not assigned to any episode, although it was assigned to the Middle Formative period, Rincon/Tres Alamos phase (Deaver 2010:Appendix C-8), a time equivalent to the Middle Formative B period in the Mescal Wash chronology. These temporal assignments were consistent with the northward migration pattern during the Middle Formative B period that was evident in Loci A and C.

Structure Size and Function

In total, 114 houses were identified during SRI's Phase I and II investigations at the Mescal Wash site (see Table 16). Temporal, size, and limited functional information was available for 90 of these structures. Comparable information was available for 15 additional houses investigated by WestLand (Deaver 2010), bringing the total sample of Mescal Wash houses to 105 (Table 17). These houses are distributed as follows: Locus A, 20 houses; Locus C, 15 houses; Locus D, 67 houses; Locus G, 3 houses.

The houses were divided into five broad temporal groups for this analysis. Temporal assignments were based on chronometric determinations by Lengyel (Volume 2, Chapter 2) and ceramic information (Garraty and Heckman, Volume 2, Chapter 3) when absolute dates were not available. Group 1 consisted of 12 structures dated to a broad time period ranging from ca. 1500 B.C. to A.D. 700, a time that includes houses assigned to the Late Archaic/Early Formative period, the Early Formative period, and the Early to Middle Formative period. Group 2 consisted of 16 houses that were assigned to the general Middle Formative period, as well as several structures that were dated to an indeterminate time in the Formative period but were included in this group, based on architectural style. Group 3 consisted of 32 structures dated to the Middle Formative A period, ca. A.D. 735–950. Group 4 consisted of 38 houses assigned to the Middle Formative B period, ca. A.D. 950–1050. Two additional structures assigned to the Middle to Late Formative period also most likely date to the Middle Formative period but could not be assigned to any group based on their architectural style. Finally, Group 5 consisted of 5 structures assigned to the Late Formative period.

As might be expected, Group 1 structures tended to be quite small; Late Archaic period structures were most likely temporary residences used by small task groups rather than complete households (see Ciolek-Torrello 1995; Whittlesey and Ciolek-Torrello 1996). But when Early Formative period structures were included, the range was quite high, from 3.2 m^2 to 24.7 m^2, with a mean of 11.8 m^2 (Figure 35). These structures contained few interior features; structures under 5 m^2 in area contained no hearths, although one contained two small, basin-shaped nonthermal pits. Three of the larger structures contained formal hearths, and two contained informal firepits. In the two largest structures in this group, the areas where the hearths were expected were missing as a result of trench excavations or intrusive features that may have destroyed the hearths, if they were present.

The Middle Formative A period structures exhibited a similar range in floor area, from 3.2 m^2 to 30.1 m^2. That was surprising, because houses are expected to have been relatively permanent residences by that time and of sufficient size to contain food-preparation and storage facilities as well as work and sleeping spaces for entire households. The mean size (15.8 m^2) of the Middle Formative A period structures, however, was significantly larger than among the Group 1 structures, suggesting that most houses were relatively permanent residential facilities for households. The function of the smaller structures was unclear. Of the 8 structures with floor areas under 11 m^2, 4 had formal hearths, including the smallest house (Feature 4526). Four of the small structures had other interior pits. Feature 7558, which did not have a hearth, contained a bell-shaped pit, and Feature 3582 contained a firepit, one bell-shaped pit, three basin-shaped pits, and one straight-walled pit in a floor with a total area of only 9.7 m^2. Among the larger houses in which hearths were found, 9 had formal hearths, and 8 had informal firepits, including the largest structure in this group (Feature 438). Feature 8655, a moderate-sized structure, contained only a burned depression in place of a hearth. Four of the larger houses in this group also contained other interior pits; two of them (Features 7880 and 8655) contained two basin-shaped pits each.

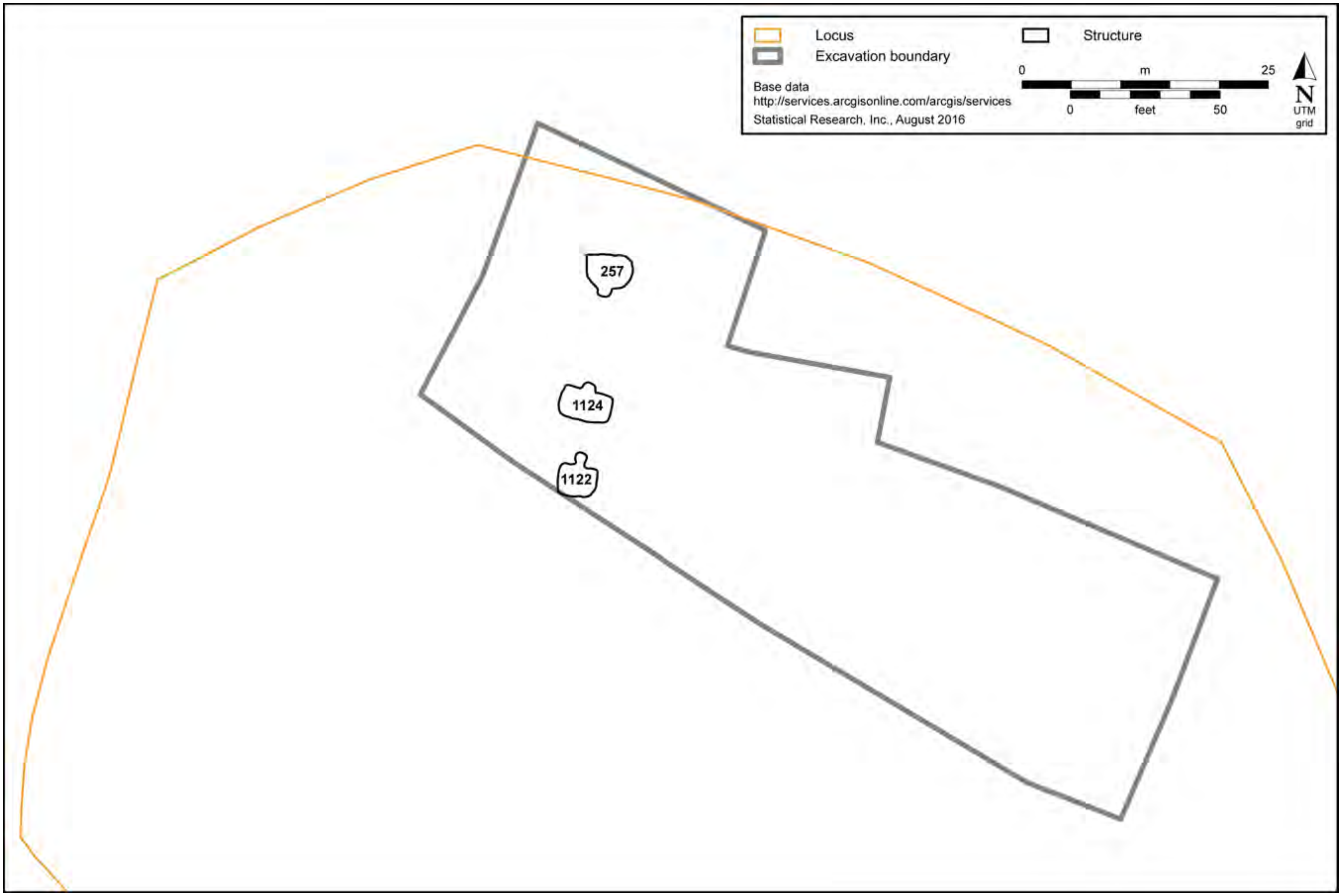

Figure 34. Map of WestLand Resources, Inc., excavations in Locus G (adapted from Deaver 2010:Figure 3-2).

Table 17. Floor Areas and Interior Features of Excavated and Sampled Structures at Mescal Wash

Locus	Feature No.	Temporal Period	Total Floor Area (m^2)	Hearth	Pits
			Group 1		
D	448	Early/Middle Formative	21.9	missing	
D	726	Early/Middle Formative	24.7	missing	
D	1815	Late Archaic to Early Formative	3.9	none	
D	1816	Late Archaic to Early Formative	3.7	none	
D	3641	Early Formative B	13.5	hearth	
D	4003	Late Archaic to Early Formative	19.2	firepit	
D	4462	Late Archaic to Early Formative	11.2	firepit	
D	4642	Early/Middle Formative A	15.8	hearth	
D	4912	Late Archaic to Early Formative	3.2	none	
D	4935	Late Archaic to Early Formative	4.7	none	2 basin-shaped nonthermal
D	7879	Early Formative	15.8	hearth	
D	11251	Late Archaic to Early Formative	3.5	none	
Mean size, Group 1			11.8		
			Group 2		
C	276	Middle Formative	18.2	hearth	ash pit
C	3545	Middle Formative	19.3	hearth	4 bell-shaped, 7 others
C	6139	Middle Formative	14.0	unknown	
D	376	Middle Formative	12.6	H/FP	
D	575	Middle Formative	31.8	hearth	
D	1571	Middle Formative	7.1	firepit	
D	3596	Middle Formative	12.8	hearth	
D	3677	indeterminate Formative	11.3	firepit	
D	3817	Middle Formative	6.4	firepit	large, bell-shaped; 3 basin-shaped
D	3869	Middle Formative	11.7	hearth	2 basin-shaped
D	3921	indeterminate Formative	10.5	firepit	
D	4333	Middle Formative	17.6	missing	
D	4441	indeterminate Formative	18.9	firepit	
D	4682	Middle Formative	10.1	firepit	2 bell-shaped, 1 basin-shaped
D	4733	Middle Formative	3.3	none	1 bell-shaped, 1 basin-shaped
D	5518	Middle Formative	19.3	hearth	
Mean size, Group 2			14.1		
			Group 3		
A	8643	Middle Formative A	18.4	hearth	
C	834	Middle Formative A	17.9	firepit	
D	438	Middle Formative A	30.1	firepit	shallow
D	492	Middle Formative A	22.4	hearth	
D	565	Middle Formative A	9.6	hearth	
D	2195	Middle Formative A	18.2	H/FP	
D	3582	Middle Formative A	9.7	firepit	1 bell-shaped, 3 basin-shaped, 1 straight-walled
D	3617	Middle Formative A	13.5	firepit	
D	3670	Middle Formative A	8.1	hearth	2
D	3679	Middle Formative A	24.6	hearth	1
D	3681	Middle Formative A	16.1	hearth	
D	3710	Middle Formative A	10.9	firepit	

Locus	Feature No.	Temporal Period	Total Floor Area (m^2)	Hearth	Pits
D	3868	Middle Formative A	21.9	missing	
D	3879	Middle Formative A	14.2	hearth	small, basin-shaped
D	4516	Middle Formative A	3.2	hearth	
D	5781	Middle Formative A	14.8	firepit	
D	5795	Middle Formative A	13.8	firepit	
D	5986	Middle Formative A	15.8	none	
D	5994	Middle Formative A	22.7	firepit	
D	6010	Middle Formative A	17.3	unknown	
D	7558	Middle Formative A	4.3	none	bell-shaped
D	7559	Middle Formative A	3.5	none	
D	7880	Middle Formative A	15.8	hearth	2 basin-shaped
D	7942	Middle Formative A	8.7	hearth	1
D	7943	Middle Formative A	16.2	hearth	shallow
D	7978	Middle Formative A	19.4	none	
D	8644	Middle Formative A	18.4	hearth	
D	8655	Middle Formative A	18.0	burned area	2 basin-shaped
D	8841	Middle Formative A	23.0	firepit	
D	8842	Middle Formative A	22.1	hearth	
D	10560	Middle Formative A	12.8	missing	
D	10561	Middle Formative A	19.9	firepit	
Mean size, Group 3			15.8		
		Group 4			
A	200	Middle Formative B	21.2	hearth	pit
A	207	Middle Formative B	15.2	hearth	
A	290	Middle Formative B	17.0	hearth	
A	1189	Middle Formative B	17.5	H/FP	
A	2157	Middle Formative B	15.8	burned area	
A	2192	Middle Formative B	19.4	hearth	ash pit
A	7461	Middle Formative B	20.7	hearth	
A[a]	210	Middle Formative B	16.5	hearth	
A[a]	215	Middle Formative B	9.6	none	
A[a]	216	Middle Formative B	13.7	hearth	
A[a]	298	Middle Formative B	23.0	hearth	
A[a]	299	Middle Formative B	22.2	hearth	
A[a]	304	Middle Formative B	18.0	hearth	
A[a]	311	Middle Formative B	13.0	hearth	
A[a]	346	Middle Formative B	8.7	none	
A[a]	349	Middle Formative B	14.8	hearth	
A[a]	362	Middle Formative B	13.0	none	
A[a]	1875	Middle Formative B	16.3	unknown	
A[a]	1876	Middle Formative B	9.0	firepit	
C	379	Middle Formative B	51.2	hearth	bell-shaped
C	995	Middle Formative B	17.8	hearth	large, bell-shaped
C	2160	Middle Formative B	21.2	hearth	
C	6095	Middle Formative B	14.0	H/FP	
C	6098	Middle Formative B	35.0	hearth	bell-shaped

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Locus	Feature No.	Temporal Period	Total Floor Area (m²)	Hearth	Pits
C	6129	Middle Formative B	13.9	hearth	large, bell-shaped
C	6153	Middle Formative B	18.9	H/FP	
C	6154	Middle Formative B	21.9	hearth	large
C	7201	Middle Formative B	19.7	H/FP	
D	3569	Middle Formative B	6.7	hearth	
D	3663	Middle Formative B	10.0	hearth	
D	4768	Middle Formative B	16.8	hearth	
D	10729	Middle Formative B	10.7	hearth	
D	10781	Middle Formative B	17.3	hearth	
D	10782	Middle Formative B	9.6	hearth	
G[a]	257	Middle Formative B	15.6	firepit	
G[a]	1122	Middle Formative B	11.5	hearth	
G[a]	1124	Middle Formative B	14.7	hearth	
Mean size, Group 4			17.1		
			Group 5		
C	235	Late Formative	9.2	hearth	
D	1575	Late Formative	22.1	hearth	2 basin-shaped
D	4683	Late Formative	19.4	hearth	small pot rest
D	4684	Late Formative	25.4	firepit	1 basin-shaped, 1 shallow
D	4729	Late Formative	25.2	hearth	1 basin-shaped, 2 shallow
Mean size, Group 5			20.3		

[a] WestLand Resources, Inc., locus.

Key: H/FP = formal hearth or informal firepit.

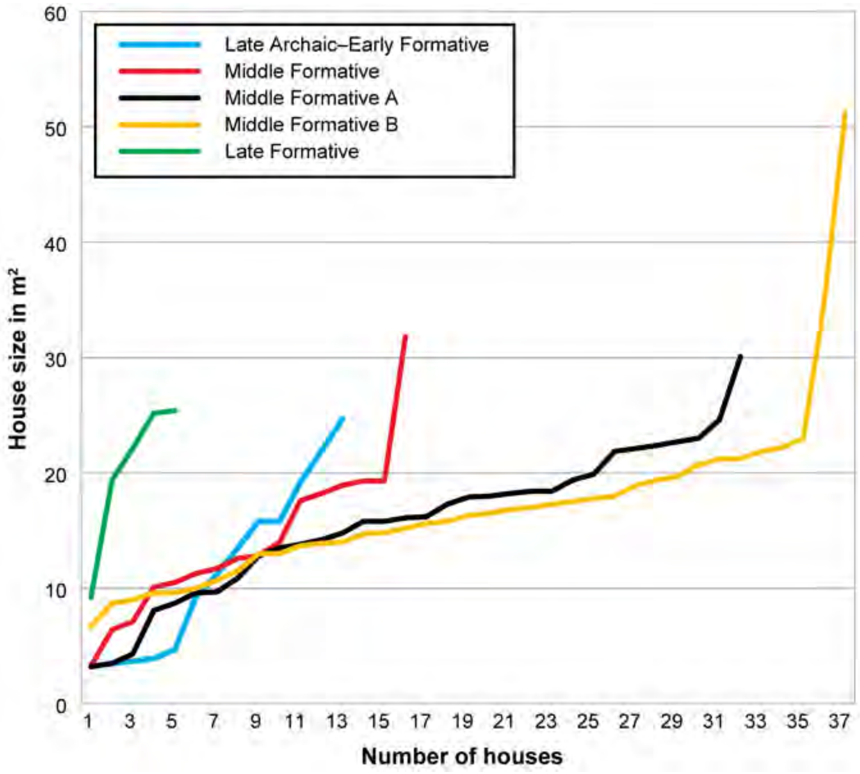

Figure 35. Chart of house size by time period at Mescal Wash.

The Middle Formative B period structures tended to be slightly larger, having a mean floor area of 17.1 m^2. They ranged in area from 6.7 m^2 to 51.2 m^2, and many of them continued to be quite small. Feature 379, in Locus C, however, was an extremely large structure that may have been a communal house (Figure 36; see Figure 31). It was a Hohokam-style house-in-pit with a recessed hearth area, but was distinguished from all of the other structures with recessed hearth areas by its extremely large size and the presence of a series of parallel grooves extending across its short axis, which may have contained logs that supported a raised wooden floor. One groove that was much wider and shorter than the others extended from the center of the recessed hearth area to the west wall. It is possible that it represents a foot drum (J. Altschul, personal communication 2016).

Large communal houses, generally considered characteristic of the Mogollon architectural type (Anyon and LeBlanc 1980; Ciolek-Torrello 1998), may have been present in Pioneer period Hohokam settlements, as represented by the P-4 style houses at Snaketown (Haury 1976). Although Haury (1976:68) believed that they were domestic structures, others have compared them to Mogollon communal houses (Ciolek-Torrello 1998). Haury (1976:57) also identified at Snaketown three exceptionally large S-3-type houses that ranged in size between 52 and 56 m^2 and were coeval with Feature 379. Apart from their large size, which was identical to that of Feature 379, they appeared to be typical Hohokam-style Sacaton phase houses. Haury (1976:62) speculated that they might represent council houses, as those once used by the Pimas.

Thus, Feature 379 may not be a typical domestic structure, although it probably was used for domestic activities, as suggested by the presence of a hearth and a bell-shaped pit. If it is excluded from the other Middle Formative B period

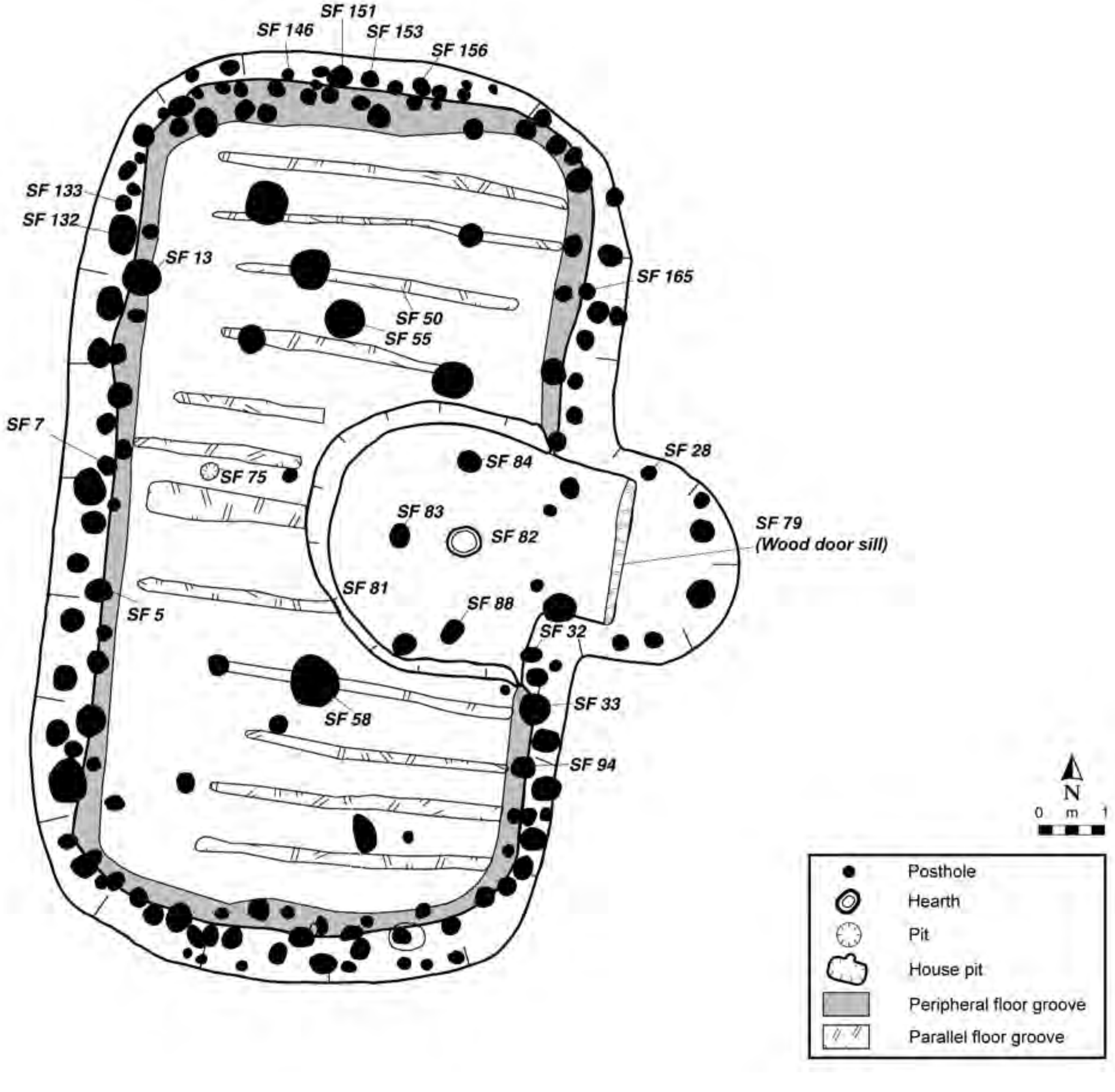

Figure 36. Plan view of Feature 379, a possible communal house in Locus C.

structures, the mean floor area for this group (15.7 m^2) is virtually identical to that of the Middle Formative A period structures. Unlike the latter, however, almost all the Middle Formative B period structures contained formal hearths. Only four structures, all under 14 m^2 in area, contained either an informal firepit or no hearth at all. Where it could be determined, all but one of the larger structures contained formal hearths, suggesting a higher degree of permanent residency during this later time period. The exception to that rule was Feature 2157, a moderate-sized structure that contained only a burned depression in place of a hearth. Other interior features were found in only six Middle Formative B period houses. Four contained a single bell-shaped pit each, two contained one pit each, and Feature 2192 contained an ash pit associated with a formal hearth.

Group 2 houses, which could not be assigned to either the Middle Formative A period or the Middle Formative B period, exhibited a similar range in size (3.3–31.8 m^2) to that of houses in the other temporal groups and only a slightly smaller mean size (14.1 m^2) than that of the Middle Formative A and B period structures. The smallest structure in this group, Feature 4733, contained one bell-shaped pit and one basin-shaped pit but no hearth, and it appeared to differ little from small Late Archaic to Early Formative period brush huts (Figure 37). Where it could be determined, six of these structures contained informal firepits, and five contained formal hearths. Interior pits were found in five of the larger structures. Feature 3545, a moderate-sized structure, contained four bell-shaped pits and seven other pits, in addition to a formal hearth. Feature 276 contained an ash pit associated with a formal hearth in a pattern similar to Middle Formative B period structure Feature 2192. Based on a predominance of informal firepits and a higher frequency of interior storage pits, Group 2 houses resembled Middle Formative A period structures most, although they could not be assigned to a more specific time period based on those characteristics alone.

The sample of Late Formative period houses was very small in comparison to the other groups. They exhibited a wide range in size, from 9.2 to 25.4 m^2, although they exhibited a much higher mean floor area of 20.3 m^2. If the small structure from Locus C is excluded, all the Late Formative period structures in Locus D are roughly 20–25 m^2 in area. Four of the five structures contained formal hearths, and the largest contained an informal firepit. Each of the three largest structures contained multiple interior pits, although all were either basin-shaped or shallow pits. None contained bell-shaped pits.

Taken together, this information suggests that Mescal Wash houses do not fit well into the typology developed from previous studies of Hohokam house function (Ciolek-Torrello 1998; Ciolek-Torrello et al. 2000; Doyel 1981; Whittlesey 2010a). Group 1 houses tended to be small to moderate in size and best fit the functional category of storage or small habitation, although even in this group, some houses were quite large. The largest for which information was available had an informal firepit rather than a formal hearth. The relationship between floor area and hearth type was weaker in the Middle Formative period structures. Although there was a clear tendency for larger structures (>15 m^2) to have formal hearths (69.4 percent), almost half (48.5 percent) of the structures of less than 15 m^2 in area also had formal hearths (Table 18). Looked at graphically for all time periods, structures without formal hearths tended to be small, less than 15 m^2 in total area, but with a few exceptions among the largest structures, those with formal hearths exhibited a similar range in size to those with informal firepits or no hearth (Figure 38). A one-tailed t-test of the hypothesis that structures with formal hearths were larger than those lacking these features was rejected ($p = .56$; $df = 88$).

A comparison with the West Branch site, which is largely Middle Formative period in age, is illustrative. Houses with formal hearths at West Branch exhibited a wide range of variability in floor area from 4.5 to 38.0 m^2 (Figure 39) similar to the size range of structures at Mescal Wash, and 57.4 percent of those houses were larger than 15 m^2. However, 81.8 percent of the structures lacking hearths of any type or having informal firepits were small (less than 15 m^2 in area). In this case, a one-tailed *t*-test testing the same hypothesis as above was accepted ($p < .001$; $df = 74$), indicating a much stronger relationship between house size and type of hearth. Overall, houses at West Branch tended to be smaller than Middle Formative period houses at Mescal Wash; 41 of the 76 houses (54.0 percent) at West Branch were under 15 m^2 in area, compared to only 38 of 85 houses (44.7 percent) at Mescal Wash.

Even in the small sample at Mescal Wash from the Late Formative period, the relationship between house size and hearth type was weaker than expected. The smallest house (Feature 235, 9.2 m^2 in area) contained a hearth, whereas the largest (Feature 4684, 25.4 m^2 in area) contained a firepit.

Although the evidence indicated that the typology that distinguishes large or standard habitations from other smaller structures does not work well at Mescal Wash, there appeared to be a temporal trend in the emergence of standard habitations; that is, larger houses with formal hearths become more common in the later periods. If structures are divided into two broader temporal groups that combine the Late Archaic/Early Formative and Middle Formative A period groups and the Middle Formative B and Late Formative period groups (excluding the general Middle Formative period group), larger structures (those greater than 15 m^2 in area) appear to have been more common in the later occupational episodes (63.4 percent) than in earlier times (54.5 percent) (Table 19). More striking is that structures with formal hearths composed 81.1 percent of the later houses but only 44.7 percent of earlier structures (see Table 19).

Figure 37. Photograph of Feature 4733, a small brush hut with an intrusive pit in Locus D dating to the Middle Formative period.

Table 18. Middle Formative Period Hearth Types, by House Size

House Size	Hearth Type				Total
	None or Firepit		Formal Hearth		
	n	%	n	%	
Small (<15 m^2)	17	51.5	16	48.5	33
Large (>15 m^2)	11	30.6	25	69.4	36

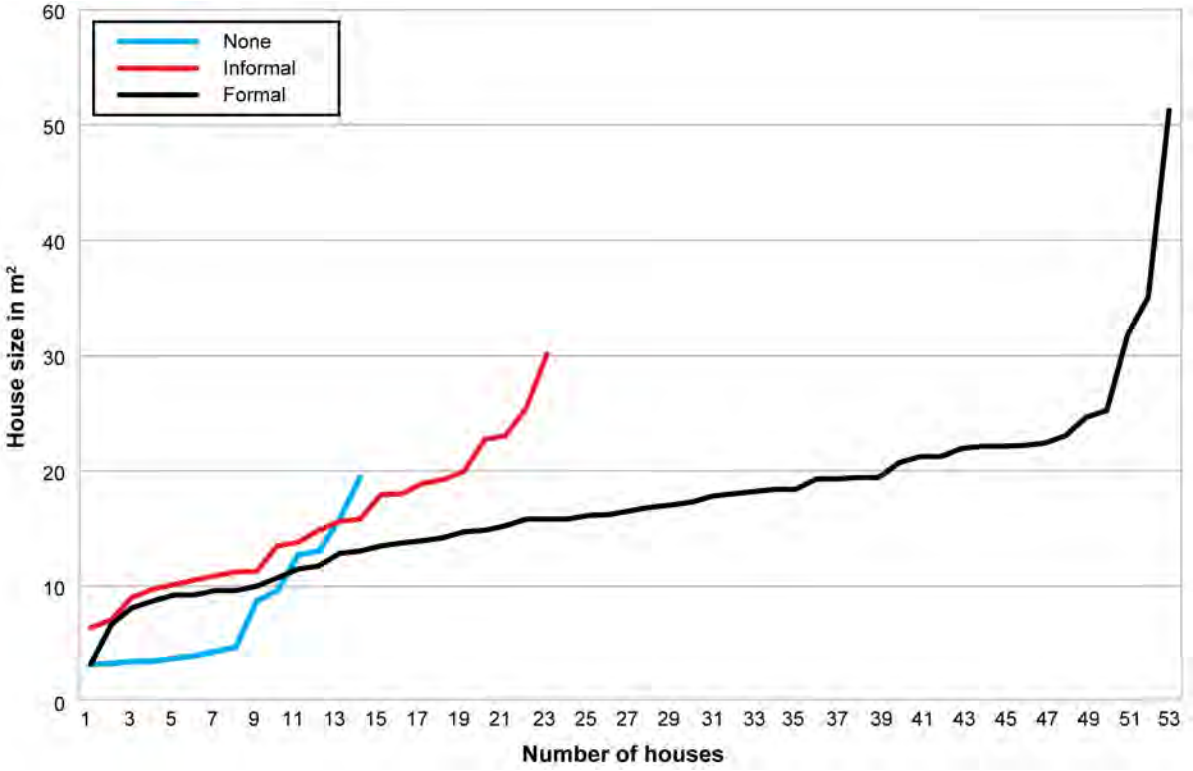

Figure 38. Chart of house size by hearth type (none, informal, and formal) at Mescal Wash.

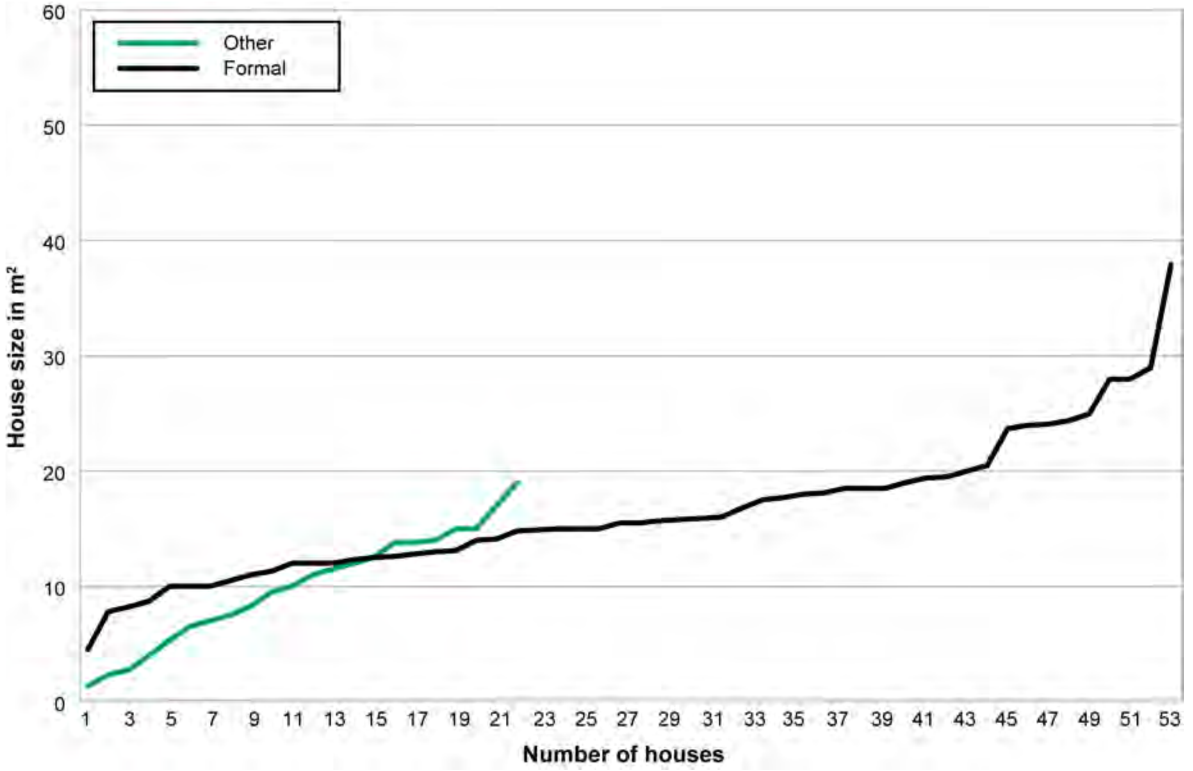

Figure 39. Chart of house size by hearth type (other and formal) at the West Branch site.

Table 19. House Sizes and Hearth Types, by Temporal Period

House Size, by Temporal Period	Total	Hearth Type: None or Firepit	Hearth Type: Formal Hearth	Hearth Type: Total
Late Archaic, Early Formative, and Middle Formative A				
Small	20	13	7	20
Large	24	8	10	18
Subtotal	44	21	17	38
Middle Formative B and Late Formative				
Small	15	4	11	15
Large	26	3	19	22
Subtotal	41	7	30	37
Total	85	28	47	75

Mescal Wash Households

If we apply the data on structure size at Mescal Wash to Cook's (1972) formula for the numbers of persons per square meter of floor area and Cook and Heizer's (1968) estimates of typical household size, we can develop an idea of how households may have been distributed through time and space at Mescal Wash. As indicated above, structure size at Mescal Wash was overestimated, because it was calculated by overall pit size rather than actual floor area, a calculation that did not take into account the area of the floor groove and peripheral posts that make up the walls of houses-in-pits, As a result, it was necessary to increase Cook and Heizer's areas for different types of households. That adjustment was also necessary because Cook's house-density estimates were derived primarily from hunter-gatherer populations, and farmers would have needed additional domestic space for food storage and processing.

Based on previous household studies (Ciolek-Torello et al. 2014; Ciolek-Torrello et al. 2000; Lightfoot 1994; Whittlesey 2010a) and the above discussion of structure size and hearths at Mescal Wash, the following areas were used: absolute minimum household size, 12 m^2; minimum average household size, 15 m^2; and conventional household size, 20 m^2. These household-size estimates represent a necessary but slight modification to Cook's constants. For the sake of comparison, if we were to use Brown's constant of 6 m^2 per person, the floor area required to house even the minimum-sized household would be 27.9 m^2, and the floor area required for an average-sized family would be 37.2 m^2. Only a very few structures at Mescal Wash or any other pit-house settlement in the region would meet those minimum requirements. Thus, the use of Brown's constant in this analytic context would be completely impractical.

Using estimates based on the modification of Cook's constant, we calculated the number of each type of household that could be contained within individual structures during different time periods at Mescal Wash (Table 20). That was a maximum estimate, because it was based on house size, included houses that lacked information on hearth type, and did not distinguish structures with informal firepits from those with formal hearths. In that circumstance, large houses lacking hearths or only with firepits were interpreted as less-permanent residences than those with formal hearths. For the purposes of this analysis, we added a fourth household type—partial households—for households that did not meet the absolute minimum size estimated by Cook and Heizer (1968).

Several patterns are observable in Table 20. First, not surprisingly, half the structures dating to the Late Archaic/Early Formative period could not have housed even the minimum sized household. None of these small structures contained formal hearths, suggesting that they represent either temporary structures or partial households and were used in combination with other spatially associated structures to complete the household space. What is surprising about this early period is that average- and conventional-sized households were present at least by the Early Formative period and could have been housed in single structures. All three of the average-sized households from this period contained hearths, and they indicate that standard habitations were being used at that early date, as well.

Average-sized households were dominant during the Middle Formative A and B periods. Significant proportions of the houses from those two periods, however, continued to represent partial households, suggesting that multihouse households containing a variety of structures should have been common during those times. However, as many as half of all the very small houses contained hearths, which did not fit the documented pattern of Hohokam multihouse households (composed of a standard habitation and one or more smaller structures). Contrary to the information from Table 19, which suggests an increase in structure size from the Middle Formative A period to the Middle Formative B period, these data indicate that the increase translated into

Table 20. Household Types, by Temporal Period

Temporal Period	Partial	Minimum-Sized	Average-Sized	Conventional-Sized	Total
Late Archaic/Early Formative	6	1	3	2	12
Middle Formative	7	3	5	1	16
Middle Formative A	8	5	12	7	32
Middle Formative B	8	7	14	8	37
Late Formative	1	—	1	3	5

only slightly higher frequencies of average- and conventional-sized households.

Despite the small sample size, there appears to be clear evidence of a much higher proportion of conventional-sized households when Mescal Wash was reoccupied in the Late Formative period. The preponderance of formal hearths in the large structures indicates that the standard habitation room was the dominant structure during that time period, particularly in Locus D.

The presence of many partial and minimum-sized households during most of the occupation at Mescal Wash suggests that pairings or clusters of houses were present in typical courtyard arrangements, as evidenced at Scorpion Point Village and the West Branch site. As Deaver (2010) observed in his discussion of Locus A, the distribution of houses in all loci showed little evidence of either the pairings or the courtyard clusters evident at Phoenix and Tucson Basin Hohokam sites (Figures 40–44). Contemporaneous houses showed no evidence of the angled pattern in which doorways face at acute angles to one another and open onto a shared courtyard area. The dominant pattern at all Mescal Wash loci was one of houses facing either north or south; in most cases, adjacent structures faced away from each other. East-facing houses were evident in a few instances, such as the possible communal house, Feature 379. But like the other east-facing structures, the doorway of Feature 379 did not open onto a common area shared with any other structure in Locus C. The only exception to that rule in the Middle Formative period was a pair of Middle Formative A period structures in Locus D. Feature 5994 faced east onto a common area with Feature 8643, the earlier, south-facing structure in the house pit shared with Feature 8644 (see Figure 43). Feature 5994 is a large house that could have housed a conventional-sized household, and Feature 8643 is a moderate-sized house that could have housed an average-sized family. The larger house contained a firepit, and the smaller house contained a hearth. Thus, it is possible that this pair of structures represents a big-house/little-house pair, but not in the common way represented in Hohokam courtyard groups.

Several house pairs or clusters, however, may be indicated by contemporaneous houses with parallel or facing entryways. One such group was represented by Features 834, 8644, and 8841/8842, in the center of Locus D (see Figure 43). Features 7879/7880 may be part of that group but were located over 10 m away, with a large gap in between. Feature 4642 faced this cluster of parallel facing houses but was also over 10 m away. Feature 4682 was closer and faced the same direction as the three houses, but the AM-contemporaneity study suggested that it was younger and was not contemporaneous with Feature 8642 (Lengyel, Volume 2, Chapter 2). Feature 4682 was a very small structure with a firepit and fits well the definition of a secondary habitation. It is possible that this structure was part of a larger household that may have resided in Feature 834, which could have housed an average-sized household; but this structure also had a firepit. Features 8841 and 8842 were both large structures sharing the same pit that could have housed a conventional-sized household. One contained a firepit and the other contained a hearth, suggesting a change in household use. Thus, Feature 8644, the later of the two structures built in the Feature 8643/8644 house pit, probably represented the primary residence in this house cluster, and Feature 8842 may have represented a second paired household when that structure was in use. At other times, the household could have comprised the primary residence, Feature 8644, one or two additional large habitations, and a small secondary habitation, Feature 4682, which could represent a newly established household or the household of a “retired” parent.

Features 7942/7943 and 9867 may also represent paired structures dating to the Middle Formative A period located in the northwestern corner of Locus D (see Figure 43). Although the latter was somewhat set back from the house pit shared by Features 7942 and 7943, it was separated from them by less than 5 m, and all three had south-facing entries. Feature 7943, the earlier and larger structure built in the shared house pit, was moderate in size and could have housed an average-sized household (Figure 45). By contrast, Feature 7942 was a much smaller structure that could not have housed even a minimum-sized household. Both structures appeared to have shared the same hearth, indicating a remodeling event by the household that greatly reduced the size of the house. Feature 9867 was the middle of three superimposed structures in a single house pit. No temporal information was available for Features 9729 and 11390, although they were tentatively assigned to the Early to Middle Formative and Middle to Late Formative periods, respectively, based on their stratigraphic associations with Feature 9867, which was AM dated to the

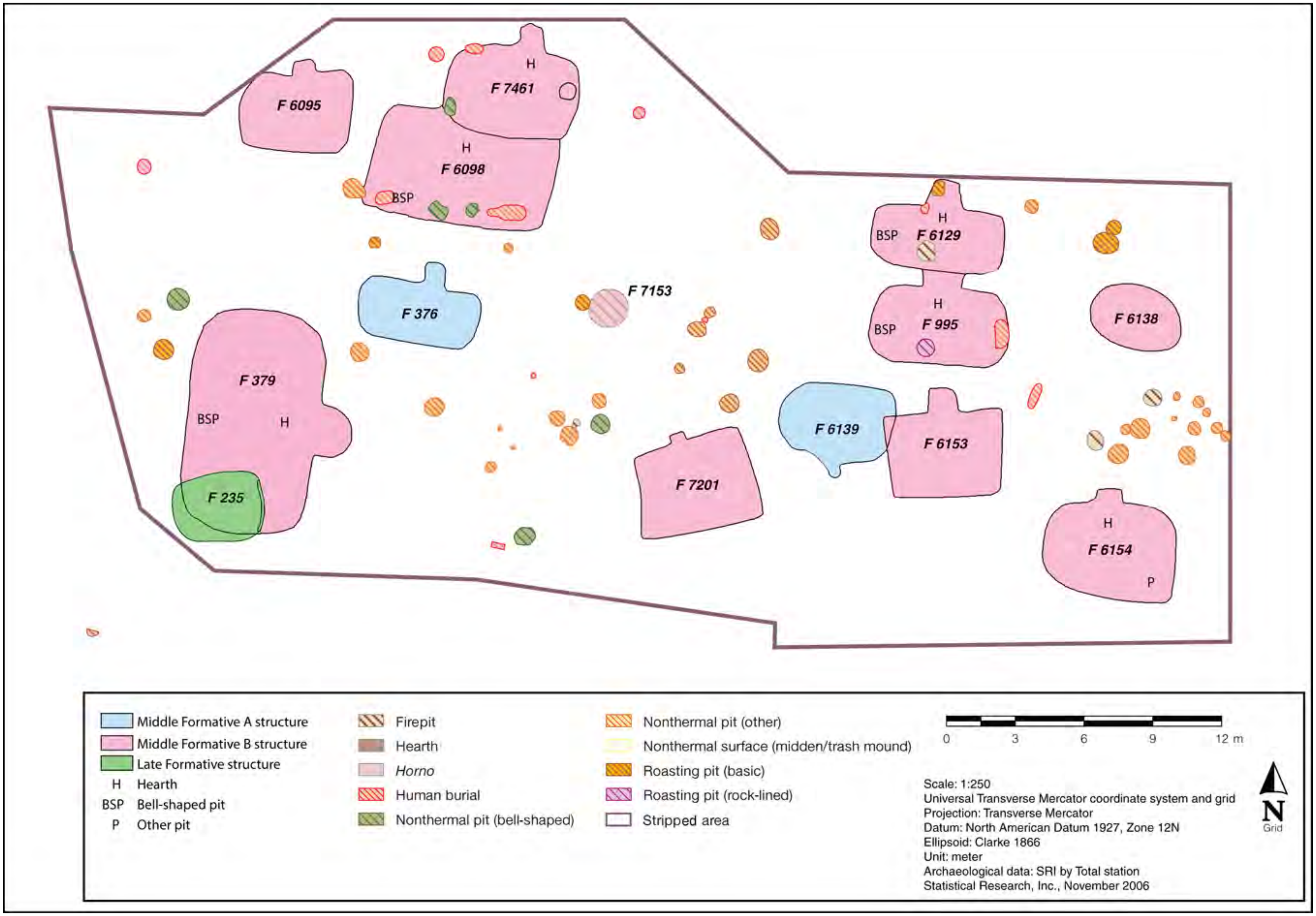

Figure 40. Map showing the locations of Middle Formative A and B period houses in SRI Locus A.

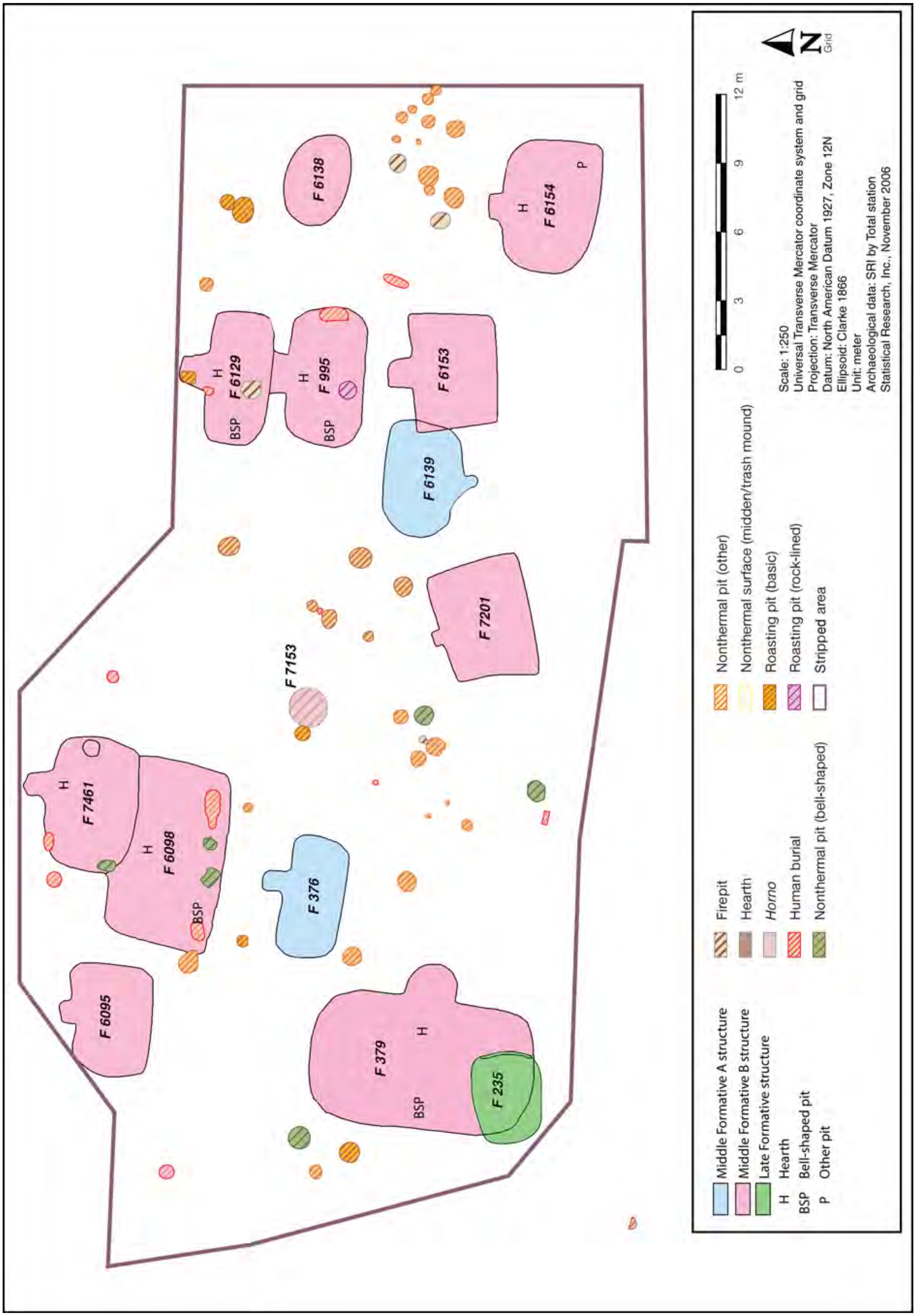

Figure 41. Map showing the locations of Middle Formative A and B and Late Formative period houses in the eastern part of Locus C (*Note*: The color-coded features are all either extramural or intrusive).

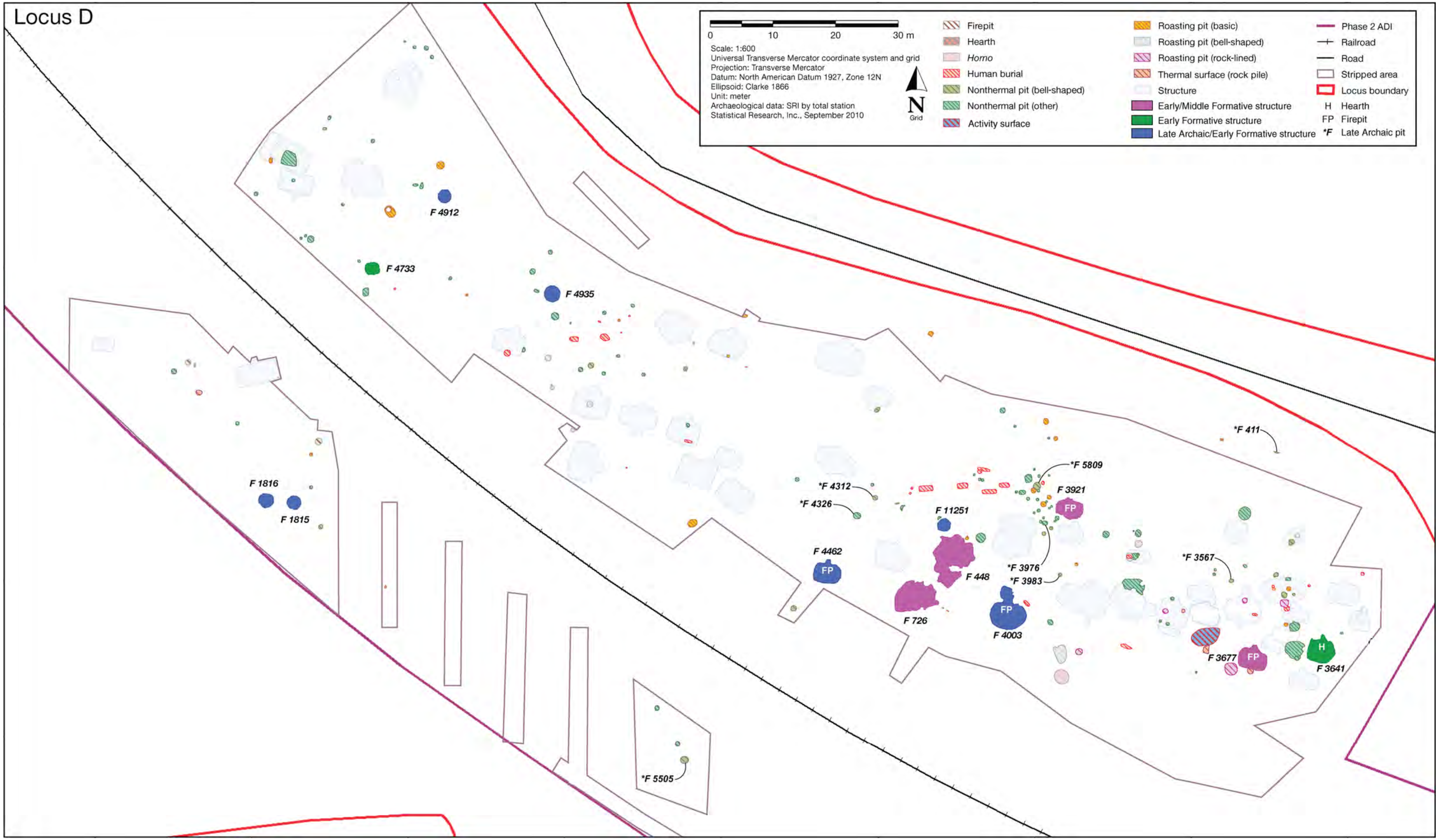

Figure 42. Map showing the locations of Late Archaic and Early Formative period houses and pits in Locus D.

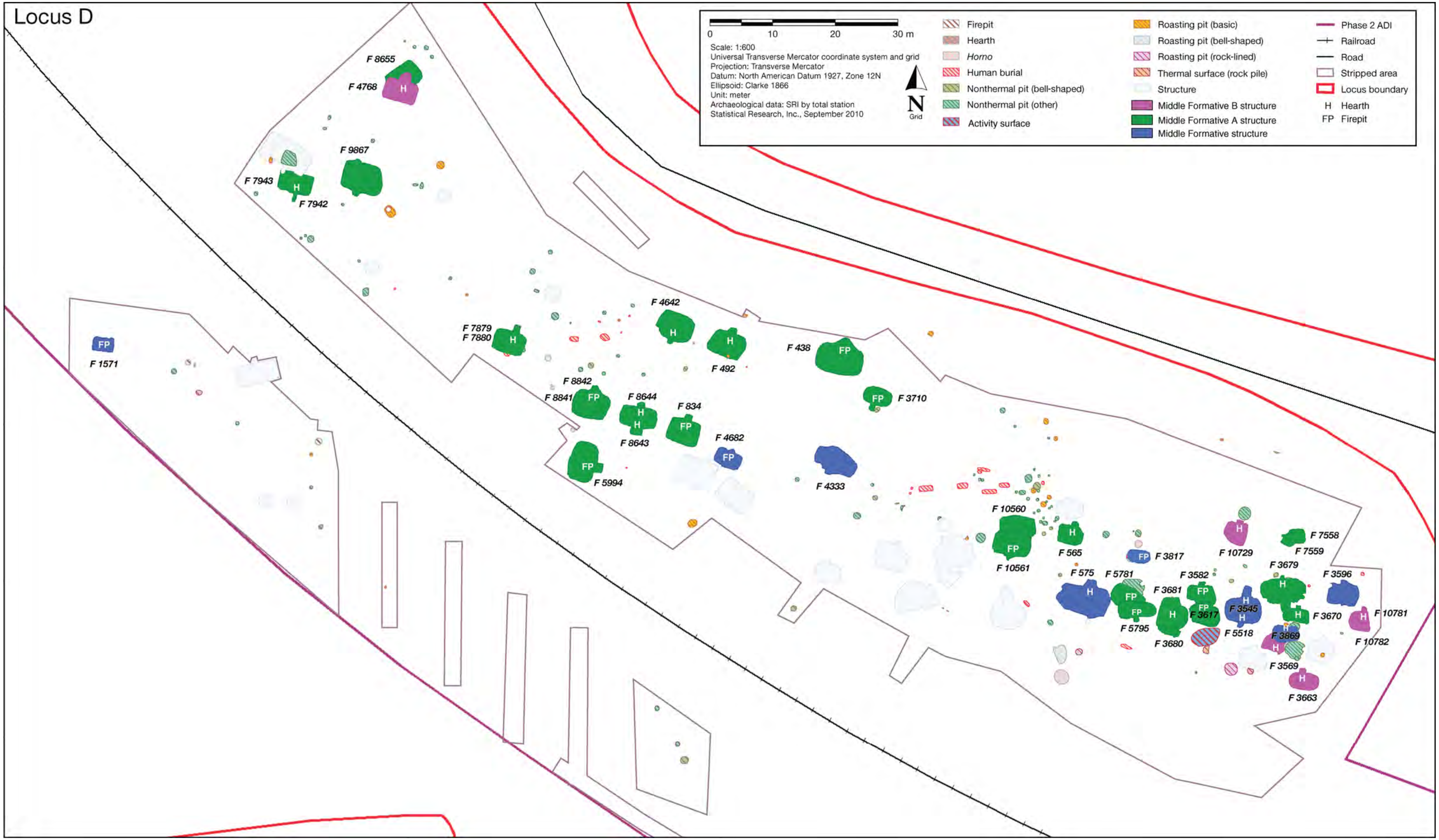

Figure 43. Map showing the locations of Middle Formative period houses in Locus D.

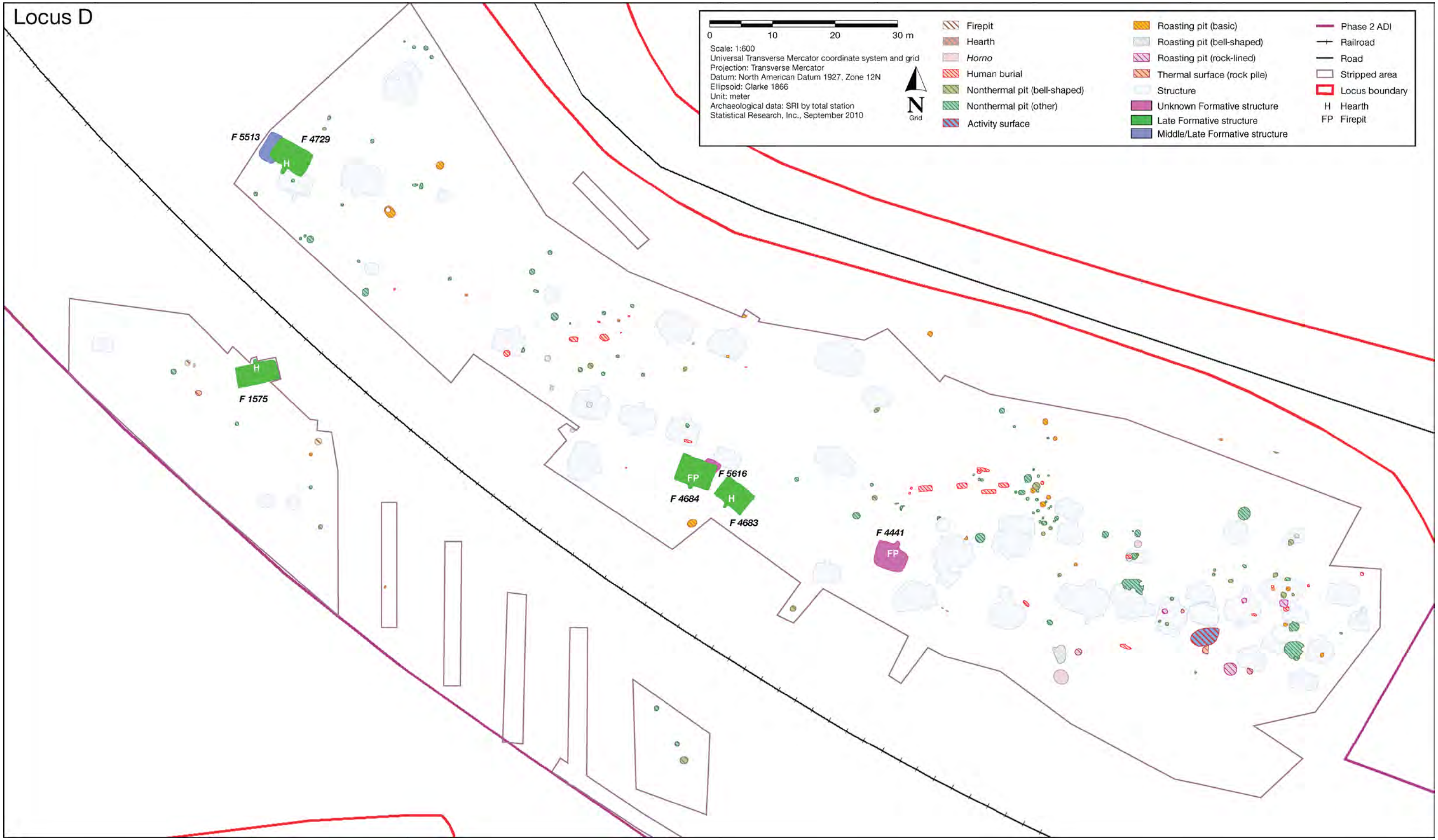

Figure 44. Map showing the locations of Middle to Late Formative and Late Formative period houses in Locus D.

Figure 45. Photograph of two superimposed Middle Formative A period houses (Features 7942 and 7943) and a Late Formative period house (Feature 4729) in Locus D.

Middle Formative A period. The presence of another possible Middle to Late Formative period structure and a dated Late Formative period structure in the immediate vicinity suggests a long potential span of occupation in that area. No dimensions were available for any of those structures, but Feature 9867, which had a formal hearth, appeared to be equal in size to, if not larger than, Feature 7943. Thus, the Middle Formative A period household in that area may have originally comprised a pair of related average-sized households. At some later point in the Middle Formative A period, Feature 7943 was remodeled and greatly reduced in size, suggesting that the size of the resident household shrank.

Another possible house pair was represented by Features 3617 and 3681, in the eastern concentration of features in Locus D (see Figure 43). The former was a small structure that could have housed a minimum-sized family but contained only a firepit. By contrast, Feature 3681 was a larger house that could have housed an average-sized family and contained a hearth. Together, the two houses could have comprised a conventional-sized household. At some point in the Middle Formative A period, Feature 3582, a much smaller house with a firepit and a number of interior storage pits, was built over the entryway of Feature 3617. Too small to house even a minimum-sized family, this replacement house probably represented a temporary or short-term occupation by a smaller task group.

Features 6095 and 6098 may represent a similar scenario in Locus C (see Figure 41). Feature 6098 was a very large structure with a formal hearth that could have housed a large conventional-sized household. Feature 6095 was a much smaller house that the AM study indicated was contemporary. Together, the two structures housed what was probably one of the largest households in the community. Feature 7461 was superimposed over the entryway of Feature 6098 and was not contemporary with either household (Figure 46). Although much smaller than Feature 6098, Feature 7461 also contained a hearth and could have housed a conventional-sized household. Given the spatial association of these three structures, Feature 6098 could represent a descendant household that was greatly reduced in size from its predecessor. Features 6153 and 7201 and Features 995 and 6138 may represent additional house pairs in Locus C. The AM-contemporaneity study, however, suggested that they were not contemporaneous.

Features 200 and 290 may represent a house pair in Locus A (see Figure 40). One was a large structure that could have housed a conventional-sized household, and the other, slightly smaller, could have housed an average-sized household. Both contained hearths, suggesting that a pair of related households resided in that area. Feature 200 may have been the residence of a primary, established household, and Feature 290 may have been the residence of an offspring household.

The final and perhaps best examples of a house pair are Late Formative period Features 4683 and 4684 in Locus D (Figure 47; see Figure 44). They were both south-facing structures with entryways slightly angled toward each other. It appears to have been a nontraditional pairing; the large structure, Feature 4684, had the capacity to house a conventional-sized household but had a firepit, and

Figure 46. Photograph of Feature 7461 and 6098, a pair of superimposed houses in Locus C.

Figure 47. Photograph of Features 4683 and 4684, a Late Formative period house pair in Locus D, with Middle Formative period house Feature 4682.

the smaller structure contained a formal hearth but could only have housed an average-sized family. Together, these structures represent a relatively large, stable residential group. By contrast, the other three Late Formative period structures were all isolated. Two structures in Locus D contained formal hearths and could have housed conventional-sized households. The single Late Formative period structure in Locus C, Feature 235 (see Figure 41), was too small to house even a minimum-sized household but, paradoxically, contained a hearth. The only known Late Formative period structure in Locus C, Feature 235 clearly was not a household comparable to its contemporaries in Locus D, but what it represents is unclear.

Perhaps more common than examples of house pairs and clusters was a pattern of sequential occupations at Mescal Wash. The replacement of the house pair of Features 3617 and 3681 by Feature 3682 in Locus D, the replacement of Feature 7943 by Feature 7942 in Locus D, and the replacement of the house pair of Features 6095 and 6098 by Feature 7461 in Locus C are but three examples of that pattern. In all three cases, a large household comprising one large habitation and a smaller habitation or two large habitations was replaced by a much smaller habitation; in the case of Locus D, these large households were replaced by habitations that could not even have housed minimum-sized households. This pattern of replacement of larger households by smaller ones was also evident in Locus C, in the case of Feature 995, a structure that could have housed an average-sized household (Figure 48; see Figure 41). Feature 995 was replaced by Feature 6129, a structure that could have housed only a minimum-sized household.

The opposite pattern, in which a smaller household was replaced by a larger one, was less common. The previously discussed household comprising Features 8841/8842, 8644, and 834 in Locus D may represent a replacement of the household comprising Features 8643 and 5994, because both households were centered on the house pit containing Features 8643 and 8644 (see Figure 43). If these two households were related, the change represents a shift from a large south- and east-facing household to a much larger one that faced north. Ultimately, however, the household comprising Features 8841/8842, 8644, and 834 may have been replaced by a much smaller one associated with Feature 4682.

Features 10560 and 10561 may also represent an increase in household size (see Figure 43). Located in the eastern concentration of structures and features in Locus D, Feature 10561 was a moderate-sized structure that could have housed an average- to conventional-sized household. It contained only an informal firepit, however. Feature 10560 was a much smaller structure that could only have housed a minimum-sized household. It is unknown whether a hearth was present, because the presumed location of that feature was removed by the construction of the later house.

Figure 48. Photograph of Features 995 and 6129, partially superimposed houses in Locus C.

Summary and Conclusions

Households at Mescal Wash were largely average in size, using Cook and Heizer's (1968) modified estimates, and most were housed in single structures. Typical Hohokam-style courtyard groups with angled or facing entryways were extremely rare; clusters of houses with parallel entryways were slightly more common. Households composed of paired houses, which were the dominant pattern at West Branch, were also very rare, and in the few cases that were present, pairs of similar-sized houses and pairs of one big house and one small house were equally common.

The matching of small structures that could not have housed even a minimum-sized household with larger structures to form multistructure households, as was common in the Verde Valley (Ciolek-Torrello et al. 2000) was also rare at Mescal Wash. Rather, many of the smaller structures, often with formal hearths, were isolated and suggested the presence of sub-household units that could represent temporary or short-term residence by task groups smaller than households. A recent study of Anasazi households from roughly contemporaneous sites suggested an alternative possibility (Ciolek-Torello et al. 2014). Formal hearths were found in many pueblo rooms that were much too small to contain more than the minimum of domestic activities. That pattern was seen as part of a larger domestic arrangement in which the Anasazi divided domestic activities into very small, specialized spaces rather than the more-open arrangements in Hohokam and Mogollon households. In the Anasazi case, however, those small, specialized spaces were usually parts of much larger, multiroom households containing several semi-independent commensal units. The occurrence of very small isolated and independent households at Mescal Wash is much more difficult to interpret but may reflect an element of the Anasazi-type pattern. That is not to suggest that there was an Anasazi influence but rather that extremely small, independent households, perhaps consisting of only one or two individuals, were not an impossibility.

Conventional-sized households were also present at Mescal Wash throughout most of the occupation, from the Early Formative period to the Late Formative period. Though not common, they increased slightly in number by the Middle Formative B period and were most common in the very small Late Formative period sample. For the most part, however, there appeared to be a pattern of the replacement of larger households by smaller ones over the course of the Middle Formative period.

The eastern portion of Locus D exhibited a pattern of intense occupation and reoccupation in the numerous superimposed structures and the reuse of house pits from the early Formative period to the Middle Formative A period. That occupation may have had roots in the Late Archaic period, because features, particularly bell-shaped pits, were found in that area (see Figure 42). By the Middle Formative B period, occupation began a gradual shift northward; most of the Middle Formative B period structures were located in Loci A and C. The Middle Formative B period pattern of occupation was very different from patterns in preceding times; there was much less superpositioning of structures and reuse of house pits. Although there was some evidence of replacement of households, for the most part, new houses were constructed without reference to older ones, suggesting occupation by new, unrelated households.

The presence of a large, possibly communal house, Feature 379, suggested some level of community integration in the Middle Formative B period. Although located in a cluster of contemporaneous structures, Feature 379 faced east, away from all the nearest houses (see Figure 41), which faced north, and did not appear to be a focal point for them. Feature 379, however, was located at the southern edge of the excavation area, which itself was located in the northern part of Locus C. It is unknown whether other structures may have been present south of that large house.

Overall, Mescal Wash appears to have been an important location for occupation, with evidence of intense and concentrated occupation at least during certain periods of time. There was some evidence of some time depth in occupation and reoccupation by individual households, suggesting a concept of land tenure had developed. For the most part, however, occupation was by small to average-sized and independent households (see Deaver 2010). Though in the same general area as preceding households, new households were not established with reference to the locations of their predecessors, for the most part, which was indicative of a weak concept of land tenure. In contrast to the Hohokam courtyard group, which reflected a pattern of multigenerational use and ownership by a distinct corporate group (Howard 1985; Wilcox et al. 1981), the pattern at Mescal Wash was more suggestive of multiple, shifting, intermittent short-term occupations by unrelated households. This conclusion was supported by the absence of discrete trash mounds and burial areas, typical components of Hohokam courtyard groups, and the almost random distribution of extramural pits in residential areas and in abandoned houses. The latter suggests that some occupants of Mescal Wash used the site for food processing and storage but did not reside there on a permanent basis. Thus, households and smaller task groups may have come and gone over the generations, establishing occupations for a few years, at best, before moving on. Their descendants may have come back at a later date, with only a general idea of where their ancestors had resided.

As discussed above, the forager-farmer model suggests that large but loosely structured residential groups are associated with communal ownership of land and resources in economies with relatively low investment in food production. By contrast, intensification of food production, increased labor investment, and the development of concepts of land ownership are associated with the emergence of more nucleated and structured arrangements of smaller households as the primary residential groups. The results of this investigation of households at Mescal Wash were consistent with important aspects of the model, especially those related to a broad-spectrum subsistence strategy associated with large, loosely structured household arrangements. Initial settlement of Mescal Wash during the Late Archaic and Early Formative periods reflected an increasing level of settlement permanence from isolated bell-shaped pits and small huts to the first permanent dwellings. Settlement size was likely very small at any point during that long period of time, and feature density was very low. The Middle Formative A period witnessed a much larger and more intensive occupation, with considerable evidence of remodeling and reoccupation, especially in the eastern concentration of features in Locus D, suggesting some degree of development of the concept of land tenure. The absence of defined burial, extramural food-processing, and refuse-disposal areas suggests that this concept of land tenure was weak. Settlement was loosely structured to an extreme, with only a very small number of multi-household clusters and house pairs. The vast majority of households were contained in single isolated structures that were not spatially associated with any contemporaneous structures. Most unusual was the presence of many structures that were too small to house even a minimum-sized household. Although a few of them could be paired with other contemporaneous structures to form complete households, many couldn't and appeared to represent the temporary residences of smaller task groups or the more permanent residences of one or two individuals.

An even looser structure was evident in the Middle Formative B period. Households gradually shifted northward to Loci A and C. Settlement in these loci exhibited a much lower degree of remodeling and superposition of houses. The presence of a possible communal house suggested the development of a higher level of organization in the Middle Formative B period, but it currently remains unclear how it was structured.

Examples of replacement of one household by another, apparently related, household may represent examples of the developmental cycle. Most of those examples, however, appeared to reflect the decay of households rather than their growth and development, because larger, establishment-phase households were more commonly replaced by much smaller ones. Only one or two examples were found of possible expansion of households. With the exception of the eastern concentration in Locus D, all evidence pointed to short-term, recurrent occupation of Mescal Wash by independent households that resided there for relatively short periods of time before moving on. They rarely stayed long enough to grow and establish offspring. The pattern was more one of a reduction in size as households resided at Mescal Wash, suggesting that resources were quickly exhausted, and the remnants of the household moved away. They or their descendants may have returned to Mescal Wash as conditions improved and reestablished residence, with only a distant memory or vague understanding of the locations of their original residences.

The Mescal Wash area may have been a marginal environment where resources or soils were rapidly depleted or could be productive only under certain conditions—during especially wet periods, for example. Though clearly a persistent place that was intensively used for well over a thousand years, Mescal Wash did not have the resources to sustain large residential groups for more than a single generation, as suggested by the household organization and settlement structure. It did, however, have sufficient resources and possibly good arable land to continue to attract resettlement.

Based on the existing evidence, Mescal Wash was abandoned at the end of the Middle Formative period. After a hiatus, the site was reoccupied in the latter part of the Late Formative period, although it is possible that a few structures assigned to the Middle to Late Formative period were occupied during that apparent hiatus. The Late Formative period occupation, however, was not like that found in the Tucson Basin or San Pedro Valley, where large, highly formalized structures and nucleated settlements were established. The Late Formative period occupation at Mescal Wash consisted of a few isolated houses representing the same short-term type of occupation that characterized the Middle Formative period. It remains unclear whether the Late Formative period Mescal Wash settlement was smaller than its predecessors or represents only the briefest period of time. Although many more houses were occupied during the 400-year span of the Middle Formative period, only a handful of houses may have been occupied at any single time. For example, our sample contained 86 Formative period structures. If we divide the 400-year span by 20 years (the life of a single generation) and divide the 86 Formative period structures in our sample by that quotient (20), only a little more than 4 houses may have been present at any time—a number comparable to the number of Late Formative period houses. Thus, the Mescal Wash data informed little on the village-farmer component of the model, other than suggesting that agricultural intensification never occurred in the area.

This analysis also shed some light on the issues of who the people that lived at Mescal Wash were and whether they changed over time. The dominant architectural forms at Mescal Wash, variations on the house-in-pit style, clearly reflect a Hohokam connection, if not actual settlement by Hohokam people from the Tucson Basin or other areas. Significantly, the possible communal house (Feature 379, in Locus C) was of a Sacaton phase style rather than a contemporaneous Mogollon equivalent. Deaver (2010) suggested that several examples of true pit houses in the Middle Formative B period component of Loci A and G represented the Mogollon style. Feature 4003, a Late Archaic to Early Formative period structure in Locus D, was similar in construction and may represent an earlier example of Mogollon presence. These structures constitute only a very small minority in what is an otherwise-dominant Hohokam architectural style. The recessed-hearth pattern and the parallel floor grooves found in Feature 379 appeared to represent a local variant of the raised-house-floor pattern found in many Hohokam settlements in the Phoenix Basin (Motsinger 1994) and surrounding upland areas, where there is strong evidence of actual Hohokam residence (Ciolek-Torrello 1994). Whether that variation represents a local interpretation of Hohokam style or local construction needs is unknown. The adobe-walled pit houses representing the Late Formative period occupation at Mescal Wash suggested a continuation of the dominant Hohokam style. Interestingly, most of the Late Formative period houses, Features 4683, 4684, and 1575, also contained parallel rows of postholes across their floor surfaces (Figure 49; see Figure 47), suggesting that they also had raised floors—a pattern that has not been noted during that time period in the Phoenix Basin or other neighboring areas.

The architectural style suggested a dominant Hohokam influence, if not actual settlement by Hohokam migrants, but the household arrangements suggested something else. Pairs of large and small houses and larger courtyard groups were rare at Mescal Wash and represent only a minority of households. The great majority of households appeared to have been housed in isolated structures that were not spatially associated with any others. The presence of parallel rows of houses with entryways facing in a common direction was suggestive of small Mogollon settlements. The dominant north- and south-facing pattern at Mescal Wash, however, contrasted with the dominant east-facing arrangement in Mogollon settlements. It is possible that the rarity of Hohokam-style household arrangements was a product of the inability of the local environment either to support the larger multihouse households typical of Middle Formative period Hohokam settlements or to sustain occupation long enough for small households to grow into such larger ones. Alternatively, the residents of Mescal Wash may have been influenced enough by Hohokam culture to build Hohokam-style houses but not sufficiently imbued in Hohokam culture to organize their households in a typical Hohokam arrangement. This may be the case, as even in other regions marginal to the Phoenix Basin, Hohokam organized their households into typical courtyard groups. For example, people closely affiliated with the Hohokam, as evidenced by material culture and burial practices, occupied the Sycamore Creek area, an upland area with limited agricultural potential northeast of the Phoenix Basin. Here they resided in small settlements occupied for short periods of time. Nevertheless, they organized their households into courtyard groups.

Overall, however, the Mogollon influence on both architecture and household arrangement appeared even weaker. Mogollon-style houses were rare. Although houses were arranged in loose clusters, few faced eastward, and no Mogollon-style communal house was identified. As this discussion has suggested, architecture and household arrangements alone cannot answer the question of who the residents of Mescal Wash were, but they do provide important insights.

Figure 49. Photograph of Late Formative period Feature 1575, showing the parallel posthole patterns suggestive of a raised floor.

CHAPTER 5

Food Preparation, Storage, and the Social Construction of Space at the Mescal Wash Site: An Analysis of Intramural and Extramural Pits

Christopher P. Garraty and William M. Graves

In this chapter, we employ three different approaches to the study of the various forms, sizes, and spatial distributions of pit features at the Mescal Wash site. The three approaches are (1) how pits factored into food preparation and consumption, (2) how they functioned as storage containers, and (3) how they were arranged and organized spatially to socially define space and promote or limit their accessibility. In the next sections, we first briefly explore each of these approaches, followed by summarizing studies of pit features in the region and reviewing the Mescal Wash pit sample. Next is the actual analysis, which covers issues such as inferring pit size, shape, and volume; pit classification based on metrics; functional assessment; diachronic changes; and the role of pits in the social construction of space. In the concluding section, the analysis results are compared against the three research approaches that guide the study.

Research Approaches

Food Preparation and Consumption

An emphasis on the social contexts of the production and consumption of food is an obvious focus for the study of pit features at the Mescal Wash site. Pit features from archaeological sites in the southern deserts of Arizona are usually linked to practices involving the processing, preparation, and consumption of food (see Craig 2000; Hackbarth 1993; Halbirt, Kaler, and Dongoske 1993; Mabry 2005a; Wöcherl 2005). So, pit features and their forms and contents provide information crucial to understanding the production and consumption of food and its central role in the social lives of the inhabitants of the Mescal Wash site through its long span of occupation.

Food, as a focus of human action and practice, permeates much of the material culture preserved in the archaeological record. In fact, the common material remains most often encountered in the archaeological record of southern Arizona are either directly or indirectly implicated in food production, including agricultural pursuits and the procurement of non-domesticated foods (hunting and gathering), storage, processing, preparation, and consumption. Flaked stone tools, ground stone tools, and ceramics were most often used to store, process, prepare, and consume food. Some stone tools would also have been used to collect and process wild-plant and animal resources and to tend, harvest, and process domesticated crops. Many fixed features common in the archaeological record also have their primary uses situated in the food-production process—pits to store, process, and prepare foods; hearths inside houses and thermal pits outside for cooking; and canals and field systems for the farming of domesticated and cultivated crops.

Several authors have made the distinction between the biological and cultural aspects of food and its study. Gosden (1999:1–2) has argued that much of archaeology's focus on food and food production has emphasized the ecological, nutritional, and genetic aspects of food. Food is most often seen as the basis of the economy, and its study has emphasized the role of food production in (1) the biological fitness or adaptation of individual and groups and (2) underwriting major adaptive or evolutionary changes in human history, either generally or locally (see Childe's [1936] Neolithic Revolution or the stage developments of neo-evolutionary theory [Yoffee 1993]). Such a biological or adaptive emphasis in the study of food is not without its place in anthropology and archaeology, but the production and consumption of food also has an important social or cultural component (see Gosden 1999; Sherratt 1999). Gosden (1999:1) stated that "food is vital in constructing culture." It embodies cultural categories and cultural change, reflects social structures, and plays central roles in both the political lives and the communal rituals of people cross-culturally (see chapters in Dietler and Hayden [2001]).

Crown (2000) offered an interesting distinction between diet and cuisine that neatly captured the opposition between the biological and cultural/social aspects of food. *Diet* refers to the "actual foods consumed, their proportions, and their nutritional values" (Crown 2000:225). *Cuisine*, on the other hand, refers to the sociocultural constructs that give form and meaning to food preparation and consumption, including "rules for the appropriate manner of preparation of foods (recipes, tools, combinations of foods), the traditional flavorings of staples, the number of meals consumed per day, the manner of serving completed dishes, the use of food in ritual activities, and the importance of food taboos" (Crown 2000:225).

Both diet and cuisine are inherently conservative and thus can be good indicators of status, health, and social relations in past societies. Food often plays a central role in many interactions and social relationships in middle-range societies (see Appadurai 1981; Crown 2000; Weismantel 1989; see also chapters in Gosden and Hather [1999] and Wiessner and Schiefenhövel [1996]). Thus, understanding patterns in diet and cuisine in the past can tell us something about intrahousehold and interhousehold relations, ritual, status and sociopolitical interactions, and the creation and maintenance of cultural difference in past societies (see Appadurai 1981; Crown 2000; Sassaman 1993).

As some of the tools or facilities used for food preservation and preparation, pits can be viewed as parts of the "technology" of cuisine (sensu Crown 2000:227). They are among the tools used to prepare food for consumption, often through cooking (e.g., roasting or boiling) or some other thermal activity (e.g., parching) (see Halbirt, Kaler, and Dongoske 1993) and through the preservation of food items (e.g., storage), and their uses in the past likely both determined and were determined by other socioeconomic trends or concerns, such as the degree of population mobility of groups; the conservation of time, energy, and resource expenditures of the food preparers; and other household labor (see Crown 2000:229–230).

As alluded to above, *cuisine* also includes the rules and conventions regarding the social contexts and frameworks of both food preparation and food consumption. As a part of the technology of cuisine, pit features can tell us something about the sociopolitical contexts of food preparation and consumption and, in particular, the social relations involved in such domestic activities. The most prevalent recent literature concerning the political contexts and social relations of food preparation and consumption in small-scale agrarian and forager societies focused on feasting.

Theoretical and methodological treatments of feasting from an archaeological perspective define feasting so broadly (see Dietler and Hayden 2001; Grimstead and Bayham 2010:841–842; Hayden 1996:Figure 8.1) that the concept can be construed to include most kinds of multihousehold or interhousehold food-preparation and consumption practices. Given that broad and inclusive definition of what is meant by feasting, we can think of the various types and typologies of feasting behaviors presented in the literature (e.g., Dietler 2001; Dietler and Hayden 2001; Hayden 1995, 1996) as identifying variability in both the sociopolitical contexts in which food-preparation and consumption activities are embedded as well as the sociopolitical outcomes of such food preparation and consumption. Thus, variability in the kinds of foods prepared and consumed and the manner in which such food is prepared and consumed can be identified through archaeological evidence (e.g., Hayden's [1995, 1996] alliance and cooperation feasts vs. diacritical feasts). The social scale of food preparation and consumption can also be identified through archaeological evidence (e.g., Hayden's [1995, 1996] intracommunity economic feasts vs. community-wide diacritical feasts). Also, the social or political logic behind food-preparation and consumption activities in the past can also be evaluated with archaeological data (e.g. Dietler's [2001] empowering feasts vs. diacritical feasts or Grimstead and Bayham's [2010] elite competitive feasting vs. non-elite, alliance, or cooperation feasting).

As parts of the technology of cuisine, pit features can provide one of several lines of potential evidence concerning food preparation and consumption in the archaeological past. Their characteristics and distribution through time and space can be studied to explore the social and political contexts and consequences of food preparation and consumption in past communities.

Storage

Storage pits can be considered a type of formal storage feature that requires at least a modest investment in construction, maintenance, and upkeep. Kent (1999:80) defined formal storage as "the placement of objects in facilities use specifically for storage." In addition to pits, formal storage areas include structures, platforms, pottery vessels, gourds, barrels, and other portable and importable container options. Informal storage refers to placement of objects in places that are not specifically designed or intended as storage locations, such as open areas or rooftops (Kent 1999:80). These storage areas are not usually archaeologically detectable but in some cases may be indirectly inferred or assumed based on the prevalence and capacities (or lack thereof) of formal storage areas.

On the surface, use of pits as storage containers is straightforward. They satisfy a simple need for safekeeping of food and other items in a known location, unexposed to weather and other elements. However, the practice of storage implies various social and economic behaviors. First, construction of storage pits or other formal storage facilities implies surplus production and retention in a single location of those surpluses for future need (Halperin 1994:167). Hence, they provide a means of buffering against future shortfalls. Storage pits thus fulfilled an essential economic need by helping ancient families and groups preserve and protect their surplus goods over long spans. Hendon (2000) aptly pointed out that many social theorists have emphasized surplus production and exchange in the development of social complexity, but few have factored in the important role of the storage and protection of those surpluses.

Second, pits are durable and—compared to aboveground or portable storage facilitates and devices—less frequently subjected to destruction or degradation by wind, rain, fire, decay, or deliberate destruction by outside invaders (Hendon 2000:43–44). They also are more readily camouflaged or hidden from thieves or predators than aboveground facilities. Storage pits (along with burials or subterranean ovens) provide a longstanding and durable connection to, and investment in, a particular piece of land. They thus likely contributed to fostering a sense of place and bolstered land claims in the face of outside encroachment (or the perception of it), possibly more so than residential structures. This is a crucial point with reference to the Mescal Wash site, given the frequent superimposition of structure footprints, suggesting long-term investment in place by the specific families or groups that repeatedly reused and rebuilt houses in the same locations. Perhaps storage pits, burials, or other subterranean features provided an "anchor" around which those structures were continually reconstructed.

Hendon (2000) explored additional social dimensions of storage pits. She (2000:45) linked storage to the establishment and maintenance of social differentiation and public displays of wealth, for example, by contrasting the use of publically visible aboveground storage in the socially stratified Classic Maya site of Copán with the use of less-visible belowground storage pits typically observed in earlier Formative period villages in Oaxaca (Winter 1972), where social hierarchies were less pronounced. Hendon (2000:46) also stressed the symbolic importance of storage, citing the example of the Aztecs of central Mexico (Sahagún 1950–1982:Book 10). Among the Aztecs, heads of households held a moral obligation to consistently store and maintain surplus food and goods for their households, but Aztec people considered it shameful to waste surpluses or to fail to stock the maize bins. Even mundane storage of food and non-wealth goods provided a credible basis for garnering social prestige. Storage areas thus communicated a symbolic link with the household's or family's social prosperity, status, and well-being. In Hendon's view, storage pits involved broader social and symbolic meanings beyond their more obvious economic importance for surplus production and buffering against future shortfalls. As Hendon (2000:47) explained, "Through storage, past labor is preserved, the potential for future labor is embodied, and the different (and differently valued) contributions of woman and men [are] actualized."

Importantly for our study, analyses of pits can also be informative about mobility and residential stability (Kent 1992; Kent and Vierich 1989). Kent (1992) observed, based on a cross-cultural ethnographic comparison, that the presence of formal storage areas correlates strongly with anticipated lengths of stay of about 6 months or greater. She found that when mobile groups anticipate residing at a specific location for less than about 6 months, they rarely invest effort in creating formal storage space and rely instead on informal storage. Similarly, Kent (1992, 1999:90–91) observed a strong correlation between discrete trash deposits (e.g., in middens or previously used pits) and sedentary or semisedentary occupations. In short-term settlements, trash is typically scattered and not deposited in specific loci. This is relevant to our study of storage pits, given the high frequency with which people in the ancient Southwest reused thermal and nonthermal pits as trash receptacles (see below).

The biggest challenge to studying storage pits is distinguishing them from other kinds of nonthermal pits, such as pits related to processing activities or those created specifically to contain refuse. In situ storage materials are rarely recovered in pits (except for caches). Kent (1999) presented an argument based on the diversity of fill materials, arguing that dedicated trash pits tend to have a lower diversity of materials than storage pits with trash deposits related to a limited range of activities in the vicinity of a reused pit. However, inferring the final use of a pit is not an accurate means of inferring a pit's initial or previous uses. As explained below, we rely on indirect evidence to infer storage function, such as the absence of oxidized or burned walls, the size and inferred volumetric capacity of the pit, and the location of the pit relative to structures (including an intramural or extramural location) and other features. For example, some archaeologists have inferred storage functions for some pits based on their relative depths and bell-shaped profiles or vertical walls (Craig and Walsh-Anduze 2001; Hackbarth 1993). By the same token, shallow pits or pits with conical profiles probably were not used for storage. In the case of bell-shaped pits, food or other items were probably placed directly in the pits, which probably were lined with stone or perishable materials (e.g., wood or grass) to protect against insects or rodents (Craig and Walsh-Anduze 2001:132). Their narrow openings made for easier sealing or camouflaging and also restricted access to contents by surface predators or scavengers. In pits with vertical walls, however, it is more likely that food was placed in sealed storage pots or other protective containers prior to being positioned in the pit.

In making our interpretations of storage pits and their importance at the Mescal Wash site, we must also be mindful of the possibility of aboveground storage facilities, such as platforms or structures, and undetectable informal storage loci. Structures likely used for storage have been identified at many Hohokam sites in central and southern Arizona, many of which closely resemble residential pit houses but were typically smaller and less substantial and lacked hearths (Crown 1987; Doyel 1974; Haury 1976; Henderson 2001). In addition, ceramic containers were important storage tools for the ancient inhabitants of southern and central Arizona. How the use of ceramics as storage containers affected the use of pits as storage features in the past and the distribution and character of pit features in archaeological contexts is not well understood.

Social Construction of Space

Our third approach to studying pits at the Mescal Wash site focuses on how they were spatially arranged and organized into the built environment of the Mescal Wash settlement. Pits played a role in the social constitution of the settlement space during the long history of occupation at the Mescal Wash site. From this perspective, the spatial distribution of pits and other features at the Mescal Wash site sheds light on how ancient people perceived, configured, and moved through the settlement space.

One component of the spatial analysis of pits concerns the accessibility of the pits and their contents to various segments of the community. The spatial arrangement of features can shed light on this issue. The physical placement of a pit relative to other features can be read in terms of which members of the settlement could or could not observe and/or gain access to the pit's contents. For instance, some pits may have been situated to limit access to a specific group of family members (intramural pits) or a group of households (pits located in common space within a house group). Other pits may have been deliberately situated to facilitate access to an entire settlement community or segment of the community. This "space syntax" perspective (see Hillier and Hanson 1984) complements the above view that pits are more than just economically efficient locations of food preparation or surplus storage; they are also symbols that provide a mechanism for creating and sustaining social orders of hierarchy and/or egalitarianism (Donley 1982; Parker Pearson and Richards 1994). Their spatial arrangement provides clues about their symbolic meanings.

Another component of this study concerns the public visibility of pit-related activities and the ability of groups or individuals to socially monitor other people's behaviors. The best-known example of this approach is the concept of the panopticon, a type of institutional building designed by English philosopher and social theorist Jeremy Bentham in the late eighteenth century. Most influentially, the idea of the panopticon was invoked by philosopher Michel Foucault (1975) as a metaphor for modern "disciplinary" societies. This concept refers to a prison arrangement characterized by a "multisided, domed building in which all inmates were visible from one central position, from which all could be observed, but in which no inmate could see any other" (Leone 1995:256). This concept is frequently cited to refer to spatial arrangements that facilitate social monitoring and maintenance of a social order. Similar ideas have been posited by archaeologists working in the U.S. Southwest. For example, Ortman (1998) argued that in the Mesa Verde region, grinding activities shifted from indoor to outdoor plaza areas to facilitate monitoring of women's activities following a period of aggregation. A related theme concerns the visibility of pit-related activities during the performance of communal feasts or other events involving public assembly (Mills 2007).

We concentrate our analyses below on the spatial distributions of pits relative to cotemporaneous features (structures, burials, possible open spaces, and other pits) at Mescal Wash and infer what they tell us about the social construction of household space or group space vs. more widely accessible communal spaces. In a similar vein, these analyses also provide insights into the public visibility vs. the seclusion of different pit-related activities. The long time span of the Mescal Wash habitation offers an opportunity to assess how practices and social constructions of space changed over the long term.

In sum, these three theoretical approaches or themes serve as the bases for the interpretations and discussions below. In the following sections, we shift our focus away from "high-range" theoretical approaches to studying pits to "middle-range" theory about how we classify pits and infer their functions.

Inferring Pit Functions in the Archaeological Context

In this section, we review studies of pit features found in archaeological context in the southern deserts of Arizona. This overview is not meant to be an exhaustive summary of studies of pits over this large region. We focus instead on a small but informative sample of analyses from cultural resource management projects in a variety of archaeological contexts. Our objective is to highlight examples of different kinds of archaeological studies of pits and the conclusions that these researchers have drawn from them. These studies also clue us into several interpretive obstacles that can arise when considering the morphological characteristics of pits, the fill contained within them, and the relationship of the fill to their intended or initial uses in a past systemic context (sensu Schiffer 1996).

Halbirt, Kaler, and Dongoske (1993) provided a detailed discussion of pit functions based on ethnographic case studies from the Great Basin and the desert Southwest. Our work here, as well as some of the other studies of pits reviewed below, relies on either the Halbirt, Kaler, and Dongoske (1993) detailed descriptions of ethnographically documented uses of various types of pits or their inexplicit understanding of how pits were used in ethnographic contexts (for storage, cooking, and so on). Halbirt and other researchers have compared various archaeologically recorded attributes of pits, such as morphology and fill contents, to attributes of ethnographically known pits used for different purposes. With those observations, archaeologists can infer possible functions or uses of pits discovered in archaeological contexts.

Based on their ethnographic overview, Halbirt, Kaler, and Dongoske (1993:144) developed a typology with eight functional categories (excluding burial pits and postholes): (1) pits used for cooking over open fire (oxidizing atmosphere); (2) covered pits that created reducing atmospheres for cooking, such as a pit oven; (3) pits used for cooking in hot ashes; (4) pits used for storage; (5) pits used for processing foodstuffs or other materials; (6) basket rests; (7) pot rests; and (8) tool caches. These eight pit types are divided into two broad functional groups: thermal (1–3 above) and nonthermal (4–8 above) pits. These pit types do not constitute an exhaustive list of all possible pit types or functions. However, they do provide quite a comprehensive list of many of the functions of pits and the activities for which they may have been utilized in the past.

Halbirt, Kaler, and Dongoske (1993) used their typology based on ethnographic observations to examine and interpret pit features found during the excavations of a Late Archaic period site, Coffee Camp, in the Santa Cruz Flats area of the Santa Cruz River drainage, north of Marana, Arizona. Their sample consisted of 214 pit features. The authors examined numerous lines of evidence: plan and profile shapes; length, width, and depth measurements; the presence of several indicators of thermal uses (oxidized or reduced burned walls, ash, charcoal, and FCR); and artifact content and ethnobotanical and faunal remains from pit fill. Based on these lines of evidence, they inferred 11 pit functions in their study area: (1) pits used for cooking over open fire; (2) pits used for cooking with indirect heat, such as a pit oven; (3) pits with unknown or miscellaneous thermal use; (4–5) two subtypes of processing pits; (6–9) four subtypes of storage pits, including possible caches; (10) basket rests; and (11) postholes (Halbirt, Kaler, and Dongoske 1993:171).

In another study, Hackbarth (1993) examined pit features excavated at seven Classic period Hohokam sites also located in the Santa Cruz Flats area. The seven sites encompass a mix of village, farmstead, and non-habitation sites that the excavators described as "resource-procurement areas" and "limited-activity loci" (Martynec and Henderson 1993). Hackbarth's (1993:513) stated goals in his study were to "summarize the variability in pit features" at these sites, assess their potential functions or uses, and compare types of pits among the sites. The data he examined consisted of plan and profile shapes; length, width, and depth measurements; the presence of several indicators of thermal use (oxidized or reduced burned walls, ash, charcoal, and FCR); and ethnobotanical and faunal remains from pit fill. Based on those data, he developed functional categories of pits: open thermal pits, hearths, ash-filled pits, pit ovens, rectangular thermal pits, storage pits, processing pits, water-retention basins/borrow pits, tombs, postholes, and pits of unknown function.

Examining the distribution of his different pit types through time and among different sites, Hackbarth (1993:538–540) inferred several conclusions. First, the ratio of processing pits to storage pits (1.3:1) was relatively constant across different habitation sites. Second, he observed substantial differences among habitation sites in the frequencies of postholes, but the reason for that disparity was not clear. Limited-activity sites had relatively high frequencies of postholes, perhaps because of the construction of temporary structures, such as windbreaks, in those locales (Hackbarth 1993:539). Third, although the relative frequencies of storage and processing pits did not change over time, a substantial increase was evident in the frequency of thermal pits during the Classic period, the reason for which was also unclear.

More recently, Craig and Walsh-Anduze (2001) examined pit features encountered during excavations at the Grewe site, a pre-Classic period (approximately A.D. 550–1150) settlement, and the Horvath site, a Classic period (approximately A.D. 1150–1450) settlement, both of which are situated adjacent to the Casa Grande National Monument, near Coolidge, Arizona. Their study focused on plan and profile shapes, metric attributes (length, width, and depth), and several indicators of thermal use (oxidized or reduced burned walls, ash, charcoal, and FCR). Based on those lines of evidence, they defined four functional types: (1) open-fire thermal pits, (2) covered thermal pits, (3) storage pits, and (4) processing pits (Craig and Walsh-Anduze 2001:131).

Craig and Walsh-Anduze (2001:132) identified what they saw as several trends or patterns in food preparation, consumption, and storage at the Grewe site. They concluded that food was cooked inside structures more often than in extramural areas. In addition, food was cooked more often in open firepits than in covered thermal pits. The baking of food appeared to have been carried out in extramural communal or suprahousehold contexts, because a concentration of covered thermal pits was identified in an extramural space. Food also appeared to have been predominantly processed in extramural spaces, but food storage was more frequent in intramural spaces. Processing pits outnumbered storage pits by four to one, substantially greater than the ratio of processing to storage pits in the Archaic and Classic period sites in the Santa Cruz Flats area (see Hackbarth 1993; Halbirt, Kaler, and Dongoske 1993).

Wöcherl (2005) summarized data on extramural pits from a number of Early Agricultural period and Early Formative period sites in the Tucson Basin. She relied on several lines of evidence, including field identifications of different morphological pit types; length, width, depth, and volume measurements; oxidation; and artifact content. Her analyses suggested that different sites within the Tucson Basin have different sets of pits that may reflect differences in site activities, such as storage and food processing. These differences among sites may have to do with increases in the reliance on agriculture through time and variations in the kinds of subsistence adaptations employed by the residents of different sites during the long transition to an agricultural-based economy in the Tucson Basin.

All of these studies highlight the obstacles involved in examining pits, especially the complex relationship between pit fill and the use(s) of such features in the systemic context. In trying to understand that relationship, we are confronted with at least three options for interpreting the fill materials in the pits: (1) the fill was deposited as part of the original, intended use of the pit in the systemic context (cultural formation processes), (2) the fill of the pit was deposited as part of the secondary reuse of the pit as a refuse receptacle in the systemic context (cultural formation processes), or (3) the fill of the pit was deposited by natural formation processes (e.g., infilling with sediments) after the pit fell into disuse and entered the archaeological context (Schiffer 1996).

Archaeologists face difficult challenges in discerning what kinds of activities or discard behaviors may have resulted in the deposition of artifacts in pit fill and whether those contents reflect primary or secondary cultural refuse vs. natural formation processes. For example, regarding Classic period Hohokam sites along the Santa Cruz floodplain, Hackbarth (1993:539) concluded that the fill of pit features was most likely not associated with the original uses of the pits in the systemic context. Based on the ubiquity of several plant species in pollen and flotation samples from pit features, he argued that the pits contained secondary trash deposits. Halbirt, Kaler, and Dongoske (1993) arrived at similar conclusions based on a lack of variability in the pollen and flotation samples taken from pits at the site of Coffee Camp. The distributions of different plant remains across pits suggested to them that the plant remains in the fill of the features had not been deposited as a result of the activities that took place as the primary or original uses of the pits but instead represented secondary deposition of materials and related more to an "array of activities that occurred" throughout the site (Halbirt, Kaler, and Dongoske 1993:169).

Wöcherl (2005) arrived at similar conclusions regarding pit fill at Early Agricultural period sites in the Tucson Basin. She argued that pit fill and contents did not necessarily inform on pit function, because they frequently represent secondary refuse that entered the pit after it had been abandoned from its original intended function (or functions). In some cases, however, she identified what appeared to be de facto refuse, which she interpreted as evidence of increasing levels of sedentism and a lack of long-term abandonment of sites through time. Her examinations of artifact content shed light on site activities as well as occupational duration and intensity, thereby highlighting the utility of separately examining feature fill as a means to exploring topics such as site occupation, mobility and sedentism, and changes in subsistence and domestic organization through time.

In all, these studies provide a useful framework for identifying the relevant attributes and characteristics required to meaningfully examine pit-related activities. In the analyses below, we heed the lessons learned from these previous studies and attempt to disentangle the forms, functions, and fill characteristics of pit features and discuss what they might tell us about past activities and the domestic life of the inhabitants of the Mescal Wash site. For analysis purposes, we treat the dimensional and formal characteristics of pits separately from examinations of their fill. In doing so, we analytically separate inferences of feature function based on metric attributes from most inferences of trash and refuse disposal based on analyses of fill content. These latter analyses potentially provide information about trash and refuse disposal across space and through time and changes in the consumption of materials and food.

The Pit Sample

In total, 2,112 extramural pit features were identified at Mescal Wash during the Phase 1 and 2 investigations (Table 21). Many of them were recorded as "indeterminate pits" and were not further investigated (see Volume 1, Chapter 3). Those that were subjected to further investigation received varying levels of effort. Many were selected for full or partial excavation. Some were merely probed, to detect evidence of human remains or cultural materials, and others were sampled for macrobotanical and pollen analyses. The latter features did not generate sufficient information about metric attributes or artifact content to be included in our current study. Smaller numbers of intramural pit features were also identified, and nearly all of them (a total of 148, excluding postholes) were excavated. The present study is focused on the 413 pit features (148 intramural and 265 extramural) in Loci A, C, and D that were either partially or fully excavated. The partially excavated features were mostly bisected, to inspect the feature profile, but in a few cases, smaller fractions of the feature matrix were excavated. Burials (human and animal) are not included in this inventory, but caches and borrow pits are. The 265 excavated extramural features are summarized in Table 22.

Importantly, the sample of pits selected for full or partial excavation does not represent a random or a systematic sample. As described in Chapter 3 of Volume 1, roughly 15 percent of identified extramural-pit features were subjected to excavation. The sampling procedure was judgmental and was intended to gain as much non-redundant

Table 21. Extramural Pit Features Identified at the Mescal Wash Site

Type/Function (Preliminary)	Phase 1[a]	Phase 2[b]	Total
Borrow pit	1	7	8
Cache	—	3	3
Firepit	—	24	24
Hearth	—	6	6
Horno	1	6	7
Roasting pit	30	109	139
Unknown function	129	1,796	1,925
Total	161	1,951	2,112

[a] From Volume 1, Table 3.4.
[b] From Volume 1, Table 3.8.

Table 22. Summary of Extramural Pits Excavated at the Mescal Wash Site (Both Phases)

Feature Type	Locus A		Locus C		Locus D		Subtotal		Total
	Phase		Phase		Phase		Phase		
	1	2	1	2	1	2	1	2	
	Thermal Pits								
Firepit	—	—	—	4	—	5	—	9	9
Hearth	—	—	—	1	—	1	—	2	2
Horno	—	1	—	1	—	2	—	4	4
Roasting pit, basic	—	5	—	11	7	17	7	33	40
Roasting pit, bell-shaped	—	—	—	—	2	6	2	6	8
Roasting pit, rock-lined	—	—	—	2	1	5	1	7	8
Subtotal	—	6	—	19	10	36	10	61	71
	Nonthermal Pits								
Borrow pit	—	—	—	—	—	7	—	7	7
Cache	—	—	—	—	—	3	—	3	3
Nonthermal pit, bell-shaped	—	—	—	8	2	20	2	28	30
Nonthermal pit, general	—	32	1	36	2	83	3	151	154
Subtotal	—	32	1	44	4	113	5	189	194
Total	—	38	1	63	14	149	15	250	265

information as possible regarding each of the various previously defined pit types (see below for typology description). Hence, one basis for selecting pits for excavation in the field was investigation of a range of feature types and functions, as inferred from surface attributes or probing evidence (i.e., prior to excavation). In some cases, the excavation team targeted less-frequent pit types—such as the bell-shaped pits that were presumed to date to the Late Archaic period—at the expense of the more-frequent types. Also, many extramural pits were excavated because they appeared to be spatially and stratigraphically associated with structures.

Intramural-pit features are overrepresented in our sample, because they were excavated at a much greater frequency. Of the 118 structures identified during Phase 1 and 2 work, 97 structures were partially or completely excavated (see Table 10 in Volume 1). When exposed, all intramural features were completely excavated. Thus, there was a greater relative frequency of identified intramural-pit than extramural-pit features excavated.

In light of these sampling vagaries, we are unable to reconstruct the systematic context (see above) of pit use at any given time at Mescal Wash. That is, we are unable to accurately identify proportional differences in the ratios of the various pit types or infer variability in their use and construction frequencies. Nor are we able to infer the relative frequencies of the different behaviors and practices associated with the various types of pits. For example, we cannot determine the frequencies of thermal vs. nonthermal pits in use during any given time period with a high degree of confidence—a problem that was further exacerbated by the dearth of chronometric information collected from extramural features. With the exception of the suspected Late Archaic period bell-shaped pits, few extramural pits were subjected to Lengyel's AM study and detailed chronological analysis (see Volume 2, Chapter 2). Consequently, we are unable to organize the pit features in groups based on contemporaneity as Lengyel has done for the structures.

Despite these complications, we are able to make reasonable inferences about activities and practices related to pits at Mescal Wash based on the sizes, shapes, and contents of the investigated pits. For instance, variability in roasting-pit sizes might relate to differences in the scale of food-production activities. Also, we are able to infer temporal associations for some of the extramural pits based on associations with dated features (based on proximity) or the presence of temporally diagnostic materials (such as painted ceramics and projectile points). With that kind of information, we can start looking at changes over time in the ratios of various pit types or attributes (e.g., thermal vs. nonthermal). Such diachronic analyses highlight changes in the contexts of cooking and storage activities over a long span of occupation (Graves 2011). Increases in intramural vs. extramural storage, for example, imply changes in the social conditions of food preparation, consumption, and intracommunity interaction.

Classifying the Pit Features

As explained above, dimensional and formal characteristics of pits are commonly examined to identify possible pit functions and related activities. For example, relatively large diameters and depth measurements (along with specific aspects of feature fill and location) are often used as indicators of roasting pits. Likewise, pits with relatively small orifices and bell-shaped profiles are often identified as storage pits. More generally, pits with evidence of burning, either along their walls or within their fill, are categorized as fulfilling various thermal functions, such as cooking and generation of heat for warmth or for production-related activities. The locations of pits within or outside habitation structures or at a distance away from habitations (or other features) also provide insight into possible pit functions.

Here, we examine different dimensional and formal attributes of pit features and characterize the pits in several ways. Characterizing pits based on different sets of attributes allows us to examine the distribution of pit features over time and their spatial relationships to other pit and non-pit features. In addition, it allows us to infer loosely defined pit functions that provide insights into site activities. Our pit types and functional categories are based largely on metric attributes. In some cases, fill contents shed light on intended pit use. For example, it is possible to tentatively identify caches of artifacts in pits and to examine relationships between burned material in pit fill and the uses of those features for thermal or cooking purposes. In most cases, however, pit contents indicate postdepositional reuse of pits as receptacles for domestic trash.

In the following discussions, we define two separate and overlapping sets of pit types, based on metric attributes: (1) small and deep pits, (2) small and shallow pits, (3) medium-sized and deep pits, (4) medium-sized and shallow pits, (5) large and deep pits, and (6) large and shallow pits. Below, we explain our bases for defining size and depth categories. The second set of types is based on the context in which the pits were found (either inside or outside habitation structures) and direct evidence of burning on the pit walls: (1) extramural thermal pits, (2) extramural nonthermal pits, (3) intramural thermal pits, and (4) intramural nonthermal pits. We use these two typologies to infer possible pit functions, such as various cooking activities, storage purposes, caches, borrow pits, and some combination of processing and storage activities.

One goal of this exercise is to compare our inferred pit classifications and functions with the typology previously developed by Vanderpot (2001b:14–15; Vanderpot and Altschul 2000:23–24) based on inferred functions, which was used to characterize pit features in Volumes 1 and 2 (for feature-type descriptions, see Volume 2, Chapter 1). In that classification scheme, the nonthermal pits were classified as borrow pits, bell-shaped pits, caches, or pits of one more-inclusive and less-precisely defined type that encompassed the majority of the nonthermal pits. Thermal pits were classified using a larger number of types, including rock-lined roasting pits, bell-shaped roasting pits, roasting pits (all such features without bell-shaped profiles or rock-lining), hearths, *hornos*, firepits, and indeterminate thermal pits. We conclude this section with a comparison of these two feature-classification systems.

Inferring Pit Size, Shape, and Volume

To examine the metric attributes of the pits, we relied entirely on measurements of the feature depths and the lengths and widths of their openings. We used those measurements to characterize the horizontal dimensions (size), vertical dimensions (cross-section shape), and volumes of the pits in our sample. Field observations included characterizations of the plan-view and cross-section shapes of pits. However, those descriptions often did not appear to match the drawn plan views and profiles. In addition, it was often unclear how much of a role postdepositional processes, such as erosion or bioturbation, had played in creating the shapes and sizes of pits observed after excavation.

Deaver (2010) developed two indices to characterize the sizes and shapes of pit features based on the metric attributes. The diameter index (horizontal dimension) for a pit is calculated as

$$d = (l \times w)^{1/2}$$

where d is the diameter index, l is the maximum length (cm) of the pit opening, and w is the minimum length (cm) of the pit opening. This index accounts for potential irregularities in the plan shapes of pits.

The shape index, based on the pit cross-section, is calculated as

$$s = dp/d$$

where s is the shape index, dp is the maximum depth measurement (cm) of the pit, and d is the aforementioned diameter index. This calculation provides a way of quantifying the shallowness or depth of a pit relative to the pit's opening.

In addition to Deaver's indexes of size and cross-section shape, we calculated volume estimates using various formulae, depending on each pit's plan and cross-section shapes. Volumes were estimated based on in-field length, width, and depth measurements. However, those measurements were variable, for example, for pits with ovate or circular plans or with basin-shaped, conical, or cylindrical (i.e., rectangular-profile) cross-sections. Table 23 lists the formulae employed to estimate volumes of pits with different combinations of plan and cross-section shapes. For pits with complex profiles, especially bell-shaped pits, each feature was divided into separate portions that were calculated separately. For example, in the case of a pit with different profile shapes in its upper and lower portions, volumes were calculated separately for those portions and then combined.

Notably, the quality and breadth of attribute information gleaned from the 413 excavated pit features at the Mescal Wash site were highly variable, given the different levels of effort during the excavations. For that reason, the size, shape, and volume indices described above were calculated for different numbers of pits. In all, the size and shape indices were calculated for 391 features. However, pit volume could only be estimated for 347 features. In the following section, we discuss how we used size and shape indices (for 391 pits) and volume estimates (for 347 pits) to infer potential pit functions. The feature-count breakdowns for the three different pit samples are shown in Table 24, and breakdowns of the samples of 391 and 347 features, respectively, are detailed in Tables 25 and 26. In the following discussions and tables, we will consistently make clear what particular samples we are talking about.

Pit Classifications Based on Metric Attributes

To evaluate these calculations and classify the pits, we created histograms to detect possible modalities based on size, shape, and volume information, which is illustrated in Figures 50–52. All three histograms showed at least subtle modalities that allowed us to qualitatively divide the sample into size, shape, and volume classes. Our recognition of these modalities was somewhat impressionistic, and the value of this exercise lies not in assigning a specific feature to an exact size or shape class but in providing a means to characterize the overall distribution of different pit sizes and shapes across the sites and time periods of interest. In other words, our recognition of these modalities was intended to be an etic indicator to facilitate our interpretations of pit variability, but we do not wish to imply that these classifications had conceptual (emic) meaning to the ancient inhabitants of the Mescal Wash site.

The histogram of the diameter-index scores is illustrated in Figure 50, using intervals of 0.05 m. We recognized two breaks in the distribution, from which were inferred areal-size classes. One break was evident at about 0.65 m; a second was evident at about 1.15 m. Based on these modalities, we defined three size classes: small (index score of less than 0.65 m), medium-sized (0.65–1.15 m), and large (greater than 1.15 m). Roughly two-thirds of the pits were classified as small (262 features, or 67 percent), and smaller proportions were classified as medium-sized (100 features, or 28 percent) or large (19 features, or 5 percent).

Intervals of 0.05 m were also used to calculate the histogram for the shape index (see Figure 51). We defined two shape groups based on a break between two peaks at about 0.7 m (pits with depths that were roughly 70 percent of their average diameters). Lower values (less than 0.7 m) were classified as shallow pits; higher values (0.7 m or greater) were classified as deep pits. Shallow pits were those that, regardless of size, had depths less than or equal to about 70 percent of their respective average diameters. Deep pits were those that had depths greater than 70 percent of their average diameters. In this classification system, the majority of pits were classified as shallow (322 features, or 82 percent), and 69 pits (or 18 percent) were classified as deep.

The histogram for pit volumes employed a smaller interval of 0.025 m^3. The distribution of the volume measurements of the pits in the sample was heavily skewed to the left (see Figure 52), which underscored the prevalence of generally low-volume pits in the Mescal Wash sample. We could detect no obvious breaks or modalities in the distribution of pit volumes, especially considering the heavy skew of the histogram. One obvious peak

Table 23. Formulas for Estimating Pit Volumes Based on Shape Attributes

Plan and Cross-Section Shapes	Geometric Estimate	Equation
Circular, basin-shaped	partially filled sphere	$(Pi \times h^2 \times r) - (Pi \times h^3/3)$
Circular, conical	cone	$Pi \times h/3 \times (r1^{2)}$
Circular, cylindrical	cylinder	$Pi \times radius^2 \times length$
Ovate, basin-shaped	elliptical dome	$(Pi/6 \times (major \times minor \times vertical))/2$
Ovate, conical	elliptical cone	$\pi \times {}^{1}/_{3} \times R \times H$
Ovate, cylindrical	elliptical cylinder	$Pi \times major \times minor \times length/4$
Rectangular, basin-shaped	half a rectangular prism	$B \times {}^{1}/_{2} \times H \times D$
Some bell-shaped pits	truncated cone	$Pi \times h/3 \times (r1^2 + (r1 \times r2) + r2^2)$

Table 24. Breakdowns of Features within the Different Study Samples

Total Sample of 413 Excavated Features

- 146 thermal and 267 nonthermal
- 148 intramural pits
  - 75 thermal and 73 nonthermal
- 265 extramural pits
  - 71 thermal and 194 nonthermal

Sample of 391 Features with Known Width/Depth (i.e., Size/Shape)

- 137 thermal and 254 nonthermal
- 141 intramural pits
  - 69 thermal and 72 nonthermal
- 250 extramural pits
  - 68 thermal and 182 nonthermal

Sample of 347 Features with Known Volume

- 124 thermal and 223 nonthermal
- 119 intramural pits
  - 62 thermal and 57 nonthermal
- 228 extramural pits
  - 62 thermal and 166 nonthermal

Table 25. Breakdown of the Sample of 391 Intramural and Extramural Pits with Known Size/Shape

Feature Type	Total
	Thermal Pits
Extramural	
Firepit	7
Hearth	2
Horno	4
Indeterminate pit	3
Roasting pit, bell-shaped	8
Roasting pit, general	36
Roasting pit, rock-lined	8
Intramural	
Hearth	69
Subtotal, thermal pits	137
	Nonthermal Pits
Extramural	
Borrow pit	4
Cache	2
Nonthermal pit, bell-shaped	29
Nonthermal pit, general	147
Intramural	
Ash-filled pit	4
Pit	68
Subtotal, nonthermal pits	254
Total	391

Table 26. Breakdown of the Sample of 347 Intramural and Extramural Pits with Known Volume

Feature Type	Total
	Thermal Pits
Extramural	
Firepit	7
Hearth	2
Horno	4
Indeterminate pit	3
Roasting pit, bell-shaped	4
Roasting pit, general	34
Roasting pit, rock-lined	8
Intramural	
Hearth	62
Subtotal, thermal pits	124
	Nonthermal Pits
Extramural	
Borrow pit	3
Cache	1
Nonthermal pit, bell-shaped	22
Nonthermal pit, general	140
Intramural	
Ash-filled pit	4
Pit	53
Subtotal, nonthermal pits	223
Total	347

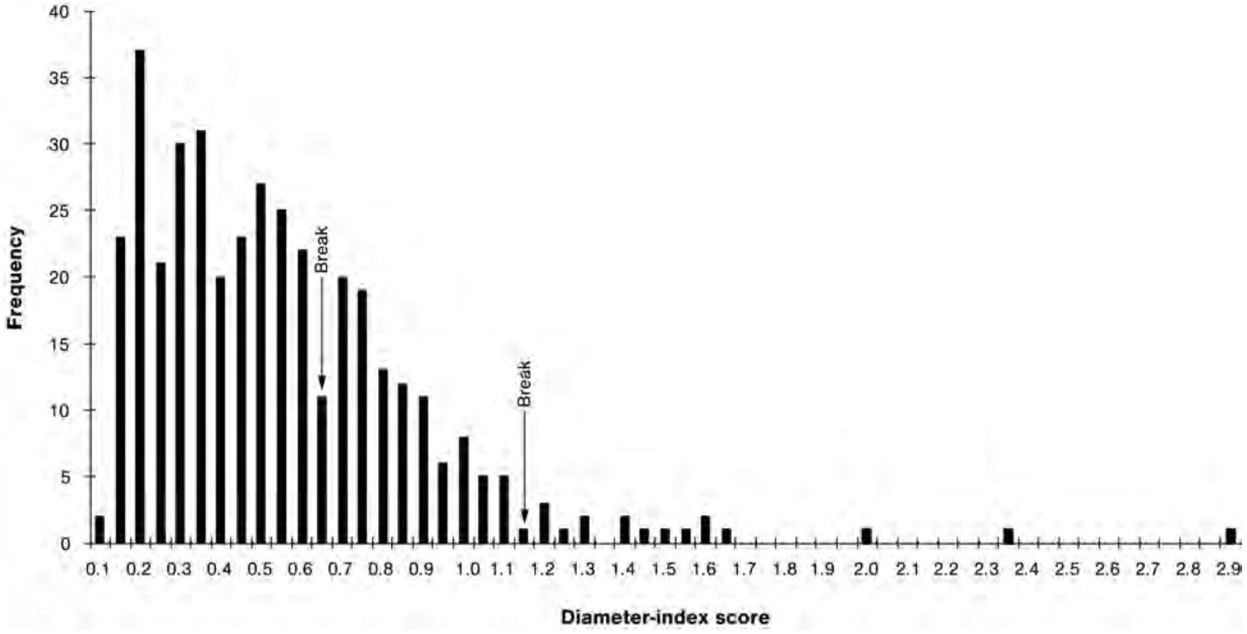

Figure 50. Histogram of diameter-index scores (0.05-m intervals).

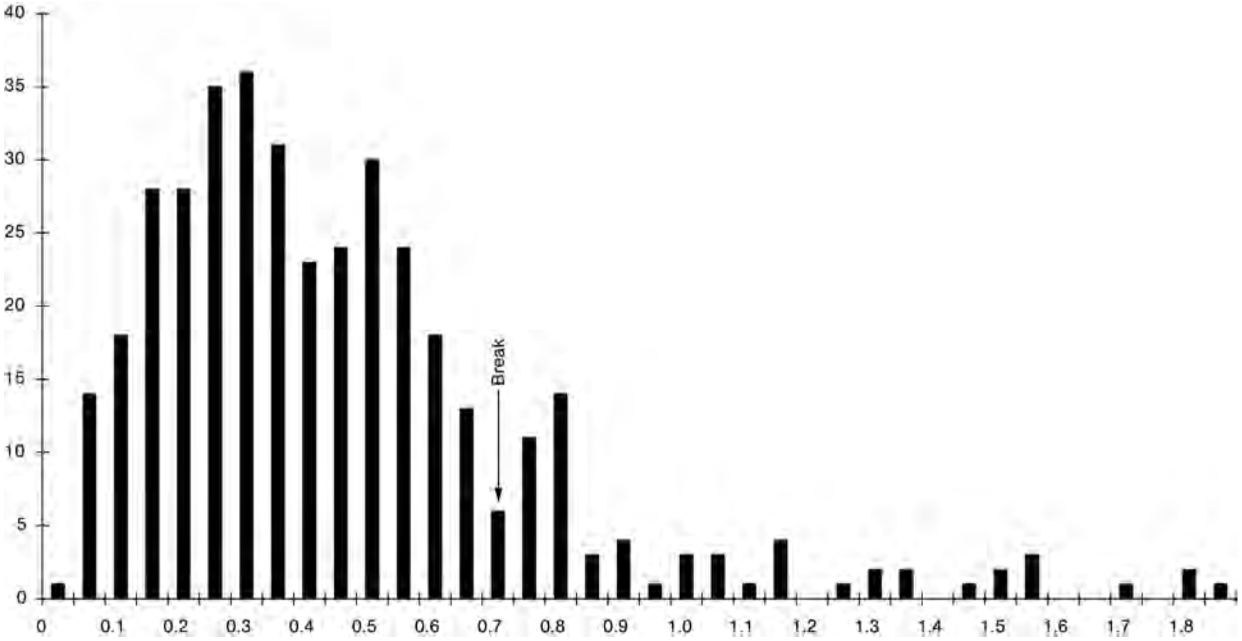

Figure 51. Histogram of shape-index scores (0.05-m intervals).

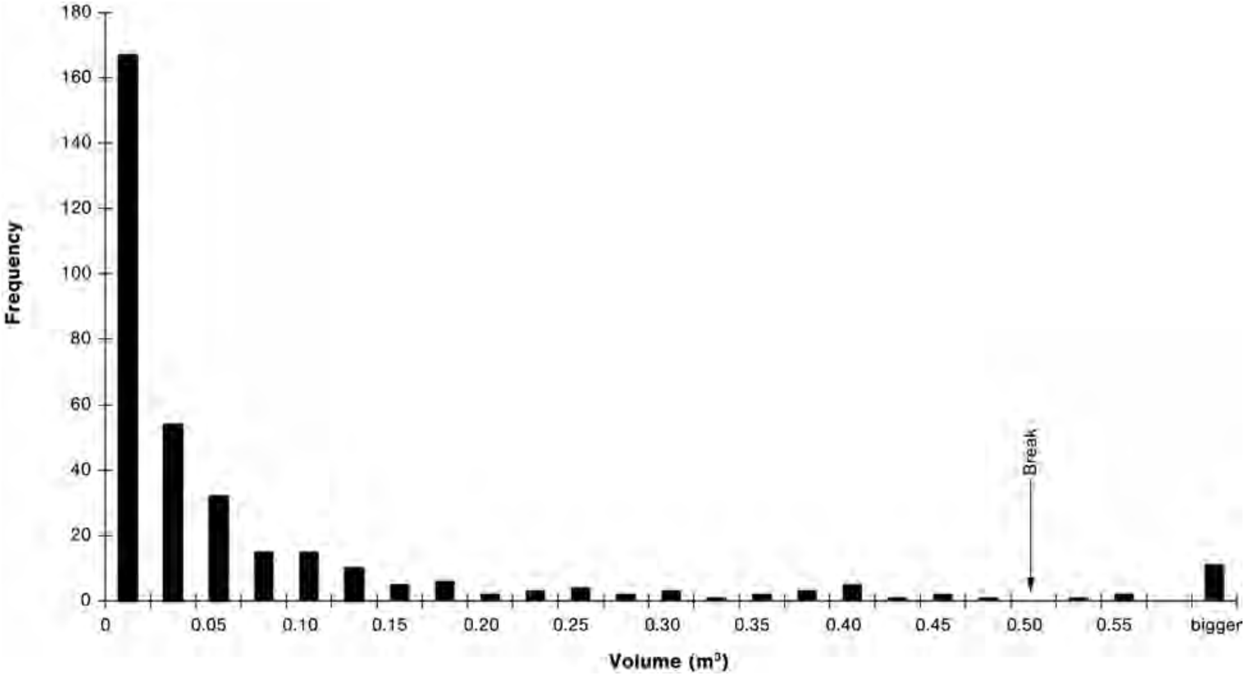

Figure 52. Histogram of estimated pit volumes (0.025-m^3 intervals).

encompassed the lower intervals in the histogram (0.125 m^3 or less), but no additional modalities were evident to the right of that peak. Rather, the distribution above 0.125 m^3 was relatively continuous. No pits were classified in the 0.500–0.525-m^3 interval, however, which provided a suitable break for distinguishing volume classes. We thus classified the 347 features in the study sample as low-volume pits (less than 0.500 m^3) and high-volume pits (0.525 m^3 or greater). The overwhelming majority of features in our sample were classified as low-volume pits (333 features, or 96 percent); only 4 percent (14 features) were classified as high-volume pits.

Combining the diameter and shape indices, nearly 80 percent of the features were classified as either small, shallow pits (212 features, or 54 percent) or medium-sized, shallow pits (93 features, or 24 percent), all of which were also classified as low-volume pits. Less than 10 percent of the pits were classified as large and shallow (4.4 percent) and either medium-sized or large and deep (4.4 and 0.5 percent, respectively). Not surprisingly, all the high-volume pits were classified as either large or deep, but only one large and deep pit was recorded. Overall, these trends underscore the pervasiveness of modest-sized pits at Mescal Wash. Large-capacity pit features were relatively infrequent.

Intramural and Extramural Pits

Two variables are important for inferring pit function. One is the spatial context of the pits—i.e., whether they were used in intramural (within structures) or extramural (in outdoor space) locations. The second variable is the presence or absence of thermal alteration—i.e., past use involving some form of cooking or heating activity during final use in the systemic context (Schiffer 1996). We explore the former variable in this subsection and the latter in the following subsection.

In most cases, the spatial contexts of the pits were easily inferred: intramural pits are within the confines of structure walls, and extramural pits are outside structures. In a small number of cases, however, that distinction was not always readily evident. Some features at Mescal Wash were superimposed over older features, resulting in complex amalgams of overlapping features (mainly in Locus D). For the most part, the superimposed features consisted of overlapping structures. In some cases, however, pit features overlapped with structures, which complicated efforts to infer whether the pits had been either intramural features that were contemporaneous with the structures or extramural pits that had superimposed upon, or were superimposed by, earlier or later structures. As explained in Volume 1 (e.g., see Volume 1, Chapter 7), the superimposed features were carefully and systematically investigated, to make reasonable inferences about stratigraphic relationships among the individual features. Also worth noting are two extramural hearths excavated at Mescal Wash, both of which might have been intramural hearths in which evidence of a surrounding structure (e.g., postholes or a wall trench) was no longer visible.

In the excavated sample from Mescal Wash, roughly two-thirds of the 413 partially or completely excavated pits (255 features, or 63 percent) were from extramural contexts, and about one-third (148 features, or 37 percent) were from intramural contexts (see Table 24), suggesting a roughly 2:1 ratio of extramural to intramural pits. These differences in frequency should not be viewed as indicators of the frequency of use or construction in the systematic context. As noted above, given the vast number of features exposed during the Phase 1 and 2 investigations, SRI archaeologists were unable to fully or partially excavate many of the recorded features. In general, however, the excavations focused heavily on structures, and there was a higher fraction of intramural features than extramural features excavated. Hence, the ratio of extramural to intramural pits in use at any given time was likely greater than 2 to 1.

Based on the above classifications, and using the sample of 391 pits with known size and shape (141 intramural and 250 extramural), intramural pits tend to have smaller openings but deeper profiles than extramural pits (Table 27). Slightly more than 1 in 5 intramural pits (30 of 141 features, or approximately 21 percent) were classified as deep, compared to 16 percent among the extramural pits (39 of 250 features). Yet nearly all the intramural pits were classified as small in horizontal extent (130 of 141, or approximately 92 percent), and the rest were classified as medium-sized. By contrast, only about half of the extramural pits (132 of 250 features, or approximately 53 percent) were classified as small, and medium and large pits constituted approximately 40 and 8 percent, respectively (99 and 19 features out of 250, respectively). Also, a notably higher percentage of extramural pits (13 of 288 features, or 5.8 percent) than intramural features (1 of 199 features, or 0.8 percent) were classified as having large volume (not listed in Table 27). In all, the smaller size and greater depth of the intramural pits to some extent probably reflect efforts to conserve floor space within the structures. Such restrictions probably were not equally pertinent in extramural spaces. The tendency toward larger volume among the extramural pits is also probably attributable to the increased availability of horizontal space.

Thermal and Nonthermal Pits

Inferring what constitutes a thermal pit also requires explanation. In extramural contexts, thermal use was inferred based on the presence of oxidized walls. Oxidation of pit walls could only have occurred if the walls had been in contact with open flames in an oxidizing atmosphere for an extended period of time. Other pit studies (e.g., Hackbarth

Table 27. Distribution of the Size- and Shape-Index Groups among Intramural and Extramural Pits

Shape Group, by Size Group	Extramural Pits		Intramural Pits		Total	
	Count	Column Percentage	Count	Column Percentage	Count	Column Percentage
Large						
Deep	2	0.8	—		2	0.5
Shallow	17	6.8	—		17	4.4
Subtotal	19	7.6	—		19	4.9
Medium						
Deep	12	4.8	5	3.5	17	4.3
Shallow	87	34.8	6	4.3	93	23.8
Subtotal	99	39.6	11	7.8	110	28.1
Small						
Deep	25	1.0	25	17.7	50	12.8
Shallow	107	42.8	105	74.4	212	54.2
Subtotal	132	52.8	130	92.2	262	67.0
Total	250	100.0	141	100.0	391	100.0

Note: Size and shape could not be calculated for all 413 pits in the sample. The data above are from the 391 pits for which both attributes could be calculated.

1993; Halbirt, Kaler, and Dongoske 1993) have considered additional lines of evidence to identify burning in pit fill, such as the presence of charcoal, ash, and/or thermally affected rock. However, as discussed above, the fill of a pit does not necessarily relate to its original or intended use and function. Prior to abandonment, pits in the southern Arizona deserts were often used as receptacles for refuse disposal. Cultural fill also may accumulate in abandoned pits as a result of infilling by natural processes (see Wöcherl 2005). However, oxidized walls provide direct evidence that the pit at some point was used for a thermal function, regardless of any potential prior uses.

It is possible, however, that some thermal uses would not result in the oxidation of the pit walls. For example, use of a pit for heating or cooking may not take place for a sufficient period of time to cause visible oxidation of the surrounding soils. Also, some cooking or heating techniques may have resulted in the creation of a reducing atmosphere (i.e., deprived of oxygen and air intake) rather than an oxidizing atmosphere. Creating a reducing atmosphere—such as by using thermally affected rock and charcoal as fuel—may leave the sides of a pit blackened but not oxidized, depending on where and to what degree the fuel expended within it was rendered to charcoal (see Halbirt, Kaler, and Dongoske 1993:135–136; Haury 1976:160). However, we assume here that instances in which the fuel used in a thermal pit created reducing conditions or was heated elsewhere are rare in the archaeological record. It is much more likely that the fuel used for heating in a reducing atmosphere was rendered to charcoal within the pit (sensu Halbirt, Kaler, and Dongoske 1993:136). In those cases, it is likely that the walls of a pit used for such a function would have been oxidized to some degree. Those that were used intensively developed a thick, black "rind."

Equally important is that the presence of oxidized walls does not necessarily indicate the presence of a thermal pit. Wöcherl (2005:22), for instance, discussed features in the Tucson Basin of which the pit walls were thermally hardened, although they had been used for storage (i.e., a nonthermal function). In those cases, the fire-hardened walls would have retarded the ability of rodents and insects to access the pit contents. How often, or in what contexts, such modifications to storage pits were made is poorly understood, but the pits excavated at Mescal Wash provided no evidence of having been modified in that manner. Despite this possibility, we assume here that the presence of oxidized walls in a pit indicates thermal use and, indeed, provides the most accurate and conservative manner in which to identify a thermal function.

In intramural contexts, we altered our criteria for identifying thermal features to accommodate the prevalence of obvious hearths *without* oxidized walls. Most of the structures at Mescal Wash were house-in-pit constructions in which hearths were consistently and predictably situated adjacent to entrances (see Haury 1986; Motsinger 1993). In comparison, the presence and placement of additional intramural pits were variable, suggesting that the placement of a hearth adjacent to entryways was a widely and consistently heeded canon of pre-Hispanic architecture in the U.S. Southwest. These features were very likely used for thermal functions (heating, light, and cooking), but in some cases, the heat generated by the hearths may not have been sufficient to oxidize the pit walls. Despite the absence of oxidized walls in some intramural hearths, most of them contained evidence of thermal use, such as charcoal, ash, and FCR in the fill (especially ash, see below). Although we cannot rule out that some of that thermal debris was deposited in the hearth pit as secondary deposition of refuse, all intramural hearths were classified as thermal pits.

The sample of all 413 excavated pits included 148 intramural pits and 265 extramural pits (see Table 24). About equal numbers of intramural pits were classified as thermal (75 features) and nonthermal (73 features). In contrast, nearly three-quarters of the 265 extramural pits were classified as nonthermal (194 features, or 73 percent), compared to 27 percent classified as thermal pits (71 features), a 3:1 ratio of nonthermal to thermal pits. The excavated frequency of thermal and nonthermal pits in intramural contexts is probably fairly representative of their ratio in the ancient past, because the probability of encountering either class of pits would have been roughly equal within the fully or partial excavated structures. We thus reasonably assume that, on average, the occupants of Mescal Wash constructed a roughly equal number of thermal and nonthermal pits in intramural spaces. However, as explained above, many extramural features were unexcavated or were only probed or sampled, and thus the sample chosen for excavation was judgmental and not determined using random, systematic criteria. Hence, we cannot be sure that the 3:1 ratio of nonthermal to thermal pits in extramural contexts is representative of their ratio in the systemic context, and we suspect that it was greater.

As evident from the 391 pits for which size and shape could be calculated, the distributions of both the diameter- and shape-index scores in the thermal and nonthermal categories were virtually identical (Table 28). According to the diameter-index calculations, the majority of thermal pits and the majority of nonthermal pits were equally small in lateral extent (approximately 66 and 67 percent, respectively), and roughly the same proportions were medium-sized (approximately 28 percent for both categories) and large (5.8 and 4.3 percent, respectively). For the shape index, approximately 84 and 82 percent, respectively, of the thermal and nonthermal pits were classified as shallow, indicating nearly equal proportions of shallow and deep pits. Furthermore, 96 percent of both thermal and nonthermal pits were classified as having low-volume capacities (not listed in Table 28). Overall, these results indicate roughly equitable size distributions of the thermal and nonthermal pits.

Comparing Classification Systems

As noted above, one goal of this analysis was to compare the results of our classification system with the function-based system employed to classify pit features in Volumes 1 and 2 and earlier reports (Vanderpot 2001b:14–15; Vanderpot and Altschul 2000:23–24). The latter classification already accounts for variability in the thermal-nonthermal and intramural-extramural dimensions. That is, none of the functional types can be subdivided into thermal and nonthermal categories or intramural and extramural categories. We therefore focus on their relationship with the metric-based classifications outlined above (Tables 29–31). Unfortunately, only five function-based type categories (nonthermal pit, intramural

Table 28. Distributions of the Size- and Shape-Index Groups among Thermal and Nonthermal Pits

Shape Group, by Size Group	Thermal Pits		Nonthermal Pits		Total	
	Count	Column Percentage	Count	Column Percentage	Count	Column Percentage
Large						
Deep	2	1.5	—		2	0.5
Shallow	6	4.4	11	4.3	17	4.4
Subtotal	8	5.8	11	4.3	19	4.9
Medium						
Deep	7	5.1	10	3.9	17	4.3
Shallow	31	22.6	62	24.4	93	23.8
Subtotal	38	27.7	72	28.3	110	28.1
Small						
Deep	13	9.5	37	14.6	50	12.8
Shallow	78	56.9	134	52.8	212	54.2
Subtotal	91	66.4	171	67.3	262	67.0
Total	137	100.0	254	100.0	391	100.0

Note: Size and shape could not be calculated for all 413 pits in the sample. The data above are from the 391 pits for which these two attributes could be calculated.

Table 29. Distribution of Pit Types, by Size Classification

Feature Type[a]	Small		Medium		Large		Total	
	Count	Column Percentage	Count	Column Percentage	Count	Column Percentage	Count	Column Percentage
Ash-filled, nonthermal intramural pit	3	1.1	1	0.9	—		4	1.0
Bell-shaped nonthermal pit	7	2.7	21	19.1	1	5.3	29	7.4
Bell-shaped roasting pit	1	0.4	6	5.5	1	5.3	8	2.0
Borrow pit	—		1	0.9	3	15.8	4	1.0
Cache	2	0.8	—		—		2	0.5
Extramural hearth	2	0.8	—		—		2	0.5
Firepit	1	0.4	6	5.5	—		7	1.8
Horno	—		1	0.9	3	15.8	4	1.0
Indeterminate thermal	2	0.8	1	0.9	—		3	0.8
Intramural hearth	68	26.0	1	0.9	—		69	17.6
Intramural nonthermal pit	59	22.5	9	8.2	—		68	17.4
Nonthermal pit (general)	100	38.2	40	36.4	7	36.8	147	37.6
Roasting/thermal pit (general)	16	6.1	18	16.4	2	10.5	36	9.2
Rock-lined roasting pit	1	0.4	5	4.5	2	10.5	8	2.0
Total	262	100.0	110	100.0	19	100.0	391	100.0

Note: Size and depth could not be calculated for all 413 pits in the sample. The data above are from the 391 pits (141 intramural and 250 extramural) for which these attributes could be calculated.

[a] All features are extramural unless indicated otherwise.

Table 30. Distribution of Pit Types, by Depth Classification

Feature Type[a]	Shallow Pits		Deep Pits		Total	
	Count	Column Percentage	Count	Column Percentage	Count	Column Percentage
Ash-filled intramural pit	4	1.2	—		4	1.0
Bell-shaped nonthermal pit	20	6.2	9	13.0	29	7.4
Bell-shaped roasting pit	3	0.9	5	7.2	8	2.0
Borrow pit	4	1.2	—		4	1.0
Cache	2	0.6	—		2	0.5
Extramural hearth	2	0.6	—		2	0.5
Firepit	7	2.2	—		7	1.8
Horno	4	1.2	—		4	1.0
Indeterminate thermal	2	0.6	1	1.4	3	0.8
Intramural hearth	62	19.3	7	10.1	69	17.6
Intramural pit	45	14.0	23	33.3	68	17.4
Nonthermal (general)	132	41.0	15	21.7	147	37.6
Roasting pit (general)	30	9.3	6	8.7	36	9.2
Rock-lined roasting pit	5	1.6	3	4.3	8	2.0
Total	322	100.0	69	100.0	391	100.0

Note: Size and depth could not be calculated for all 403 pits in the sample. The data above are from the 391 pits for which these attributes could be calculated.

[a] All features are extramural unless indicated otherwise.

Table 31. Distribution of Pit Types by Volumetric Classification

Feature Type[a]	Low-Volume Pits		High-Volume Pits		Total	
	Count	Column Percentage	Count	Column Percentage	Count	Column Percentage
Ash-filled intramural pit	4	1.2	—	0.0	4	1.2
Bell-shaped nonthermal pit	19	5.7	3	21.4	22	6.3
Bell-shaped roasting pit	4	1.2	—	0.0	4	1.2
Borrow pit	1	0.3	2	14.3	3	0.9
Cache	1	0.3	—	0.0	1	0.3
Extramural hearth	2	0.6	—	0.0	2	0.6
Firepit	7	2.1	—	0.0	7	2.0
Horno	1	0.3	3	21.4	4	1.2
Indeterminate thermal	3	0.9	—	0.0	3	0.9
Intramural hearth	62	18.6	—	0.0	62	17.9
Intramural pit	52	15.6	1	7.1	53	15.3
Nonthermal (general)	137	41.1	3	21.4	140	40.3
Roasting pit (general)	34	10.2	—	0.0	34	9.8
Rock-lined roasting pit	6	1.8	2	14.3	8	2.3
Total	333	100.0	14	100.0	347	100.0

Note: Volume could not be calculated for all 409 pits in the sample. The data above are from the 347 pits for which volume could be calculated.

[a] All features are extramural unless indicated otherwise.

hearth, intramural pit, thermal/roasting pit, and bell-shaped nonthermal pit) encompassed more than 10 features each, with frequencies ranging from 29 to 147. We thus primarily focus on these more-robust types in our comparative study. We discuss the intramural and extramural pits separately.

Intramural Pits

As noted, the intramural pits (n = 141) tended to be smaller than the extramural pits in average diameter, and none was classified as large. Worth noting, however, is the variability among intramural hearths and intramural nonthermal pits. All intramural thermal pits (n = 69) in our sample of 391 features were hearths (see Table 25), and all but 1 (1.4 percent) were classified as small; 1 was classified as medium-sized (see Table 28). A higher percentage of intramural nonthermal pits (n = 72), however, were classified as medium-sized (13 percent). Intramural nonthermal pits also tended to be deeper than intramural hearths. Only 10 percent of the intramural hearths were classified as deep (7 of 62 features), compared to 34 percent among the intramural nonthermal pits (23 of 68 features). Not surprisingly, given these differences, the mean volume among 53 intramural nonthermal pits for which an estimation was feasible was 0.07 m^3 (standard deviation = 0.14 m^3), more than 15 times the mean among the 59 intramural hearths (mean = 0.004 m^3; standard deviation = 0.006 m^3).

The larger intramural nonthermal pits probably functioned primarily as domestic storage loci, and in some cases, it may have been necessary to increase their widths and/or depths to accommodate increased storage needs (e.g., because of increase in household size or longer durations of occupation). It is unlikely that such size alterations would have been pertinent to intramural hearths, which were probably intended to maintain small fire for generating warmth, light, and heat for cooking and production activities (e.g., heat treatment of stone tools).

The intramural nonthermal pits were also more variable in size than the intramural hearths. To quantify that variability, we calculated coefficients of variation (CVs) of the volume estimates for both the intramural nonthermal pits and the intramural hearths. Calculating CV scores (the standard deviation divided by the mean) offers an effective way of comparing the dispersion of metric values around two or more different means, despite scalar difference in means and ranges of scores. Higher scores indicate greater variability in the range of values. For intramural hearths, the CV for the volume estimates was 1.3, which is considerably lower than the value of 2.2 for intramural nonthermal pits—i.e., the standard deviation was more than two times greater than the mean. This greater range of variability for intramural nonthermal pits probably reflects varying levels of storage capacity and needs, or possibly a more diverse array of functions, for these pits. For instance, different pit sizes might have been required for the storage of seeds or grains (small) and for the storage of one or several storage pots or water containers (large). For intramural hearths, the CV score certainly does not suggest standardization in size, but the smaller range of variability probably reflects a more limited array of functions—the pit probably only needed to be large enough to maintain a small fire.

Extramural Pits

Among the extramural thermal pits (in the sample of 391 pits), the most prevalent were roasting pits (general [n = 36], bell-shaped [n = 8], and rock-lined [n = 8]), which accounted for a 52 (76 percent) of the 68 extramural thermal pits in our sample (see Table 25). Other, low-frequency types were *hornos* (4 features), firepits (7 features), extramural plastered hearths (2 features), and indeterminate thermal pits (3 features). Most of the extramural nonthermal pits were classified as bell-shaped pits (29 features) or in the broader, more-inclusive category of general nonthermal pit (147 features), which together accounted for 97 percent (176 of 182) of the extramural nonthermal pits. Six other extramural nonthermal pits were classified as borrow pits (4 features) and caches (2 features). In light of the large number of extramural-pit categories, we separately discuss the thermal and nonthermal types in the following sections.

Extramural Thermal Pits

Given their high frequencies, we mainly focus on roasting pits. Three subtypes of roasting pits were distinguished in the function-based typology: bell-shaped roasting pits, rock-lined roasting pits, and a broader and more general category of general roasting pits that were neither rock-lined nor bell-shaped (Vanderpot 2001b:15) (see Volume 1, Chapter 3). All of the roasting pits generally contained fill possibly related to the thermal use of the features, such as FCR, charcoal, and ash (Vanderpot 2001b:14). Like the bell-shaped nonthermal pits, bell-shaped roasting pits were distinguished by their bell-shaped cross-section profiles. Rock-lined roasting pits were "slab-lined, often [had] heavily oxidized walls, and [had] several large rocks covering [their] bases" (Vanderpot 2001b:14).

The majority of bell-shaped and rock-lined roasting pits in our sample were medium-sized (75 and 63 percent, respectively) or large (13 and 25 percent, respectively) in average diameter; only 13 percent of both types were classified as small (see Table 29). In contrast, nearly all the features included in the general-thermal-pit category (n = 36) were classified as small (44 percent) or medium-sized (50 percent) in average diameter, and only 6 percent were classified as large. On the surface, these differences suggest a size difference between rock-lined or bell-shaped roasting pits and "regular" roasting pits, but the low frequencies of rock-lined or bell-shaped roasting pits (eight apiece) undermined the reliability of this evidence. A Fisher's exact test (a significance-testing technique tailored for low cell counts) indicated a probability of .12 that the distributions of size classes among the three types were statistically different. That probability does not suggest significance at the 0.05 level (or even the 0.10 level), but it is low enough that we cannot discount the possibility of a statistically different distribution among the diameter-index size classes. Moreover, if we combine the rock-lined and bell-shaped roasting pits, creating a more robust category, the Fisher's exact test generates a probability of .04, suggesting a significant difference in the distribution of size classes at the 0.05 level.

Similarly, as can be deduced from Table 30, a higher percentage of rock-lined (3 of 8) and bell-shaped (5 of 8) roasting pits—especially the latter—were classified as having deep profiles (38 and 63 percent, respectively) compared to those in the general-roasting-pit category (6 of 36, or 17 percent). Again, combining the two former categories, the Fisher's exact test indicated a probability of .02, a significant difference. In the sample of 347 features (see Table 31), none of the bell-shaped roasting pits (4 features) or general roasting pits (34 features) was classified as having a large volume, but two of eight rock-lined roasting pits were classified as high-volume pits. Furthermore, the mean volumes of the bell-shaped roasting pits (mean = 0.33 m^3; standard deviation = 0.11 m^3) and rock-lined roasting pits (mean = 0.42 m^3; standard deviation = 0.52 m^3) are about three to four times higher than the mean volume of the features classified in the general-roasting-pit category (mean = 0.11 m^3; standard deviation = 0.12 m^3).

In all, these data provide strong evidence that rock-lined and bell-shaped roasting pits tended to be deeper and had larger diameters and higher volumetric capacities than the other roasting pits, suggesting the possibility of a specialized function related to large-scale cooking activities. One credible hypothesis stemming from these results is that most of the "regular" roasting pits were constructed to heat food for a small number of people, such as household or small kin groups. In contrast, the larger rock-lined and bell-shaped roasting pits may have been used to prepare food for larger groups, such as communal gatherings or other extrahousehold congregations. Additional evidence will be required to evaluate this hypothesis.

Among the other extramural thermal-feature types, the two extramural hearths appeared to be similar in size attributes to the intramural hearths (see above). Both were classified as small in diameter and shallow and had low volumetric capacities. Seven features (in the sample of 347 features) were classified as firepits, which are characterized by oxidized walls and an absence of FCR (Vanderpot 2001b:15). These pits may have functioned as informal and expediently prepared hearths. The firepits were classified as shallow, low-volume pits with mostly medium-sized openings (one opening was classified as small). They thus tended to be wider than hearths but similarly shallow. Little can be inferred about the indeterminate thermal pits from our classifications. The three features in this type were differently classified in the diameter and cross-section index, although all three were classified as low-volume pits.

Finally, *hornos* are defined as having diameters of at least 1 m and thick, carbonized rinds (Vanderpot 2001b:14) and thus are assumed to have been used for large-scale cooking activities, especially roasting agave. Hence, it is not surprising that the four *hornos* in our sample were classified as large (3 features) or medium-sized (1 feature) in horizontal extent and had maximum diameters ranging from 1.2 to 2.1 m. Three of the four *hornos* also were classified as having large volumetric capacities. However, all four were also classified as shallow. According to these criteria, *hornos* tended to be shallow thermal pits with wide openings.

Extramural Nonthermal Pits

The majority (n = 147) of the extramural nonthermal pits in our sample of 391 features were classified in the generic nonthermal-pit category (see Table 25). Like the intramural nonthermal pits, however, we suspect that many of these pits were probably used for storage. However, unlike most thermal pits with oxidized walls, storage pits rarely leave trace evidence of their initial functions, and thus, we usually cannot discount the possibility of other nonthermal functions, such as food processing. Most of the extramural nonthermal pits were classified as small (n = 100, or 68 percent) or medium-sized (n = 40, or 27 percent) in diameter (see Table 29) and had shallow profiles (n = 132, or 90 percent) (see Table 30) and low volumes (n = 137, or 98 percent) (see Table 31). With some exceptions, these features generally appeared to have been low-capacity pits.

Another nonthermal-pit type was distinguished based on the presence of a bell-shaped profile (n = 29) (see Table 29). These pits, also probably used as storage loci, were singled out because of their suspected association with Late Archaic period occupation at the site, in Locus D (Vanderpot 2001b:14) (see also Volume 1, Chapter 3). In contrast with the generic class of nonthermal-pit types, these pits tended to be larger: nearly three-quarters (n = 21, or 72 percent) were classified as medium-sized in the diameter index, and only about one-quarter were classified as small (n = 7, or 24 percent). Also, 31 percent of the bell-shaped pits were classified as having deep profiles—more than three times the frequency among the generic nonthermal-pit category (10 percent) (see Table 30). Fourteen percent were classified as high-volume pits, seven times as many as the generic nonthermal-pit category (2 percent) (see Table 31). Not surprisingly, the mean volumes of the bell-shaped pit (0.31 m^3; standard deviation = 0.27 m^3) was about 4.5 times greater than those among the generic nonthermal-pit category (mean = 0.07 m^3; standard deviation = 0.13 m^3). However, the high standard deviation in the latter category indicated substantial variability.

Overall, the evidence clearly indicated larger volumetric capacities among the bell-shaped pits than the generic nonthermal pits. If the bell-shaped pits were in fact constructed during the Late Archaic period, this difference could partly reflect a diachronic trend of decreasing nonthermal-pit sizes over time. However, it also could indicate a specialized storage function for the bell-shaped pits that required higher containment capacities. We address this question in more detail below.

Two low-frequency nonthermal-pit types were borrow pits and caches. Borrow pits are by definition large-diameter quarrying pits that were likely used for creating and obtaining clay for construction purposes (e.g., for making adobe walls). Consistent with this definition, four borrow pits included in our sample were classified as large (3 features) or medium-sized (1 feature) in diameter but shallow in depth. Three of the four were classified as high-volume pits, however, because of their large horizontal dimensions. Two pits were classified as caches; both contained mainly ground stone objects, and both were classified as small, shallow pits with low volumes.

Burned Materials in the Fill of Thermal and Nonthermal Pits

During the excavation of pit features, crews recorded the presence or absence of various thermal materials in the feature fill, specifically charcoal, ash, and FCR. In most cases, these materials probably entered the feature fill as a result of the burning of fuel or the heating of rocks used as thermal mass, activities that could have been carried out for a wide variety of purposes in the past, such as cooking, food processing, heating, and so on (see Halbirt, Kaler, and Dongoske 1993). As explained above, however, the presence of these materials in the fill does not necessarily relate to the original, intended function or functions of a feature. Pit fill may also consist of secondary refuse or the deposition of sediments, artifacts, and other materials via natural erosional processes. Here, we examine the distribution of charcoal, ash, and thermally affected rock among intramural and extramural pits and thermal and nonthermal pits.

In general in the total excavated sample of 413 features, a higher percentage of thermal pits (77 percent, or 113 of 146 features) than nonthermal pits (68 percent, or 176 of 267 features) contained at least one of the three aforementioned thermal materials. The thermal pits with no recorded thermal materials may have been cleaned following their final episodes of thermal use. Notably, all but 1 of the 32 thermal features with no thermal materials were classified as intramural hearths; 1 was a roasting pit (general category). Inferable from these results is that the 75 excavated intramural thermal features, all of which were hearths, were probably more regularly and frequently subjected to cleaning than were extramural thermal features. Even so, 50 percent (44 of 75 features) of all intramural hearths contained at least one category of thermal debris (charcoal, ash, and FCR). These features either were not cleaned prior to abandonment (and thus contain in situ thermal remains) or were filled following abandonment as a result of secondary trash deposition and/or natural infilling with culture-bearing sediments. To be sure, this same caveat pertains equally to the extramural thermal pits: despite the higher ubiquity of thermal debris among these features, we are currently unable to unequivocally distinguish in situ thermal debris left in the pits as a result of thermal use and secondary deposits of thermal refuse (from trash deposition or natural infilling).

Charcoal, ash, and FCR were recovered in two-thirds of nonthermal pits (176 of 267 features), of which we posit three possible interpretations. First, some of the pits defined here as nonthermal (based on the absence of oxidized walls) may have actually functioned as thermal pits, resulting in the in situ accumulation of charcoal, ash, and/or FCR. Second, as noted, the presence of thermal materials could represent refuse that was deposited in these features subsequent to the original, intended (presumably nonthermal) functions of these pits. Third, it is also possible that the deposition of charcoal, ash, and thermally affected rock in thermal pits did not relate to the original functions of those features and was also a result of cultural or natural depositional processes. It is likely that a combination of these three scenarios explains the ubiquity of thermal remains among the features defined here as nonthermal pits.

Worth noting also is that thermal remains were recovered from 88 percent of all excavated extramural pits (230 of 265) but only 40 percent of the excavated intramural pits (59 of 148), a disparity that Graves (2011) also observed in his study of pits from sites in the Queen Creek area, east of Phoenix. Intramural pits probably had to be regularly cleaned of thermal debris to prevent the possibility of fire damage to standing structures. For this reason, we suspect that most of the intramural pits with thermal remains thus probably contain postabandonment thermal refuse or redeposited sediments rather than in situ thermal remains. Some rapidly abandoned structures may contain thermal debris that was left in situ following the hearth's final episode of use. The higher percentage of thermal debris in the extramural pits probably reflects inclusion of a mix of in situ thermal remains, thermal refuse, and postabandonment deposition. However, if we assume that thermal refuse was equally likely to have been deposited in an abandoned intramural pit as in an abandoned extramural pit, then the higher percentage of thermal debris in extramural contexts could suggest a higher proportion of in situ thermal debris. The extramural thermal features probably were less frequently cleaned—possibly because of the diminished danger of unintended conflagrations—and thus, a higher proportion of them contain in situ thermal remains.

Inspection of the thermal remains collected from intramural and extramural pits corroborated this argument. Among the 59 intramural pits with thermal debris, 46 (78 percent) contained *only* ash and no FCR or charcoal. Very small ash particles would have been difficult to remove during cleaning episodes; however, the generally larger FCR and charcoal pieces would have been more easily removed. In contrast, only 12 percent of the extramural pits with thermal debris (28 of 230 features) contained ash only. A much larger percentage contained some combination of charcoal, ash, and FCR (74 percent). These differences in the thermal contents of extramural and intramural features are likely attributable to the level of effort devoted to cleaning out the pit contents following their final episodes of use. Most intramural thermal pits were probably cleaned of easily removed debris, such as chunks of FCR and charcoal. It is likely that a much smaller proportion of extramural pits were cleaned out following their final use. Because of the ambiguity in the relationship between pit fill and original pit function, we have decided not to analyze pit contents in any explicit manner as a means to infer or understand pit function in this chapter.

Final Functional Assessment

Based on the various classification exercises outlined above, we present here a final inference of probable function for each pit. These final inferences synthesize several of the attributes separately classified above (e.g., size, shape, context, and thermal/nonthermal). Graves (2011) employed this approach to categorize pit features at various sites in the Queen Creek area of Arizona (following Halbirt, Kaler, and Dongoske [1993]). He inferred five functional categories that incorporated various combinations of attributes: cooking, storage, storage and/or processing, caches, and borrow pits. We adopted his criteria for making inferences about pit functions, but with slight modifications and refinements to his cooking category (see below). In this section, we review the functional categories and our bases for inferring them.

Table 32 summarizes the defining criteria and frequencies of the inferred pit functions at Mescal Wash. Halbirt, Kaler, and Dongoske (1993) defined numerous kinds of nonthermal-pit functional types, including storage pits, food-processing pits, and borrow pits. Storage pits seem to consistently have relatively small orifice diameters and large depths relative to orifice diameters (Hackbarth 1993:516; Halbirt, Kaler, and Dongoske 1993:137–138). We therefore define all small and deep extramural and intramural nonthermal pits as storage pits.

We classified nonthermal pits with shallow cross-section shapes, regardless of diameter size, as processing and/or storage pits (see Table 32). Halbirt, Kaler, and Dongoske (1993) identified various food-processing activities related to pit features, all of which require relatively shallow pits with variable-diameter orifices, presumably to accommodate access to the food or other materials by hand or with a hand-held tool. Food-processing activities included leaching and ripening, both of which often require relatively large-diameter pits (Hackbarth 1993:517; Halbirt, Kaler, and Dongoske 1993:140–141). Other activities, such as grinding or pounding, threshing, or mixing, typically require relatively shallow pits of varying diameters (Hackbarth 1993:517; Halbirt, Kaler, et al. 1993:141–142). Despite these observations, we cannot rule out storage or occasional storage as a function of the relatively shallow pits. Consequently, we defined these features as processing and/or storage pits.

Table 32. Criteria for Defining Final Functional Pit Categories at Mescal Wash

Possible Function	Definition	Count	Percent
Borrow pit	Based on the description in Vanderpot (2001) and Vanderpot and Altschul (2000).	4	1.0
Cache	Based on the description in Vanderpot (2001) and Vanderpot and Altschul (2000).	2	0.5
Cooking, large	All extramural thermal pits with deep cross-section shapes or large diameters.	21	5.3
Cooking, small	All extramural thermal pits with shallow cross-section shapes and small or medium diameters.	47	12.0
Cooking/heating/lighting	All intramural thermal pits, regardless of diameter or cross-section shape.	69	18.7
Processing and/or storage	All nonthermal, shallow pits, regardless of diameter and context (intramural [n = 49] and extramural [n = 154]).	203	52.0
Storage	All nonthermal, small or medium-sized *and* deep pits, regardless of context (intramural [n = 23] and extramural [n = 22]).	45	10.5
Total		391	100.0

Note: Size and depth could not be calculated for all 413 excavated pits. The data above are from the 391 pits for which these attributes could be calculated.

Graves (2011) inferred a single cooking function for thermal pits in his earlier study. We further refine that category here, however, based on the context and dimensional attributes of the pits. Intramural pits probably were used for various purposes, including cooking, heating, and warmth, as well as lighting of a structure's interior. Hearths provided light and heat in connection with various activities, and the area surrounding the hearth was the primary locus of indoor activities; at the Grewe site, this inference was evidenced by a virtual absence of floor features in the areas immediately surrounding the intramural hearths. Also, evidence of production activities—such as manufacture or curation of shell jewelry and stone tools—has been reported in the vicinities of indoor hearths at some Hohokam sites (Marmaduke and Martynec 1993; Seymour 1988). For these reasons, the intramural thermal pits investigated at Mescal Wash are inferred here to have functioned as sources of heat and light for cooking, production, and many other activities.

We also inferred two different functional categories of extramural thermal pits based on their dimensions. Like the intramural hearths, these pits probably provided both heat and light for various activities, but we suspect that they were primarily used as cooking loci in these contexts, based on ethnographic observations (see Halbirt, Kaler, and Dongoske 1993:134–136). We distinguish a large-cooking-pit category based on the presence of either wide diameter ("large") or deep cross-section shape ("deep"), or both. All others were classified as small cooking pits. We made this distinction because the sizes of cooking pits may vary depending on whether the meals were prepared for a single household, a small group (e.g., an extended family), or a larger congregation (e.g., a communal feast).

We have also defined two additional functional types based on the inferred functions reported in Vanderpot's (2001b:14–15; Vanderpot and Altschul 2000:23–24) original function-based classifications. Three pits at the site were defined as caches; all of them were small, shallow nonthermal pits containing one or more complete ground stone implements, and all were observed in extramural locations (see also Graves 2011). Caches are specific types of storage pits, of course, but their form and inferred functions are specialized enough to warrant a separate classification from the many other pits inferred to have been used as storage locations. Seven additional nonthermal pits excavated at the site were inferred to have functioned as borrow pits. They are generally shallow, medium-sized to large pits situated in extramural areas and are inferred to have functioned as areas for puddling mud for adobe construction and plastering (Vanderpot 2001b).

In sum, these pit functions allow gross characterizations of the kinds of possible activities that were carried out at Mescal Wash in the past and how they varied over time and space. As with the diameter and cross-section-shape indexes discussed above, the value in defining these possible pit functions lies not in assigning a specific and clear function to each individual feature but in providing a means to characterize the broad uses of different kinds of pits across the sites and time periods of interest.

Method of Chronological Inference

SRI's application of chronometric methods at Mescal Wash focused primarily on the many excavated structures, and relatively few extramural pits were subjected to chronometric analysis (see Volume 2, Chapter 2). In all, only nine extramural-pit features (three thermal and six nonthermal) were subjected to radiocarbon dating. All of the nonthermal features were bell-shaped pits suspected to date to the Archaic period. Indeed, all of these pits generated sigma ranges consistent with a Late Archaic period age. The three thermal pits subjected to radiocarbon dating were roasting pits in Locus D that generated dates during the Middle Formative period. Nine extramural pits (eight thermal and one nonthermal) were subjected to AM dating, including one roasting pit (Feature 3668) that was also subjected to radiocarbon dating. All but one of the nine pits subjected to AM dating were located in Locus D (the other was in Locus C).

In all, only 17 of the 255 fully or partially excavated extramural pits were subjected to chronometric analysis. Others were assigned date ranges based on the presence of time-sensitive artifacts (painted ceramics or projectile points) or stratigraphic relationships with dated features, mostly structures. Even so, period assignments were not feasible for nearly two-thirds of the extramural pits (166 features), and the majority of the inferred date ranges are vague and broadly defined (e.g., post-A.D. 500 and pre-A.D. 950).

Consequently, we made tentative temporal-period assignments for many extramural pits based on their spatial proximity to dated structures or other dated features. For example, nearly all of the chronometric information gleaned from Locus A indicated occupation during the Middle Formative B period. Moreover, most features were assigned to a single occupation episode in Lengyel's chronological reconstruction (Volume 2, Chapter 2). For this reason, we are probably safe in assuming that the undated pit features in Locus A also can be assigned to the Middle Formative B period. For Loci C and D, a more nuanced method was employed to infer chronological associations. In both loci, many of the dated structures are clustered into spatial groups, most of which generated comparable chronological information. We therefore assigned any pits located in close proximity to these clusters to the same period or date range, with the assumption that the extramural pits were constructed adjacent to affiliated structures or groups of structures. In some cases, we assumed association between isolated structures and nearby pits.

This method of assigning chronology is not ideal and is prone to error. Nevertheless, we propose that using these tentative period assignments is preferable to inferring diachronic trends based on the very small sample of better-dated features, many of which were generated to validate in-field suspicions that the bell-shaped nonthermal pits were Archaic period in age. The results of our chronological analyses presented below, of course, should be regarded as tentative.

The chronological information available for intramural pits is substantially more reliable, given the large number of structures subjected to chronometric analysis. The intramural pits could be assigned to the same date range or period as their parent structures. In our analysis, 86 extramural pits, roughly one-third, were unassigned to a period, but only 17 intramural pits—about 10 percent of our sample—were unassigned.

Storage, Processing, and Cooking Activities

Overview of Storage Pits

As noted above, in total, 45 nonthermal pits were classified as storage-only pits based on their dimensional attributes (see Table 32). Storage-only pits were those defined based on the presence of deep cross-section profiles relative to their orifice diameters (i.e., high scores on the shape index). Our rationale for making this classification is that deep pits with relatively narrow orifices would have been poorly suited for processing or other manipulative activities. Narrow orifices also would have made them easier to seal or conceal for protection from predators or thieves (Craig and Walsh-Anduze 2001:132). Many of these pits may have been lined with wood, grass, branches, or other perishable materials to help protect their contents from burrowing rodents and insects.

Of the 45 storage-only pits, almost identical numbers were excavated in intramural (23 features) and extramural (22 features) contexts. Keep in mind, however, that nearly all of the structures encountered at the site were fully or partially excavated, including their intramural pits. However, only a sample of extramural features was excavated. We assume that additional extramural storage pits were present in the area but were not subjected to archaeological investigation, and if so, then the actual number of extramural storage pits likely exceeds the number of intramural storage pits. Unfortunately, we have no way of inferring this with certainty based on the current sample of investigated extramural features. Taken as a whole, this evidence suggests storage, probably of surplus food and other materials, in both intramural and extramural contexts. Below, we explore the extent to which these practices varied over time.

Also, nearly equal numbers of intramural and extramural storage pits were classified as small (19 and 18, respectively) and medium-sized (4 in each category), suggesting comparable size ranges in both contexts. Intramural and extramural storage pits also exhibited equal average diameters (mean = 51 cm for both contexts). On average, however, intramural storage pits were slightly deeper (mean = 51 cm; standard deviation = 26 cm) than the extramural storage pits (mean = 45 cm; standard deviation = 24 cm). Surprisingly, however, despite their greater depths, the mean volumes of the intramural storage pits (0.180 m^3) were slightly lower than those of the extramural pits (0.189 m^3), which is probably attributable to differences in the pit profile shapes (see below). Nearly all of the storage pits, regardless of context, were oval or circular in plan.

On the whole, these trends show little difference in the sizes and capacities of intramural and extramural storage pits. As shown in Figure 53, however, the distributions of profile shapes of intramural and extramural pits were significantly different. Bell-shaped storage pits were substantially more frequent in intramural contexts (61 percent) than in extramural contexts (38 percent). In contrast, storage pits with cylindrical profiles were more prevalent in extramural contexts (38 percent) than in intramural contexts (13 percent). Worth noting also is that conical pits were exclusively observed in extramural contexts, albeit in low frequencies (8 percent).

We suspect that the prevalence of bell-shaped pits in intramural contexts reflects a concern with concealing pit locations and controlling access to their contents (Hendon 2000). Security and access-restrictions would not have been as much of a concern with indoor pits, but outdoor pits were less easily monitored and more exposed to theft or scavenging. The narrow openings of bell-shaped pits were readily covered or camouflaged from outsiders and scavengers. Many or most of these pits probably contained surplus food and other necessities, and hence, security and protection would have been a crucial concern.

Camouflaging pit openings also may have had social implications, according to Hendon (2000). As explained above, Hendon explored the extent to which storage facilities were used to flaunt wealth and status by augmenting the size or elaborateness of the storage facilities in the Classic period Mayan center of Copán (Hendon 2000:46). Similarly, among the Aztecs of central Mexico, well-stocked storage facilities and demonstrations of ability to maintain ample domestic surpluses enhanced a household head's social status and clout within the local community. In contrast with these Mesoamerican groups, at Mescal Wash, the use of subterranean-storage extramural pits with narrow and easily concealed openings suggests a possible *de*-emphasis on expressing social differences in wealth or status using the medium of storage facilities. It could reflect either a relatively egalitarian social order with respect to surplus accumulation or a deliberate effort to downplay differences in household-level accumulation. This argument is not meant to suggest that social hierarchies were absent from the Mescal Wash community, but they were probably not expressed through displays of accumulated surplus and storage (sensu McGuire and Saitta 1996; Rautman 1998).

In sum, sizes and capacities of storage pits were relatively consistent in intramural and extramural contexts, but intramural and extramural pits varied substantially in cross-section shape. Intramural pits were typically cylindrical, basin-shaped, or conical and had wide openings that facilitated accessibility and manipulation of contents. In contrast, the majority of extramural pits were bell-shaped in profile and had narrow openings that were amenable to concealment and camouflaging. The low visibility of storage pits could have reflected an economic concern with security from theft, but it also may have helped promote an ethic of social equality by concealing differences in accumulated surpluses among the group.

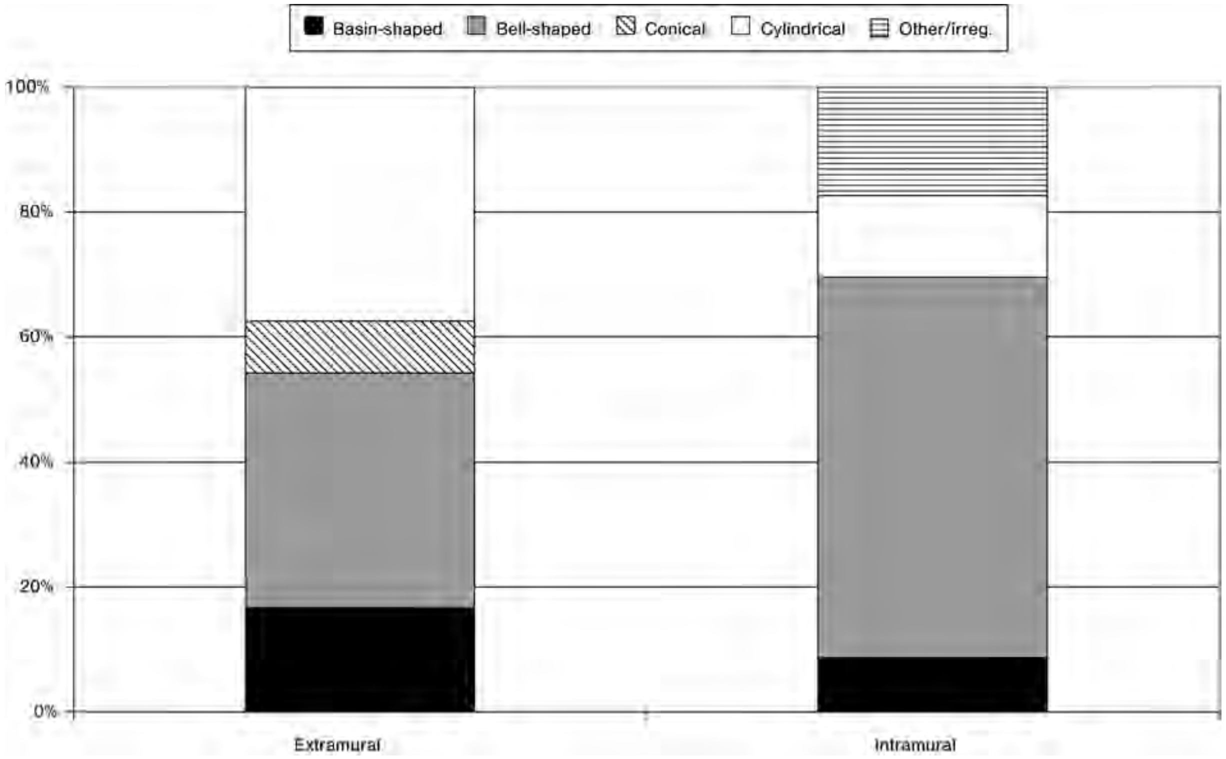

Figure 53. Bar chart showing the distributions of pit cross-section shapes among intramural and extramural pits.

Overview of Storage/Processing Pits

A large number of the nonthermal pits investigated at Mescal Wash (203 features in our sample of 391 pits) were classified as processing and/or storage pits (see Table 32), which were defined based on shallow profiles relative to their orifice diameters (i.e., low scores on the shape index). Unlike the deeper storage-only pits, the shallowness and increased openness of these pits facilitated mechanical accessibility of the pits contents, suggesting use as processing loci. As noted, however, we cannot rule out a storage function, especially as expedient or informal storage loci. The inferred processing/storage pits outnumbered storage-only pits; the ratio was about 4.4:1, matching the ratio of about 4:1 observed by Craig and Walsh-Anduze (2001:132) at Grewe. This ratio probably reflects differences in pit use. Processing/storage pits were used for pounding, threshing, or mixing of foods and, therefore, were frequently subjected to mechanical disturbance and movement. Consequently, they were more prone to damage and attrition than were storage pits, which were infrequently subjected to mechanical disturbance. Processing/storage pits likely were abandoned and remade more regularly than were storage pits.

Also, in contrast to the storage-only pits, the overwhelming majority of processing/storage pits were recovered in extramural contexts by a ratio of 3.2:1 (154 extramural pits and 49 intramural pits). This evidence suggests that processing activities related to pits, such as pounding, threshing, or mixing of foods, normally occurred in extramural contexts, another finding consistent with the evidence from Grewe (Craig and Walsh-Anduze 2001:132).

Intramural processing/storage pits also tended to be smaller than their extramural equivalents: 90 percent of the intramural processing/storage pits were classified as small in area, compared to 58 percent among the extramural processing/storage pits. Also, no intramural processing/storage pits were classified as large, and only 10 percent were classified as medium-sized, whereas the percentages among the extramural features were 37 percent medium-sized and 5 percent large. The size differences were also reflected in the mean diameters of intramural and extramural processing/storage pits (respectively, means = 44 cm and 72 cm, and standard deviations = 17 cm and 32 cm) and in mean volumes (respectively, means = 0.022 m^3 and 0.088 m^3, and standard deviations = 0.303 m^3 and 0.142 m^3). The smaller sizes of the intramural processing/storage pits may reflect limited available indoor space but also probably reflect different processing activities. Again, many of these pits also may have been used occasionally as storage loci, possibly for expedient purposes.

As with the storage-only pits, the proportions of pit shapes in plan were virtually identical among the intramural and extramural processing/storage pits. For both classes, about 95 percent of the pits were circular or oval in shape, and small numbers of pits had subrectangular or irregular shapes. Also, the variability in vessel profiles between intramural and extramural processing/storage pits was also not as pronounced as it was between intramural and extramural storage-only pits. The same percentages of intramural and extramural processing/storage pits were basin-shaped in cross-section (63 percent); however, the percentages varied considerably among the other one-third of processing/storage pits. Nearly all of the remaining intramural processing/storage pits were cylindrical in cross-section (26 percent), whereas most of the remaining extramural processing/storage pits were bell-shaped (13 percent) or cylindrical (12 percent).

The main difference thus hinged on the presence of bell-shaped pits in our sample of extramural processing/storage pits. Although these pits were classified as processing/storage pits based on the criteria outlined above, we suspect they were in fact storage pits that were shallower than those classified as storage-only pits and had smaller capacities. Their narrow orifices would not have been conducive to the mechanical manipulation of contents, which would have rendered them poorly suited as processing pits. Excluding these cases, the percentages of profile-shape classes are comparable, indicating a roughly similar range of variability in the forms and shapes of processing/storage pits in intramural and extramural contexts.

In sum, these data suggest a preference for constructing processing pits in outdoor contexts. A relatively small proportion of inferred processing pits were located in intramural contexts, and most were small in size and capacity, possibly suggesting different processing activities in indoor and outdoor contexts. Despite the differences in size, the ranges of pit shapes and forms were similar in our sample of intramural and extramural pits. As noted, many of these features, especially the bell-shaped pits, may have been used as storage loci or as multifunctional storage and processing features.

Overview of Cooking Pits

In total, 137 pits (in our sample of 391 pits) with evidence of thermal use were classified as cooking pits, each in one of three categories: small cooking pits, large cooking pits, and more-multifunctional pits used for cooking, heating, and lighting (see Table 32). Cooking pits were distributed evenly between intramural (n = 69) and extramural (n = 68) contexts in the data set. Despite that even distribution, we strongly suspect that the actual proportion of cooking pits in extramural space is greater than what was represented by the excavated sample and that the frequency of extramural cooking pits is greater than that of intramural cooking pits, all of which were hearths. However, as with storage pits (see above), we have no way of precisely estimating the proportion of cooking that took place inside houses and in extramural space at Mescal Wash.

Variabilities between the intramural and extramural cooking pits did, however, suggest differences in cooking practices in different contexts. All of the 69 intramural thermal pits were classified as cooking/heating/lighting pits, and over 94 percent of those (65 of 69) were small. On the other hand, 69 percent of extramural cooking pits were classified as small (47 of 68) and 31 percent (21 of 68) were large. This trend of larger extramural cooking pits was also reflected in the higher relative frequency of deep pits among extramural pits (21 percent) when compared to intramural features (10 percent) and the substantially greater average volume of extramural cooking pits (0.247 m^3) compared to intramural cooking pits (0.004 m^3).

These differences among intramural and extramural cooking pits suggest that rather significant differences existed in the past in the cooking practices that employed pit features in the two contexts. Intramural thermal pits were small in capacity and were possibly used for heating small amounts of food. We suspect that heating or boiling foods such as stews in ceramic jars or heating small items over a direct flame were the most common cooking techniques that employed intramural thermal pits. Techniques such as roasting were likely not common indoor activities. And in addition to cooking, intramural thermal pits were likely used for heating and lighting purposes, as well.

Outside houses, cooking pits were more variable in function and size, suggesting more variability in past cooking techniques and greater variability in the amounts of food prepared per feature. Extramural cooking pits consisted of a variety of different types: roasting pits, bell-shaped roasting pits, rock-lined roasting pits, *hornos*, and various smaller features (see Tables 29–31). The larger capacities of extramural pits overall suggest that when compared to indoor cooking, greater amounts fuel were required for the types of cooking techniques employed outdoors, or meals prepared outdoors tended to be prepared for larger groups than meals prepared indoors (e.g., suprahousehold consumption vs. household consumption), or some combination of the two. In addition, although cooking pits in our feature sample were found in similar frequencies in intramural and extramural contexts, we suspect that extramural pits were underrepresented in our data and that cooking was more frequently carried out in extramural contexts than what was reflected in the available pit-feature data set.

Diachronic Changes in Storage and Nonthermal-Processing Practices

The analyses presented in this section relied on the tentative period assignments described above to analyze temporal trends in the use of nonthermal storage and processing/storage pits. The emphasis of the study is on the relationship between the pits and the site's habitation structures. We focus most of our temporal analyses on four time periods: the Early Formative period, the Middle Formative A period, the Middle Formative B period, and the Late Formative period. Nine extramural nonthermal pits were assigned to the Late Archaic period, but no structures could be confidently assigned to that period, which undermined our ability to compare intramural and extramural pits and pit-related activities. Hence, we present a separate analysis of the Late Archaic period extramural pits below. Furthermore, the analyzed sample excluded all pits without temporal designation and thus included fewer than are listed in Table 32. Our inferred temporal assignments and counts for excavated structures (based on Lengyel's assigned date ranges) and intramural and extramural pits are listed in Table 33. In the next section, we analyze changes in the total frequencies and capacities of storage pits (i.e., intramural and extramural storage pits, combined) over time at Mescal Wash. In the subsequent section, we discuss a comparative study of changes in the frequencies and capacities of intramural and extramural storage pits. In the section after that, we focus on diachronic trends in the frequencies and capacities of processing/storage pits. And, finally, in the last section, we examine possible changes in cooking practices at Mescal Wash over time.

Changes in the Use of Storage Pits

As shown in Figure 54, and also evident in Table 33, the total per-structure storage-pit frequency and capacity generally declined from the Early Formative period through the Late Formative period. That is, the two trend lines are almost identical. The per-structure frequency and capacity of storage pits peaked during the Early Formative period, and there were roughly similar frequencies and capacities during the Middle Formative A and B periods. The per-structure storage-pit frequency reached its lowest point in the sample in the Middle Formative B period, and the per-structure storage-pit capacity reached its lowest point in the Late Formative period. Again, these results may have been biased by the low counts of features assigned to the Early and Late Formative periods, and thus, these trends should be considered tentative.

Several explanations account for these diachronic trend lines. They could reflect a reduction in occupational intensity—assuming a correlation between occupation span and storage capacity. The Middle and Late Formative period site occupants may have constructed relatively small storage pits in anticipation of short-term occupation spans. In contrast, the Early Formative period site occupants may have constructed storage pits in anticipation of long-term, possibly year-round habitation at the site.

An alternative explanation, however, concerns changes in storage practices and technologies. It is plausible that the

Table 33. Numbers of Early, Middle, and Late Formative Period Intramural and Extramural Storage and Processing/Storage Pits per Structure

Temporal Period	Structures	Intramural Pits	Intramural Pits/ Structure	Total Intramural-Pit Volume/Structure (m^3)	Extramural Pits	Extramural Pits/ Structure	Total Extramural-Pit Volume/Structure (m^3)	Ratio of Intramural to Extramural Pits
Storage Pits								
Early Formative	2	2	1.00	0.170	—			
Middle Formative A	42	13	0.31	0.020	8	0.19	0.020	1.60
Middle Formative B	29	2	0.07	0.040	6	0.21	0.002	0.30
Late Formative	4	2	0.50	0.001	—			
Subtotal	77	19			14			
Processing/Storage Pits								
Early Formative	2	1	0.5	0.250	5	2.50	1.250	0.20
Middle Formative A	42	24	0.6	0.010	43	1.00	0.020	0.60
Middle Formative B	29	3	0.1	0.004	52	1.80	0.060	0.06
Late Formative	4	7	1.8	0.440	1	0.30	0.060	7.00
Subtotal	77	35			101			
Total		54			115			

Note: The sample consisted of 19 intramural and 14 extramural storage pits and 35 intramural and 101 extramural processing/storage pits (a total of 169 features). It excluded 9 Late Archaic period extramural processing and/or storage pits as well as all pits without temporal designation, making the sample smaller than what is indicated in Table 5.12.

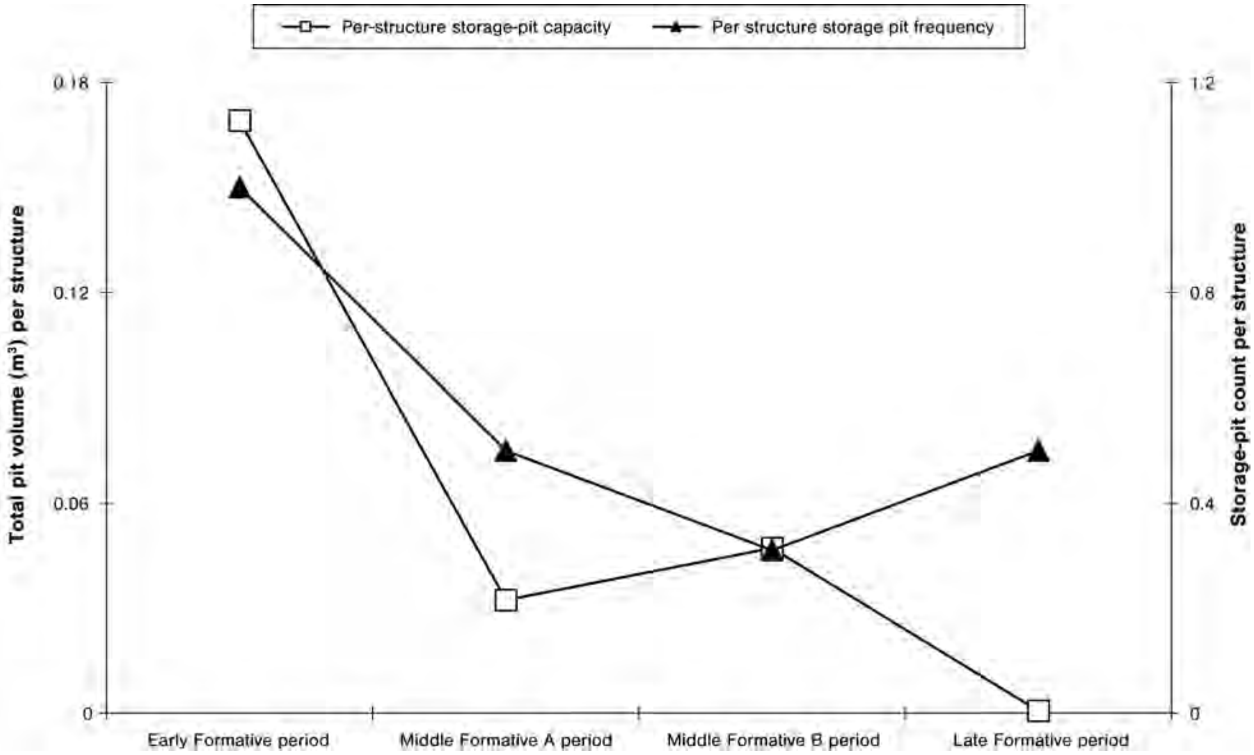

Figure 54. Line graph showing changes in total per-structure storage frequency and capacity over time (combined intramural and extramural storage pits).

Early Formative period inhabitants of Mescal Wash primarily used storage pits to maintain and preserve surplus for future needs (Hendon 2000). However, later generations of site occupants during the Middle and Late Formative periods may have increasingly relied on other storage technologies, such as pottery and aboveground-storage structures, both of which could account for the decline in the frequencies and capacities of storage pits. Increased use of storage pots was increasingly pertinent for the Middle and Late Formative periods, given the greater abundance of sherds that have been recovered from features assigned to these periods throughout the U.S. Southwest.

In sum, possibly both decreased occupation intensity and use of alternative storage technologies could account for the declines in per-structure storage-pit frequencies and capacities. Increased used of pottery vessels for storage is probable, although we are unable to assess the extent to which they may have eclipsed pits as storage containers. Additional lines of evidence will be needed to corroborate the possibility of decreased occupational intensity.

Changes in Intramural and Extramural Storage Practices

This analysis focused on changes in the ratios of intramural and extramural storage pits. Quantifying changes in these ratios was tricky, however, given that the number of intramural pits directly reflected the number of excavated structures assigned to any given period, and theoretically, at least, the number of extramural pits was not directly related to those counts (although there was an *indirect* correlation based on the use of dated structures to make period assignments for some of the extramural pits). To help counter this bias, we calculated the frequencies of intramural and extramural pits as ratios of the numbers of structures assigned to each period (see Table 33). We also calculated the total volume of intramural and extramural pits in the same way, thus achieving an estimate of intramural and extramural storage capacity per structure.

The relative frequencies of intramural and extramural storage pits per structure shown in Table 33 are for the Early Formative, Middle Formative A, Middle Formative B, and Late Formative periods; features dating to the Late Archaic period and those that could not be assigned to a specific time period are excluded. These frequencies are also graphically illustrated in Figure 55. None of the inferred extramural storage-only pits was assigned to the Early or Late Formative period, which likely reflects a preference for intramural storage as much as a low overall frequency of features assigned to these periods. It also reflects the difficulty inherent in assigning extramural pits to either of these periods (all focused in Locus D) based on spatial proximity to dated structures, given the low frequency of dated structures assigned to these periods and the complex mix of features assigned to different periods in this locus. In other words, we were unable to clearly

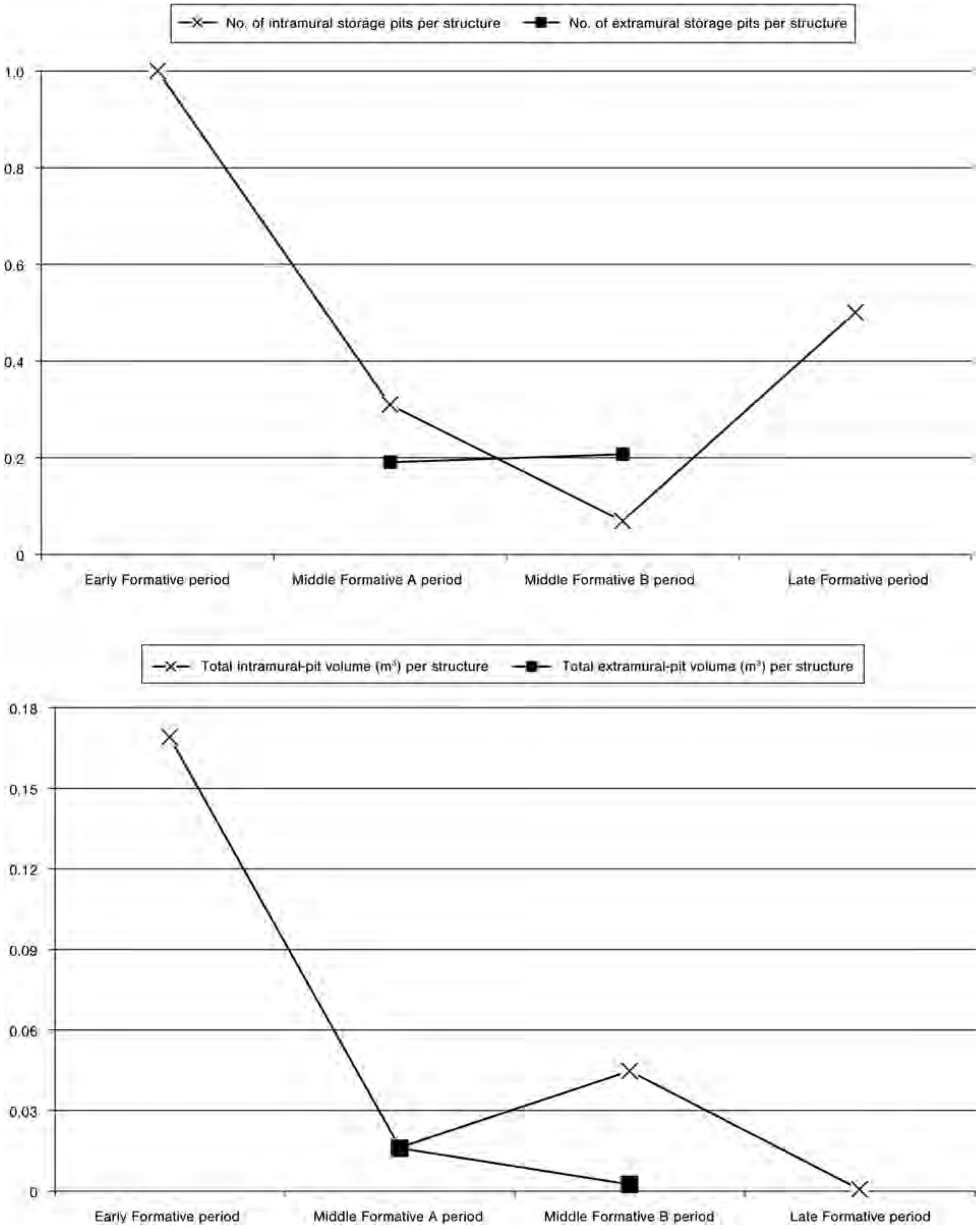

Figure 55. Line graphs showing changes over time in per-structure frequency (upper) and capacity (lower) for intramural and extramural storage pits.

establish association between extramural features and nearby structures assigned to the Early and Late Formative periods because of the many Middle Formative period structures in the same vicinity.

The frequency data for the Middle Formative A and B periods were more robust. The frequency of extramural storage pits per structure remained roughly consistent over both periods, and the frequency of intramural pits declined (see Table 33; Figure 55). Viewed from the perspective of storage capacity (pit volume), however, the per-structure volumetric capacity of extramural pits declined from 0.02 m^3 to 0.002 m^3 from the Middle Formative A period to the Middle Formative B period. Analysis of differences in the mean volumes of intramural and extramural storage pits complements this trend. As shown in Table 34, the mean volume of extramural storage pits declined nearly tenfold from the Middle Formative A period (0.112 m^3; n = 6) to the Middle Formative B period (0.012 m^3; n = 6). Concurrently, the mean volume of intramural storage pits increased roughly fivefold, from 0.086 m^3 (n = 8) to 0.432 m^3 (n = 3).

Altogether, these data suggest a change in intramural-pit storage from more smaller-capacity pits to fewer larger-capacity pits. The frequency of extramural storage pits remained roughly consistent, but their capacities appear to have declined. On the whole, the results imply a trend of slightly increasing intramural storage relative to extramural storage during the Middle Formative period. This trend might reflect a pattern of increased privatization of resources in the latter half of the Middle Formative period.

Changes in Intramural and Extramural Processing Practices

Figure 56 illustrates temporal changes in the per-structure frequency and capacity of all processing/storage pits (combined intramural and extramural pits) (also see Table 33). The frequency was fairly consistent for all four periods, suggesting a fairly consistent per-structure rate of use and replacement of these pits. However, the capacity decreased over time, which could reflect a decline in the scale of the processing activities for which these pits were used. One possibility is that there may have been a reduction in the scale of food-processing activities from the extended kin group (multiple households) to the individual household or nuclear family.

As stated above, the evidence was more robust and reliable for the Middle Formative A and B periods. Most notable is that in the Middle Formative A period sample, extramural processing/storage pits outnumbered intramural pits by 1.8 to 1 (43 to 24). However, in the Middle Formative B period sample, extramural processing/storage pits outnumbered intramural pits by a much higher margin of about 17 to 1 (52 to 3). This trend indicates a major change in pit-related processing practices from a mixed indoor-outdoor activity to an almost exclusively outdoor activity over the course of the Middle Formative period. This may reflect a major change in social organization and activity coordination during the Middle Formative B period. For instance, the processing of food may have shifted from a semiprivate to a public and group-oriented activity during the latter part of the Middle Formative period. If so, it shows a contrasting trend from the one evidenced by the storage pits, which suggested a process of privatization of storage during the latter half of the Middle Formative period. Interestingly, the decreasing capacities of processing/storage pits also suggest that the social scale of food preparation may have decreased (perhaps changing from multiple households or extended households during the earlier part of the Formative period to individual families or households later in time).

Changes in Cooking Practices

The distribution of intramural and extramural thermal pits at Mescal Wash suggests some possible trends in cooking practices. The relative frequencies and capacities per excavated structure for intramural and extramural cooking pits increased from the Middle Formative A period to the

Table 34. Mean Volumes of Extramural and Intramural Storage Pits Assigned to Four Temporal Periods

Temporal Period	Extramural-Storage-Pit Count	Extramural-Storage-Pit Capacity[a]	Intramural-Storage-Pit Count	Intramural-Storage-Pit Capacity[a]	Ratio of Intramural to Extramural Storage Pits
Early Formative	—		2	0.169	
Middle Formative A	6	0.112	8	0.086	0.8
Middle Formative B	6	0.012	3	0.432	36.2
Late Formative	—		1	0.003	
Total	12		14		

Note: The sample consisted of the 14 intramural and 12 extramural storage pits dating to these four time periods. Late Archaic period features and all pits without temporal designation are excluded from these counts.

[a] Mean volume (m^3)

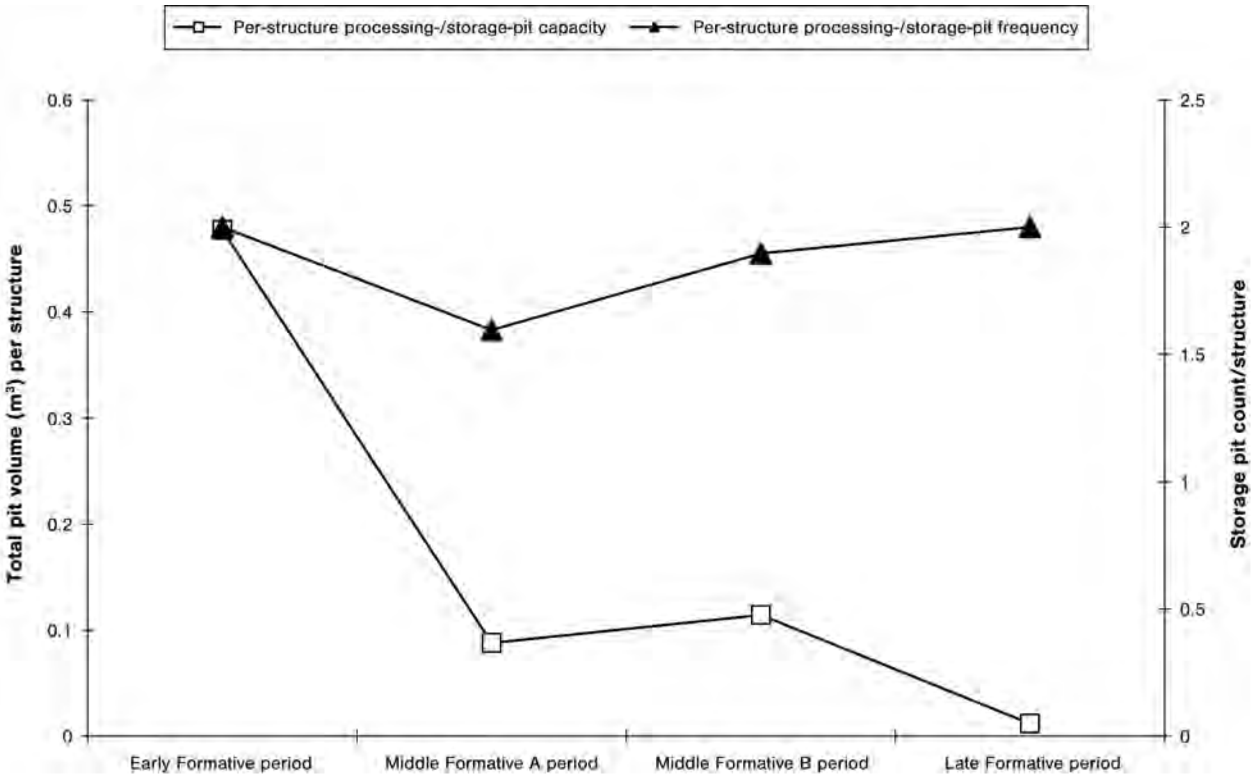

Figure 56. Line graph showing changes in total per-structure processing/storage frequency and capacity over time (combined intramural and extramural storage pits).

Middle Formative B period (Table 35). The low frequencies of excavated structures and pits that dated to the Early Formative or the Middle Formative period precluded any real examination of cooking-pit frequencies or capacities for these periods of time (see Table 35).

The increase in both intramural and extramural cooking features per structure suggests that the amount or frequency of cooking activities per habitation increased over time during the Middle Formative period. The increasing frequency and capacity of cooking pits, especially of extramural cooking pits (see Table 35), suggest an increase in the scale of food preparation, and possibly consumption, over time, as well. Greater amounts of food prepared in outdoor settings suggest the possibility of an increase in the social scale of food preparation and consumption. Perhaps household size increased from the Middle Formative A period to the Middle Formative B period, or food preparation and consumption were more frequent at the suprahousehold scale over time.

In contrast, rather than potential changes in cooking practices over time, the increasing frequency of intramural pits per excavated structure may indicate an increasing ratio of habitation structures to non-habitation structures from the Middle Formative A period to the Middle Formative B period. It is possible that the number of storage structures per habitation structure decreased through time, and that could indicate a decrease in the overall storage capacity of households.

Overall, the ratio of intramural to extramural cooking pits decreased from the Middle Formative A period to the Middle Formative B period (Table 36). This trend suggests that food may have been cooked outside more frequently over time, as intramural cooking declined in popularity over the course of the Middle Formative period. Because we do not have a representative sample of extramural pits excavated at Mescal Wash, it is difficult to understand potential changes in extramural cooking practices or the frequency of such practices through time. However, as we discussed above, we suspect that many types of extramural pits may have been underrepresented in our sample. If this was the case for cooking pits, it would strengthen the argument that extramural cooking increased through time at the site. Interestingly, the average volume of extramural cooking pits decreased from the Middle Formative A period to the Middle Formative B period (see Table 36). This suggests the possibility that the average size of the social group for which food was prepared and cooked may have decreased over the Middle Formative period.

Table 35. Numbers of Early, Middle, and Late Formative Period Intramural and Extramural Cooking Pits per Structure

Temporal Period	Structures	Intramural Cooking Pits	Intramural Cooking Pits/Structure	Total Intramural-Cooking-Pit Volume/ Structure (m^3)	Extramural Cooking Pits	Extramural Cooking Pits/Structure	Total Extramural-Cooking-Pit Volume/ Structure (m^3)	Ratio of Intramural to Extramural Cooking Pits
Early Formative	2	1	0.50	0.001	—			
Middle Formative A	42	32	0.76	0.002	16	0.38	0.150	2.0
Middle Formative B	29	27	0.93	0.003	19	0.66	0.198	1.4
Late Formative	4	5	1.25	0.008	1	0.25	0.101	5.0
Total	77	65			36			

Note: The sample consisted of the 65 intramural and 36 extramural cooking pits dating to these four time periods. It excluded cooking pits without temporal designation, making the sample smaller than what is indicated in Table 5.12.

Table 36. Mean Volumes of Extramural and Intramural Cooking Pits Assigned to Four Temporal Periods

Temporal Period	Extramural-Cooking-Pit Count	Extramural-Cooking-Pit Capacity[a]	Intramural-Cooking-Pit Count	Intramural-Cooking-Pit Capacit^{y}a	Ratio of Intramural to Extramural Cooking Pits
Early Formative	—		1	0.002	
Middle Formative A	16	0.395	32	0.003	2.0
Middle Formative B	19	0.302	27	0.003	1.4
Late Formative	1	0.403	5	0.007	5.0
Total	36		65		

Note: The sample consisted of the 65 intramural and 36 extramural cooking pits dating to these four time periods. It excluded cooking pits without temporal designation, making the sample smaller than what is indicated in Table 5.12.

[a] Mean volume (m^3).

Extramural Storage and Processing Activities during the Late Archaic Period

The Late Archaic period pits were all excavated in Locus D and all were extramural features; no structures could be securely assigned to the Late Archaic period. Six of these pits were assigned to the Late Archaic period based on radiocarbon dates (Features 411, 3557, 3976, 3983, 4849, and 5505); three others were assigned to this time period based on diagnostic artifacts in the fill. Lengyel (Volume 2, Chapter 2) analyzed the radiocarbon assays to infer 1-sigma ranges for these pits. Five of them generated overlapping date ranges with an inclusive range of 1280–880 B.C. One pit (Feature 4849) generated a more recent date range (820–760/620–590 B.C.). These assays broadly indicated dates of construction during the late second millennium to early first millennium B.C.

Of the nine extramural pits assigned to the Late Archaic period, seven were defined as storage/ processing pits, and two were defined as storage pits. No Late Archaic period thermal or cooking pits were identified. All but one of the storage/processing pits were also classified as bell-shaped in cross-section. As noted, pits with bell-shaped profiles have narrow orifices and, therefore, would have been poorly designed for manipulating contents or performing processing activities. Consequently, we strongly suspect that the six bell-shaped storage/processing pits in fact functioned as storage loci but were smaller and shallower than the subsequent storage-only pits assigned to the Early, Middle, and Late Formative periods. Their shallowness (recall that storage/processing and storage-only pits were distinguished based on depth) might indicate short-term storage pits that were constructed during brief occupation spans. The dearth of substantial architecture assigned to this period supports a low level of investment in residential living spaces, further supporting a hypothesis of short-term occupation.

Worth noting, however, is Kent's (1992) observation that formal storage areas correlated strongly with anticipated lengths of stay of about 6 months or more (see above). If that is so, then the presence of formal bell-shaped storage pits at Marsh Station implies a fairly long-term, multiseasonal occupation and/or frequent reoccupation over many years. In the latter scenario, the Late Archaic period site inhabitants may have returned to the site on a yearly or seasonal basis and reused the same bell-shaped pits during each occupation episode. As noted above, the narrow orifices of bell-shaped pits made them readily concealed and camouflaged between site occupations. Perhaps seasonal occupants constructed insubstantial structures adjacent to the pits during each visit and occupation span; if so, the pits, rather than the structures, may have anchored the occupation location over a long span. Mescal Wash has been interpreted as a persistent place (Schlanger 1992), and this argument supports the possibility that it emerged as a recurrently occupied location as early as the Late Archaic period.

We are limited in our ability to infer detailed information about storage and processing practices during the Late Archaic period, given the absence of intramural features and the unknown number of additional Late Archaic period pits among the many unexcavated and undated features in Locus D. However, we are able to compare the Late Archaic period extramural-pit attributes—mainly metric attributes—with those of later (i.e., Formative period) storage and storage/processing pits, with the caveat that the small number of Late Archaic period pits in our sample heightened the sampling vagaries.

The mean estimated volume of the two inferred Late Archaic period storage-only pits was 0.81 m^3 (standard deviation = 0.64 m^3), which is substantially larger than the mean volume of storage-only pits in the Formative period (0.11 m^3; standard deviation = 0.19 m^3; n = 30). Aside from the obvious problem of sample size, as noted, we suspect that seven other Late Archaic period bell-shaped pits classified as storage/processing pits likely functioned as storage loci. If we include these in our Late Archaic period sample, the mean estimated volume declines to 0.45 m^3 (standard deviation = 0.41 m^3; n = 6), still more than twice the estimated capacity of the Formative period storage pits. This same pattern persists even if we only include the bell-shaped nonthermal pits in our Formative period sample (mean = 0.19 m^3; standard deviation = 0.16 m^3; n = 8).

Setting aside the problem of sampling vagaries, these data suggest substantially higher storage capacities for Late Archaic period storage pits than for later, Formative period pits. On the surface, this may seem counterintuitive, assuming that the Late Archaic period site occupants were more mobile than the Formative period occupants. However, the smaller average capacity of Formative period extramural storage pits could have been offset by additional storage capacity in intramural pits and pottery vessels. Unfortunately, the absence of well-defined Late Archaic period structures prevents us from evaluating the possibility of intramural storage during that period. Furthermore, the Formative period inhabitants of Mescal Wash may have used multiple storage pits per household that were perhaps specialized according to location or stored contents. That is, Late Archaic period groups may have constructed a small number of large-capacity and generalized storage pits, whereas Formative period groups may have constructed a larger number of specialized storage pits in different locations.

These inferential problems are exacerbated by the absence of Late Archaic period structures. If we had been able to detect Late Archaic period structures, we could at least estimate storage capacity per structure. Nor are we able to accurately control for the number and locations of extramural storage pits associated with any specific structure or affiliated group of structures, especially given the large number of unexcavated pits. As a consequence, we cannot accurately estimate storage capacity in a quantitatively standardized way (i.e., per person or per household).

In addition to the probable storage pits, one inferred storage/processing pit was described as conical in cross-section, and we suspect that it was in fact used as a processing feature. Shallow, conical pits with inward-sloping bases and unrestricted orifices would have been better suited for accessing and manipulating the pit contents. Likely additional storage/processing pits are present at the site, among the unexcavated pits exposed during the stripping in Locus D. As with the storage pits, the Late Archaic period storage/processing pit exhibited more than twice the volumetric capacity (0.18 m^3) of the Formative period storage/processing pits (mean = 0.06 m^3; standard deviation = 0.13 m^3; n = 130). Again, this may indicate a larger number of functionally specialized storage/processing pits in the Formative period sample.

In sum, in the Late Archaic period sample of extramural pits, both storage and processing pits had larger volumetric capacities than was exhibited in our combined Formative period sample. The reason for that difference is not empirically obvious. We speculate that Formative period groups constructed a larger number of smaller, functionally specialized storage and storage/processing pits than did the earlier, Late Archaic period site inhabitants, although we are unable to corroborate this hypothesis.

Pits and the Social Construction of Space

This section focuses on the spatial distribution of extramural pits relative to structures and other features. In this case, the study sample concerns the 250 excavated extramural pits at Mescal Wash (all in Loci A, C, and D) for which width and depth (i.e., size and shape) could be calculated: 38 in Locus A, 64 in Locus C, and 151 in Locus D. For Locus D, however, a smaller subsample of 85 pits was used (see below). To facilitate analysis, we separately analyzed the distribution of pits in Loci A, C, and D (Table 37). For Loci A and C, this task was relatively straightforward (especially for Locus A), because most of the features were assigned to the Middle Formative B period. Thus, we could analyze all of the extramural-pit features as a single unit of analysis, with the caveat that a small number of the features may predate or postdate that period. Also, the majority of exposed pits in those loci were excavated, providing a robust sample.

In Locus D, the task was much more challenging, given the very large size of the locus and the complex mix of occupation episodes and period assignments. Another complicating factor was that a very high proportion of extramural pits were not excavated, and thus, the sample coverage of pit features was spotty and inconsistent—especially for nonthermal pits, because most of the exposed thermal features were subjected to investigation, to avoid overlooking potential cremations. Therefore, given the large size and complexity of this locus, we divided it into three separate analytical units—Areas D1, D2, and D3—that together provided a sample of 85 extramural pits (17 in D1, 37 in D2, and 31 in D3) of the total of 151 extramural pits excavated in this locus. Pits in outlying areas of Locus D are not discussed.[1] In their analysis of mortuary features, Garraty et al. (see Volume 2, Chapter 11) defined three clusters of burials and associated structures in Locus D, all of which were inferred to have been occupied during the Middle Formative A period. We used those same clusters to define variability in the distribution of extramural-pit features.

One cluster (D1) of a burial and structures was in the west-central portion of the locus and encompassed Stripping Units (SUs) 6801, 6795, and 6789. A second cluster (D2) was in the central portion of the locus and

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[1] The sample of 85 pits excluded 6 radiocarbon-dated Late Archaic period pits; the 60 extramural pits excavated in Locus D outside Areas D1–D3 are not discussed here, either.

Table 37. Distribution of Extramural Pits in Loci A, C, and D, by Type

Pit Category	Locus A		Locus C		Locus D		Total	
	n	%	n	%	n	%	n	%
	Nonthermal							
Borrow pit	—	0.0	—	0.0	4	3.2	4	1.9
Cache	—	0.0	—	0.0	2	1.9	2	1.2
Processing/storage	29	76.3	38	59.4	87	58.1	154	61.1
Storage	3	7.9	7	10.9	12	9.0	22	9.3
Subtotal	32	84.2	45	70.3	105	72.3	182	73.5
	Thermal							
Cooking, large	—	0.0	5	7.8	16	10.3	21	8.2
Cooking, small	6	15.8	14	21.9	27	17.4	47	18.3
Subtotal	6	15.8	19	29.7	36	29.0	68	27.2
Total	38	100.0	64	100.0	151	100.0	250	100.0

Note: The data above are from the 250 extramural pits for which width and depth (i.e., size and shape) could be calculated.

encompassed SUs 3033, 6791, 2495, 3035, and 2492. The final cluster (D3) was in the eastern portion of the locus and encompassed SUs 6787, 3006, 3008, 1759, 1869, 1881, and 1883.

Locus A

In total, 38 extramural pits were excavated in Locus A: 32 nonthermal pits (84 percent) and 6 thermal pits (16 percent) (see Table 37). Notably, among the 6 features classified as small thermal pits, 1 feature (Feature 1149) had been defined in a previous classification as a *horno* that was large in lateral size but shallow. The feature may have been functionally different from the other, smaller thermal pits. Our Locus A analysis highlights settlement structure and spatial organization during the Middle Formative B period.

Figure 57 is a map of Locus A that shows the locations of the various pit-feature classes. Perhaps most notable are the large, somewhat linear clusters of processing/storage pits. These pits tended to be located adjacent to structures or groups of structures and probably functioned as domestic food-processing locations or short-term storage locations. The most prominent cluster was located in the south-central portion of the stripped area, in the southeastern corner of SU 1151. At least five additional clusters were recognizable, in the northeastern, northwestern, and south-central portions of SU 1151 and in the northwestern and east-central portions of SU 1137. It is possible that, at any given time, each household or group of households maintained a dedicated area devoted to processing activities that corresponds to each of these clusters.

Various explanations can be proffered for the clustering of the features. One possibility is a pattern of "drift," as damaged or exhausted pits were replaced with newer ones in an adjacent location. As noted above, these pits probably had to be frequently abandoned and reconstructed because of their use as loci for mechanical manipulation of pit contents. Over time, this continual process of abandonment and construction would generate a clustered arrangement of processing/storage pits. If this explanation is valid, perhaps the number of pits can be *roughly* correlated to the length of occupation or frequency of reoccupation at the adjacent structures. A second possible explanation is that the various processing/storage pits were roughly contemporaneous and functionally specialized for processing different classes of food or other materials.

The distribution of storage-only pits was not as clearly patterned as the distribution of processing/storage pits. Worth noting, however, is that two of the three inferred storage-only pits were situated in a relatively open area (i.e., devoid of structures and other features) in the southeastern portion of the stripped area. That might indicate that the storage pits were shared among multiple structures and households in the vicinity (Features 207, 1189, 2143, and 2157 are located nearby).

Nor was spatial patterning evident among the thermal features. Three thermal features were located adjacent to structures in the central portion of the stripped area, near structure Features 290, 2160, 2195, and 2198 (the last was not excavated). These thermal pits likely functioned as domestic cooking loci affiliated with one or a few nearby structures and households. Three other thermal features were located in what may have been perceived as communal space, away from the structure. Features 1146 and 1149 were located in the northeastern corner of the stripped area, away from any structures. Feature 6463 was located in the southwestern corner of the stripped area. It intruded on an earlier structure (Feature 2192) and was not clearly associated with any of the other structures. Perhaps these three thermal features, including the abovementioned *horno*, were used for communal cooking activities, such as food preparation for public feasts or ceremonies. Another possibility is that they were used for cooking or heating

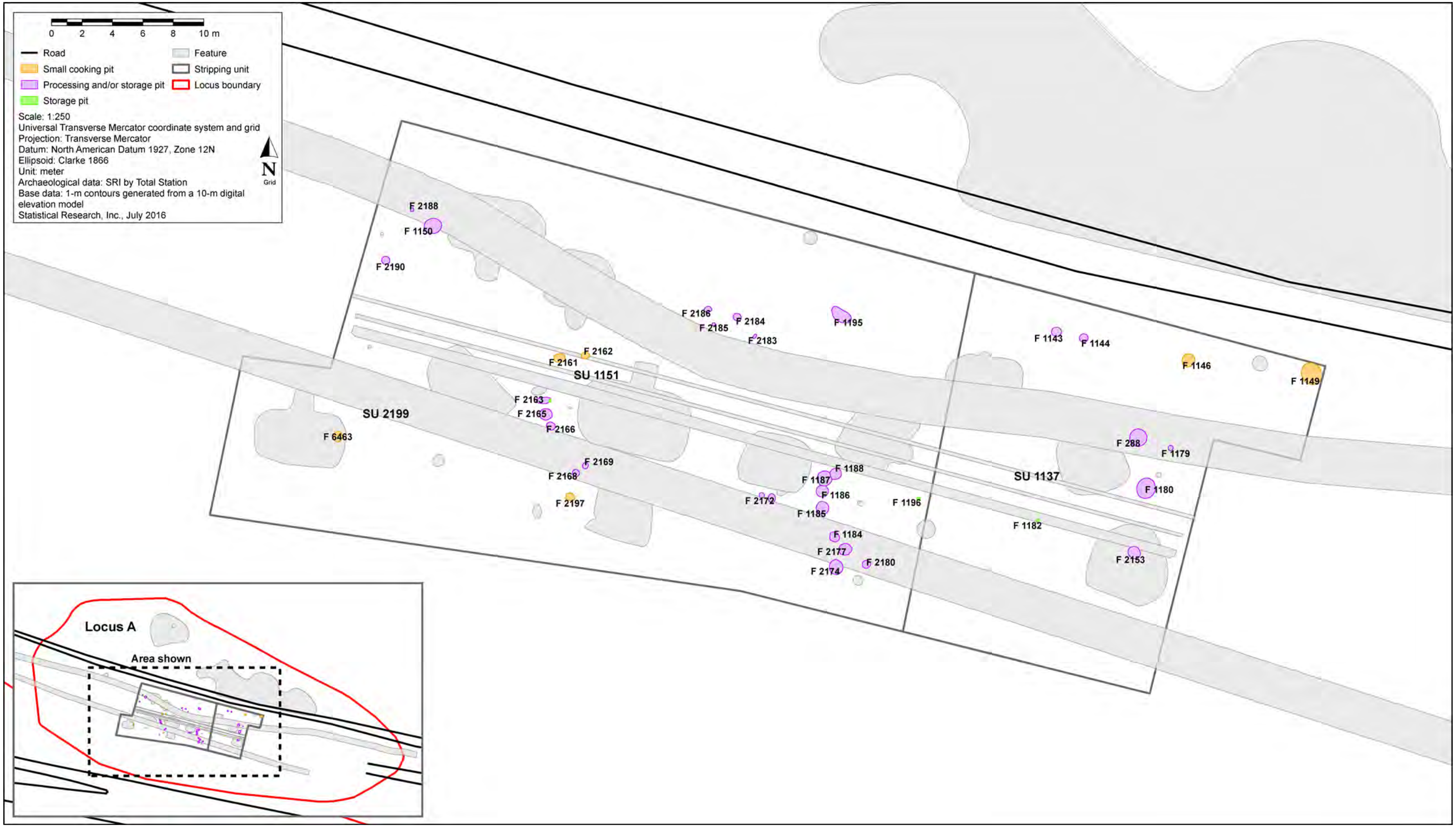

Figure 57. Map showing the locations of pit features, by category, in Locus A.

materials that produced unpleasant smoke or odors and thus were used away from the primary activity areas surrounding the structures. One caveat is that it is possible that additional structures were present just outside the stripped area, in which case, a few of these thermal features may have been located adjacent to structures.

Locus C

In total, 64 extramural pits were excavated in Locus C: 45 nonthermal pits (70 percent) and 19 thermal pits (30 percent) (see Table 37). The reason for the higher frequency of thermal pits than in Locus A is unknown (Locus D exhibited a similar proportion to Locus C; see below). The Middle Formative period inhabitants in Locus C (as well as Locus D) may have more frequently prepared and cooked meals in outdoor contexts than did the inhabitants in Locus A. Also notable in Locus C is the presence of large extramural thermal pits (including 1 *horno*), which were absent from Locus A. Our analysis in Locus C generally indicates settlement structure during the Middle Formative B period.

Our spatial analysis here primarily focuses on SUs 5190 and 5195 (Figure 58). The other stripped areas were smaller and thus did not offer as revealing a "window" into site structure than did these two large, adjacent stripped areas. As in Locus A, processing/storage pits tended to be clustered in Locus C, although the clusters were not as clearly defined as in Locus A. A very clear cluster was observable in the east-central portion of SU 5195; however, their distribution was more scattered and continuous in SU 5190. Even so, a fairly continuous, somewhat linear arrangement of processing/storage pits extending from the south-central portion of SU 5190 to the east-central portion, between the two clusters of structures in the eastern and western portions of the stripped area. The same processes described above—temporal "drift" and functional specialization—also explain the arrangement of processing/storage pits in Locus C.

As in the stripped area in Locus A, only three features classified as storage pits were excavated in SUs 5190 and 5195, and no patterning was clearly evident in their distribution. In each case, the storage pits were located in close proximity to several processing/storage pits, suggesting a possible functional linkage. The foods or other materials kept in these storage pits may have been processed in the nearby processing/storage pits. As noted above, storage pits were not subjected to frequent mechanical manipulation and thus were not as frequently abandoned and rebuilt as processing/storage pits. In this sense, the storage pits may have "anchored" the activity loci related to food-processing activities on the landscape, around which processing/storage pits were continually built and rebuilt. Notably, a tightly concentrated cluster of four storage pits was excavated in SU 5188, adjacent to structure Feature 276. The reason for that concentration is unknown, however.

The distribution of extramural thermal pits was considerably denser than in Locus A. These features were not as concentrated as the processing/storage pits, however, and were generally scattered throughout the two stripping units. One exception was the northeastern area of SU 5195, which encompassed five thermal features in fairly close proximity to one another (Features 6114, 6135, 6136, 9409, and 10380). By comparison, only one nonthermal pit was recorded in that area (Feature 6134), although several unexcavated pits also were recorded nearby. Perhaps the area functioned as a locus for communal cooking activities for feasts or public ceremonies. Three of the thermal pits in the area—Features 6114, 9409 (a rock-lined thermal pit), and 10380—appeared to be aligned and roughly evenly spaced at ca. 5-m intervals. Perhaps these three features represent separate thermal "stations" for different cooking or other thermal activities. The presence of one rock-lined thermal pit in this group could reflect that functional specialization.

The large *horno* was located in an open area—possibly a public plaza area—between the eastern and western concentrations of structures in SUs 5190 and 5195 that may have functioned as a public food-preparation locus possibly related to baking agave hearts, cholla buds, or other xerophytic plants. Again, it could have been used to cook specific foods for communal feasts or public ceremonies.

Locus D, Area D1

The portion of Locus D we refer to as Area D1 encompasses a concentration of structures in the west-central portion of the locus (Figure 59). Notable in this area are two roughly east–west lines of pit structures in the northern and southern parts of the area. Between was a presumed common area, possibly a courtyard or plaza shared among the residents of these structures. Excluding Late Archaic period features, 17 extramural pits were excavated in Area D1: 11 nonthermal pits and 6 thermal pits. Our analyses in the three proposed settlement areas in Locus D mainly highlight spatial organization and settlement structure during the Middle Formative A period. Most of the surrounding structures were assigned to this period.

As in the other loci, the majority of pits were classified as processing/storage pits (n = 10, or 59 percent). Unlike in Loci A and C, the processing/storage pits in Area D1 did not appear to be tightly concentrated; rather, they were generally scattered throughout the area. The reason for this difference is not clear. One plausible hypothesis is that this area was inhabited on a short-term basis and/or less frequently reinhabited by returning families or groups. Above, we explained the clustering of processing/storage pits as a reflection of the continual need to abandon them because of the frequent occurrence of damage related to mechanical manipulation and to rebuild new pits in adjacent areas. If that was so, the sizes of concentrations may indicate the amount of time spent in each settlement location. By the

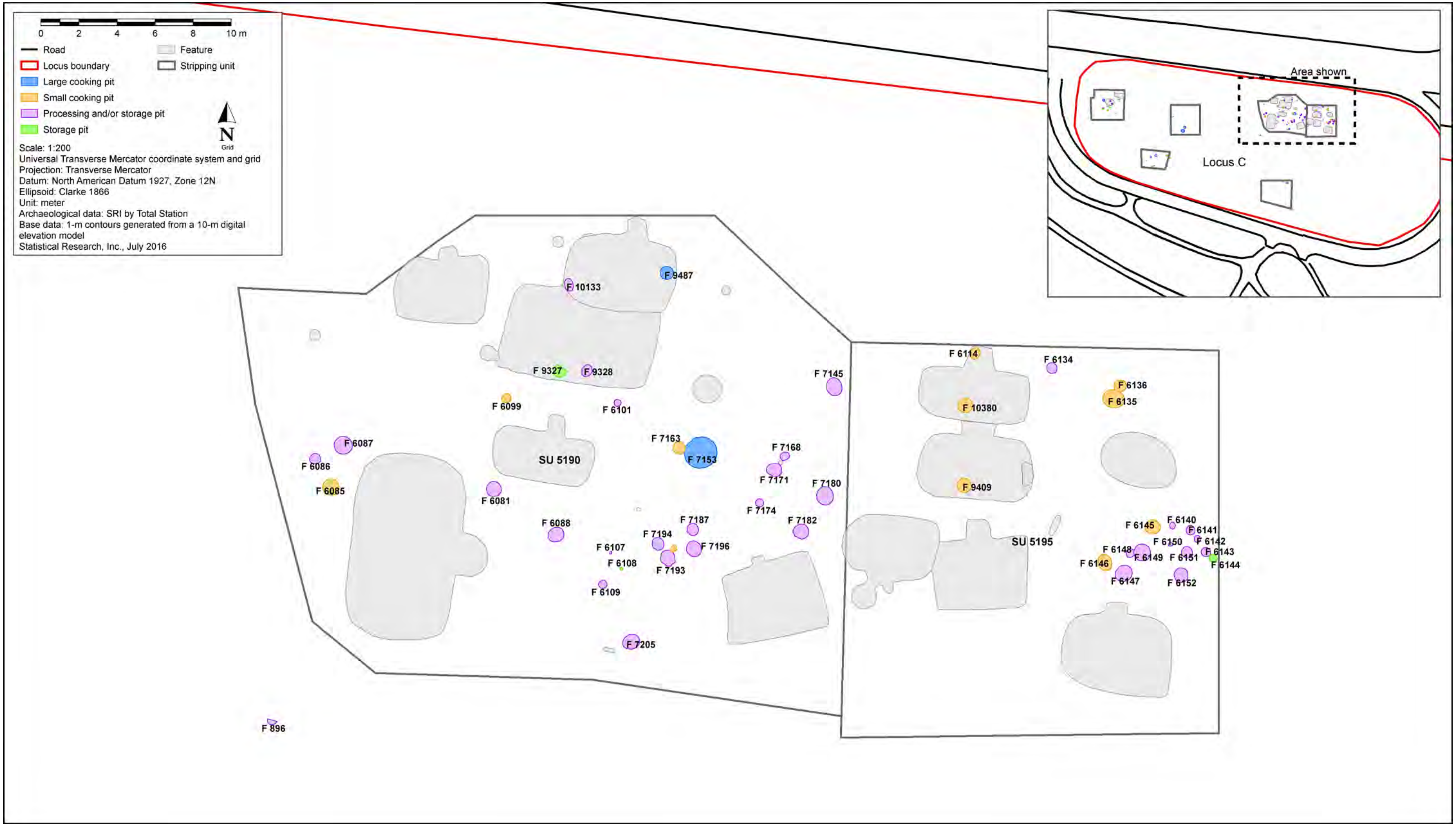

Figure 58. Map showing the locations of pit features, by category, in Locus C.

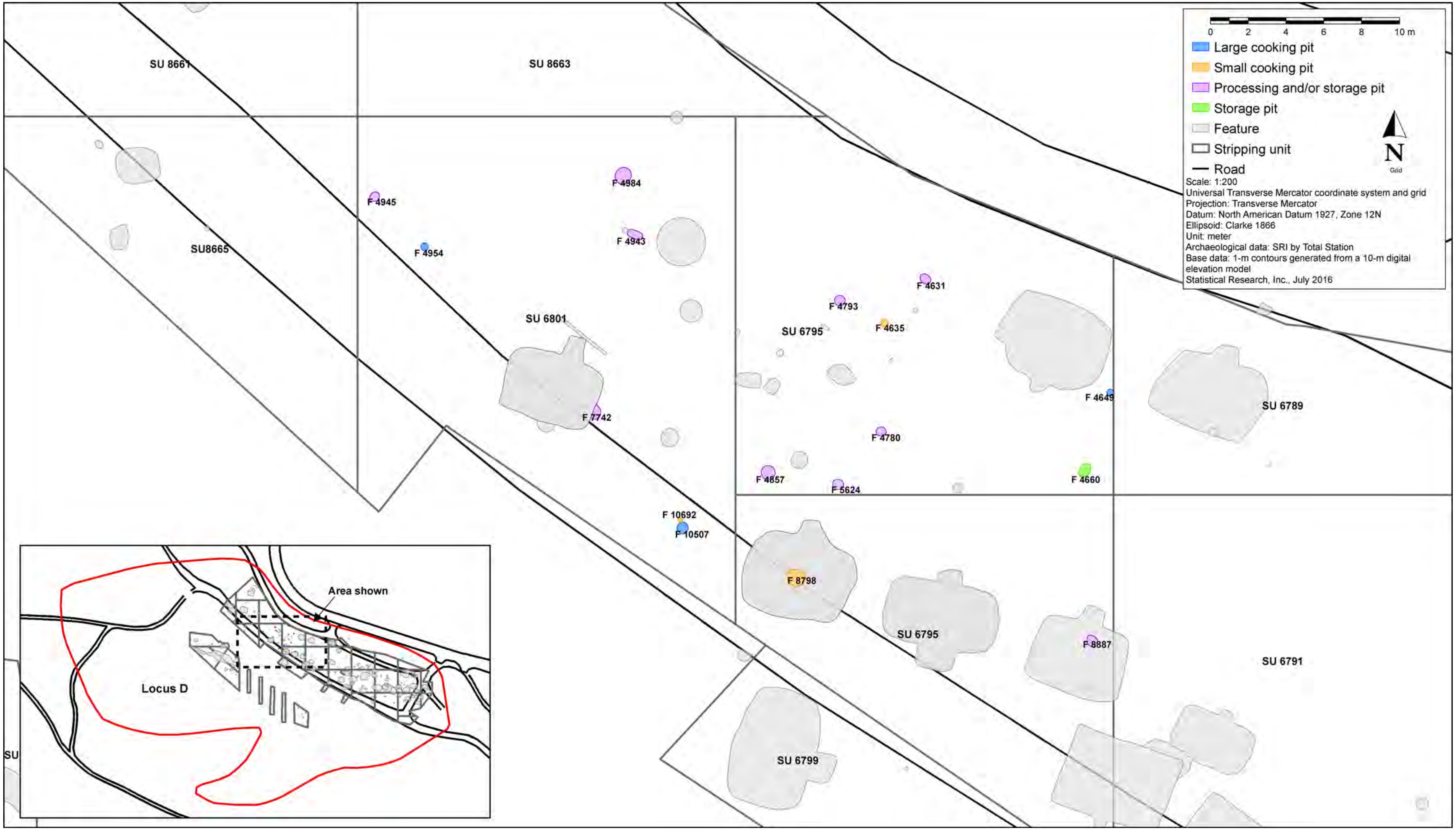

Figure 59. Map showing the locations of pit features, by category, in Locus D, Area D1.

same token, the absence of clustering could reflect short-term habitations—i.e., those in which processing/storage pits were not continually abandoned and rebuilt within a specified activity area. Additional evidence will be needed to corroborate this hypothesis.

Only one storage pit was excavated in Area D1 (Feature 4660); one other storage pit in the area was assigned to the Late Archaic period. Like most of the processing/storage pits, this pit was located in the proposed plaza or courtyard area. This area may have functioned as a common area for communal activities during the Middle Formative A period. The six thermal features, consisting of three large thermal pits and three small thermal pits, were also scattered throughout the area and were not spatially concentrated. Worth noting is that none of the features was located within the proposed plaza or courtyard area between the two lines of structures. Hence, the possible common area may have been used for communal activities related to food preparation or other nonthermal processing activities, but it did not appear to have been used for thermal activities, possibly to avoid smoke inhalation or fire danger in the heavily traversed and frequently used communal activity area.

The presence of just one storage pit is surprising; however, it is possible that additional pits were present among the many unexcavated features in the area. Also, two of the thermal pits (Features 8798 and 10507) are bell-shaped in cross-section and were located near one another in the eastern portion of Area D1.One of them, Feature 8798, underlies (and predates) a set of overlapping structures (Features 8841 and 8842). It is possible that these pits had been used for storage and were later reused as roasting pits, given the above-mentioned benefits of bell-shaped pits for the purpose of concealing and safeguarding storage areas.

Locus D, Area D2

Area D2, in the east-central portion of Locus D, consists of a dense concentration of structures generally arranged along an east–west line (Figure 60). A possible courtyard or plaza area is present between two lines of structures, but only 1 pit (Feature 3983) was excavated in that area (dozens of additional pits were located but not excavated). The majority of pits were excavated in a dense concentration of features in the northeastern portion of Area D2. In all, 37 pit features were excavated in this area: 32 nonthermal pits and 5 thermal pits. The nonthermal pits consist of 24 processing/storage pits (65 percent of all excavated pits), 7 storage pits (19 percent), and 1 borrow pit (3 percent). The 5 thermal pits (14 percent) were all classified as small cooking pits.

Unlike Area D1, the processing/storage pits are fairly concentrated, but that might partly reflect the limited spatial coverage of excavated pits in the area. Many of these pits were located in the northeastern portion of Area D2, within a continuous “arc” of pit features in the vicinity of structure Features 10560/10561/4043, 565, and 3921. A second, less discrete cluster of processing/storage pits was located in the northwestern portion of Area D2, in the vicinity of structure Features 4299 and 4333. Again these somewhat-linear arrangements of processing/storage pits may be attributable to the continual process of abandonment and reconstruction of these pits over a long span of time. If so, Area D2 may have been inhabited for a longer span of time and/or more frequently and consistently reoccupied, presumably by several kin-related families or households.

Seven storage pits are scattered throughout the area, including four within the dense cluster of pit features in the vicinity of Features 10560/10561/4043, 565, and 3921. Generally, the storage pits were located in close proximity to processing/storage pits, perhaps suggesting a functional complementarity. The food items or other materials stored in those pits may have been processed in the nearby processing/storage pits. No inferred storage pits were observed in the vicinity of the second cluster of processing/storage pits near Features 4299 and 4333, but it is possible that storage pits are present among the unexcavated pits in the area.

The five inferred thermal pits were all classified as small cooking pits. Three were situated within the dense cluster in the vicinity of Features 10560/10561/4043, 565, and 3921. Two others were located just outside and to the north of the dense cluster. In this case, the spatial association of thermal pits with storage and processing/storage pits could indicate that they were used to cook the foods (or to heat the nonfood materials) stored and processed in the nearby nonthermal pits.

Locus D, Area D3

Our proposed Area D3 lies in the easternmost portion of the locus and also consists of a very dense concentration of structures that exhibited no clear patterning or arrangement (Figure 61). The frequent reoccupation and reuse of this area likely obfuscated spatial patterning related to any one occupation episode. Even so, like the other two proposed areas, the arrangement of structures is generally linear along an east–west axis, and an extramural area between that line of structures and several structures to the north (Features 7558/7559 and 10729) could have functioned as a courtyard or plaza area where communal activities took place.

In total, 31 pit features were excavated in this area: 22 nonthermal pits and 9 thermal pits. The nonthermal pits consist of 18 processing/storage pits (58 percent of all excavated pits), 2 storage pits (6 percent), and 2 borrow pits (6 percent). The 9 thermal pits (29 percent) are 7 large thermal pits, 1 small thermal pit, and 1 thermal pit of unknown size.

As in Area D1, the processing/storage pits are not clearly concentrated in area D3, and again, that could have resulted from the spotty coverage of the excavated sample—no sizable extramural areas were subjected to complete or nearly complete excavation. Worth noting is the number

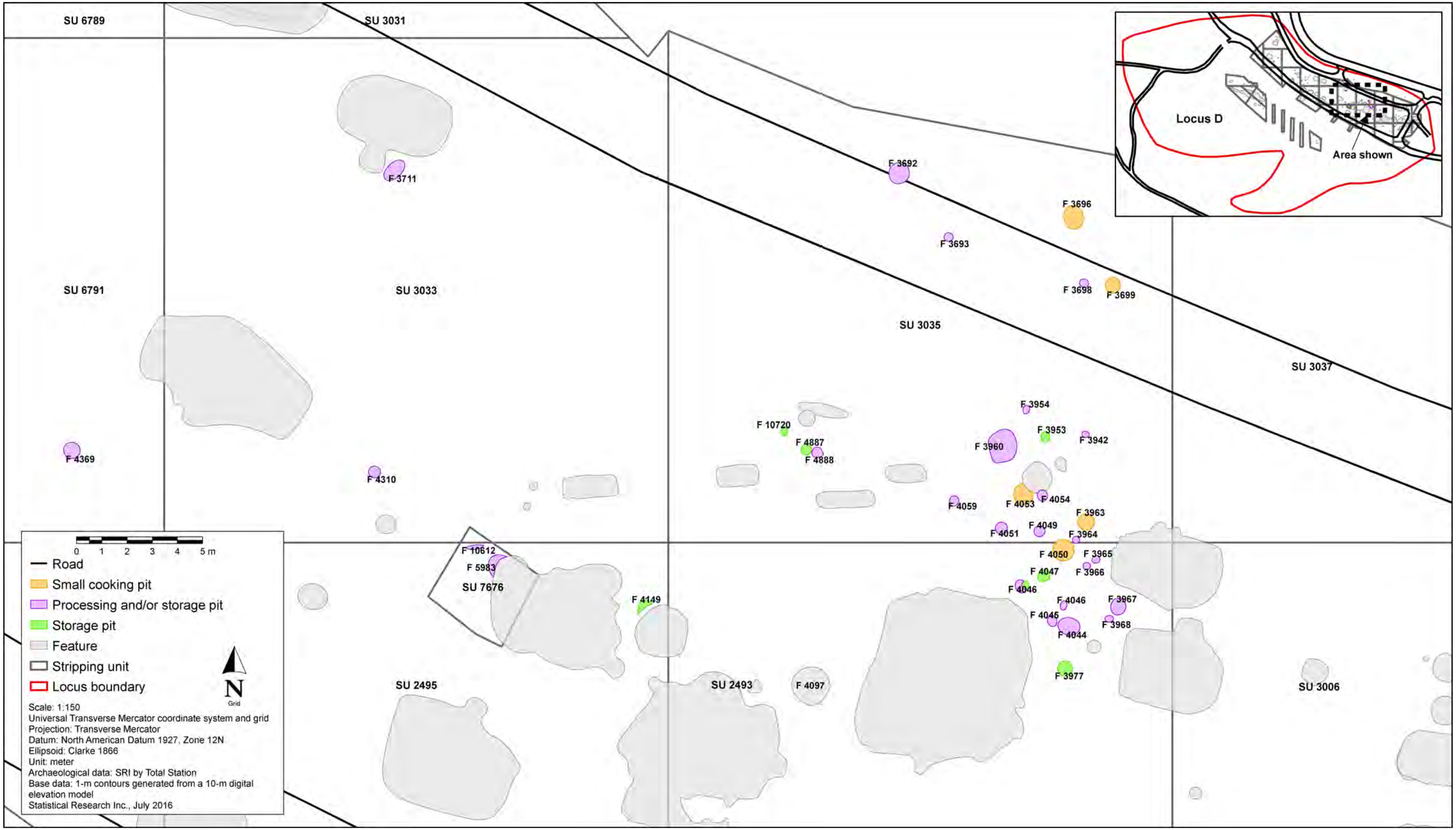

Figure 60. Map showing the locations of pit features, by category, in Locus D, Area D2.

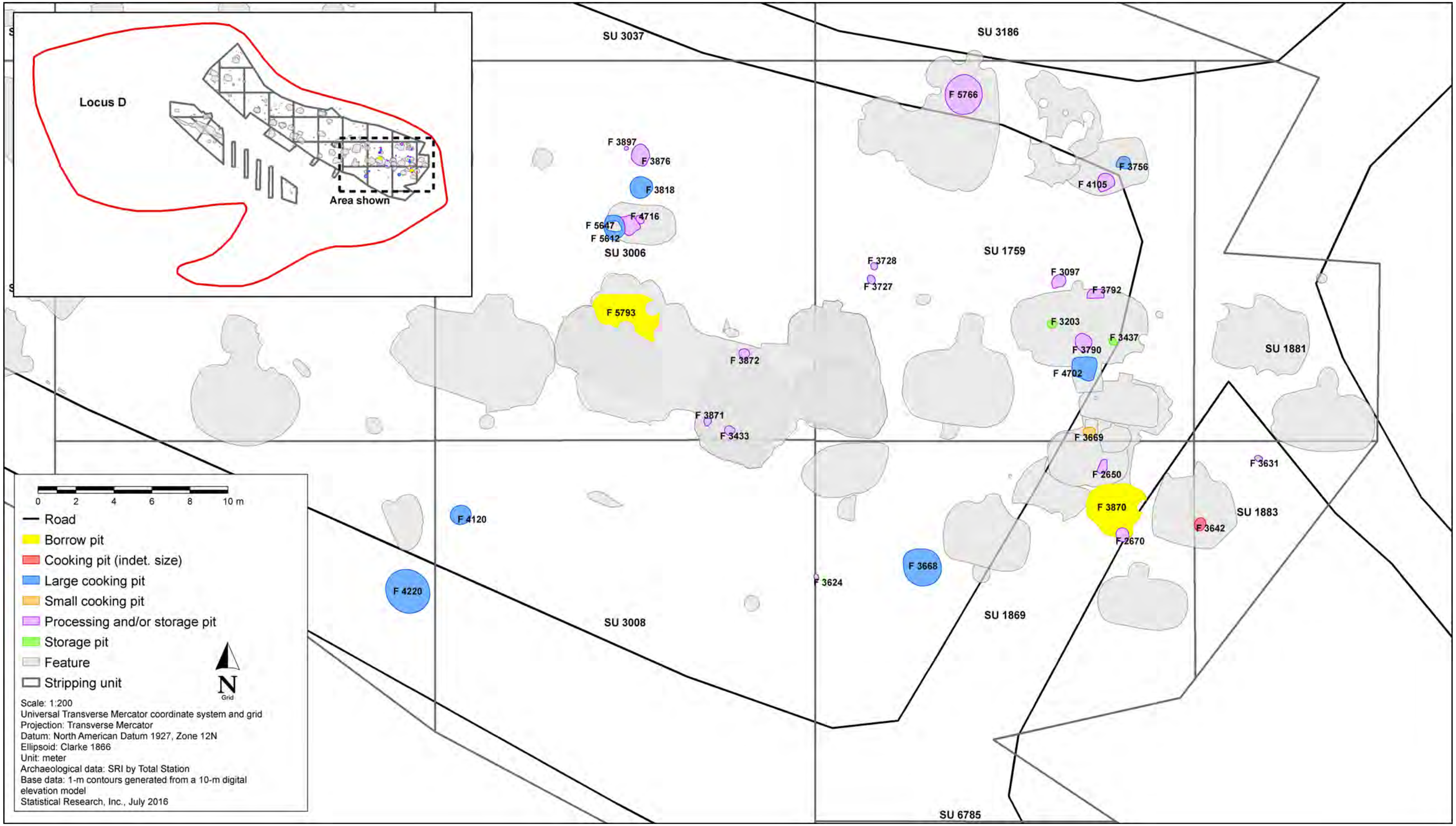

Figure 61. Map showing the locations of pit features, by category, in Locus D, Area D3.

of processing/storage pits that were excavated in the possible courtyard or plaza area noted above. That area also included a large number of unexcavated features, however. If we were to assume that some of these would be classified as processing/storage pits in our classification, then a concentration would be evident in this area.

Two storage pits were excavated in Area D2, within or adjacent to the footprint of an overlapping set of structures (Features 3679/3868). However, stratigraphic evidence showed that one of the two storage pits predates these structures (Feature 3203), and the other postdates them (Feature 3437). Hence, these storage features were clearly not part of the settlement structure during any given occupation episode. The area in which they were situated may have been part of the posited plaza or courtyard area before and after the use lives of the two overlapping structures.

Two additional nonthermal pits were classified as borrow pits, both situated within a cluster of structures near the east-central edge of Locus D. These features presumably were used to create and mix adobe in connection with construction of the adjacent pit structures.

Most salient among the extramural thermal features in this area was the high proportion of large cooking pits (n = 7) to small cooking pits (n = 1), which was not the case in any of the other areas or loci. The higher frequency of large thermal pits in this area might suggest a preference for group- or community-level cooking preparation of meals rather than meal preparation at the scale of the individual household or small group of households. In their mortuary analysis, Garraty et al. (Volume 2, Chapter 11) observed different burial practices in this area than in the other two proposed areas, suggesting the possibility that the settlers in this area adhered to different cultural traditions and practices. It is therefore plausible that this possible distinct cultural group also adhered to food-preparation and communal-meal-sharing practices that were different and distinct from the practices of the inhabitants in Areas D1 and D2.

Two of the large thermal pits (Features 3818 and 4220) were classified also as *hornos*, indicating probable baking activities in the area, possibly of xerophytic plants. The other thermal pits were classified as roasting pits, three of which exhibited rock-lined bases. The large thermal pits were mostly situated along the edges of the area, and none was located within the possible courtyard or plaza area. That may suggest a preference for segregating cooking activities away from the communal activity areas in the courtyard or plaza area.

Summary and Conclusions

We conclude this chapter by summarizing our conclusions in terms of how pit features at Mescal Wash inform on the practices identified in the three themes introduced at the beginning of this chapter: (1) food preparation and consumption, (2) storage, and (3) the social construction of space.

Pits and Food Preparation and Consumption

Food-preparation and consumption activities were reflected in the features classified as processing and/or storage pits and various kinds of cooking pits. In a sample of 391 excavated intramural and extramural pits, 203 features were identified as processing and/or storage pits (see Table 32). These pits were likely used, at least in part, to process materials, perhaps for pounding, threshing, or mixing foods. Processing pits in extramural contexts outnumbered those in intramural contexts by a ratio of 3.2:1, indicating a preference for locating food-processing activities outside residential structures. The smaller sizes of intramural processing pits suggest that processing activities varied from extramural to intramural contexts. Through the Middle Formative period, it appears that pit-related processing practices changed from a mixed indoor-outdoor activity to an almost exclusively outdoor activity. This may reflect a major change in social organization and activity coordination and scheduling over time. It also suggests that food processing became an increasingly public activity and that food preparation may have been increasingly visible or monitored over time. The decreasing sizes of processing pits over the course of the Middle Formative Period also suggest that the social scale of food preparation may have decreased through time, perhaps from multiple or extended households to individual households or families.

In total, 137 pits (of the 391 features) were classified as cooking pits. The cooking pits were evenly distributed between extramural and intramural contexts, although we suspect that extramural thermal pits were underrepresented in the excavated sample we examined for this chapter. It does appear that the types of cooking practiced in indoor and outdoor settings varied, however. The intramural cooking pits (all formal hearths, most of which were plastered) were generally small in capacity and would possibly have been used to heat up small amounts of food, perhaps heating or boiling stews in ceramic jars or heating small amounts of food over direct flame. Intramural thermal pits were also likely used for heating and lighting purposes, along with cooking. The outdoor cooking pits were more variable in size, shape, and likely function. Thus, we suspect that cooking techniques employed in outdoor settings were more varied. The generally larger capacities of extramural pits also suggest that greater amounts of fuel were required for outdoor cooking techniques or that meals prepared outdoors were consumed by larger social groups than those prepared indoors, or some combination of the two. We also saw some possible changes in cooking practices over the course of the Middle Formative period. The ratio of intramural to extramural cooking pits decreased through time in our data set, suggesting that food may have been cooked outdoors more frequently in the Middle Formative B period. In addition, the increasing relative frequency and capacity of extramural cooking pits per excavated and dated structure suggest the possibility that the scale of food preparation and consumption increased over time. Perhaps household size increased from the Middle Formative A period to the Middle Formative B period, or suprahousehold food preparation and consumption were more frequent over time. However, as discussed above, the average size of processing pits decreased over time, possibly contradicting that pattern. Interestingly, the average volume of the extramural cooking pits did decrease over time in our data set, which supports the possibility that the average size of the social group for which food was prepared may have decreased over the Middle Formative period.

Pits and Storage

Storage practices were also reflected in the pit features excavated at Mescal Wash. Forty-seven pits in the sample were classified as storage-only features in our data set (see Table 32). The sizes and capacities of storage pits were relatively consistent in both extramural and intramural contexts. However, storage pits in the data set did vary considerably in indoor and outdoor settings in the cross-section shapes represented, suggesting that the kinds of items stored and their accessibility differed between the two contexts. The relative frequency of bell-shaped storage pits in extramural contexts indicated a concern with visibility of stored resources and could reflect an economic concern with theft, and it may have also promoted an ethic of social equality, by concealing potential differences in resource accumulation and surplus within the settlement.

Over time, from the Early Formative period to the Late Formative period, per-structure storage-pit relative frequencies and capacities declined. This suggests at least two possibilities. First, there may have been a reduction in occupational intensity over the Formative period at Mescal Wash. Smaller storage capacities per structure over time could reflect a decrease in occupation spans over time by the households who inhabited the site. Alternatively, the decreasing storage capacity may indicate changes in storage practices and technologies. Specifically, the inhabitants of Mescal Wash may have increasingly relied on storage technologies such as pottery containers and aboveground storage facilities more than pit features over the course of the Formative period.

We did not encounter any thermal pits that could be dated to the Archaic period; however, nine storage and processing/storage pits that dated to the Late Archaic period were excavated, and they give us a glimpse of storage behaviors from that period of time and how they may have differed from the subsequent Formative period pits. Although the sample was small, the Late Archaic period pit features had larger volumetric capacities than later pits. Formative period groups who inhabited Mescal Wash may have constructed and used more smaller-sized and more functionally specialized storage and processing/storage pits than did the earlier Late Archaic period residents of the site. What such changes in pit sizes indicates about possible differences in storage and processing practices over time is not known.

Pits and the Social Construction of Space

As discussed earlier, our analysis of the spatial patterning of the pit features concentrated on excavated areas within Loci A, C, and D. Because the majority of the dated contexts in Locus D dated to the Middle Formative A period, and the majority of dated contexts in Loci A and C dated to the Middle Formative B period, we could identify possible change or lack of change through time in the spatial distribution of pits and in how space was utilized in the activities reflected in the past uses of such features.

In Locus D, processing/storage pits appeared to be generally scattered and did not concentrate in linear clusters to the extent that we saw later, in the Middle Formative period, in Loci A and C. The relative absence of clustering could reflect comparatively short-term habitation at the site where processing pits were not as continuously abandoned and rebuilt as they appeared to have been in the Middle Formative B period.

Only a handful of storage pits were excavated in Locus D, and little patterning could be discerned from their spatial distribution. In Area D2, seven storage pits were located within a concentration of processing/storage pits, suggesting a functional complementarity between the two feature types. However, the other concentration of processing/storage pits in Area D2 lacked excavated storage pits.

For the most part, extramural cooking pits appeared to be scattered and were generally not spatially concentrated. Extramural cooking pits were not concentrated in any potentially communal or public spaces in Locus D. Their location away from such possible communal spaces suggests that although food processing may have been considered a communal activity, the cooking of food took place away from those public spaces. Despite this possible spatial pattern, a high proportion of large extramural cooking pits in Area D3 suggests that the food cooked in outdoor spaces was at least sometimes prepared for consumption at a communal scale. Thus, cooking may have been segregated from more public spaces, but that does not mean there was an absence of food consumption at a more communal social scale during the Middle Formative A period.

In Loci A and C, linear clusters of processing/storage pits were identified. These clusters suggest that during the Middle Formative B period, household groups may have maintained specific areas dedicated to processing or short-term storage. The linear nature of these clusters may indicate a pattern of "drift," whereby damaged or exhausted features were replaced over time with new pits. A continual process of feature abandonment and construction may have resulted in the clusters of archaeological features.

The spatial distribution of storage pits in Loci A and C were not as clearly patterned. However, it appeared possible that storage was shared among multiple households, as was indicated in Locus A, as well as "anchored" to food-processing-activity loci, as suggested by the spatial distribution of these features in Locus C.

The distribution of extramural cooking pits in Loci A and C identified possible domestic cooking loci that would have been affiliated with one or several surrounding households. In addition, thermal pits were often also located away from habitation structures, in what appeared to have been more communal spaces in the settlement. That is in contrast to the Middle Formative A period pattern described above, in which all extramural cooking pits, large and small, were located outside the public areas of the settlement.

CHAPTER 6

Between Grassland and Desert: Subsistence Practices at an Ecological Edge

Rein Vanderpot

The subsistence studies in previous chapters focused on material culture, paleobotany, the modern environment and the paleoenvironment, and pit features. The primary focus of this chapter is to explore how the site's food-processing and storage features may have been used, to learn what was processed and how exactly that processing was done. Picking up from where the previous chapter ended, different pit types will be correlated to the specific plants—and, in some cases, animals—processed in or with them. To lay the groundwork for this endeavor, we will first take a quick look at the local environment and its plants and animals and also excerpt the results of the project's paleobotanical and faunal analyses. Then follows a summary of what we know of the local agricultural potential and a breakdown of the possible farming strategies used.

The rest of the chapter consists of three main parts. First is a review of the types of food-processing and storage features excavated at Mescal Wash. Second, we will discuss, based on a review of the ethnographic literature, the methods used to process the various foods suspected to have been available to the people living at the site. Interwoven through these discussions, first the different plants and then the animals, are overviews of the different processing steps and the archaeological signatures remaining as a result of those steps. In the third part, we will assess how the signatures match the project evidence and what it says about the importance of the various resources. We then look at Mescal Wash subsistence in the context of Chihuahuan Desert grasslands and compare it to Hohokam subsistence in the Sonoran Desert, to the west. The comparisons highlight the importance of Mescal Wash as a persistent settlement center uniquely placed at a crossroads of different ecological and cultural areas.

This chapter is primarily about human behavior and archaeological signatures, and few chronological considerations are made. From previous chapters, it is already clear that subsistence strategies in the project area persisted virtually unchanged for three millennia. As to the expected signatures, the reader should note that they pertain only to preserved features and materials; perishable items, such as wooden grinding implements and basketry, though discussed in the ethnographic overview because they are critical components of the subsistence activities, are not considered.

Environment

The Mescal Wash site is located in the Cienega Creek valley, along the transition between the Chihuahuan and Sonoran Deserts, at an elevation of approximately 1,103 m AMSL. Situated at an ecological crossroads along a riparian zone—an extensive *cienega*[1]— between grassland and desert, the Mescal Wash site offered its occupants access to highly diverse economic resources. The Cienega Creek valley is part of the Santa Cruz River watershed and is bounded by the Rincon Mountains to the north, the Empire Mountains to the southwest, and the Whetstone Mountains to the southeast. The mountains are between 5 and 10 km away from the site, all within a day's walk back and forth, and the Rincon Mountains are particularly close. The Mescal Wash site was optimally placed to collect a wide range of wild-plant foods as well as to farm along Cienega Creek and Mescal Wash. It is likely that access to nearby surface water in the creek was another important reason for settling in the area. Although these were perhaps not the only reasons people kept coming back to this location

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[1] In Spanish, *cienega* means "marsh" or, literally, "hundred springs" (*cien* = one hundred; *ega* or *agua* = water or spring) (Barnes 1988:96). In the Spanish period, Cienega Creek was known as "Ciénega de los Pimas" (Marsh of the Pimas) (Dobyns 1981:18).

for 3,000 or more years, they certainly were the main ones. Although agriculture played a significant role from Late Archaic period times, the abundant wild-plant resources of the surrounding grassland always remained important. As evident from the project's modern-plants study, a rich suite of edible plants grows (and grew) in the site vicinity, and as shown by the paleobotanical analyses, some plants competed with maize in importance.

Plants

Because the valley is in a transitional area (elevation 987–2,881 m AMSL), its vegetation is quite diverse. The site is surrounded by Chihuahuan desertscrub (directly to the east, extending as far as the Rio Grande and beyond) and Chihuahuan semidesert grassland (to the north, south, and west) (Brown 1994; Brown and Lowe 1994). Major plant communities farther away include Madrean evergreen woodland (on the surrounding mountains) and the Arizona upland subdivision of Sonoran desertscrub (10–20 km to the west of the site).

Cienega Creek originates in the southern Canelo Hills and flows northward through a broad, grassy valley. Just north of where it is joined by Mescal Wash, the creek makes a broad curve to the northwest, and rolling, grassy hills marked with occasional yucca or agave give way to saguaro-studded hills 10 km downstream, in the vicinity of the tributary Davidson Creek, which is where the Sonoran Desert proper begins. Soon after, Cienega Creek enters Pantano Wash, which flows northwestward into the Rillito River and then westward into the Santa Cruz River, the most important drainage in the Tucson Basin. Cienega Creek is flanked by a large riparian zone with diverse trees, including thick mesquite bosques. Prior to downcutting in the late 1800s (Dobyns 1981; Webb et al.2007:278), the creek had a high groundwater table that prevented the growth of woody trees. Instead, there was an extensive growth of water-loving plants, such as reeds and cattails, as well as native bunchgrass species, such as sacaton (*Sporobolus* sp.)[2] (Spencer et al. 2002:5; Webb et al. 2007:278). Mescal Wash originates along the Rincon Mountains, 13 km to the northeast of its confluence with Cienega Creek, and hosts abundant mesquite and, as the name indicates, agave. It is estimated that from their pre-1890 states, the water table in Cienega Creek has dropped by as much as 5 m, and the water table of Mescal Wash has dropped as much as 8 m (Spencer et al. 2002:5, 6). Extant cienegas can still be found in Empire Valley, south of the project area.

Chihuahuan desertscrub is a mixed succulent-scrub community with scattered cacti, shrubs, desert trees, and various grasses and forbs. The desert grasslands that cover the Cienega Creek valley and the surrounding region are the northernmost extension of a desert grassland community that covers much of southeastern Arizona, the southern half of New Mexico, and trans-Pecos Texas and extends 1,500 km south through 13 Mexican states, from Sonora to Puebla (McClaran 1995). Grassland distribution is typically discontinuous, resulting in a mosaic of grasslands intermingled with desert scrub at lower elevations and evergreen-oak (-*Quercus* spp.) woodland at higher elevations. Desert grasslands formed about 9,000 years ago in the middle Holocene with the emergence of a summer monsoon rainfall pattern and the retreat of woodlands to higher elevations (Van Devender 1995). More-arid conditions after approximately 4,000 years ago have resulted in a slow increase in scrubby plant species. In southeastern Arizona, these vast expanses of perennial grasses are located between the desertscrub below and the uplands above and were severely degraded in the late 1800s and early 1900s through cattle grazing but once contained abundant native bunchgrasses. The location of the Mescal Wash site adjacent to stands of native bunchgrasses would have supplied a dependable food resource.

Animals

The site's location near several different vegetation and topographic zones would have given the people of the Mescal Wash site access to a wide variety of fauna—principally, small mammals at home in the nearby grassland and desert scrub and larger game found at higher elevations. In the immediate site area, these animals include several different mouse, rat, gopher, and squirrel species, many of which would have been hunted opportunistically (Rea 1998; Russell 1908). Along the nearby creek, riparian-oriented small mammals may have included beavers, raccoons, weasels, and muskrats, and species such as ringtails, skunks, and badgers would also have been found, but not necessarily near water. Jackrabbits and cottontails make up the other category of small mammals that frequent the Mescal Wash site area and formed an important component of native-human diets. Cottontails are most often found in areas with brushy cover—for example, hills and canyons. By contrast, jackrabbits prefer open areas without extensive vegetation. Among the most economically important large mammals of the greater area were mule deer and pronghorn. The latter, as with jackrabbits, are found mainly in open grassland areas, where they can outrun pursuers. These larger animals, as well as bighorn sheep, also can be found in higher elevations, within the piñon-juniper and Madrean vegetation zone. The Cienega Creek watercourse

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[2] Sacaton grass is prone to fire, and natural or human-caused fires would have restricted growth of woody plants along the margins of the marshes of Cienega Creek. A photograph taken in 1880 of the area just east of the Mescal Wash site shows an unentrenched stream without trees but with a dense grass cover (Webb et al. 2007:Figure 22.5). By 1890, the same area already had a large, deeply incised channel (Spencer et al. 2002:5).

and ponds provided habitats for fish, freshwater shellfish, toads, and aquatic turtles. The riparian habitat would also have attracted waterfowl of many types, including ducks, geese, herons, egrets, cranes, plovers, and sandpipers, at least seasonally, particularly during the winter months.

Farming

Small pockets of prime farmland existed in the Cienega Creek–Mescal Wash confluence area, although they were far less significant than the large expanses of prime farmland along the Santa Cruz River to the west and in the Sulfur Springs Valley to the east. Though never the only means of subsistence, agriculture was of great economic importance for Formative period populations of the Southwest. Farmland along Cienega Creek was much more limited in extent than along the nearby Santa Cruz River to the west and even the San Pedro River to the east, but the location of the Mescal Wash site was undoubtedly linked to the nearby arable land. Ancient farmers in the Cienega Creek valley were probably familiar with three basic agricultural strategies: irrigation, floodwater farming, and dry farming.

Irrigation involves the conveyance of water from a source by means of gravity flow through human-made ditches or canals. For channeling water from drainages, irrigation technology can vary greatly in degrees of scale and sophistication, but for a moderate-sized drainage, such as Cienega Creek, it would have consisted of not more than simple ditch-diversion of streamflow. Requirements for ditch irrigation include a stream with reliable perennial or seasonal flow and ample arable land located in or close to the floodplain. Near the site, settings appropriate for prehistoric irrigation agriculture would have been level terraces or the margins of floodplains of Cienega Creek and Mescal Wash. Although suitable soils are (and were) available, we know little about the actual locations of field areas and the farming methods used by the people living at Mescal Wash. We can only speculate. We do know that there were plots of arable land along Cienega Creek, at its confluence with Mescal Wash. Those plots were small, and agriculture, though practiced consistently throughout the site's long sequence of occupation, probably was never of sole or primary importance.

For several reasons, irrigation was probably not a very practical method along Cienega Creek. First, the window of time (during the spring) when sufficient water was available *and* temperatures were high enough for crop germination would have been narrow, limiting successful harvests based on irrigation. Maize requires between 100 and 120 days for growth and development and generally matures in the fall. Double cropping would not have been feasible in most years. Huckell (1990:34) presented climatic data demonstrating that frosts severe enough to destroy a maize crop occur on average every 7 years in the middle San Pedro Valley, an environment much like that of the Cienega Creek valley. Second, the patches of arable land along the floodplain were likely so small that irrigation would hardly have been worth the effort. Irrigation near the Mescal Wash site, if it *was* practiced, would have consisted of simple diversion of streamflow onto the Holocene alluvium of the stream terrace. Given the presence of a *cienega* near the site, ditches could also have been dug to lead water from the *cienega* to nearby, non-inundated floodplain areas. Small ditches would have been easy to build and repair but, if no longer used, could also easily disappear without a trace. Welch (1994:105–108) described Apache use of small ditches in similar circumstances. Such ditches and associated diversion and control features made of brush and dirt quickly fell into disrepair upon abandonment and completely disappeared in a few years. It is not surprising that we found no evidence of irrigation during our search of the Cienega Creek floodplain.

Three types of floodwater farming would have been possible along Cienega Creek or in the adjacent valley: overbank floodwater, *ak chin*, and runoff farming. Overbank floodwater farming is the simplest and also one of the more productive systems. It likely was the primary method used by the farmers living at the Mescal Wash site. Agricultural fields are planted in rich soils deposited on the floodplain, and those fields, typically placed along the upper margins of the floodplain, are inundated with floodwater during peak seasonal discharges. This method would have been limited to the broader, alluviated portions of the lower terraces. Again, a variant of this kind of farming was possible at the nearby *cienegas* by simply planting seeds in the wet soil along their margins. No water-diversion features would be needed, and this method would have left no archaeological traces.

Ak chin is associated with unconfined streamflow, such as on alluvial fans, possibly aided by water-diversion features such as ditches, dams, and weirs. Most of the Tohono O'odham farming systems rely on natural flooding at the mouths of discontinuous, ephemeral channel systems where runoff spreads over the fan surface (Doolittle 2000:312–315; Fontana 1983:131; Nabhan and Teiwes 1983:16–17). The practice of diverting rainwater from the mouths of shallow arroyos onto adjacent fields gave such places the O'odham name *ak chin* ("arroyo mouth"). This type of farming relies on seasonal (summer) sheet flooding in places where surface flow spreads water and nutrient-rich sediments laterally across the surfaces of alluvial fans (Bryan 1925; Field 1992; Foster et al. 2002; Huckleberry and Billman 1998). Based on studies elsewhere (e.g., Gasser 1990; Waters and Fields 1986), the most likely settings for *ak chin* farming are arable alluvium at the distal ends of these fans, where sheet flooding is slow and fine-grained sediments accumulate. The streams must have a large enough catchment area to supply sufficient water to the fields. Using low earthen mounds or rock-and-brush structures, water could have been spread out evenly across the field areas (Nabhan 1986). No such landforms exist near the site, although they do in other portions of the valley, and they certainly were an option on the slopes below the nearby mountains, particularly in the Rincon Mountains to the north.

Appropriate settings for runoff agriculture are places where arable soil is located on slopes of less than 5 percent that are situated below slopes of more than 5 percent (Van West and Altschul 1998:355). Other requirements are a warm (south-, east-, or west-facing) exposure and a relatively low elevation. Similar to *ak chin* farming, no good areas for runoff field systems are present near the site, but they may have been available elsewhere in the valley and, as noted for *ak chin*, below the slopes of the surrounding mountains.

Dry farming uses rainwater that falls directly on fields to irrigate crops. In the case of highly water-dependent crops, such as maize, dry farming is successful only when there is ample rainfall (Rankin and Katzer 1989). Given the high evaporation rate of fields in arid lands such as in the project area, dry farming of maize may have been restricted to wetter-than-average years (see Russell 1977) or could only have been successful with the aid of water-conservation features. Where rainfall is low and evaporation rates are high, rock piles were often used as a mulch to conserve moisture for crops, which were grown in or around these rock features. In much of Arizona, agave, rather than maize, is most commonly associated with this type of farming (Fish, Fish, and Madsen, eds. 1992a; Homburg 1998; Rankin 1989; Vanderpot 1992). Some of the few rock-pile features recorded on the Mescal Wash site surface (mostly a Pleistocene terrace) may have been associated with agave growing. Localized areas of gravelly and cobbly soil could certainly have served as natural mulch for agave cultivation. The substratum of the site is a well-developed, cobbly, argillic to calcic paleosol with a thin mantle of Holocene alluvium. These argillic soils on which the site is located have good moisture retention and are favorable to runoff and rock mulch agriculture. However, ample native agave would have been available along Mescal Wash and in the general site area, as it still is now. Agave, such as Palmer's agave (*Agave palmeri*) (easily transplanted from nearby areas) or *A. murpheyi* (a popular cultivar) would thrive well here. Other drought-tolerant crops, such as cholla, may also have been transplanted at or near the site, similarly to what has been reported at other prehistoric sites in Arizona.

Paleobotanical and Faunal Studies

Extensive paleobotanical and faunal collections were made from Mescal Wash, not just from SRI's 2000 and 2001 excavations, but also during two subsequent excavation projects at the site. SRI analyzed 112 flotation samples, 203 macrobotanical specimens (fragments of larger, charred plant remains), and 52 pollen samples from the Mescal Wash site (see Volume 2, Chapters 9 and 10). Subsequent to SRI's work, data recovery in different areas of the site was conducted in 2008 by WestLand (Deaver 2010) and in 2009 by EcoPlan Associates, Inc. (EcoPlan) (Neuzil 2013a, 2013b). WestLand analyzed 20 flotation samples, 11 macrobotanical specimens, and 19 pollen samples (Buckles, Adams, et al. 2010). EcoPlan analyzed 119 flotation samples and 19 pollen samples from a cluster of three sites—Mescal Wash and two other sites (AZ EE:2:437 [ASM] and AZ EE:2:438 [ASM]) located nearby, to the west, on the opposite bank of Cienega Creek (Phillips 2013). Further, phytolith samples were analyzed by EcoPlan, of which 8 came from the Mescal Wash site (McNamee 2013). In addition, in 2007, William Self Associates, Inc. (WSA), conducted data recovery at the Marsh Station Road site (AZ EE:2:44 [ASM]), located on the opposite bank of Cienega Creek from the Mescal Wash site (Medeiros et al. 2010, 2011). Results from the macrobotanical (Adams 2010, 2011) and pollen (Phillips 2010, 2011) studies for that project will also be touched upon here.

Based on the macrobotanical analyses, plant foods for the people at Mescal Wash included the cultigens maize (*Zea mays*), squash (*Cucurbita* sp.), beans (*Phaseolus* spp.), and cotton (*Gossypium* sp.) and a broad suite of wild plants, including cheno-ams (Chenopodiaceae-Amaranthaceae) (e.g., goosefoot, pigweed, white mat [*Tidestromia* sp.], and saltbush), melon-loco (*Apodanthera* sp.), Agavaceae, cacti (prickly pear, cholla, hedgehog cactus, and barrel cactus, but no saguaro), walnut (*Juglans* sp.), Asteraceae (sunflower), Poaceae (grasses); seeds of various weedy plants (e.g., tansy mustard [*Descurainia pinnata*], purslane [*Portulaca* sp.], horse purslane [*Trianthema portulacastrum*], wild buckwheat (*Polygonum convolvulus*), and carpet weed [*Mollugo verticillata*]); and water-loving plants, such as bulrush (*Scirpus* sp.). Maize was grown throughout the 3,000-year history of the site and was fully integrated into the local diet by the Late Archaic period. *Hornos* and bell-shaped roasting pits had the clearest evidence of roasting of agave-type plants; agave parts, yucca seeds, and sotol tissue were found. Grass stems within the pits may have been wrapped around products for protection during processing. Pollen analysis identified a core suite of taxa interpreted as potential important economic resources. The cultigens were maize, squash, and cotton, and edible native plants included prickly pear, cholla, other cacti, mesquite, palo verde, cattail, hackberry, sunflower, grasses, and weedy taxa such as cheno-ams, mustard, and mint—all exploited for seeds and greens. The cotton pollens all came from intramural contexts, particularly hearths, similar to what was noted for the charred cotton seeds.

Faunal bone from Mescal Wash was dominated by leporids, including black-tailed jackrabbit (*Lepus californicus*), antelope jackrabbits (*L. alleni*), and cottontails (*Sylvilagus* spp.), followed in number by artiodactyls (or artiodactyl-sized) specimens, including deer (*Odocoileus* spp.), pronghorn (*Antilocapra americana*), and bighorn sheep (*Ovis canadensis*). The collection further included—in small numbers—various rodents, birds (Gambel's quail [*Callipepla gambelii*] was the most common), and reptiles (turtles and desert tortoise were the most common). During the Late Archaic period, the focus was on hunting artiodactyls, which is what we would expect for a site of that time period in this location. During the Formative period, the focus was on leporids, similar to what we know for the Hohokam settlements in the Tucson and Phoenix Basins. There were also some main differences from the Hohokam, especially early in the sequence. One big difference was that Mescal Wash yielded no fish bones, even though the site was located along a well-watered area, a perennial stream with edible fish species. Another difference is that there were no waterfowl in the Mescal Wash collection. These same absences of fish and fowl were also noted in the faunal analyses for other projects at Mescal Wash or neighboring sites conducted by WestLand (Buckles, Adams, et al. 2010), EcoPlan (Chapin-Pyritz 2013), and WSA (Medeiros et al. 2010, 2011).

It appears, then, that hunters went to the mountains and *bajada* for large game, such as deer, pronghorn, and bighorn sheep. They also did some hunting for jackrabbits and cottontails in the site area and opportunistically caught a few rodents, tortoises, and other animals. From the nearby riparian area, they collected turtles as well as freshwater mollusks, but surprisingly, they did not fish or hunt waterfowl. The latter is significant, given that although fish and other aquatic animals never formed a large part of the diet in the region at any time, they did contribute minority components to many Tucson and Phoenix Basin sites. For instance, the faunal collection from Pueblo Grande, near the Salt River, in present-day Phoenix, contained bones from at least nine species of freshwater fish (James 1994).

Food-Processing and -Storage Features

Of the over 2,000 features documented by SRI at Mescal Wash, 423 were excavated,[3] and of those, 97 were structures, and 326 were extramural features (see Volume 1, Table 10). Of the extramural features, 255 were pits (excluding caches, borrow pits, and burials): 71 thermal pits and 184 nonthermal pits. Large numbers of intramural features were also excavated (see Chapter 5 of this volume), of which 148 were pits (not counting postholes): 75 thermal pits (mostly plastered hearths) and 73 nonthermal pits (likely used for storage/processing).

The present discussion will only deal with those features that probably had a food-processing or storage function. To keep things simple, the focus is solely on the extramural pits, because it was with these that the bulk of food was prepared. In the next sections, we will discuss five types of extramural-pit features excavated at Mescal Wash: basic (basin, cylindrical, or irregular-shaped) thermal pits, rock-lined roasting pits, bell-shaped roasting pits, basin-shaped nonthermal pits, and bell-shaped nonthermal pits (Table 38). Extramural hearths (similar to plastered hearths in houses) were also found but are not considered here. Functionally, the five pit types consist of three thermal types: (1) pits used for cooking over an open fire (oxidizing atmosphere); (2) covered pits that create reducing

Table 38. Extramural Food-Processing and Storage Pits Excavated at the Mescal Wash Site

Feature Type	No. Recorded by SRI	No. Recorded by WestLand Resources, Inc. (Deaver 2010)	No. Recorded by EcoPlan Associates, Inc. (Neuzil 2013a)	Total
	Thermal Pits			
Basic thermal pits	49	13	12	74
Bell-shaped roasting pits	8	1	—	9
Hornos	4	4	1	9
Plastered hearths	2	1	—	3
Rock-lined roasting pits	8	7	—	15
Subtotal, thermal pits	71	26	13	110
	Nonthermal Pits			
Basin-shaped pits	154	51	9	110
Bell-shaped pits	30	3	—	33
Subtotal, nonthermal pits	184	54	9	247
Total	255	80	22	357

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[3] This count does not include 37 probed features or 14 feature conglomerates.

atmospheres for cooking, such as a pit oven; and (3) pits used for cooking in hot ashes. The nonthermal pits may have been used for (1) storage, (2) processing foodstuffs with low or no heat, (3) basket or pot rests, and (4) milling stone supports.

Additional extramural-pit features were excavated at the site by WestLand in 2008 and by EcoPlan in 2009 (see Table 38). WestLand excavated 80 extramural pits that were subsistence related, of which 26 were thermal pits and 54 were nonthermal pits (Buckles, Klimas, and Deaver 2010). All were in Loci A and G. The thermal pits were 13 basic thermal pits, 1 plastered hearth, 4 *hornos*, 7 rock-lined roasting pits, and 1 bell-shaped roasting pit. Of the nonthermal pits, 3 were bell-shaped, and the other 51 were basic. EcoPlan found archaeological features in Locus B only, and they included 13 extramural thermal pits (1 *horno* and 12 basic thermal pits) and 9 extramural nonthermal pits (Neuzil 2013a:84–85, Table 3.5). All thermal pits were basin shaped, and except for a few, including the horno, they were small and shallow (Neuzil 2013a:84, Table 3.5). The nonthermal pits were also all basin shaped.

For pit size, shape, and volume, this chapter uses the same classes defined in Chapter 5 of this volume based on diameter, shape, and volume-index scores. There are three size classes: small (<0.65 m), medium-sized (0.65–1.15 m), and large (>1.15 m). As noted in Chapter 5, roughly two-thirds of the pit sample were classified as small (67 percent), and lesser proportions were classified as medium (28 percent) or large (5 percent). Using the shape index, two shape groups were identified. Shallow pits are those that, regardless of size, have depths of less than or equal to about 70 percent of their average diameters. Deep pits are those that have depths of greater than 70 percent of their average diameters. The majority of pits were classified as shallow (82 percent), and 18 percent were classified as deep. As to volume, the overwhelming majority (96 percent) were classified as low-volume pits (>0.05 m^3), and only 4 percent (14 features) were classified as high-volume pits (0.05 m^3 or greater).

Thermal Pits

Of the 71 extramural thermal pits excavated by SRI, 49 were basic thermal pits, 8 were rock-lined roasting pits, 2 plastered hearths, 8 were bell-shaped roasting pits, and 4 were *hornos* (see Table 38). Thermal pits are features showing oxidization, and this definition is descriptive—it means that the pits were thermally altered but does not necessarily mean that the feature had a thermal (i.e., heat-providing) function.[4] At the same time, because fill is not always indicative of a feature's original use, the presence of FCR, ash, or charcoal does not define a pit as thermal. Functionally, there are at least three thermal pit types: (1) pits used for cooking over an open fire (oxidizing atmosphere), (2) pits used for cooking in covered pits (reducing atmosphere), and (3) pits used for cooking in hot ashes.

Oxidizing atmospheres occur in shallow, open pits—like many of our basic thermal pits—where oxygen can readily fuel the flame. These were termed "open pit fires" by Halbirt et al. (1993:132–134). Based on ethnographic analogy, they may have been used for broiling, grilling, toasting, or parching foods over an open fire (Halbirt et al. 1993:131–134; Vanderpot et al. 2008). In the case of parching, they may have provided burning embers to be used for parching in a basket or pottery vessel. They may also have supplied hot rocks for use in adjacent pits or for boiling foods in waterproof baskets.

Reduction atmospheres are associated with roasting or baking pits, also known as earth ovens, pit ovens, or *hornos* (Spanish for "ovens") (Castetter 1935; Castetter et al. 1938; Hackbarth 1993:522; Russell 1975:70). *Hornos*, bell-shaped roasting pits, and rock-lined roasting pits all used a reduction atmosphere and were used to slowly bake or roast plant and animal foods. In Arizona, plants typically processed in these pits are agave (in *hornos*) and cholla (in rock-lined roasting pits). The reduction atmosphere results from placing a layer of soil or vegetal matter, such as grass or reeds, over the pit containing the hot rocks, cinders, and food (Castetter et al. 1938). The covering material "chokes" the fire, allowing it to slowly smolder over a long time. The resulting heat slowly "bakes" or "roasts" the food or animal products. Often a thick, dark "rind" is found around the perimeters of these features.

Pits used for cooking in hot ashes are distinct from other thermal pits by having no FCR in the fill, only ashes (see below). In general, they are deep but narrow and have well-oxidized walls.

Basic Thermal Pits

Basic thermal pits were the most common extramural thermal features in the Mescal Wash sample: SRI excavated 49 of these pits in Loci A, C, and D.[5] Given their copious use throughout the site's long history, they are important for the study of household food processing. A wide range of plant and animal foods was cooked in such features. They likely represent a variety of processing methods besides just roasting, including seed parching. Most basic thermal pits were found in areas away from the often-dense clusters of nonthermal extramural pits at the site. This suggests that cooking was preferably kept separate from the activities associated with the nonthermal pits.

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[4] For instance, storage pits may have been intentionally oxidized with fire to harden the walls. In the present discussion, however, we assume that all the thermal pits had a thermal function.

[5] This category also includes firepits (n = 9), originally (in Volume 1) considered a separate type because of their fill, which contained ash but little or no FCR and few or no artifacts.

The pits varied in size and shape (basin-shaped pits were most common, but conical and cylindrical forms were also noted), but all had oxidized walls and, in most cases, fills of FCR, charcoal, and/or ashes. The basin-shaped variety was most common, and of these, the shallow examples were consistent with "open" thermal pits defined by Halbirt et al. (1993:132–135) as "a shallow, saucer-shaped pit with a high surface area to depth ratio." In contrast to the larger and deeper roasting pits (including *hornos* and the bell-shaped and rock-lined variants) used to bake food within a reduction atmosphere, open thermal pits used an oxidizing atmosphere for food roasting, seed parching, and other types of cooking on hot coals or even over an open flame. Nearly all of the features included in the general-roasting-pit category were classified as small (44 percent) or medium-sized (50 percent) in average diameter, and only 6 percent were classified as large. Most of the pits were shallow (only 17 percent had steep profiles) and had low volumes.

In general, as based on ethnographic and ethnobotanical accounts, cooking pits were intentionally filled with the cooking debris after use. Thus, although not *everything* encountered in feature fill can be equated with feature use, most was probably part of the cooking process. Flotation samples from the pits included a wide variety of plant materials, such as monocotyledon fibers (suggesting Agavaceae roasting), maize cupules, melon-loco, cheno-ams, and grass stems, in addition to the usual fuelwoods. The inferred date ranges suggest that basic thermal pits were constructed and used at the site over its entire span, from the Late Archaic period through the end of the Late Formative period.

Rock-Lined Roasting Pits

This unique type of roasting pit has slab-lined, moderately to heavily oxidized walls and often several large rocks covering its base. Eight rock-lined roasting pits (two in Locus C and six in Locus D) were excavated by SRI. In addition, WestLand excavated seven pits of this type, all in Locus A (Buckles, Adams, et al. 2010:3-37–3-39). The pits were mostly basin shaped in cross section and had steep walls and round or flat bases. Rock lining typically formed a regular, formal multitiered pattern, with smaller rocks interspersed between the larger ones, so as to completely cover the walls and base. Rock-lined pits of this type have previously been recorded in the Rosemont area, in the Santa Rita Mountains (Ferg 1984a:163, 1984b:746). They are also discussed in the ethnographic literature, particularly in relation to the baking of cholla buds (see below). Five features in the eastern portion of Locus D originated near the modern ground surface, suggesting that they dated to the late prehistoric or even protohistoric period. Cholla seeds had a higher ubiquity in the rock-lined-roasting-pit samples than in those from other thermal-feature types, suggesting that cholla buds were roasted in the pits. Monocotyledon tissues were present at lower ubiquity levels than noted for other types of roasting pits, suggesting that agave roasting was not the typical use for these pits. The pits contained relatively few artifacts, probably because most of them were used during the Late Formative period, when sparse and scattered settlement accumulated relatively little trash.

The majority of rock-lined roasting pits were medium-sized (63 percent) or large (25 percent); only 12 percent were classified as small. These size differences may reflect variability in family or group size or the variable use of rock-lined roasting pits for both household-level (smaller) and communal-level (larger) cooking activities. Many of the rock-lined roasting pits were classified as having deep profiles (38 percent). Two of the eight rock-lined roasting pits were classified as high-volume pits—together with the four *hornos*, the only pits at Mescal Wash to have this honor. These high-volume pits likely had a specialized function related to large-scale, communal cooking activities, particularly the baking of cholla in rock-lined pits and of agave in *hornos*.

Bell-Shaped Roasting Pits

Eight bell-shaped thermal pits were excavated, all in Locus D, where they were mostly clustered in a small area in the western part of the locus. An additional bell-shaped roasting pit was excavated by WestLand in Locus G (Buckles, Klimas, and Deaver 2010:3-35). Most were relatively large and had evidence of repeated use. All features had oxidized walls, and fill included a variable mix of charcoal, ash, FCR, cobbles, and artifacts. Analysis of flotation samples indicated that a wide variety of edible plants were cooked. Sotol tissue found in one pit probably was residue from roasting of the heads. Yucca seeds suggested potential fruit roasting. Monocotyledon parts probably belonged to members of the agave family. Clearly, like *hornos*, these pits were used to roast Agavaceae.

Bell-shaped *nonthermal* pits—all likely used for storage—frequently date to the Archaic period in southern Arizona. It is uncertain whether the bell-shaped roasting pits at Mescal Wash were reused storage pits or were constructed specifically for roasting purposes. Based on spatial context and artifacts (including early plain ware and red ware ceramics), this type of roasting pit is definitely early, as opposed to the much-later rock-lined pits.

The bell-shaped roasting pits at Mescal Wash were similar in shape to bell-shaped *hornos* documented at Gleeson and Tres Alamos, in the Sulphur Springs Valley, by Fulton and Tuthill (1940:20–25, Figure 2; Tuthill 1947:Figure 4, No. 2) and nearby, in the same area, by Trischka (1933). These features appeared to be restricted to the early Ceramic (i.e., Early Formative) period horizons across southern Arizona and northern Mexico. A subtype of bell-shaped roasting pit with secondary holes in its base found at Gleeson (Fulton and Tuthill 1940:Figure 2, Nos. 35–37 and 39) was called a "Dragoon type pit oven" by Tuthill (1947:35). Fulton and Tuthill (1940:23) suggested that deep, undercut (bell-shaped) pit ovens are a hallmark of southeastern Arizona, specifically the Dragoon "culture," whereas flare-rimmed (basin-shaped) pit ovens were the hallmark of the Hohokam. It is interesting to note that the Mescal Wash features lack the secondary holes in their pit bases that were found at Gleeson.

The majority of bell-shaped pits are medium-sized (75 percent) or large (13 percent); only 13 percent were classified as small. A high percentage of bell-shaped roasting pits were classified as having deep profiles (63 percent). Although they were relatively large, none was classified as high volume. Even so, like the rock-lined roasting pits and *hornos*, they were likely used by a larger group composed of multiple families or for preparation of large, communal meals (e.g., for feast congregations).

Hornos

Hornos—defined as roasting pits with diameters of 1 m or more and coated with a thick, carbonized rind—were relatively rare at the site. *Hornos* are also known as "pit ovens" (Fulton and Tuthill 1940:20; Halbirt et al. 1993:135; Tuthill 1947:35) or mescal pits (Ferg 2003a, 2003b) and are the largest of the thermal pits. Found throughout the U.S. Southwest and dating from the Archaic period through the historical period, *hornos* are often visible on the surface as circles of rocks. They were constructed to produce an extremely hot roasting context (as evidenced by their carbonized surface); thick surrounding middens indicate multiple cooking events. Ethnographically, *hornos* were often used for agave, yucca, and sotol processing during special cooking events for an entire community (Castetter et al. 1938; Dobyns 1988; Ferg 2003a, 2003b). Although *hornos* were typically used for roasting of members of the agave family, other plant products and animal remains are often encountered in flotation samples.

Four *hornos* were excavated by SRI: one in Locus A, one in Locus C, and two in Locus D. All had well-defined, oxidized walls and blackened rinds averaging 3–10 cm in thickness and were 2 m at the widest. All four *hornos* were classified as large (3 features) or medium-sized (1 feature), with maximum diameters ranging from 1.2 to 2.1 m. Three of the four *hornos* also were classified as having large volumetric capacities. However, averaging 1 m in depth, all four were also classified as shallow. Thus, *hornos* tended to be shallow thermal pits with wide openings. Four additional *hornos* were excavated by WestLand, all in Locus A and all with the same characteristics (Buckles, Klimas, and Deaver 2010:3-37).

Flotation samples contained monocotyledon-fiber fragments, indicating that plants of the agave family had been roasted in the pits. Other charred plant materials included maize and *Chenopodium* as well as various fuelwoods. Although the overall taxon richness was low, the ubiquity of monocotyledon parts in the samples was relatively high. This indicates a focus on roasting of members of Agavaceae, particularly agave, sotol, and yucca. All dated features were from the Middle Formative period.

Nonthermal Pits

The nonthermal extramural pits would have had two main functions: food processing and storage. As explored in the next part of this chapter, the following are only some of the functions these features may have had:

- Seed thrashing or pounding areas (e.g., sunflower or mesquite)
- Plant-part ripening or drying areas (e.g., maize or mesquite)
- Plant-part leaching areas (e.g., saltbush, ironwood, or acorns)
- Earthen mortars
- Milling-stone supports
- Basket or pot supports
- Cake molds
- Thermal function needing only low heat

Ethnographic data suggest that several different types of storage pits were used, including pits used for storing dried foods (often lined with perishable materials) and pits in which vessels or baskets with food were placed (see below). Such storage pits have cylindrical or bell-shaped profiles and are deep and voluminous.

Basin-Shaped Pits

Features in this nonthermal class predominantly are basin-shaped pits that vary in size and have nondescript fill. Although the vast majority of these pits were basin-shaped, rectangular, cylindrical, conical, and other shapes are also classified as this general style, which includes all shapes except bell-shaped pits. In most cases, the exact functions of these pits remain unknown, even after complete excavation. Many of the larger and deeper pits probably had a food-storage function, and smaller and shallower pits served as basket or pot rests or as supports for grinding equipment. Features of this type may also have had a thermal (i.e., cooking) function, albeit one requiring little heat (e.g., seed parching) and therefore leaving no evidence of thermal use in the form of oxidization. The large number of pits of this type identified at the site attests to their importance. In general, these nonthermal pits formed distinct clusters near structures, and there was a noticeable paucity of thermal pits in these clusters. A good example is the 20-by-15-m cluster of more than 80 features between the two house groups in the eastern half of Locus C. Selection for excavation favored pits in clear spatial association with structures. A relatively large number (n = 154) of nonthermal "general" pits were excavated (32 in Locus A, 37 in Locus C, and 85 in Locus D), many in the search for bell-shaped pits.

Most of the pits were classified as small (60 percent) or medium-sized (27 percent) in diameter, and the vast majority had shallow profiles (90 percent) and low volumes (98 percent). With only a few exceptions, the features were all low-capacity pits. These data suggest generally small volumetric capacities probably intended for short-term storage and use. Widely used bulk goods, such as surplus food and grains, presumably would have been stored in intramural locations or in non-pit containers (e.g., pottery). Caching of miscellaneous items may have been another possible function. Two pits contained restorable vessels, lending support to the inferred storage function of this feature type.

Charcoal, ash, and FCR were commonly encountered, but some contained no fill materials, suggesting probable storage pits that had not been reused as trash receptacles. Some of these pits might have been deliberately constructed as trash receptacles, but most probably were originally created as storage loci or for other nonthermal activities. In these latter cases, fill materials probably consisted of domestic trash deposited in the pits after they were no longer used for their original intended purpose. Macrobotanical remains included a variety of charred wood, including acacia, saltbush, and mesquite, as well as monocotyledon parts, maize cupules, grass-stem fragments, and seeds of melon-loco (*Apodanthera undulata*) and goosefoot—similar to what was found in the fill of the thermal pits.

None of the extramural pits was subjected to chronometric analysis, and approximate date ranges for about half were obtained based on associations with dated features, stratigraphic relationships, or the presence of temporally diagnostic painted ceramics. Dated features encompassed the Middle Formative period sequence, and one pit was used during the Late Formative period.

Bell-Shaped Pits

Thirty extramural bell-shaped pits were excavated: 22 in Locus D, 8 in Locus C, and none in Locus A. Storage is the most plausible function attributed to these features. Unlike what was noted for the basin-shaped pits, we did not see evidence of any clear clustering or associations with specific features or feature types. Overall, the excavated features are distributed fairly evenly across the loci. Although no oxidation was present in the walls or fills of the features, ash and charcoal were commonly present. Both the frequencies and the varieties of artifacts and faunal remains present in the fills of these pits, as well as the ubiquity of ash and charcoal, suggested to us that many nonthermal bell-shaped pits had been filled with refuse following their initial uses. The flotation samples contained a variety of charred plant materials, probably all part of secondary deposits, that say little about the features' storage function.

In contrast to the generic (or basic) class of nonthermal pit, these pits tend to be large in horizontal extent: nearly three-quarters (72 percent) were classified as medium-sized, only about a quarter were classified as small (24 percent), and 4 percent were classified as large. Fourteen percent were classified as high-volume pits, seven times as many as the generic-nonthermal-pit category (2 percent). Overall, evidence clearly indicated larger volumetric capacities among the bell-shaped pits than the generic nonthermal pits. This suggests a specialized storage function for the bell-shaped pits that required higher containment capacities.

In Locus C, five of the pits were dated to the Middle Formative B period, based on artifacts in the fill or on stratigraphic relationships. In Locus D, pits had fill containing numerous bifacial-thinning flakes and no ceramics, some included dart points, and several were intentionally capped with "calcic plugs." The bell-shaped nonthermal pits yielded the best evidence of Late Archaic period agriculture at Mescal Wash. The Late Archaic period pits had a high collective ubiquity of maize pollen (43 percent). AMS radiocarbon dates obtained from maize fragments collected from three of the features were unequivocally Late Archaic period: calibrated dates of 1060–880 B.C. (Feature 3357), 1280–1010 B.C. (Feature 3976), and 620–590 B.C. (Feature 4849). Also, an AMS date of 1100–900 B.C. was recovered from melon-loco-type seed coats from Feature 411. It is interesting to note that bell-shaped nonthermal pits had the highest grass-grain ubiquity of all feature types. Not surprisingly, of all time periods at the site, grass-grain ubiquity was highest for the Late Archaic period. Pollens showed that grasses were integral to the storage operation of bell-shaped pits.

Food-Processing Technologies: Ethnographic Examples and Archaeological Signatures

Historically, indigenous residents of the Sonoran and Chihuahuan Deserts used a wide range of plants for food. Different groups used plant resources in distinctive ways but also in ways that were often quite similar. Of the native plants, three types were particularly vital and were used widely by most groups: desert succulents, legumes, and small-seed-producing plants. Of the first two, saguaro and mesquite were by far the most dependable staples. But just as important were agave and the small seeds of grasses and various herbaceous plants. Based on the paleobotanical analyses, plant foods for the people at Mescal Wash also included the cultigens maize, squash, and cotton. Not just plants but also animals were important food sources for Native Americans. People of Mescal Wash hunted small animals in the immediate site area and large game farther away, at higher elevations. In the next discussion, we will look at how the most important of these plant and animal species were processed and what kinds of traces that processing would have left in the archaeological record. Critical to our study are the numerous thermal- and nonthermal-pit features excavated at the site. Although we may never completely understand how individual features functioned, it is only by comparing them to data from ethnographic narratives that we can obtain some idea of what processes resulted in the particular makeup of the features.

In the following sections, the plants definitely processed at the site—maize, squash, cotton, mesquite and other legumes, small seeds, nuts, berries, cacti, other succulents, and leafy vegetables[6]—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. Of course, the time leap backward from the ethnographic period to the Late Archaic period (3500–1200 B.C.) is big, which might argue against using such recent data. Yet there are only a limited number of ways to process these plants and animals, and given the great similarity in processing methods between different people in different regions, we can surmise that in general, the processing options were similar through time. Most relevant for our comparisons are ethnographic groups who lived (or still live) in the deserts of the greater Southwest, including the Akimel O'odham, Maricopa, Tohono O'odham, Western and Northwestern Yavapai, Western and Chiricahua Apache, Comanche, Paiute, Shoshone, Mohave, Quechan, Cocopah, and Cahuilla. There is a considerable body of ethnographic and ethnobotanical literature describing plant use by hunter-gatherers and groups that practice limited to full-fledged 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 (1932, 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.

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 native 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 have been mixed with water to produce cakes that were prepared by baking them on hot rocks (or left 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 1991a; 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 important components 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).

In the sections below, ethnographic data are explored to establish the possible methods used to process the various food resources suspected to have been used by—or to have been available to—people at Mescal Wash. Cultivated plants—maize, squash, and cotton—are discussed first, followed by native plant species and animals. Importantly, each of the desert plants listed 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 "signatures" 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 food processing.

Based on previous research, archaeological signatures of plant procurement and plant processing consist of thermal

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[6] Not every single plant species likely processed at the site is discussed. Either the excluded species (e.g., cattail, bulrush, and various tubers) were consumed in small quantities or their processing would have left few traces, making them unfit for the present study.

features (e.g., features with oxidized surfaces and with or without FCR, 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. Given the abundance of water near the site, stone boiling and other water-intensive processing methods are also discussed. Animal resources will be discussed also, including hunting activities important in the project area. Ethnobotanical data and expected archaeological signatures for selected plant species processed with the aid of fire for food purposes are summarized in Table 39. 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 and subsequently refilled with secondary geologic and/or trash deposits.

Cultivars: Maize, Squash, Beans, and Cotton

Based on the paleobotanical analyses, maize, squash, beans, and cotton were the main crops grown near the site. Maize was fully integrated in the subsistence base by the Late Archaic period, and squash, beans, and cotton were introduced at the same time or soon thereafter. In addition, other, native plant species may have been encouraged or transplanted (see agave and cholla, below) or thrived in the field areas as garden weeds (see cheno-ams, below).

Maize

Maize was a staple of prehistoric groups in the U.S. Southwest and is often the most abundant cultigen at archaeological sites (Gasser and Kwiatkowski 1991b). Chapalote—a primitive type of maize from Mesoamerica—was firmly established in the Southwest by the Late Archaic period (Mabry 1998; Wills 1988). Excavations at sites along the Santa Cruz River in the Tucson Basin have revealed extensive and densely occupied agricultural settlements with irrigation facilities dating to as far back as 1200 B.C. and possibly earlier (Diehl 2005a, 2005b; Ezzo and Deaver 1998; Gregory et al. 2007; Mabry 2005b). As Formative period societies developed, maize gained importance, and its production was bolstered by extensive irrigation systems in Hohokam riverine locales. Maize was also intensively grown at sites away from the core areas, using alternative techniques, such as *ak-chin*-style and floodwater farming. Akimel O'odham along the Gila River had two growing seasons: spring planting produced a summer crop, and summer planting resulted in a mid-fall harvest. Given the reliability of monsoon rains, the summer planting was more common (Castetter and Bell 1942). At Mescal Wash, with its higher elevation, the growing season is shorter, and its residents likely planted only a single crop each year.

Ethnography

O'odham farmers harvested maize by pulling up the whole plant or breaking it off at the ground and throwing it in a pile (Castetter and Bell 1942:181). Women and older children would then carry the ears to their dwellings in burden baskets. Initial processing involved roasting of unhusked ears, which burned much of the husk away. Ears were then dried and stored in various ways for later use. Sometimes ears were completely husked prior to storage. Maize was stored as whole cobs, kernels, and meal. When desired, stalks and leaves could be dried and used (e.g., for fuel or matting) at nearly any time during the growing season. The kernels would be taken off the cob with a stone scraper, parched, and dried on a mat on the roof; alternatively, whole ears might be roasted (Castetter and Underhill 1935:34–35). The roasting was the most involved of the two processes, and there were several ways to accomplish it. One way was to put the ears in piles and cover them with brush, which was set on fire using green mesquite branches to stir and turn the ears. After several minutes of roasting, the ears were thrown on a bed of freshly picked grass (Castetter and Bell 1942:181). During roasting, much of the husk burned away, and the ears were dried on a sotol mat on top of a house. In a slightly different scenario,

> a fire was made in an open pit and the ears thrown in on the hot coals when it had burned down. Two women turned the ears with green mesquite sticks (*Prosopis velutina*), allowing them to roast for several minutes and throwing them out on a bed of grass. These roasted ears were dried and beaten to remove the grains, which were then winnowed and stored in a basket to be ground into meal when needed; they were also cooked whole with meat [Castetter and Underhill 1935:34–35].

Such partial roasting improved the storage capabilities and made it easier to grind the corn. After partial roasting, the corn was shelled, which was most commonly done by placing the ears on a sotol mat, beating them with a club, and removing the remaining grains by hand; the kernels were then placed in a large basket. Shelled kernels were often ground into meal. Grains were then winnowed in a large, shallow basket by tossing them in the air, to fall gradually on a sotol mat or cotton cloth. Storing of the shelled, roasted ears, or kernels was done in several ways.

Table 39. Processing Methods and Archaeological Correlates for Selected Native Plant Foods Used at the Mescal Wash Site

Species, by Family	Common Name	Most Common Habitat	Annual (A)/ Perennial (P)	Harvest Season	Plant Parts Used	Processing Method	Archaeological Correlates			End Products
							Features[a]	Artifacts	Paleobotany	
Asparagaceae (Agavaceae)	agave family									
Agave palmeri	Palmer 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 diameter) roasting pit (*horno*)	tabular knives, large flakes with cutting edge, steep-edged scrapers	charred agave parts, monocots	sliced baked hearts, cakes
Yucca baccata	banana yucca	upper *bajada*, mountain flanks	P	August - October	fruits, seeds	pit baking, roasting on coals or ashes, boiling, grinding	large (over 1 m diameter) roasting pit (*horno*)		charred parts, monocots	
Dasylirion wheeleri	sotol	upper *bajada*, mountain flanks	P	May-June	flower stalks, roots	pit baking, pounding, fermenting in ceramic vessels	large (over 1 m diameter) roasting pit or *horno*	metates and manos, ceramics	charred parts, monocots	baked plant parts, alcoholic beverage
Nolina sp.	beargrass	upper *bajada*, mountain flanks	P	May-June	flower stalks, fruits	pit baking, roasting on fire	large (over 1 m [39 inches] diameter) roasting pit (*horno*)	none	charred parts, monocots	baked/roasted plant parts
Asteraceae	aster family									
Helianthus annuus	sunflower	lower *bajada*	A	fall	achenes	parching, grinding, baking	thermal pit or surface with fire-cracked rock	metates and manos, ceramics	charred achenes, pollen	cakes, gruel
Aizoaceae	mesem (ice plants, fig-marigold) family									
Trianthema portulacastrum	horse purslane	lower *bajada*	P	June–September	seeds, greens	parching, grinding, boiling	thermal pit or surface with fire-cracked rock	metates and manos, ceramics	charred horse-purslane seeds, pollen	cooked greens, cakes, beverages, 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 fire-cracked rock	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 fire-cracked rock	metates and manos, ceramics	charred cheno-am seeds, cheno-am pollen	cooked greens, cakes, beverages, 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 fire-cracked rock	metates and manos, ceramics	charred saltbush seeds, cheno-am pollen	cooked greens, cakes, beverages, 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 fire-cracked rock	metates and manos, ceramics	charred cheno-am seeds, cheno-am pollen	cooked greens, cakes, beverages, 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 fire-cracked rock	metates and manos, ceramics	charred cheno-am seeds, cheno-am pollen	cooked greens, cakes, beverages, gruel (from seeds)
Brassicaceae										
Descurainia spp.	tansy mustard	varied	A	Spring - Summer	seeds, greens	winnowing, parching, grinding, baking, boiling	thermal pit or surface with fire-cracked rock	metates and manos, ceramics	charred seeds, pollen	cooked greens, cakes, beverages, gruel (from seeds)
Cactaceae	cactus family									
Cylindropuntia spp.	cholla	upper/lower *bajada*	P	April–May	buds, fruits	pit baking, boiling, grinding	medium-sized (0.5–1 m [20–39 inches] in 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 fire-cracked rock	ceramics	charred fruits	cooked stems/pads, dried fruits, juice, syrup, jam (fruits)
Cucurbitaceae										
Apodanthera undulata	melon-loco	lower *bajada*	A	fall	fruits, seeds	boiling, parching	thermal pit with fire-cracked rock	none	charred fruits and seeds	cooked fruits, parched seeds, flour
Fabaceae	legume family									
Parkinsonia spp.	palo verde	upper and lower *bajada*, drainages	P	May–August	seeds	trashing, winnowing, parching, grinding, boiling, baking	thermal pit with fire-cracked rock	metates and manos, ceramics	charred palo verde seeds	cakes, beverages, gruel

Species, by Family	**Common Name**	**Most Common Habitat**	**Annual (A)/ Perennial (P)**	**Harvest Season**	**Plant Parts Used**	**Processing Method**	**Archaeological Correlates**			**End Products**
							Features[a]	**Artifacts**	**Paleobotany**	
Prosopis velutina	velvet mesquite	drainages	P	June–August	pods, seeds	parching, pounding, winnowing, grinding, boiling, baking	thermal pit or surface with fire-cracked rock (for parching), nonthermal 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 fire-cracked rock	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 fire-cracked rock	metates and manos, ceramics	charred chia seeds	cakes, beverages, gruel
Plantaginaceae	plantain family									
Plantago spp.	woolly plantain, Indian wheat	upper/lower *bajada*	A	May–June	seeds	parching, grinding, boiling, baking	thermal pit or surface with fire-cracked rock	metates and manos, ceramics	charred wooly wheat seeds	cakes, beverages, gruel
Poaceae	grass family									
Panicum spp.	panic grasses	lower *bajada*	P	June–July	seeds	parching, grinding, boiling, baking	thermal pit or surface with fire-cracked rock	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 fire-cracked rock	metates and manos, ceramics	charred seeds, grass pollen	cakes, beverages, gruel
Sporobolus airoides	sacaton	riparian areas, washes	P	June–July	seeds	parching, grinding, boiling, baking	thermal pit or surface with fire-cracked rock	metates and manos, ceramics	charred seeds, grass pollen	cakes, beverages, gruel
Eriogonum inflatum	wild buckwheat (desert trumpet)	lower *bajada*	P	May–July	greens, achenes	boiling	thermal pit with fire-cracked rock	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 fire-cracked rock	metates and manos, ceramics	charred purslane seeds	cooked greens, cakes, beverages, 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, 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 baskets, pots, or milling-stone rests; only large basket supports (i.e., for mesquite pods) are listed.

Akimel O'odham stored corn in crudely made arrowhead storage baskets usually (but not always) placed on roof tops (Castetter and Bell 1942:183). O'odham people also, though less frequently, used storage baskets placed outside, on stone platforms, instead of on the roof. The preferred O'odham storage method for maize, however, was to place it in large ollas, as opposed to in baskets. The ollas were often hidden in a deep storage pit, which was covered with brush and dirt.

Processing Steps

From the above, we can conclude that there were seven basic processing steps for maize. The first step was to partially roast the unhusked ears. The second step (Step 2a) was to dry the whole ears. Alternatively, the kernels were first taken from the partially roasted cobs (Step 2b) and then winnowed (Step 3), parched (Step 4), and dried (Step 5). Step 6 was to grind the kernels into a flour, which could then be baked into cakes or tortillas (Step 7a) or made into a gruel for direct consumption (Step 7b). The final (non-processing) step would be to store the various maize products. Steps 4 and 7a were similar to the parching and cake baking described in detail for mesquite and small seeds below, and the reader is referred to those sections for more information on those processes.

Archaeological Signatures

Besides archaeobotanical evidence, expected archaeological signatures at Mescal Wash for maize are manos and metates, shallow but wide thermal pits (for roasting and parching, using an open fire), deep nonthermal pits (for storage), and small, shallow nonthermal pits (for basket rests and milling-equipment supports). The most direct evidence of maize processing consists of trough metates and associated manos, both found at Mescal Wash. Trough metates are rectangular in shape and show evidence of bidirectional grinding, planar grinding surfaces, heavy grinding intensity, coarse-textured surfaces, and higher production investment than other metates. Trough manos are also rectangular and have a biplanar or plano-convex profile, one grinding surface, bidirectional-grinding patterns, evidence of heavy grinding intensity, coarse-textured (vesicular) grinding surfaces, and high production-investment values. They are longer and have larger grinding surfaces than regular manos, which have multidirectional-grinding patterns and often display two grinding surfaces. Trough metates have an advantage over basin metates in allowing the user to place greater force on the mano and, therefore, to facilitate grinding with larger manos and more grinding surface (Adams 1993). This is an important characteristic for milling maize.

The Mescal Wash site's basic and most common grinding equipment—informal slab and basin metates and round/oval one-handed manos—typically was used for the processing of small seeds of native grasses and various weedy plants (see below). At Mescal Wash, however, the wider range of length and greater diversity of shapes of the multidirectional-grinding manos suggests that besides generalized seed processing, they were also used for the intensive processing of maize. That is not surprising, because specialized maize-grinding equipment in the form of trough metates and manos did not arrive until the Middle Formative period, and maize was already being milled during the Late Archaic period at the site.

Macrobotanical evidence of maize processing consists of the roasted kernels and cobs. Given the long occupation span of Mescal Wash, this is a good place to study the evolution of maize. Describing maize-cob segments from the excavations by WSA at the nearby Marsh Station Road site (AZ EE:2:44 [ASM]), Karen Adams (2011:322) noted that San Pedro phase cobs had relatively small diameters and had 8 kernel rows. Formative period cobs were larger and had 16 kernel rows. After harvesting the ears, the remainder of the plant was left to dry in the field to be burned and mulched the following season, and so, stalks would not be expected at the habitation sites. If ears were roasted in the husk, unprotected portions of the cob might wind up in a thermal feature. After husking, some kernels and cob parts might also be lost during cooking. Dried cobs were routinely used as fuel, and so, they would be found also. Maize-pollen grains are large and do not fall far from flowering stalks. Thus, large amounts of pollen in non-field areas indicate introduction during the transport and processing of mature ears. Most pollen is expected on fresh, unhusked ears, and maize stored in that form would leave large pollen aggregates.

Squash

Flotation and pollen samples from Mescal Wash had evidence of squash, suggesting that this plant was grown as a crop near the site. Squash remains are sporadically found at Late Archaic/Formative period habitation sites, usually as small bits of charred rind or occasional pollen grains (Gasser and Kwiatkowski 1991b:431). Like with maize and beans, the Akimel O'odham planted two crops of squash and pumpkins, which likely was only a single crop at Mescal Wash. Throughout the growing season, unproductive flowers could be plucked and fried or made into cakes. Squash fruits were prepared in a variety of ways, including roasting, frying, and boiling. Seeds were roasted and eaten.

O'odham stored pumpkins immediately after harvesting them, usually in a large pit (Castetter and Bell 1942:188–190). To cook them, they cut them into cubes and simmered them on a fire in an olla. Squash were also roasted by burying the whole squash in the ashes of a fire. The seeds were considered a delicacy. They were parched by placing them in a piece of olla with live coals and stirring until they were done. No grinding tools were necessary for processing squash. Archaeological signatures would be thermal pits containing squash seeds, as found at Mescal Wash. The storage pits would show up as large nonthermal pits without evidence of what was stored.

Several factors limit the number of squash remains found in the archaeological record. The fleshy nature of squash generally prohibits preservation, with an exceptional charred rind or seed recovered via flotation. Also, squash is insect pollinated and produces relatively small amounts of pollen, and the large grains tend to remain in or near the flower. Furthermore, buds usually wither and fall off the fruits before maturity. Pollen may have been introduced to features when a resistant bud remained on harvested fruit or when flowers were prepared for consumption.

Cotton

Cotton was found in both the flotation and pollen samples from Mescal Wash and indicates good water availability near the site, because cotton needs lots of it to grow. Cotton seeds, bolls, and textiles have been recovered from prehistoric contexts throughout the U.S. Southwest, particularly along the middle Gila River in the Hohokam world (Bohrer 1970; Gasser and Kwiatkowski 1991b:430), but also in the Tucson Basin as early as the Late Archaic/Early Formative period (Fish 1998:161). Most often, cotton seeds and pollen are found in Late Formative period contexts. Cotton typically requires a relatively long time to mature, 150–180 days. Akimel O'odham traditionally made a single planting and picked the bolls in late October or early November. The fresh bolls were taken indoors and spread on a cloth in a corner of a room, where seed removal took place. Lint was transformed to cordage, then to fabric. Cotton seeds were roasted or incorporated into other cakes and meals, and eaten. The Akimel O'odham ate the seeds—which have high oil content—as a lower-choice food source in famine times (Castetter and Underhill 1935:37; Rea 1991:5). Some Mexican tribes ate the green bolls, which have a sweet taste (Huckell 1993:175–176).

With respect to cotton as a food, it is interesting that all paleobotanical evidence at Mescal Wash came from houses—in nearly all cases, it was recovered from plastered hearths. The seeds may simply have been scattered during seed removal and then swept into the hearths. Seeds may also have been spilled when parched in preparation for food. Because no significant amounts of pollen would adhere to the seeds, the pollen data probably indicate the eating of flowers or the green bolls. Likely, cotton formed no major subsistence source but was a snack enjoyed occasionally while sitting around the hearth.

Beans

Charred fragments of *Phaseolus vulgaris* (common bean) and *Phaseolus lunatus* (Lima bean) were found in the flotation samples from AZ EE:2:437 (ASM) and AZ EE:2:438 (ASM) analyzed by EcoPlan. Although none were found in the Mescal Wash site samples, it is more than likely that people living at the site grew them, also. Various bean species have been recovered from prehistoric sites in the Southwest (Gasser and Kwiatkowski 1991b), including common, tepary, and lima beans. Carbonized common beans are distinguished by their relative size, kidney shape, rounded ends, and bifid apex formed by the embryo leaves (Bohrer 1987:110); tepary beans are smaller, have embryo leaves with a single apex, and have truncated ends, a distinctive characteristic (Miller 1994:166). Lima beans are considerably larger than tepary or common beans. As was noted for maize, the Akimel O'odham grew two common-bean crops, one planted in the spring and one in the summer (Castetter and Bell 1942:191). The mature plants were harvested by pulling entire vines from the ground and placing them in piles to dry. Threshings on a prepared surface removed beans from hulls. Several methods of winnowing separated the beans from the chaff. The recovered beans were stored in sealed ollas or baskets. Lima beans were planted only once, in the spring, and the ripe beans were picked from the vine throughout the growing season. Beans almost always were boiled (Bohrer 1987:110). Because boiling was the preferred modern method of preparation, only small numbers of beans are recovered from archaeological sites. Beans are insect pollinated, and pollen is not usually expected in the archaeological record. Bean-pollen morphology has not been studied in enough detail to allow identification beyond the family level (Fish 1984:112).

Mesquite

Mesquite was the most widespread and important wild-food source for the indigenous people of the U.S. Southwest. Almost every part of the mesquite tree has a use, but here, the focus is on its food values. People consumed mesquite in three different forms: blossoms, green pods, and dried pods, of which the last named was the most important. 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. 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 (Bell and Castetter 1937:21–22; Palmer 1871). An added advantage of mesquite was that the flour could be made into rock-hard cakes that preserved a long time. Velvet mesquite (*Prosopis velutina*) is abundant in the Mescal Wash site area, with bosques likely present along the nearby creek, and its solid presence in the site's paleobotanical record is no surprise. The present discussion of mesquite is longer than for other plants in this section, but mesquite processing was the most involved and had the most different steps from harvest to storage.

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) indicated 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) reported 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, that must be broken first, which is an arduous process. 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. Crops are also highly lucrative; vast amounts of pods can be 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.

Ethnography

Gathering the Pods

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. As described below, pods can be eaten raw, soaked, boiled, roasted, pulverized, and ground and can be eaten as cakes or used to make beverages (including alcoholic drinks) and gruels. In terms of processing for food, a mesquite pod consists of four main parts: the husk (exocarp); the pulp (mesocarp); the tough, leathery, wooden pit 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 the seed. The soft inner seed, though less easy to access, can be ground into a protein-rich flour and similarly made into cakes, drinks, or gruels.

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. Processing was generally done immediately after or during the harvest to avoid spoilage of the pods, particularly 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. Collected pods were put in burden baskets, carrying nets, or blankets and brought to the processing camp. Before processing, the collected pods were stored in large, cylindrical baskets placed on house roofs or on platforms, to protect them from rodents.

Parching the Pods

There were many different variations for preparing 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). 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 that 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 that area. The surrounding hot earth is then sprinkled on top of the pods.

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). 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 drainages typically indicate mesquite-processing camps, although 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 and 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-and-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 . . . . [I]f 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. The dimensions and materials were 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 it was quite different from the more roughly shaped ones 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 processing of mesquite. Bean and Saubel (1972:109) similarly described the Cahuilla use of wooden mortars made from either cottonwood or mesquite stumps. A stump was hollowed out with hot coals, and the carbonized interior was scraped clean using flaked stone tools. It was made from a section of tree ca. 60 cm (2 feet) or more in length. The greater part of the log was sunk into 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 and 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 and were 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 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). The most detailed descriptions of winnowing mesquite meal, after crushing the pods in a mortar with a pestle, are for the Seri. 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

Like often done for flour obtained from seeds and other plant parts, mesquite-pod and mesquite-seed flour was commonly 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 dug into 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 was 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 1953:53). These cakes were broken and soaked in water, and the mixture was drunk.

The Timbisha Shoshone sifted the crushed pods to remove the fiber and seeds, and the seeds were crushed further to remove the endocarps (Fowler 1995) and 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 either in 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 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 them 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) regarding 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.

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. 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. 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."

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 and frees the inner seed, and winnowing then separates the two. Following that 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 appear 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 storage by sedentary, agriculture-based people. The first group would either not store at all, instead taking their product along on the next leg of their seasonal round, or cache the food in deep, watertight and airtight pits or, in the case of the Seri, in large ollas. 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 and 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) in depth below the ground surface and 1.5 m (59 inches) across at the mouth, narrowing 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 23–27 kg (50–60 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 with earth (Fowler 1995). In the fall, the beans were uncovered and processed before the pea weevil (*Bruchus 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 6–10 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 nest weave circular granaries" placed on pole-supported platforms (Gifford 1933:267, Plate 33).

Processing Steps

From the above, we can deduce that 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 40). All these steps likely occurred at Mescal Wash. Perishables such as wooden mortars or pestles and basketry are not listed in Table 40, because they would not have preserved at the site.

The first step was to collect the ripe pods and bring them to the processing camp in large baskets or other carrying devices. The second step was to temporarily store them onsite, likely in large baskets placed on the ground, if it was only for a short duration of time. For longer-term storage, the pods themselves, or large coiled baskets containing the pods, would be put out of reach of animals, on storage platforms or on house roofs. Archaeologically, short-term storage in baskets might appear as shallow, medium-sized nonthermal pits in an area that also contains 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 be a small, oxidized pit with a fill of FCR. 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 that there would be no FCR, 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 FCR 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 appeared that a fire of mesquite and saltbush wood had been covered with several layers of stones, after which the plant material was placed on the rock surface for parching.

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 FCR and, for Method 2, perhaps ceramics; Method 3 would result in a medium-sized to large thermal pit without associated FCR; and Method 4 would result in a broad thermal surface or large, shallow pit overlain by a broad cluster of FCR. A fifth type of parching feature was 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. In the archaeological record, this step might be detected as shallow and broad 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 40). Pounding involved mashing the pods to separate the husk (exocarp), the 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, to crush the hard endocarp and 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 the pods or the hard seed coats were crushed. Compared to Step 5, Step 10 needed a smaller mortar and pestle, and the 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. They would be shallow for

Table 40. 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 a basket with live coals	small thermal pit	fire-cracked rock, charred pods
3b	parch pods	stir in a ceramic vessel on coals	small thermal pit	fire-cracked rock, 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 thermal surface or large but shallow pit	fire-cracked rock, 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 a 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 a mortar with a 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 a basket with live coals	small thermal pit	fire-cracked rock, charred seeds
13	grind seeds	into flour	small and shallow nonthermal pit as metate support	basin metates and manos
14a	make cakes	unbaked, in a hole in the 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 a 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.

metates (5–10 cm [2–4 inches] at the most), deeper for 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. 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 they would be similar to those used for other seed grinding.

It is useful to look at the expected grinding signatures in more detail. For Step 5, deep mortars made of stone, wood, or earth have been documented in the ethnographic record. Larger mortars were particularly favored when great quantities of pods needed to be processed. Wooden mortars were large, about 76 cm (30 inches) tall and 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 Mescal Wash) wooden implements have not preserved, the only remaining artifacts associated with Step 5 would be stone mortars and pestles.

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]), the 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 that were smaller than those used for pounding the pods. Wooden mortars or pestles were not used, because they were not abrasive enough.

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; it is either in slab or block form and has a hole in its bottom. Two examples were recovered from Mescal Wash. 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 that 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, and its use probably spanned three to four millennia; the technology was abandoned after the disappearance of the region's mesquite forests in about A.D. 1100–1200 (Hayden 1967).

For both pods and seeds, the end products likely were cakes made from the flour. The 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 40). 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. The 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, and 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 that 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. That process would result in small to medium-sized (perhaps about 50 cm [20 inches] in diameter) oxidized pits without FCR or any paleobotanical evidence as to what had been 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, the roof, or a platform] or in pits [Step 4] have already been discussed.) 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 that served 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.

Archaeological Signatures

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; (2) small, deeper pits serving as earthen mortars (30 cm [12 inches] or deeper); (3) mortar supports (to 30 cm [12 inches] in depth); (4) cake molds (50 cm [20 inches] or more deep); and (5) larger pits serving to store cakes (50 cm [20 inches] or more deep). Polish or other pounding or grinding evidence on pit walls might point to 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 with or stored within 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 the fill of the fifth type might include charred seeds. Continuing the count of feature types from the previous paragraph, these are (6) thermal pits with associated FCR, (7) thermal pits with associated FCR and perhaps ceramics, (8) larger thermal pits without associated FCR, (9) broad thermal surfaces overlain by FCR clusters, (10) thermal pits with associated FCR (similar to Types 6 and 7, except possibly associated with charred seeds instead of charred pods), (11) oxidized pits without FCR or charred plant materials (cake baking), and, finally, for storage, (12) deep bell-shaped or basin-shaped pits with oxidized walls and no FCR from original use. In regard to the parching and storage features, it is important to keep in mind that the 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, and on the other hand, storage pits may have been given oxidized walls to make them more resilient and to seal them off.

Diagnostic macrobotanical remains can be expected in all thermal-feature types (except those used for baking cakes [Type 11] and storage [Type 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 40, because mesquite trees 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 pods were prepared).

Six mortars, 44 pestles, and 2 gyratory crushers were found at the Mescal Wash site, and all are diagnostic of mesquite processing. Compared with pestles, the number of mortars at the site is small, which may mean that wooden mortars were used. Pestle frequency was relatively high at the Mescal Wash site (3.4 percent of the total ground stone collection), compared with typical Hohokam sites (see Volume 2, Chapter 5). The higher frequency of pestles likely indicates greater mesquite use by the Mescal Wash site occupants than by people living in the Hohokam region, which is perhaps explained by the higher elevation of Mescal Wash and its location along a *cienega*, both of which imply greater quantities of mesquite trees than at the lower Sonoran Desert elevations. Gyratory crushers, such as the two examples from Mescal Wash, would have been useful to break down both the pods and the seeds before grinding the materials to flour on a metate (Hayden 1969).

Other Legumes: Palo Verde, Ironwood, and Acacia

Although less desirable, other legumes, such as palo verde, ironwood, and acacia, were also exploited, but they were processed in different ways. Unlike mesquite, mature pods of palo verde and ironwood have no nutritious mesocarps, and the seeds were the primary food source. Other big differences are that their pods are not as sticky and the seed coats are not as hard and 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). Palo verde and ironwood are typical Sonoran Desert trees and do not occur near the project area, and although some charred palo verde seeds were found in the flotation samples, they were unique exotics harvested from many miles to the west, in the Sonoran Desert. Various acacia species *do* occur in the project area, and all of them were prepared in similar ways. For instance, the seeds of catclaw acacia (*Senegalia greggii*), which grows near the project area, were parched, pounded, and ground into a coarse, nutritious meal that was made into *atole*, or cakes, by various indigenous people of the Sonoran Desert (Barrows 1900; Bean and Saubel 1972; Castetter 1935). Archaeological signatures would be manos and metates, parching and cake-baking features, and paleobotanical remnants.

Small Seeds: Grasses and Herbaceous Plants

Located in the desert grasslands, the Mescal Wash site was always surrounded by an abundance of economic species of grasses and edible-seed-bearing weedy plants. The project's modern-plant study documented numerous examples of these plants, including 15 native grass species (see Volume 2, Table 178 and Appendix 9A). In years of good productivity, the seeds of these plants (as well the greens of selected species) would have provided abundant sources of food. The study found the greatest quantities of these plants on the riparian floodplain of Cienega Creek. Some of the more common species were *Plantago* spp. (wooly plantain or Indian wheat), panic grass, saltbush, purslane, goosefoot, pigweed, tansy mustard, wild buckwheat (*Eriogonum*), and *Helianthus annuus* (sunflower). Many of these plants were also identified in the project's paleobotanical samples (see Volume 2, Chapters 9 and 10). Taken as a group, grasses and other small-seed-bearing plants were by far more ubiquitous than maize, highlighting their importance as a food source.

Cheno-Ams

Cheno-ams are often the most commonly recovered remains from both pollen and flotation samples at Formative period habitation or agricultural sites. In the Mescal Wash flotation samples, cheno-ams had the highest ubiquities after maize and melon-loco. This is also true for the findings from the three other data recovery projects at or near Mescal Wash (Buckles, Klimas, and Deaver 2010; Phillips 2010, 2011, 2013). *Cheno-ams* refers to members of the family Chenopodiaceae and the genus *Amaranthus*. They are bundled as a single group because their pollen grains are indistinguishable, and the seeds of many species are virtually inseparable, too. Besides seeds from native species, seeds from cultivated amaranths (e.g., *Amaranthus hypochondriacus* and *A. cruentus*) have been found in archaeological contexts (see Miksicek 1992). Preferring disturbed areas, cheno-ams are found in and around habitation areas and in agricultural fields. Though commonly considered weed types, the greens and seeds of cheno-ams were a food source (Castetter and Bell 1942; Curtin 1984; Greenhouse et al.1981). Roasting pits were lined with greens to protect other foods, produce steam, and add flavor. The seeds were also ground into meal.

Grasses

Small seeds of grasses and various weedy plants were much-favored foods of desert dwellers, especially in the desert grassland but also in the Sonoran Desert. 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. Different grass species flower and set fruit throughout the year. Grass grains are often abundant in macrobotanical samples from habitation sites, although few of the various grain types can be identified to species. Fulton and Tuthill (1940:13) noted the importance of edible seeds in the Dragoon culture area of the Sulphur Springs Valley grasslands. For paleoethnobotanists in the U.S. Southwest, identifying different grasses is a critical research objective (Vanderpot et al. 2008:196) (see Volume 2, Chapter 9).

Ethnography

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 resources. That is different along the lower Colorado River or in grassland environments, where wild cereals formed a much bigger part of the subsistence economy, similar to what it would have been in the Chihuahuan Desert grasslands.

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 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 and before grinding, grass seeds were parched. A few embers were placed in a container 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.

Panic grass seeds contain about 15 percent protein (Earle and Jones 1962:136), and Saunders (1914:136) 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 1972:98). For the Cocopah, panic grass 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 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 a gathering basket (Bean and Saubel 1972:45). The seeds were pounded to separate the seeds from the bracts and then were parched, ground into flour, and mixed with water to make gruel (mush) or small cakes. The cakes could be stored for long periods. 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, though 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.

Indian wheat 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 Indian wheat 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 and were available summer though 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).

Goosefoot and pigweed 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 and then ground, boiled, and eaten.

Pigweed seeds were collected summer through fall. Kelly (1977:36) provided 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. The material was 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 the 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.

Processing Steps

From above, we know that seed processing had eight basic steps, three of which had more than one scenario and one of which (Step 3) was included for saltbush seeds, which were baked in pits to remove their salty taste (Table 41). 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

Table 41. 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 a 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	fire-cracked rock, charred saltbush seeds
4a	parch seeds	burn bundles of seed-bearing plants on a cleared surface	broad thermal surface	charred seeds
4b	parch seeds	toast seed-bearing-plant parts on hot rocks	thermal surface with fire-cracked rock	charred seeds, fire-cracked rock
4c	parch seeds	toss pods in a basket with live coals	small and shallow oxidized pit with fire-cracked rock	fire-cracked rock, charred seeds
4d	parch seeds	stir seeds in a ceramic vessel on fire/coals	small and shallow oxidized pit with fire-cracked rock	fire-cracked rock, 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, fire-cracked rock
7b	make flour into gruel or beverage	by boiling with hot stones in a basket or ceramic vessel	small thermal pits	fire-cracked rock
8	store (seeds, cakes)	long-term storage in a 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.

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. The "heated hole" mentioned for the Akimel O'odham was a pit in which a fire had been burned, after which rocks were added to retain the heat. Needed iodinebush and cottonwood are both available in or near the project area. 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 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 FCR 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 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) 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 FCR, and the other three methods would all result in a thermal (i.e., oxidized) surface or pit with FCR. Thus, after building a fire, parching could follow three basic methods that would result in an FCR 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 as was described above for mesquite pods. 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 FCR, 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 FCR still spatially associated. But at intensively used sites like Mescal Wash, features may have been reused many times, with rocks cleaned out and used elsewhere, preventing us from linking FCR to individual features, although increased FCR densities may indicate where most thermal activities occurred. 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 preserved 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 had 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 the fourth method (placing seed-filled containers on hot rocks) would both have resulted in a similar type of archaeological feature: a small, shallow pit with oxidized base and walls, FCR 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 only be minimally altered by fire, and oxidization might be minimal. In ethnographic accounts, these two parching methods (particularly 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 FCR 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 in those areas, features 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 Mescal Wash. 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 East, in southwestern Arizona. There, large block surveys have identified several-thousand thermal features, visible on the surface as concentrations of rocks and including varying quantities of FCR. 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 because the rocks represented cleanouts, and the pits were 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 the 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.

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 41). 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 FCR, 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, small nonthermal pits that would have served as supports for baskets and ceramic vessels and deep, medium-sized storage pits, which may be bell or basin shaped and thermal or nonthermal.

Archeological Signatures

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 its 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 FCR (Step 4a), oxidized surfaces with FCR (Step 4b), and oxidized pits with FCR (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 of saltbush seeds) and 7a (baking flour into a cake). Pit baking of saltbush seeds would result in a small, relatively deep pit with remnant FCR, 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 and have oxidized walls and a fill containing FCR, 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 of 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 b (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 a notable exception. Pollens of many other seeds are easily recognized, however.

Melon-Loco

Melon-loco, a perennial vine of the Cucurbitaceae family, was found in abundance during the modern-plants study, and its seeds were very common in the flotation samples, rating second in ubiquity after maize. As suggested by its common name, melon de coyote, the fruits of *A. undulata* are very bitter tasting and foul smelling. Yet, although flotation samples included only low ubiquities of other native *Cucurbita* (all rind fragments), it was a big surprise to find a really high ubiquity of melon-loco-type seed-coat fragments—a ubiquity nearly as high as maize. These seeds have been known to archaeobotanists for a long time, but it was not until the present project that they were successfully identified to species. The seed fragments found at Mescal Wash and other sites are positively consistent with the morphological characteristics of melon-loco seeds. The fact that these seeds appear in such high ubiquity in the Mescal Wash samples can only mean one thing: they were an important economic resource, much like other plants of high ubiquity at Mescal Wash, such as maize, cheno-ams, grasses, and weedy plants. Yet, melon-loco plants have a particularly bitter taste, which would hardly make them desirable as a food source, at least if they were used as other squashes were. However, Edward Palmer collected a variant species, *A. palmeri*, near Guaymas in 1887 and said its fruits were edible when ripe in the early fall, having a taste "nearly of muskmelon" (Watson 1889:511). Moreover, and even more so, their seeds are high in protein and fat, and ethnographical accounts have reported that they are roasted and eaten in Mexico. Pennington (1969) mentioned that seeds of *A. undulata* found in Chihuahua, Mexico, in a cave used by Tepehuán, were used as food. If the seeds are indeed such a good source of nutrition, their ubiquity in the Mescal Wash samples is hardly surprising. In contrast to other squashes found in the site's floatation samples (all found as charred rinds), only the charred seeds of melon-loco were found. This suggest that the seeds were parched and eaten. Thus, it is reasonable to infer that it was not so much the fruit but the seeds that made melon-loco desirable as a food source. Like most other seeds (see above), melon-loco seeds would be parched and ground into a flour on metates. The flour could then be mixed with water to make *atole* or baked into storable cakes. The basic archaeological signatures are charred melon-loco seeds, and the milling equipment and processing features would be similar to those for other seeds.

Nuts

The macrobotanical and flotation samples from Mescal Wash included walnut-shell fragments and a few seeds from pine (*Pinus*) or oak (*Quercus*), suggesting that nuts/acorns were eaten. Walnut trees still grow near the site, along Cienega Creek, but pine and oak trees grow farther away, along the mountains, and would have required a trip of 1 or more days to obtain them. These nuts would have been snacks, rather than forming a major food source, and need no further discussion in this chapter.

Berries

Wolfberry- and hackberry-pollen types were identified in the analyzed project samples, indicating that these species grew nearby and were used by people living at the site. Other berries were also available but were less important; so, here we focus on these two. Most edible desert wolfberries (*Lycium macrodon*) flower from March to May, and the berries are collected from June through August (Hodgson 2001:236). People collected wolfberries in a basket and then generally washed, sun-dried, boiled, and ground them into flour on a metate. They mixed the meal with water to be baked into cakes or made into a beverage. The fruits were also stored in gourds, ollas, or watertight baskets. The mass was later eaten as is or was pulverized, mixed with water, and drunk. The berries were also eaten raw as a snack, sun-dried, or 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 has been reported for most indigenous cultures. Northeastern and Western Yavapai gathered the red fruits in June and 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 to simply dry the fruits, which could be reconstituted when needed.

Archaeological signatures would be manos and metates with diagnostic plant residue and charred remains of the berries in trash deposits in features.

Greens

The project's paleobotanical studies suggest that leafy wild vegetables, greens, or desert spinaches were prepared at Mescal Wash. Greens were 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*), lambsquarters (*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 was 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 boiled 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. The young stems and leaves of wild buckwheat were collected in spring and eaten raw or were boiled or pickled (Bean and Saubel 1972; Hodgson 2001:219).

In sum, preparation methods of greens varied, but most were eaten fresh, eaten like spinach, added to stews, or cooked in soups; none was 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 a shallow and relatively wide, oxidized pit, ideally containing the charred remains of the plants that were processed amongst the charcoal.

Cacti

Seven different types of cacti and five other succulents were recorded in the modern environment around Mescal Wash, all with edible parts. Cacti in the site area include saguaro (*Carnegiea gigantea*), cholla (*Cylindropuntia* spp.), barrel cactus (*Ferocactus* sp.), hedgehog cactus (*Echinocereus* sp.), Christmas cactus (*Opuntia leptocaulis*), prickly pear *(Opuntia* spp.), and nightblooming cereus (*Peniocereus greggii*). Saguaros were very few, however, and the only cacti growing around the site in significant quantities were cholla and prickly pear. The seeds of various cacti are consistently recovered from Hohokam and other prehistoric sites, often in substantial numbers. 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. Among the cacti favored by the O'odham were saguaro, cholla, prickly pear, and hedgehog cactus, as the most important ones. The plants were boiled or roasted (Castetter and Bell 1942:59; Rea 1997; Russell 1908; see Gifford [1936] for the Yavapai).

The most important of the cacti was the saguaro, whose fruit yielded nutritious beverages and jams (Crosswhite 1981). The 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. No saguaro seeds were found in the flotation samples from Mescal Wash. Saguaro is uncommon in the site area but becomes more abundant going westward, as seen in Davidson Canyon, some 10 km away. No reproductive parts of saguaro were found in the project's macrobotanical samples, and it is unlikely that saguaro was processed in any important quantities at Mescal Wash.

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/thermal pit and ceramic containers or waterproof baskets (Fontana et al. 1962).

Cacti are insect pollinated, and pollen grains are not expected far from the plant in natural settings. The collection and processing of flower buds would introduce more pollen into cultural settings than would fruit. On the other hand, mature fruits would be needed to introduce seeds to the macrobotanical record.

Cholla

This discussion focuses on cholla, because that is the most abundant species in the site area, is the most abundant cactus in the site's paleobotanical record, and also leaves the clearest archaeological signature. Cholla not only was an important wild resource for prehistoric groups such as the Hohokam but also was cultivated (Bohrer 1991; Gasser and Kwiatkowski 1991b; Miksicek 1995).

Ethnography

Cholla-flower buds were an important component of the O'odham and Apache diets (Castetter and Bell 1942). The buds were collected during the spring and early summer and, after baking, could be consumed immediately or stored. The buds of the cholla were gathered in May and June, before the monsoon rains, and the fruits were gathered in late summer. The buds were favored over the fruits. 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). Cholla collecting and processing followed a pattern different from the one established for saguaro. 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, spines could be rubbed off, and the cholla was spread out and dried (Kearney and Peebles 1960:581). 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 number of calories used to gather and process cholla in relation to the number 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.

Archaeological Signatures

Basketfuls of buds were carried to the roasting location, and the only material culture used in collecting and processing cholla were wooden tongs, coiled baskets, and the rocks in the baking pit. Archaeologically, the presence of cholla-processing camps can be inferred from isolated, medium-sized to large roasting pits that are frequently rock lined and, on the surface, visible as piles of FCR (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, FCR, 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 (*Ephedra* 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 cases in which 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 in which the dried buds were prepared to produce meal.

Agavaceae

Agave was an important cultivated resource for the Hohokam and other prehistoric people and historically was a staple of lowland groups like the O'odham and highland peoples like the Apache and Yavapai. Leaf fibers were (and often still are) used for cordage, and the emerging flower stalks, caudex, and hearts of agave are edible after baking them. Members of the agave family growing in the site area are Palmer's agave, soaptree yucca, banana yucca (*Yucca baccata*), and sotol (*Dasylirion wheeleri*), all of which have edible fruits, heads/hearts/crowns, or stalks. Most, particularly agave, were found along Mescal Wash, and only a few were found along Cienega Creek. The agave and agave-type remains identified in the project samples likely originated from these local Agavaceae. It is interesting that Mescal Wash and other sites in its vicinity did not produce a more substantial record of agave use, but likely that as result of poor preservation. Palmer's agave is abundant along Mescal Wash to the north of the site and is edible, in addition to providing fiber and other nonfood uses. Palmer's agave does not form bulbils, but it produces offsets instead and can be easily transplanted.

Known species of agave that have been cultivated prehistorically in the Southwest include *Agave murpheyi, A. delamateri,* and *A.* sp. nov. *Agave murpheyi,* also known as "Hohokam agave," found from central Arizona to Sonora, Mexico (Hodgson 2001). The Hohokam cultivated this species, and plants are usually found along major drainages in association with prehistoric agricultural and habitation features. The Tohono O'odham and ranchers in Sonora, Mexico, continue to cultivate the plant, which has relatively benign leaves that make it easy to handle. The plant is easy to propagate, not only by suckers that rapidly form large stands, but also through bulbils that are produced abundantly on the pedicels. The importance of this plant in the Hohokam diet was underestimated until the early 1980s. The discovery of agave macrofossils from large roasting pits or *hornos* (ovens) at sites along the Salt-Gila Aqueduct (Miksicek 1984) provided the first evidence of the significance of this plant to the Hohokam. Since then, prehistoric agave fields have been identified within the *bajada* of the Tortolita Mountains near Tucson (Fish, Fish, and Madsen, eds. 1992a, 1992b) and in the New River area (Rankin and Katzer 1989), north of Phoenix. In some of these fields, remnants of the ancient populations still grow, and species show evidence of human selection. No *A. murpheyi* has been identified in the living-plant inventory of the project area.

Ethnography

Agave was a dietary staple of many indigenous peoples in arid portions of North America (see Castetter et al. 1938; Dobyns 1988; Doyel and Eiler 2003; Nabhan 1985; Parsons and Parsons 1990). In the southern Southwest, the Hohokam gathered and cultivated agave throughout the Sonoran Desert (Fish, Fish, and Madsen, eds. 1992a, 1992b; Fish, Fish, Miksicek, and Madsen 1985), and many tribes of the Apache lived principally on wild agave, as well as sotol and other native plants and wild game (Castetter et al. 1938:35). Typically, the plant was harvested by cutting off the heart at ground level, after which the leaves were removed. The heart was then wrapped in a protected vegetal covering, such as cheno-am greens; the package was then placed over a bed of heated stone; and the whole was covered with earth. After a day or more, the cooked heart was removed, cleaned, and eaten; it has a sugary flavor. 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—flowers, leaves, and stalks (also including 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 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 a *horno* 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.

O'odham and Apache people similarly prepared agave by baking or roasting it—most commonly the heart but also the leaves and stalks—in large pit ovens or *hornos.* Although processing details vary depending on specific people or places, overall preparations were similar (Castetter et al. 1938:28–29). Just before flowering—usually in spring—plants were dug out with wooden sticks, and stone knives were used to chop off the leaves. The pits were up to 4 m in diameter and over 1 m deep and were often lined with flat rocks, with a large rock in the center. Wood was placed on top of the rocks and set on fire. After the fire had died down, a layer of moist grass or other plants was placed on the burning coals, to create a steam bed. Next, the agave hearts were placed in the pit, and another layer of steaming material was put on the agave, followed by a layer of dirt to prevent steam from escaping. After baking for about 2 days and nights, the mescal was removed. The roasted crowns and leaves could be eaten immediately or were pressed into large, thin cakes, which were traded and could be kept for years (Castetter et al. 1938:38).

Of soaptree yucca (*Yucca elata*), the young flower stalks and the flowers themselves served as food (though not as a significant resource), the leaves were used as cordage in basketry, and soap and shampoo were made from the roots (Bell and Castetter 1937). Banana yucca, in contrast, was a significant food resource. Castetter and Underhill (1935) reported O'odham expeditions to the mountains to collect the big, fleshy fruits, which were often pit-baked. The fruit pulp was eaten fresh or cooked and often was made into cakes to be stored or traded with neighboring people (Bell and Castetter 1937; Rea 1997). The young flower stalks, flowers, and seeds were also cooked in various ways, and the seeds often were stored.

Baking the rounded inflorescences or heads of sotol was done in *hornos* similar to those used for agave. The inflorescence, or head, of the sotol contains a sugary sap that, when fermented, is used to produce a potent beverage called *sotol* by Native Americans (Bell and Castetter 1941). The sap would have been extracted from the sotol heads by pounding and manipulating them with hand stones or other stone tools. The liquid would then be poured into ceramic containers and possibly mixed with other plant materials to aid the fermentation process, which takes several days.

Archaeological Signatures

Hornos or other large roasting pits, agave knives, and Agavaceae parts are the primary diagnostic traces of the cooking of agave, yucca, and sotol. In addition, agave production may be indicated by the presence of rock-pile features, which would have helped retain water, trap nutrients, and provided protection against predators. Rock-pile features throughout southern and central Arizona have been found associated with tabular tools and provide evidence of the possible cultivation of agave in or with the features (Fish et al. 2004; Greenwald and Greenwald 1996:109–110; Kruse 2009; Vanderpot 1992). Ethnographic studies (Castetter et al. 1938; Russell 1975), experimental and phytolith studies (Bernard-Shaw 1983, 1984, 1985), artifact analyses (Greenwald 1988:172–187; Irwin 1990:385–386), and archaeological associations (Ciolek-Torrello and Halbirt 1987; Fish, Fish, and Madsen 1985; Fish, Fish, Miksicek, and Madsen 1985; Kruse 2009; Vanderpot 1992, 1995, 2004) have all pointed to prehistoric use of tabular knives for removing or trimming agave leaves. Tabular knives at Mescal Wash commonly had well-executed, serrated and beveled use edges, indicating that considerable effort went into their production. Two percent of the Mescal Wash ground stone collection consisted of tabular tools or knives, and most of those were from Classic period contexts, suggesting an increase in the use of agave during that time. Taking into consideration their narrow time frame of use, they may have been one of the most important tool types during the final years of site use.

Charred remains of agave are frequently recovered from large thermal pits and are an important signature of its processing. Agave hearts are most nutritious when harvested just prior to flowering, in early spring. Because no flowers are present when agave is cooked, and also because agaves are insect pollinated and produce little pollen, agave is rare in pollen samples.

Agave or sotol roasting requires no water, and ethnographically, containers are not associated with the roasting process. Processing of other parts of the plants (or associated activities, such as feasting) would require containers, however. Making a sotol beverage drink required both pottery and hand stones and manos. Feasting in Locus A was indicated by large quantities of painted ceramics (see Volume 2, Chapter 3) and was likely associated with the communal *hornos* in that locus.

Hunting and Animal Processing

A variety of large- and small-game animals found along Cienega Creek, on the *bajadas*, and in the nearby mountains would have been potential prey for the hunters residing at the site, including mule deer (*Odocoileus hemionus*), desert bighorn sheep (*Ovis canadensis mexicana*), pronghorn, and javelina (*Pecari tajacu*) in the mountains and upper *bajada* and leporids and a host of rodents, birds, reptiles, and perhaps amphibians on the lower *bajada* and along the river nearer to the project area. Mouse, rat, gopher, and squirrel species would have lived near the residences and been hunted opportunistically (Rea 1998; Russell 1908). Leporids were hunted either individually, with projectile weapons, or communally, by trapping them along fences or driving them with fire (Rea 1998). Despite preferring different niches, the ranges of jackrabbits and cottontails overlap. Mule deer migrate seasonally between high and low environmental zones, but they generally prefer a greater amount of cover than do pronghorns. Associated hunting camps would be expected in the grassland areas on the upper *bajada* and in the canyon mouths where larger game was found and water sources were available. Hunting on the *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), and drivers chased animals into the circle, which was then narrowed, after which animals were killed with rocks, clubs, and arrows. Hunting strategies and animal use along Cienega Creek and how these changed through time are discussed in Chapter 7 of this volume.

Archaeological Signatures

Archaeological signatures of animal procurement and processing include faunal bone; diagnostic flaked stone tools, such as scrapers, bifaces, and projectile points; and thermal features with faunal bone. Aside 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 bones of small animals are often underrepresented, because bone would be ground down on metates and eaten. The Mescal Wash faunal remains indicated that the site occupants focused primarily on leporids and artiodactyls, the first emphasized in the Archaic period and the latter emphasized during the Formative period. Hunting cottontails, jackrabbits, and rodents in the site area may have been opportunistic, although it is possible that social drives were held farther away from the site, 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 rabbits, hares, and rodents, all of which were baked in a celebratory communal pit, which would have been large and not unlike a *horno*. Leporids were cooked by (1) broiling or roasting on top of hot coals in a surface fire or in a shallow pit or skewed 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 resulted in some kind of thermal feature, which might still contain burned faunal bone. Pits for communal roasting would have been large, but cooking of opportunistically caught small animals was done in small pits. 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. The small animals were baked whole in pits or grilled on the hot coals of surface fires.

Processing Steps and Expected Features

A review of the ethnographic literature has helped to identify different series of food-processing steps likely practiced at Mescal Wash, as well as their respective archaeological signatures, particularly the different excavated pit features. The examination started with a wide set of ethnographically important plants, and then, by process of elimination, that set was narrowed to only a few key plant taxa that mattered for the site. In a simpler manner, the same was then done for animals. Of the various plants reviewed above, maize, mesquite, small-seed-bearing plants, melon-loco, cholla, and agave stand out most fully at Mescal Wash, either because they had the highest ubiquity in the paleobotanical record or because they left a strong and distinct archaeological footprint. That other cultigens and wild plants, such as succulents, nuts, berries, tubers, and greens, etc., are not considered in the following discussion is not because they were less important foods in the overall subsistence economy at Mescal Wash (although they likely were less important) but because they left fewer archaeological traces. 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 distinct impressions in the archaeological record. Thus, we were able to infer the types of archaeological features and associated artifacts that together form a signature for a given plant-collecting or plant-processing activity. Let us briefly revisit the subsistence-related pit features and see how each correlated to the plants, the animals, and their processing steps.

Ideally, pit features as discussed here would have had perfect preservation, 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 FCR, charred plant or faunal materials, and associated artifacts. Although that is rarely an archaeological reality, especially at a densely occupied habitation site such as Mescal Wash, it is the only way to construct a behavioral baseline. In classifying features in these ideal circumstances, the presence or absence of oxidization (thermal or nonthermal) and FCR is considered, and so are associated paleobotanical materials. Table 42 lists the feature types that would have preserved at the project sites under ideal conditions. Nine of the feature types used for plants are thermal (oxidized), and seven are nonthermal (not oxidized). The nonthermal features are all pits used for storage (n = 3), as ground stone supports (n = 2), as mortars (n = 1), or as cake molds (n = 1). Thermal-feature types include surfaces and pits used for storage (n = 1), parching (n = 4), or baking (n = 4). FCR is associated with six of the thermal feature types and 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 two of the thermal-feature types (cake baking and pit baking/roasting/grilling of meat). Fuelwood for the thermal features is not considered, because these woods (mesquite, saltbush, creosote bush, ocotillo, and others) provide no evidence of the plant processed. Diagnostic pollen is only expected in two of the thermal-feature types: the two surfaces (with or without FCR) 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 (or associated) features: parching, baking, grinding support, cake forming, and storage. The nonthermal features likely served as basket rests (small to medium-sized, shallow pits) (Types 1 and 2), mortar or metate rests (small, shallow pits) (Types 4 and 6), mortars (small, deep pits) (Type 5), storage pits (deep, medium-sized, bell- or basin-shaped pits) (Type 3), or perhaps cake molds (small

Table 42. Expected Food-Processing Signatures at the Mescal Wash Site

Feature Type	Feature Description[a]	Feature Function	Activity	Associated Ground Stone	Fire-Cracked Rock? (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 roasted/parched maize, parched mesquite pods, or mesquite-/small-seed-flour cakes	none	no	charred maize kernels/cobs or 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 shorter 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	long-term storage of maize, parched mesquite pods, or mesquite-/small-seed-flour cakes; baking of agave, etc.	none	no	charred mesquite pods
9	small pit	provide coals for parching	parching in a 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 (maize cobs, mesquite pods)	none	no	charred maize or 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
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

continued on next page

Feature Type	Feature Description[a]	Feature Function	Activity	Associated Ground Stone	Fire-Cracked Rock? (Yes/No)	Paleobotanical Evidence
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.

but deep, elliptical pits) (Type 7) (see Table 42). Based on the project research, the parching of maize, mesquite pods or seeds, and all small seeds was likely the most routine thermal activity at the site. Because it was so common, it is not surprising that, in a simplified manner, pod parching (or roasting, toasting, etc.) and seed parching (or roasting, toasting, etc.) each have four different primary methods, in turn corresponding to four feature variants:

Maize:
1. Parch kernels by stirring/tossing in a basket with hot coals.
2. Parch kernels by stirring in a pottery vessel above hot coals or on hot stones.
3. Roast unhusked ears on the ground surface by burning a fire on top.
4. Roast unhusked ears on burning embers in an open pit.

Mesquite pods:
1. Toss in a basket with hot coals.
2. Stir in a large ceramic vessel on hot coals or rocks.
3. Toast on hot earth.
4. Toast on hot stones.

Seeds:
1. Toss in a basket with hot coals.
2. Stir in a ceramic vessel on hot coals or rocks.
3. Burn bundles of seed-bearing plants on a cleared surface.
4. Toast entire seed-bearing plants on hot rocks.

Expected feature types would be different for each of these methods, thus resulting in twelve types. But the three sets of methods can easily be collapsed into a single set of four types—each possibly containing diagnostic charred pods, cobs/kernels, or seeds—by combining Steps 1 and 5 (thermal pit with FCR), Steps 2 and 6 (thermal pit with ceramics and FCR), Steps 3 and 7 (thermal surface or pit without FCR), and Steps 4 and 8 (thermal surface with FCR). Thus, four basic types of parching features are expected in the project area: small thermal pits with FCR (Type 9), large thermal surfaces or pits without FCR (Types 10 and 12), small thermal pits with FCR and pottery (Type 9a), and broad thermal surfaces with FCR (Type 11) (see Table 42). Each of these might contain charred cobs/kernels, pods, or seeds, and the last two might also contain pollen evidence of the kinds of seeds that were processed.

Baking or roasting was likely the second-most-common thermal activity at the project site, to roast/bake agave hearts/stalks and cholla buds, make cakes from flours, remove the salty taste of saltbush seeds, and cook meat. Baking cakes primarily used the flour of seeds. Although it was sometimes done with mesquite-pod flour, it was not necessary to do that, because those cakes hardened by themselves. Thus, four types of baking pits are expected, those resulting from (1) baking cakes (Type 13), (2) baking saltbush seeds (Type 14), (3) baking cholla (Type 15), and (4) cooking meat (Type 16) (see Table 42). Cake-baking features would be small to medium-sized thermal pits containing FCR, 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 FCR and would contain saltbush seeds among the charred materials. Agave-baking pits would be large, oxidized pits, particularly *hornos* but, earlier, perhaps also bell-shaped pits. Cholla-baking pits would be medium-sized to large thermal pits, possibly rock lined, and would contain FCR, charred cholla buds, and cholla pollen. Finely, meat-baking pits would be small to large thermal pits with or without FCR and would contain burned faunal bone.

These are all ideal feature types, of course, and the reality of the project site 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, particularly those with formal basin or bell shapes, 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.

In regard 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 stronger 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 FCR in or near the feature may be all that remains. Oxidization may have been so light that it could have easily washed 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, at sites like Mescal Wash, where nearly every rock would have been 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 is often impossible to determine what FCR originally belonged to what feature.

In sum, there was a broad mix of different food-processing and storage features at Mescal Wash. Agave and cholla were baked in *hornos*, bell-shaped pits, and rock-lined pits—all typically in areas set away from houses and likely indicating communal use. These pits are relatively few, although they reflect repeated and intensive use. The bulk of the thermal pits were used for the parching of maize, mesquite, and small seeds and the baking of cakes from their flour. The nonthermal pits would have had a wider array of functions, such as storage, basket/pot rests, nonthermal plant processing, and milling-stone supports. Testing these nonthermal functions is much harder than testing the functions of thermal pits.

Summary and Conclusions

Peoples of the Grassland and Desert

Although agriculture was always important at Mescal Wash, the ubiquity of the suite of plants with small seeds (grasses, weedy species, and cheno-ams) far outdid the ubiquities of maize and other plants. Similarly, the vast number of small thermal pits at the site appears to show a preponderance of the parching of small seeds. This makes it worthwhile to examine how grasslands adaptations differ from low-desert ones and, first, how subsistence practices may have differed between distinct cultural groups.

Protohistoric and historical-period residents of the desert and grasslands of southern Arizona practiced distinctive foraging, hunting, and farming patterns that distinguish different ethnic and linguistic groups. Different cultural groups had distinctive foodways, including favorite resources, tabooed foods, and different preparation techniques and cooking methods. For instance, so important were local plants and animals that the O'odham became identified with them: the name for the Hia C'ed O'odham of far-southwestern Arizona comes from their reliance on sand food (Nabhan 1985; Rea 1997:365–366), and their eastern neighbors, the Tohono O'odham, were once referred to as "Bean Eaters" for their reliance on indigenous tepary beans. Such vital resources were bound up in O'odham expressions of cultural identity. The Mescalero Apache, of course, received their name from the Spanish word, "mescal," for agave, which they liked to gather. Along the same lines, we have seen above that although many plants were prepared in the same ways by different groups, others were not. Similar patterns that differentiate ethnic and linguistic groups likely also existed in prehistory. We know that food preferences differed among, for instance, the Hohokam and Mogollon, and often such differences were related to the different environmental zones where people lived and the availability of different foods. But there are also food-preference differences not based on environmental disparity. Mescal Wash is located fully in the Chihuahua grassland, though just east of the Sonoran Desert. Elsewhere in this report, we have noted how many aspects of the site are un-Hohokam, such as the recessed-hearth structures, the "big" house in Locus C, the informal grouping of houses, the house orientations, and the high ratio of extramural-pit features to structures. There also are marked differences in the ceramics—for example, a Dragoon ceramic tradition existing side by side with a Hohokam one. The ground stone included a metate type typically found in northern Mexico, and pestles (mesquite) and tabular knives (agave) were more abundant than at the typical Hohokam site. The faunal analysis showed that artiodactyls are more prevalent than at Hohokam sites. More significantly, people at Mescal Wash did not eat fish or waterfowl, even though these foods were widely available, whereas Hohokam people did consume these riparian resources. The absence or paucity of typical Sonoran Desert plants, such as saguaro, palo verde, and ironwood, is significant, also—all of these plants are interwoven with Hohokam subsistence. Another big difference is the high ubiquity of the seeds of grasses and various herbaceous plants in the Mescal Wash samples, as well as the high ratio of feature types used to process those seeds. Thus, from a subsistence viewpoint, Mescal Wash also was not a true Hohokam site. Although living along the edge of the Sonoran Desert, these were people of the grasslands. As to plant products, they primarily subsisted on cultivating maize, beans, and squash and collecting wild cereals, mesquite, cholla, and agave. And unlike what is known for the Hohokam, agriculture was always kept in balance with the collection of wild resources.

The Sonoran Desert hosts a wide variety of plants that provide edible parts (Felger 1975, 1977). But the variety of grass grains, small seeds, cactus fruits, nuts, berries, and legumes of the Sonoran Desert available in the summer requires complex scheduling, which may have precluded large foraging populations. In contrast, rainfall-dependent grasses dominate the flora of the grasslands. The grasses grow in such abundance that in many years, the biomass of the grasslands exceeds that of the Sonoran Desert (Hard 1988; see also Roth 1989). The extensive grasslands on the valley bottoms and *bajadas* surrounding the Cienega Creek–Mescal Wash confluence offered reliable and abundant resources upon which Archaic period groups and subsequent Formative period people anchored their subsistence systems. That economic advantage was not unique to Mescal Wash; it also existed along the nearby San Pedro River and other major grassland drainage systems in the region (Altschul et al. 2014; Vanderpot 1997). Given the relatively small areas of arable land in all these areas, wild cereals always balanced, if not outcompeted, cultivated crops, including maize.

Based on surveys in the San Pedro Valley, about 20 km to the east of the Mescal Wash site and similarly situated in the Chihuahuan grasslands, Vanderpot (1997:39–41) defined a series of rock-pile-feature types associated with grass-seed procurement and processing 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 storing of seed in containers, parching, or thrashing. Ground stone artifacts were found in abundance near all types of seed-collection and 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, such as the Late Archaic period Charleston site (AZ EE:8:11 [ASM]) and the Middle Formative period Pot Town (AZ EE:8:48 [ASM]) (Altschul et al. 2014). That subsistence economy, based on wild cereals, endured from the Late Archaic period into the Formative period and existed side by side with various forms of agriculture, including maize farming. Storage facilities at the lower-*bajada* base camps were interpreted as logistical collection centers for wild-grain procurement, presumably in the late summer. A 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 habitations.

Although seeds are a dependable food source, and their harvest is often lucrative, seed processing may be time-consuming. For example, among the Alyawara and Gugadja hunter-gatherers of the Australian deserts, 5 hours are required to process 1 kg of grass seeds, and the returns range between 340 and 750 kcal per hour (Cane 1987; O'Connell and Hawkes 1981, 1984; O'Connell et al. 1983; Simms 1984). A focus on grasses in the grasslands of southern Arizona and northern Mexico, then, not only would have dampened the need for another cereal resource but also would have limited the time available to devote to agricultural pursuits, which might not always work out, anyway, because of the relatively small expanses of arable land. Late Archaic period agriculture in the Cienega Creek valley—as it was in the middle San Pedro Valley—was a casual supplement to the existing grassland-based hunting-and-gathering economy. Although dependence on agriculture at the Mescal Wash site increased in the Formative period, it never attained the overriding importance it had for Hohokam people in the Tucson and Phoenix Basins. And in large part, especially along Cienega Creek, this was because there were no large, arable expenses like there were in the nearby Tucson Basin, where maize quickly took the place of wild cereal. The success of the new adaptation to maize was surprisingly rapid, leading to a previously unmatched focus on the riverine zone that promoted sedentism and population growth.

A Last Look: Subsistence Trends at Mescal Wash

Mescal Wash could easily fit in almost any other grasslands desert area of the world. Yet the site is also highly unique. For 3,000 or more years, Mescal Wash—situated at its ecological *and* cultural crossroads—attracted different groups from near and far. Over much of its long history, the site always remained a mixed, forager-farmer *ranchería*; it included a series of spatially shifting farmsteads and hamlets but never, or only briefly, reached village proportions. Its mix of economic plants and animals may have fluctuated over time, with maize and small animals becoming increasingly more important, but overall, it remained unchanged. Generally, the inhabitants of Mescal Wash relied on agriculture supplemented by gathered wild resources and hunting of both large and small game. Subsistence practices remained stable throughout the course of occupation, although some trends were noted. During the Late Archaic period, large game (artiodactyls) formed the focus of hunting efforts and would have required expeditions away from Mescal Wash. Maize was already a crucial resource by that time, but wild-plant resources, particularly the seeds of grasses and various herbaceous plants, were equally, if not more, important. During the Formative period, agricultural resources grew in importance, and wild resources formed a smaller (but still important) component of the diet. At the same time, the emphasis on faunal resources shifted from large to small game, particularly jackrabbits and cottontails. Typical traits of increased sedentism, these two trends suggest a contraction of the subsistence universe, wherein an increasing number of resources were obtained in closer proximity to the site. Furthermore, although the overall ratio of extramural pits to pit structures always was high at the site, that ratio decreased noticeably through time, particularly concerning larger nonthermal pits interpreted as storage features. That decrease in the number of pits appears to reflect the diminishing need for long-term storage with increasing sedentism. The importance of agriculture during the Formative period is also indicated by the settlement shifts within the site, which correlate to the condition of nearby Cienega Creek and Mescal Wash. Above, we discussed the demographic shift from south to north across the site, from the Cienega Creek side to the Mescal Wash side. In the time of increased rainfall and moisture during that time, Mescal Wash would have provided a more stable location for farming. Then, when the environment returned to a more typical pattern at the beginning of the Late Formative A period, the Mescal Wash site was completely abandoned and was resettled on a much smaller scale in the Late Formative B period. Clearly, during these times, agriculture was of overriding importance, causing settlement shifts across the site and even temporary abandonment.

How important the wild grasses and other small-seed-bearing plants were, however, is shown by their ubiquity in the paleobotanical samples, which far outcompeted maize. The importance of these wild cereals was also suggested by the large numbers of small thermal pits interpreted as seed-parching features. No large block surveys, such as along the nearby San Pedro River, have been conducted along Cienega Creek, and we do not have a complete picture of settlement and land use. We do not know, for instance, if the people at Mescal Wash set up seed-collecting and processing camps in the site catchment area, such as the seed-parching locales tethered to habitation sites found along the middle San Pedro River. However, it is easy to speculate that the Cienega Creek valley grasslands mirrored this same pattern, especially during the Late Archaic period. As noted by Stevens (2001), based on her survey along Cienega Creek, the transition from the Late Archaic period to the Early Formative period saw people moving their settlements to areas better suited for agriculture. Whereas Late Archaic period people moved seasonally between valley-bottom and upland settings, subsequent groups had a less mobile lifestyle and focused their wild-plant gathering on the floodplains, near agricultural fields. In that scenario, although Formative period task groups might periodically still have traveled to more-distant plant resources, the foraging ranges decreased through time.

Mescal Wash was not just a persistent place but also a shared one. The role of subsistence in Mescal Wash community development was evidenced by large, communal cooking features, such as the *hornos* and other large roasting pits. As ethnographically documented, the baking of agave, sotol, and cholla were shared events during which people came together from different places for ceremonies and feasting. The latter was certainly in evidence at the site. Sotol was not just a food but was also used to produce a potent alcoholic beverage served in ceramic containers and drunk ceremonially, similar to how O'odham people used saguaro wine. Numerous large serving vessels—including large numbers of painted bowls—were found in Locus A, also the location of most of the site's excavated *hornos*. This suggests that these vessels were used to serve meals and drinks to large groups gathered for communal feasts. Community-level coordination would also have been required to strategize farming efforts and to hunt jackrabbits in communal drives.

Located along the main prehistoric travel route between the middle San Pedro Valley and the Tucson Basin, Mescal Wash was a gateway between desert and grasslands—between the Hohokam and eastern peoples, such as those affiliated with the Dragoon tradition. As a shared place for different ethnic groups with ties to different areas, the exchange of goods was likely one of the reasons people came together. Typical items from the grasslands (e.g., agave, sotol, and yucca products; cakes baked from grass seed flour; and perhaps even pronghorn meat) would have been exchanged with items from the Hohokam area (e.g., pottery and saguaro foodstuffs). Tucson Basin Hohokam settlements were less than 30 km away, and for them, Mescal Wash was the nearest outpost of the Chihuahuan grasslands. Not surprisingly, in the heyday of site occupation during the Middle Formative period, coresidency was the norm at Mescal Wash, and typical Hohokam structures could be found side by side with Dragoon houses characterized by recessed hearths. In the end, it was that coming together of different peoples for such a long time that made Mescal Wash such a fascinating place for the study of prehistoric human behavior, adaptation, and subsistence.

CHAPTER 7

Hunting Strategies along Cienega Creek: Diachronic Changes in Animal Use at the Mescal Wash Site

Jesse A. M. Ballenger

The purpose of this chapter is to present newly synthesized data and describe possible research directions related to the study of human hunting strategies at the Mescal Wash site as they relate to a broader understanding of human prehistory, especially the archaeology of resource abundance and depression.

Background

The Mescal Wash site is located at about 1,120 m AMSL, in the Chihuahuan-Sonoran Desert ecotone, on a deeply dissected piedmont surface overlooking the confluence of Cienega Creek and Mescal Wash, in southeastern Arizona. Importantly, the site is located on the eastern side of the divide that separates the Santa Cruz and San Pedro Valleys. Cienega Creek is hydrologically connected to the Empire, Rincon, Whetstone, and Santa Rita Mountains. The Mescal Wash site witnessed multiple intervals of occupation beginning during the Late Archaic period, or perhaps earlier, and continuing into the Late Formative period, and there is evidence of maize from throughout the known sequence. Habitation expanded and was most frequent during the Middle Formative A and B periods (A.D. 900–1150), based on the clustering of superimposed pit houses and numerous extramural features that have been assigned to that interval via AM dating. One cultural hiatus was identified during the Late Formative A period (A.D. 1150–1300) and was followed by the appearance of renewed habitation in the form of adobe architecture in the Late Formative B period (A.D. 1300–1450). Based on distinctive architectural variation and a variety of painted ceramics, the cultural affiliations of the people who frequented the site were diverse, but items typical of Hohokam settlements were most common.

Based on the analysis of the site's animal bones reported in Chapter 8 of Volume 2, the faunal collection from Mescal Wash included at least 26 identified taxa. Fewer than 20 of those taxa were probably taken and used as food. The most numerous bones belonged to rabbits and deer, which accounted for roughly 9,600 of the 10,385 analyzed pieces of bone, quantified as the number of individual specimens (NISP) from the site. The lagomorph sample was dominated by black-tailed jackrabbit bones, which were twice as common as cottontail bones. The deer bones most likely represented mule deer. Other important small animals included tortoises and turtles, ground squirrels and gophers, and quail. Rare taxa included pronghorn, bighorn sheep, and turkey.

Guiding Research Theme

The guiding research theme of the Mescal Wash study related to persistent places (see Chapter 1). Schlanger (1992) used the term to describe areas of the landscape that have been foci of repeated cultural activity through time. Persistent places fall into two general categories: (1) features of the natural environment that may attract human occupation (e.g., wetlands and caves) and (2) durable materials and features that humans created while occupying a location and that witnessed repeated use/visitation (e.g., fields, structures, and rock art). This guiding research theme is directly related to the duration of human occupation at the Mescal Wash site.

Prehistoric Hunting Strategies

The study of hunting strategies is obviously relevant to understanding the value and possible consequences of persistent human presence at key locations during the transition from desert foragers to desert forager-farmers. The focus of southwestern faunal studies in recent history has specifically addressed the issue of widespread resource depression as it relates to the transition to food production, sedentary village life, and the natural abundance of different animals. This line of research has deep roots in the Hohokam region with the seminal work of Frank Bayham. Bayham (1982) provided the analytic framework for investigating variability in the use of large and small game, namely rabbits and deer. Bayham and Hatch (1985) observed differences in the use of lagomorphs at upland and lowland sites, but importantly, they relied on the habitat preferences of cottontails and jackrabbits to ascertain prehistoric changes in the local environment rather than changes in human prey choice.

These insights were further developed when Christine Szuter (1984) recognized that the proportion of cottontails to jackrabbits varied not by time period, as might be expected if environmental forces alone controlled their ratio, but rather by site location and site type. She reasoned that small sites resulted in less land clearing and better habitat for cottontails, whereas large agricultural villages would have destroyed cottontail habitats but potentially increased the habitats of jackrabbits. Furthermore, Szuter introduced prey behavior and hunting strategy into the equation, by reasoning that small habitation sites would not have allowed for communal jackrabbit drives. Szuter (1991) concluded that sites at elevations above 800 m AMSL in her data set (n = 10) always had lagomorph-index values of greater than 0.20, whereas valley sites had generally lower lagomorph-index values that varied according to site size and duration.

The proportion of deer to lagomorphs in archaeological deposits is likewise known to increase with elevation; large villages below 800 m AMSL generally contain fewer artiodactyls than nonriverine habitation sites situated higher on the landscape. This, too, has implications for understanding the relationships among the prehistoric environment, social organization, and human prey choice. Bayham (1982) interpreted the increase in artiodactyls at Ventana Cave as representing a change in the location's function, from an Archaic period base camp to a logistical hunting camp. Szuter (1991) thought that the variation was better explained by differences in elevation, site size, and agricultural commitment rather than time. She speculated, however, that although more artiodactyls may have been available above 800 m AMSL, factors other than natural abundance may have been at work in creating the variability she saw in the archaeological record. Namely, floodplain communities were much larger and more persistent and developed a heavy commitment to maize agriculture. That level of human presence and land disturbance is expected to have run off local deer populations, because they have not been present as an important food source in floodplain villages. In turn, because deer were so rare, farmers were unable to devote themselves to extended hunting parties. Following that line of reasoning, the presence of sparse deer remains in floodplain settings may be explained by opportunistic "garden hunting."

The accepted analytical focus on the order of artiodactyls—or, more broadly, "big game"—is elegantly simple, but it does mask profound differences in prey choice and hunting strategies (Rea 1998). Sites in the Sonoran Desert that contain significant remains of bison, elk, bighorn sheep, and antelope implicate prey switching for one reason or another, along with necessary changes in strategy, technology, and effort. The Mescal Wash site is not a well-suited background to discuss these diverse strategies at length. Again, the overwhelming majority of the vertebrate-faunal remains have been rabbits and probably mule deer. Rare[1] antelope and sheep remains may be present, but it seems more interesting to focus on the persistent but variable use of deer.

The study of small mammals has great potential, because their brief lives and limited tolerances make them highly accurate proxies for different types of natural and cultural environments (Dean 2007a), and their abundance as food items points to a lot of solitary, hand-to-mouth foraging rather than the predicted pursuit of higher-ranked prey, if those were available and accessible. Women and children are often implicated as agents for the introduction of small animals in the archaeological record. Unfortunately, the burrowing activities and natural mortality patterns of rodents are problematic in most archaeological contexts (Szuter 1991).

Resource Depression and Hunting "Diversification"

Recently, Rebecca Dean (2007b) has argued that the long period of transition from the Late Archaic period to the Classic period was characterized by animal-resource diversification in the waning centuries of the Hohokam phenomenon, indicating intensification in response to demographic stress in the heavily populated Salt and Gila River basins. That is measured using evenness values based on NISP. Dean's approach is unique to Hohokam studies, because

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[1] By "rare," I mean an NISP of 12 for antelope, whereas the San Pedro Border Village had an NISP for antelope that was an order of magnitude higher (Hopkins 2010).

rather than studying the data at the taxonomic level of lagomorphs, artiodactyls, and rodents, she organized the fauna into groups based on the strategic decisions involved in hunting them. Because previous research has stressed the correlation between elevation and prey choice, Dean limited her analysis to only those sites at elevations below 800 m AMSL (n = 85). The lack of strong evidence of resource diversification in the Santa Cruz Basin[2] was surprising to her, but for the San Pedro Valley, Rein Vanderpot (1997) has hypothesized that the intensity of local grassland adaptations during the Late Archaic and Early Formative periods may have "backfired," causing ecological degradation and resource depletion during the Middle Formative period. Did resource stress occur during the Middle Formative period in the San Pedro Valley but not until the Classic period in the Salt and Gila River basins? Were conditions of resource depression in the Phoenix Basin also occurring at upland habitation sites, such as the Mescal Wash site?

The answers to these questions obviously have broad implications for distinguishing anthropogenic from non-anthropogenic changes in human ecosystems. The important question of whether or not widespread and measurable changes in animal resource use occurred during the Hohokam (Dean 2007b), Mimbres (Cannon 2000), and Formative (Vanderpot 1997) periods in the Southwest requires landscape-scale studies of persistent places such as Mescal Wash that record diachronic changes. Of course, prey-choice models assume that foragers pursued the highest-ranked prey whenever they were encountered and ignored lower-ranked animals when higher-ranked prey were available. Because foragers are generally expected to have ranked prey based on post-encounter return rates, which are positively correlated to body mass, it is expected that large prey, such as deer, would have been pursued whenever they were available. In that context, the artiodactyl and big-game indices provide a straightforward and meaningful measurement of long-term changes in human prey choice. Access to highly ranked prey can be limited by habitat; environmental changes, such as droughts, which reduce the carrying capacity of the landscape; or social changes, such as reduced mobility frequency and range or new land-use practices that limit access to certain animals and affect local habitats (Szuter 1991).

Herein lie some subtle but important twists in the study of Hohokam hunting as it relates to resource depression. Dean assumed that rabbits were the staple source of meat throughout most of the Late Archaic/Early Agricultural and Hohokam periods.[3] In other words, she argued that the pursuit of small, often solitary, low-ranked game was foremost in the minds of pre-Classic period farmers who were dedicated to tending fields and that increases in the use of mostly higher-ranked prey that presumably required long-distance hunts signal resource depression[4]—a depression that required hunters to organize and take on the biggest local herbivores.[5] But if these generalizations are valid, then something strikes one as possibly wrong. It would seem that a more appropriate response to resource depression caused by demographic increase or environmental collapse would be a decline in the use of highly ranked animals (because resources are stressed) and a necessary increase in the pursuit of small animals, such as rabbits. On the other hand, if what Dean meant was that crop resources were depressed,[6] then a switch to a forager's diet would likely have included diversification and more frequent encounters with highly ranked prey. Therefore, it is necessary to distinguish the scale and context of the depression to model forager-farmer responses.

In Chapter 8 of Volume 2, Justin Lev-Tov and Robert Wegener showed a pattern for the site that was also predicted by Dean: a U-shaped trend in evenness values[7] between the Late Archaic and Late Formative periods. Deer hunting started big in the Late Archaic/Early Agricultural and Early Formative periods, fell to nearly nothing during the Middle Formative period, and then made a comeback in the Late Formative period. The authors of Chapter 8 of Volume 2 conceded that increases in highly ranked prey may be interpreted as indicators of resource depression. Using that rubric, Middle Formative period resources were plentiful at the Mescal Wash site when it experienced its densest concentration of horticulturists that ate lower-ranked prey, but resources were not so plentiful by the Late Formative period, when smaller farming communities were able to take much larger prey.

My point here is not to dismantle Dean's argument for the Hohokam "collapse" but to show that it should not control the analytic or theoretical scope of the Mescal Wash faunal study. There are other practical reasons to reject her analysis. She only used sites at elevations below 800 m AMSL, where she assumed that prehistoric deer were rare and distant resources, based on ethnographic analogy (Rea 1998). Therefore, the model cannot be fairly applied to sites located above 800 m AMSL, where she expected greater

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[2] This means that only "relatively local" resource stress accompanied the widespread collapse of the Hohokam.

[3] Although rabbit bones were found in a roasting pit at the Lehner site, human hunting patterns appear to have focused on the largest locally available prey for a much longer period of time before the introduction of maize, but that's not my main point here.

[4] Michael Cannon (2000) dealt with increased artiodactyl hunting as a sign of resource depression in the Pueblo period of the Mimbres Valley, essentially arguing that the increased distance to better foraging patches made deer hunting a less preferred option and therefore a sign of lower foraging efficiency.

[5] The purpose of Dean's "four-category" evenness value is to show they diversified toward smaller game, as one might expect, but it is not compelling. The "five-category" values show that they "diversified" mostly toward deer.

[6] Based on her discussion, Dean (2007b:127) was referring to non-agricultural-resource stress.

[7] The evenness values largely tracked variable proportions of artiodactyls.

numbers of local deer. More importantly, she lumped all the multicomponent sites into the latest component (usually the Classic period), which should cause an apparent increase in diversity through time. She asserted that the maneuver had no effect on the data, but one cannot help but suspect that a sample-size effect on diversity was operating.

The bottom line is that if game-animal resources were depressed, then we would expect to see a shift toward smaller prey. If domesticated-crop resources were depressed, then a shift toward more-diverse food sources, including larger game, becomes predictable. However, if domesticated crops were depressed because of wider environmental conditions unfavorable for irrigation agriculture (drought), then we would expect to see a similar decline in animal biomass across the landscape and increased selection of low-ranked prey. In this theoretically straightforward model, evidence of resource depression at the Mescal Wash site was most pronounced in the Middle Formative period, when populations were most dense and lower-ranked prey were most common.

Exploratory Analysis

I performed an independent analysis, in order to get a better look at the Mescal Wash data set at the landscape scale. To conduct the analysis, I combined all the faunal data reported by Szuter (1991), Dean (2007a), and Cannon (2000) into a Microsoft Excel spreadsheet and also added a couple of newly reported sites, such as those from SRI's U.S. 60 (Griffitts 2011) and Christiansen Wash (Griffitts 2009) projects. I also reorganized the Mescal Wash animal categories to more exactly fit Dean's hunting-strategy categories. Oddly, Dean did not include turtles, tortoises, or other likely small prey in her counts. In Chapter 8 of Volume 2, the authors took the reasonable step of including taxa that had been excluded by Dean, but in doing so, they possibly changed the playing field.[8] Furthermore, I omitted several sites that contained fewer than 100 rabbit and deer bones (NISP of lagomorphs + artiodactyls = <100), making my sample of 104 sites more robust than any published sample that has been applied to the problem.

The Relationship between Elevation and Time Period and the Artiodactyl Index

Figure 62 shows the artiodactyl index (NISP) in relation to elevation and time period. Separate linear regressions were calculated for each of three broad time periods: the Late Archaic/Early Agricultural/Early Formative period, the pre-Classic/Middle Formative period, and the Classic/Late Formative period. That analysis showed a strong correlation between elevation and the artiodactyl index during the Late Archaic/Early Agricultural period ($r^2 >$ 0.95), but the correlation declined to $r^2 = 0.06$ during the pre-Classic period and was also weak during the Classic period ($r^2 = 0.34$). I was a little amazed by that variability. What was apparent was that sites at elevations above 800 m AMSL had much greater variability in index values than sites located below 800 m AMSL, so that elevation seems to lose its predictive power for the –pre-Classic period. That is interesting, because if artiodactyl populations are held constant, it indicates that the activities structured around upland sites changed dramatically to include highly variable amounts of deer hunting. These results support Szuter's observation that elevation is not the dominant variable controlling animal-hunting strategies, but it limits that generalization to the pre-Classic and Classic periods.

The Mescal Wash site values lay close to the 1,100-m line and showed a predictable artiodactyl-index value for the Late Archaic/Early Agricultural period, a slightly higher-than-expected value for the Early/Early to Middle Formative period, lower-than-expected values for the Middle Formative period, and a return to a predictable value for the Late Formative period. Based on that pattern, large-game hunting was never that important at the Mescal Wash site compared to other sites. Furthermore, it was possibly suppressed during the Middle Formative period.

The Relationship between Evenness and Time

Figure 63 shows the inverse of Simpson's D calculated for the five "hunting strategies" developed by Dean (2007b) for individual sites or components in my data set, created using the Past paleontological statistics software package (available online at http://folk.uio.no/ohammer/past/, accessed July 9, 2016). Simpson's D is used by zooarchaeologists as a measure of evenness. The more evenly individuals (or specimens) are distributed across taxonomic categories, the larger the value of the index. Simpson's index is known as "D" because it is sensitive to dominance by a single taxon (Lyman 2008). The inverse of D is used to discuss evenness, because the lower the value, the more the assemblage is dominated by a single taxon or, in our case, a single hunting strategy. Because the proportion of artiodactyls in each sample heavily influenced this analysis, it grossly mimicked the artiodactyl index. Late Archaic/Early Agricultural period sites showed a stronger correlation between elevation and evenness than did pre-Classic/Formative period sites, but evenness increased in the Classic period.

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[8] My analysis showed the same U-shaped pattern in evenness values as theirs did.

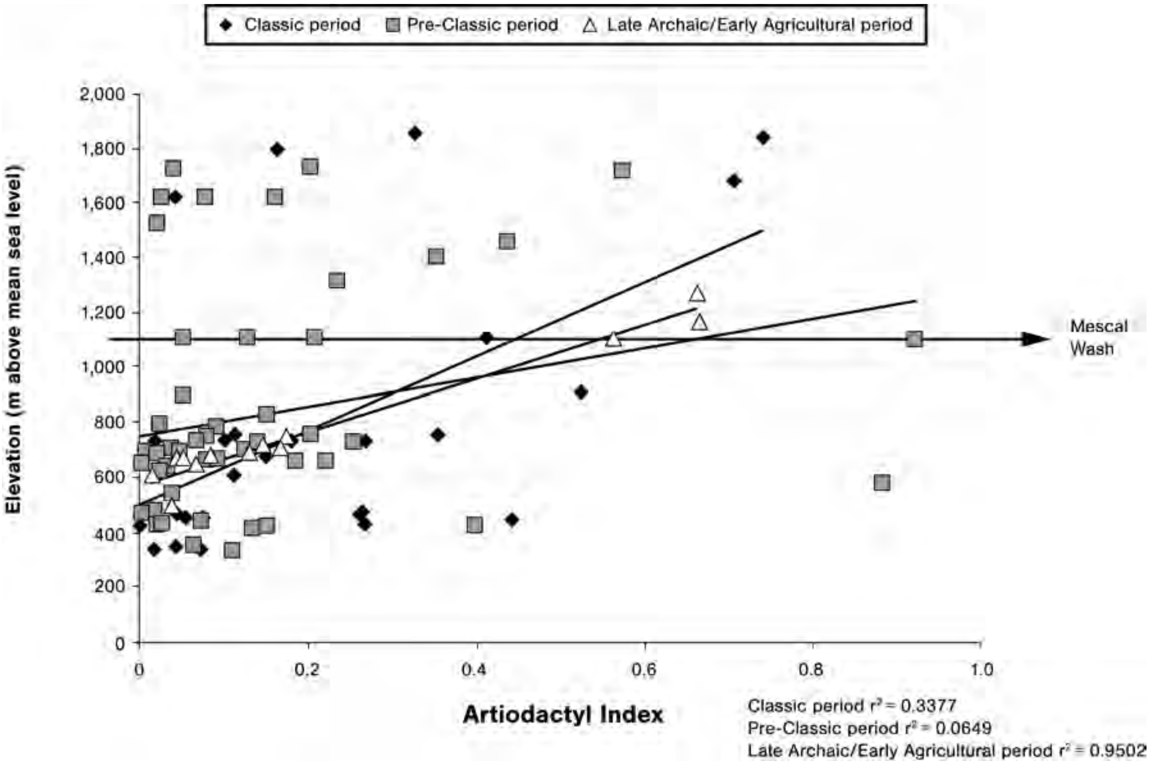

Figure 62. Chart of the artiodactyl index in relation to elevation for 104 Late Archaic to Classic period sites in Southern Arizona and New Mexico.

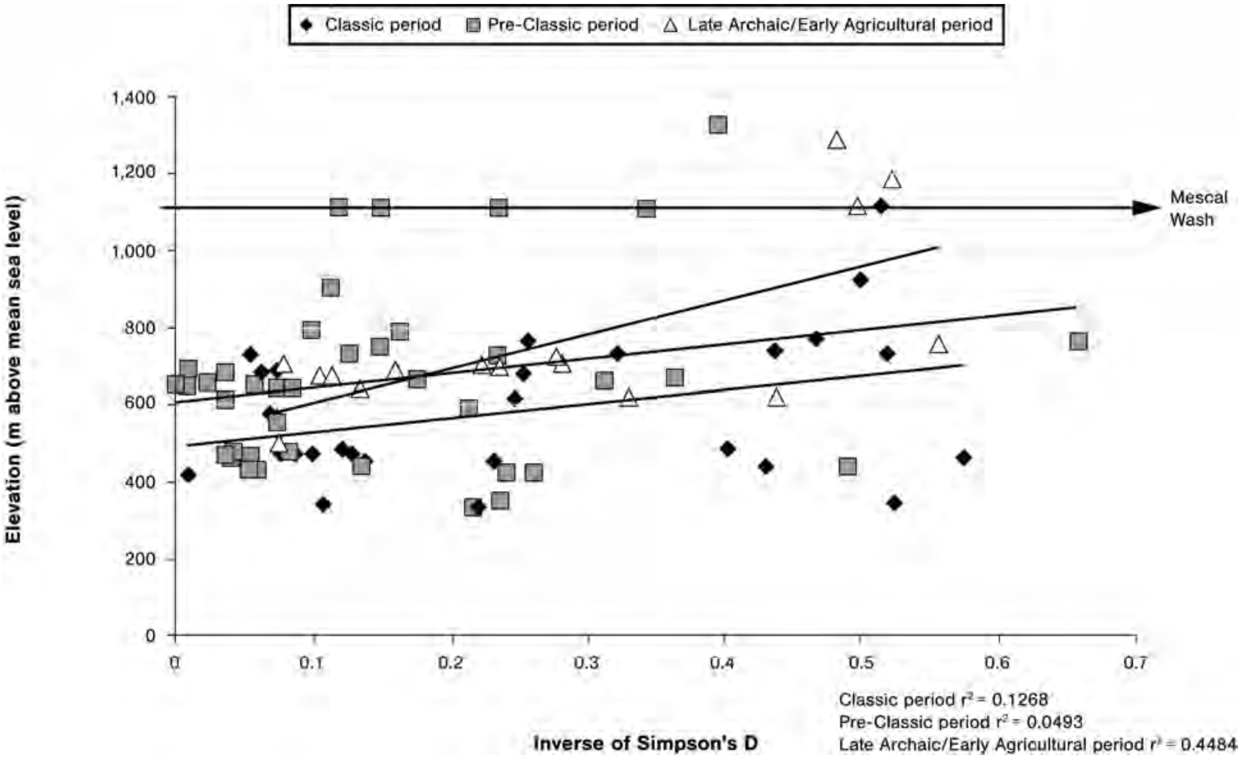

Figure 63. Chart of the evenness values in relation to elevation for Late Archaic to Classic period sites in Southeastern Arizona.

The Mescal Wash site data nearly covered the full range of evenness values. Although I made some important changes to more precisely follow Dean's analysis, the evenness values still showed a U-shaped pattern through time, and lower values occurred during the Early through Middle Formative A periods (Figure 64). The Early/Early to Middle Formative period was distinguished by a limited number of strategies focused on deer, whereas the Middle Formative and Middle Formative A periods were characterized by a limited number of strategies focused on small game. Evenness values increased in the Middle Formative B and Late Formative periods, which would seem to indicate that animal hunting was dominated by the fewest strategies and the least amount of high-ranked game during the Middle Formative A period.

Paleoenvironmental Considerations

The subsistence patterns identified in this analysis showed remarkable changes in animal use at the Mescal Wash site that obviously cannot be explained by elevation. However, climatic changes affecting animal populations pose a significant obstacle for arguments that implicate anthropogenic causes of resource depression. Sediment accumulation between A.D. 1200 and 1500 (see Chapter 2 of this volume) was indicative of wetter conditions during that time compared to the periods before and after. The A.D. 900–1200 interval correlates especially with the Middle Formative period, when human occupations not only persisted at the Mescal Wash site but also apparently expanded. Animal use during that period was characterized by low artiodactyl-index and evenness values, indicating emphasis on a few lower-ranked prey, such as rabbits and squirrels. At face value and without a more precise paleoenvironmental record,[9] the environmental evidence does not refute the interpretation that a shift away from higher-ranked prey tracks environmental productivity.

Chronology at the Mescal Wash Site Compared to the Chronologies of the Santa Cruz and San Pedro Valleys

Radiocarbon-frequency distributions are increasingly used as proxies for the relative abundance of prehistoric human populations (Buchanan et al. 2008; Gamble et al. 2005; Peros et al. 2010), based on the principle that as prehistoric populations increased or declined, so too did the strength of their archaeological signatures and the likelihood that a member of the population would be radiocarbon dated (Surovell and Brantingham 2007). Although sampling bias and taphonomic loss can significantly affect what has been preserved and subsequently sampled for radiocarbon dating (Ballenger and Mabry 2010), in this analysis, I treat the relative frequency distribution of archaeological radiocarbon dates as a measure of human presence.

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[9] Stable carbon- and oxygen-isotope ratios from the enamel of large- and small-herbivore teeth at the Mescal Wash site would be a significant contribution to the regional paleoenvironmental record and would further elucidate paleoenvironmental conditions as reflected in animal diets.

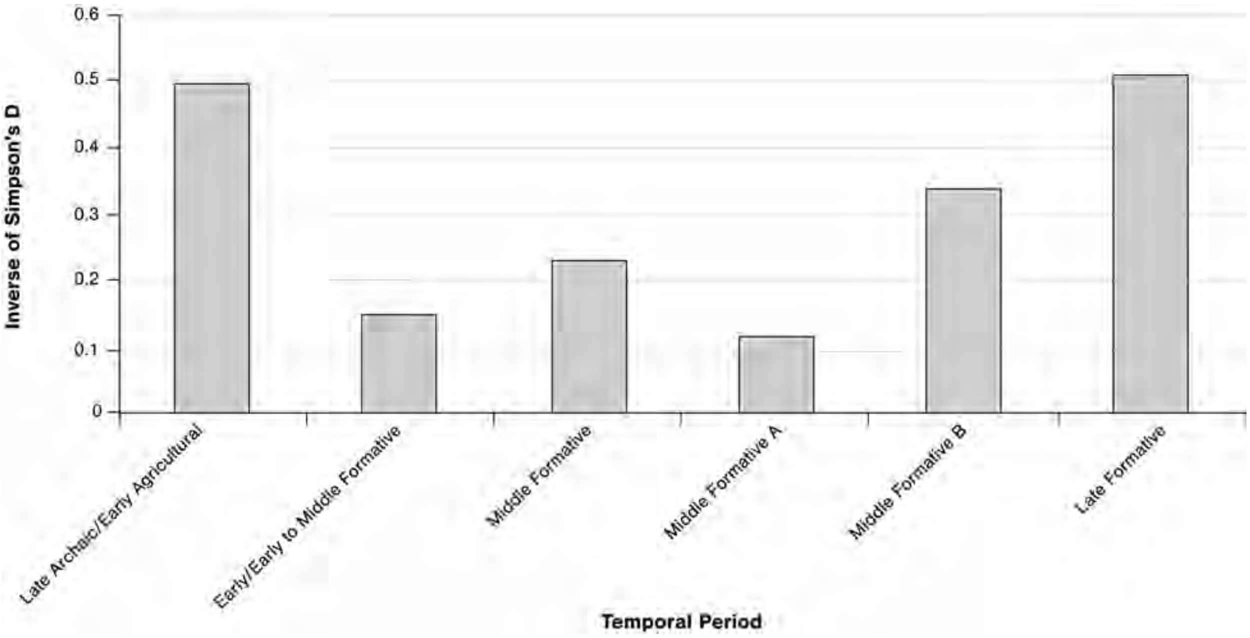

Figure 64. Chart of the evenness values for the Mescal Wash site (after Dean 2007b).

In light of the measurable, diachronic changes in animal use at the Mescal Wash site and their possible relationship to population pressure, it is useful to compare the radiocarbon chronology of Mescal Wash to the chronologies of adjacent river valleys. To do that, I compiled 109 radiocarbon dates from archaeological contexts in the San Pedro Valley and 323 archaeological radiocarbon dates from the Santa Cruz Valley. In addition to the published literature, those totals included all the radiocarbon dates contained in the index card catalog of C. Vance Haynes, Jr., several of which have been otherwise unreported in the literature. Therefore, we are comparing the Mescal Wash chronology to the largest archaeological ^{14}C data set compiled for the Southwest. To visualize the entire geochronological record from Mescal Wash, I included both radiocarbon and AM dates reported by Stacey Lengyel. Calibrated radiocarbon-frequency distributions were created using OxCal 3.10, based on the IntCal09 calibration curve (Reimer et al. 2009). I used Microsoft Excel to create a histogram of the AM dates, ordered in approximately 225-year time bins.

Figure 65 shows the radiocarbon-frequency distribution from the Mescal Wash site, and Figure 66 shows the histogram of AM dates from the Mescal Wash site. The shape of the radiocarbon-frequency distribution says more about the sampling strategy than it does about the intensity of human population at the site, but the AM dates showed a significant clustering of cultural features dated to about A.D. 800–1200. The AM data in Figure 65 are also depicted on the x axis of the radiocarbon-frequency distribution in Figure 66. Collectively, these data show an apparent hiatus in human occupation between about 400 B.C. and A.D. 100. No absolute dates occurred during that 500-year interval. A second possible hiatus occurred in approximately A.D. 1150–1300.

The radiocarbon-frequency distribution for the upper San Pedro Valley is shown in Figure 67a, and the radiocarbon-frequency distribution for the middle Santa Cruz Valley is shown in Figure 67b. Periods of human presence at the Mescal Wash site are indicated on each x axis. The Late Archaic/Early Agricultural period has been well represented in both valleys, and it correlates to the beginning of substantial human occupation at the Mescal Wash site. However, radiocarbon dates after that period, from about 400 B.C. to A.D. 100, have been essentially nonexistent in the San Pedro Valley and experienced a sharp decline in the Santa Cruz Valley, which is somewhat remarkable, because the Mescal Wash site chronology showed a hiatus at just that time. Radiocarbon dates increased slightly in both valleys after A.D. 200, but then went in opposite directions between A.D. 800 and 1200, when the San Pedro Valley had a large increase in dates and the Santa Cruz Valley had almost none. That interval correlates to the Middle Formative period, when human occupations were most intense at the Mescal Wash site.

In other words, large declines in radiocarbon dates occurred in the San Pedro Valley, Santa Cruz Valley, and Mescal Wash site chronologies at the end of the Late Archaic/Early Agricultural period. However, the Mescal Wash site demonstrated trends in human presence during the Middle Formative period that mirrored those in the San Pedro Valley rather than those in the Santa Cruz Valley. This makes one wonder whether the dense Middle Formative period population at the Mescal Wash site was related to a decline in riverine sites in the middle Santa Cruz Valley at that time. For that matter, was the increase in dates in the upper San Pedro Valley then also related to a decline in riverine sites in the middle Santa Cruz Valley? It is important to keep in mind, however, that the San Pedro Valley and Santa Cruz Valley dates were exclusively from alluvial deposits and did not include samples from sites located on Quaternary terraces and in the uplands. The trough in radiocarbon dates centered around A.D. 1100 in the Santa Cruz Valley occurred when, as better evidence has indicated, human population was high (Dean et al. 1994) and when widespread channel entrenchment appears to have brought about significant changes in Hohokam floodplain-farming practices and settlement (Waters and Ravesloot 2000).

These findings deserve more attention than they can be afforded here, but how the Mescal Wash site fits into the bigger picture of regional settlement patterns and possible resource depression must be partly explained by its chronology. What is needed to further evaluate the presence and absence of people across time and space in southeastern Arizona is a complete compilation of ^{14}C dates from upland and lowland sites. Such an analysis would probably show a much larger sample of pre-Classic period dates in the Santa Cruz Valley. If that were the case, then the Mescal Wash site might exemplify a large-scale shift in the use of non-riverine sites during the pre-Classic period in the Santa Cruz Valley—a shift in land use that may not have occurred in the upper San Pedro Valley, based on its limited sample of dates.

Discussion and Conclusions

In broad terms, the faunal data reported in Chapter 8 of Volume 2, showed nothing unusual, compared to other sites in the region, in terms of the species present.[10] What set the Mescal Wash site apart from other sites in my sample was the remarkable variation in the abundance of artiodactyls at the site through time.

This analysis bears upon the research theme of the Mescal Wash site as a persistent place and how that persistence played out in terms of local animal resources. Clearly, deer were pursued at the expense of rabbits during the Late Archaic/Early Agricultural and Late Formative periods, when the site experienced less intensive occupations. If local deer populations were highly sensitive to human predation, then obviously, we should expect to see

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[10] Except, perhaps, one turkey.

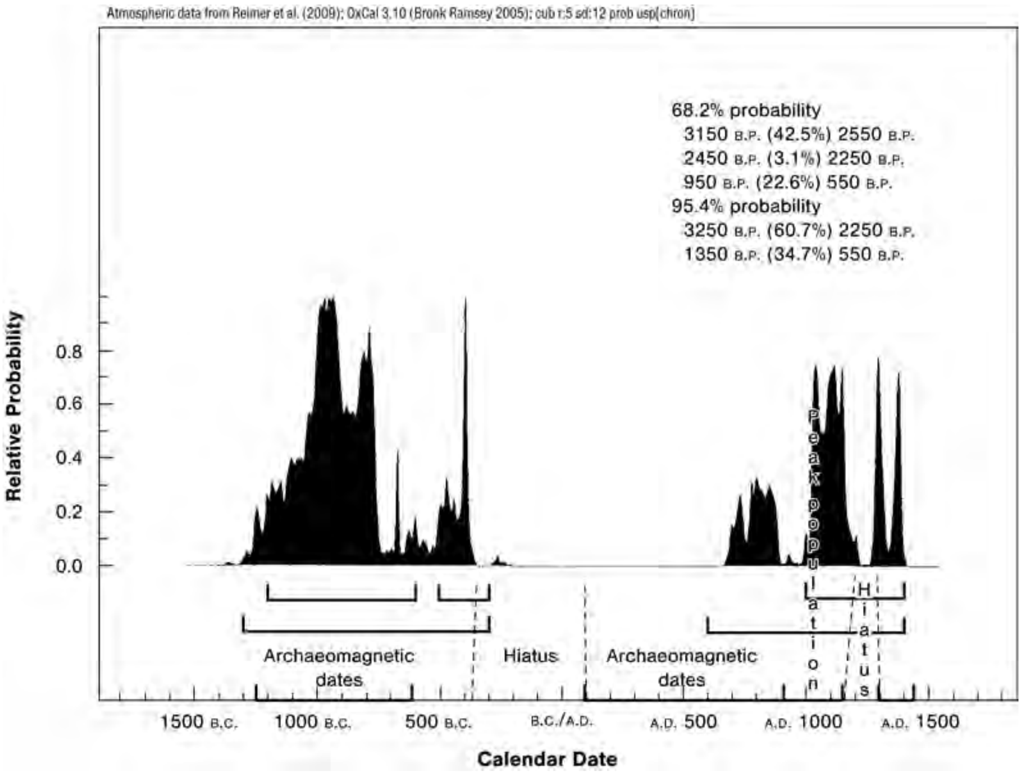

Figure 65. Chart of the radiocarbon-frequency distribution for the Mescal Wash site (*Note*: Time periods sampled according to archaeomagnetic dates are indicated on the x axis).

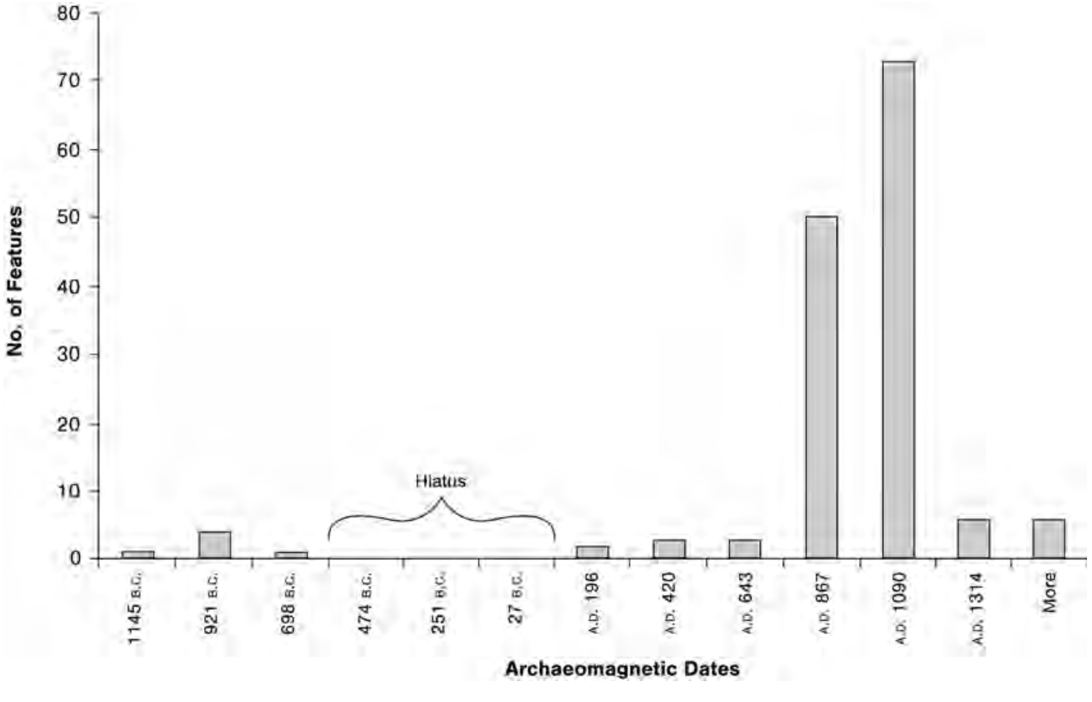

Figure 66. Histogram of archaeomagnetic dates from the Mescal Wash site, in approximately 225-year time bins.

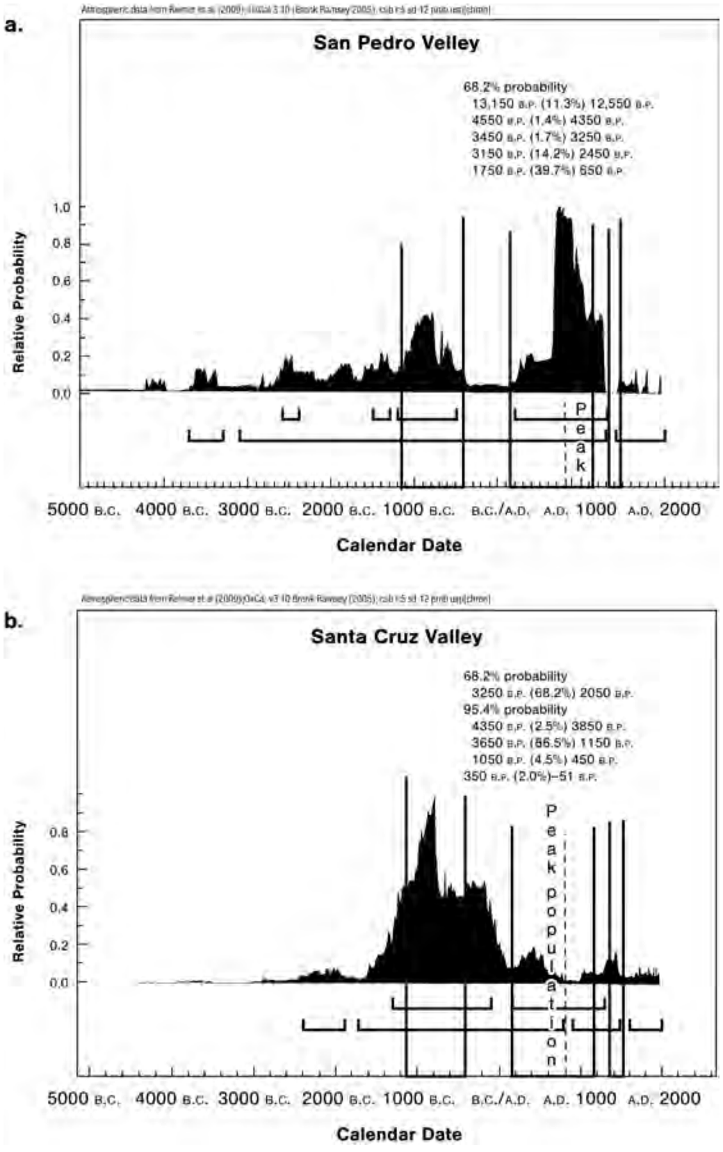

Figure 67. Charts of the radiocarbon-frequency distributions of (a) 109 archaeological radiocarbon dates from the upper San Pedro Valley and (b) 323 radiocarbon dates from the middle Santa Cruz Valley (Note: The Mescal Wash chronology is indicated on each x axis).

a decline in deer relative to smaller animals during the Middle Formative period, and we did. Large horticultural populations apparently did not lead to organized deer hunts but perhaps did increase human predation of small-animal communities around the site. Alternatively, it is possible that the relative changes in prey were simply reflections of the archaeofaunal nuances of residential vs. logistical mobility strategies, although that possibility seems unlikely, in light of important regularities throughout the occupational sequence, including houses, storage pits, and maize.

The occupational hiatus identified in the chronology makes the concept of a persistent place that much more interesting. Rather than focusing on the question of what makes a persistent place, it might be more rewarding to ask why people leave a persistent place. The 400 B.C.–A.D. 100 hiatus was duplicated in the San Pedro Valley and correlated to a sharp decline in dates in the Santa Cruz Valley, indicating that many persistent places on the floodplains were abandoned at that time. The A.D. 1150–1300 hiatus—corresponding to a period of drought in the region—occurred after a prolonged period of intensive human occupation and also correlated to a brief hiatus in the San Pedro Valley, but a more complete sample of radiocarbon dates is needed to fully evaluate those trends. The concept of *persistent place* and how it applies to the Mescal Wash site are discussed further in the next chapter.

CHAPTER 8

Connecting the Landscape: Persistent-Place Formation in Southeastern Arizona

Michael P. Heilen

Mescal Wash was the scene of repeated occupation over a period of several thousand years by various different cultures. Therefore, the site provides an ideal setting in which to examine processes of community development, particularly the concept of persistent places. Thus, identifying longevity as a key attribute of the site, the Marsh Station Archaeological Project (MSAP) research design (Altschul et al. 2000:5–14) centered on investigating the parameters of the ancient community at Mescal Wash. In essence, we wanted to understand the factors and processes that repeatedly drew people from diverse backgrounds to this locale. We also postulated that Mescal Wash was an example in southeastern Arizona of what Schlanger (1992:97) has labeled "persistent places" in Anasazi history, a concept she developed to interpret Anasazi sites and settlement patterns in the Dolores region. Schlanger (1992) linked the formation of persistent places to regional shifts in settlement patterns and correlated Anasazi persistent places to areas of enhanced landscape connectivity and resource abundance. As will be shown in this chapter, a similar situation obtains for Mescal Wash.

Chapter Organization

In order to better understand Mescal Wash as a persistent place, this chapter investigates the formation of such places in southeastern Arizona. Basic questions addressed by this chapter are (1) How rare are persistent places? (2) What kinds of sites were used persistently? (3) How are they distributed in time and space? (4) What are some of the factors contributing to their formation? and (5) How does Mescal Wash compare with other persistent places? These questions are addressed in several interrelated ways.

First, I discuss how persistent places fit within a landscape context; discuss the behavioral, ecological, and geographic factors that likely led to their formation; and define three distinct types of persistent places, based on the temporal and spatial scales at which they were used, the ways in which they were situated within landscape networks, and environmental and cultural factors that focus land use in particular ecological and geographic settings rather than others. I then present a formal model developed to estimate the expected number of persistent places based on probabilities of place reuse and the number of foundational places. The formal model helps to place our numbers in context, in comparison to what we might expect in a behaviorally neutral context. That is, the formal model estimates the number of persistent places we might expect if the reuse of a place was spatially random and was dependent only on the number of foundational places and rates of place reuse.

This analysis shows that at the scale of the archaeological phase, the formal model closely predicts the observed number of persistent places and helps to explain a paradox identified in the Hohokam data. Why did persistent-place formation increase during the Hohokam Classic period, when other indicators of network formation and change suggest overall collapse of the network? It is shown that at a purely quantitative level, elevated proportions of Classic period persistent places are expected, given the extraordinarily large founding set of places on which they are based. In other words, because the Hohokam landscape network was rapidly expanding during the Middle Formative period, when many new sites were formed, there was a very large number of sites available for reuse during the Late Formative (i.e., Classic) period, even though at the same time, abandonment was happening at a huge scale.

Despite strong evidence of discontinuity in subsistence, settlement, and social organization between the pre-Classic and Classic periods, it is argued in this chapter that a kind of continuity in place use is evident between the pre-Classic and Classic periods. As in the Anasazi case, Classic period persistent-place formation appears to have been tied to broad-scale shifts in settlement pattern and regional abandonment. Moreover, it is argued that social, spatial, and temporal scales of place formation, reuse, and abandonment likely varied among archaeological phases. Rillito and Rincon phase settlement appears to have been tied to frequent, fine-scale, household-level shifts in the locations of farmsteads or hamlets. Tanque Verde phase settlement appears to have been tied to intermediate-scale, community-level shifts in the locations of hamlets or community settlements. Tucson phase settlement appears to have been tied to broad-scale shifts in the locations of settlement systems, involving the abandonment of many locales in upper, middle, and lower Santa Cruz Valley and the formation of new, syncretic settlements in lower San Pedro Valley.

In order to assess the effect of discovery bias on our results, I also analyze the chronological distribution of Hohokam-affiliated places based on discovery methods. The data clearly show that the further one goes back in time, the more likely the case that a component was discovered as a result of subsurface investigations, as opposed to surface investigations. This presents a problem for interpretation, but not one that is easily resolved without additional fieldwork.

At the scale of archaeological periods, persistent places are consistently observed less often than predicted when the observed number of persistent places is compared to formal-model predictions, according to watershed. Consistently lower observed-versus-expected results for much of the study area suggest methodological bias in the discovery of some archaeological components. A variety of relationships between frequencies and proportions of temporal components are identified for sets of watersheds. When taken as a whole, these relationships suggest that the discovery of Archaic period and historical-period components is partly a consequence of the discovery of Formative period components. The existence of these relationships suggests commonalities between watersheds in the operation of a variety of cultural and environmental formation processes. Consistently an outlier, the middle San Pedro Valley is identified as distinctive in the formation of Archaic period, Formative period, and historical-period places.

Because of its unique location, Mescal Wash is also modeled as an edge or frontier place that may have served to connect people from different parts of southeastern Arizona, southwestern New Mexico, and northern Mexico. Mescal Wash is evaluated in two ways: (1) at a purely physiographic level and (2) according to affiliations and interactions among local ceramic traditions. At a purely physiographic level, landscape connectivity is assessed by estimating least-cost pathways between different portions of the study area. As an independent frame of reference, least-cost pathways support the hypothesis that the lower Cienega Creek valley, including places like Mescal Wash, served to connect middle Santa Cruz Valley with middle San Pedro Valley. Further, broad-scale patterns in least-cost paths traversing the study area suggest the potential existence of culturally distinctive transportation corridors that conform to patterns of cultural connectivity established through examination of the distribution of ceramic traditions.

At a more behavioral or technological level, different ceramic traditions are modeled as landscape-network components, with patterns of co-occurrence used as proxies for social or economic connections among the suppliers and users of ceramic vessels from different ceramic traditions. Patterns in the co-occurrence of ceramic artifacts from different ceramic traditions at individual sites are used to identify three major ceramic aspects occupying distinct zones of the study area: a Hohokam aspect, a Sonoran aspect, and a Mogollon aspect. Surprisingly, Mescal Wash is located at the intersection of all three ceramic aspects, suggesting that the site was located at an especially unique frontier zone for the region.

Finally, patterns revealed by these complimentary analyses are discussed. We can now estimate that for the study area, persistent places are uncommon at the level of phase, rare at the level of period, and exceedingly rare at the levels of both phase and period combined. Moreover, discovery bias plays a decided role in obscuring the signature of persistent-place formation. In all cases, observed numbers of persistent places underestimate true number of cases because of methodological bias and reporting errors. Discrepancies between these results and properties of archaeological landscapes should give archaeologists pause, because they implicate widespread, uncontrolled inconsistencies in archaeological recording, reporting, and data entry, along with biases introduced by discovery methods. Nonetheless, these analyses quantify broad-scale settlement trends using the available data set and reveal some interesting long-term patterns in the settlement of southeastern Arizona.

Landscapes and the Archaeological Record

The archaeological record is many steps removed from past behaviors. Static patterns observed in archaeological context are not direct reflections of dynamic systemic processes. Systemic processes, such as land use, and systemic entities, such as places, must be inferred from archaeological context data (Binford 1980; Schiffer 1972, 1987).

A useful approach to interpreting the archaeological record is to model land use in terms of places, landscapes, and the relationships among them (Binford 1982; Chang

1992; Heilen 2005a; Kuhn 1995, 2004; Schlanger 1992; Stafford 1994, 1995; Stafford and Hajic 1992; Whittlesey 1998b, 2004a; Zedeño 1997, 2000; Zedeño and Stoffle 2003). In constructing a theoretical framework for landscape archaeology, Heilen (2005a) made a fundamental distinction between archaeological landscapes and systemic landscapes. *Archaeological landscapes* consist of materials and patterns observed in archaeological context: artifacts, features, deposits, and sites. *Systemic landscapes* are networks of interactions, activities, people, and places connected through the exchange of matter, energy, and information. A common problem in the archaeological study of landscapes is the conflation of archaeological and systemic contexts. Archaeological landscapes are not equivalent to systemic landscapes. Instead, archaeological and systemic contexts are related to each other through the transformative effects of formation processes. Relationships between archaeological and systemic contexts can only be understood through careful development of material correlates and middle-range theory (Schiffer 1972, 1983, 1987; Reid 1985).

One place-use model that has particular relevance to interpreting Mescal Wash is the persistent-place model (Schlanger 1992). Mescal Wash hosted both transient and more-permanent occupations. Mescal Wash was used intermittently from the Archaic period through the historical period and was also the focus of repeated occupation from the Late Archaic period through much of the Formative period sequence. Historical-period use of Mescal Wash is evidenced by several linear sites crossing through its boundaries (see Volume 1, Appendix D). So, Mescal Wash was probably not a single place through time but many places to many people (Vanderpot and Altschul 2007:51). At Mescal Wash, numerous analyses suggest that the site was repeatedly reoccupied at different occupational intensities and durations through time and that its inhabitants likely had different settlement and subsistence goals (see Volume 2). Different systemic places likely converged on the same archaeological site over time. How Mescal Wash was used and how it related to other places also changed dynamically over time.

The relationships between persistent places and archaeological sites can be complex and intricate, requiring consideration of the interplay among place use, cultural deposition, and formation processes. Is a foraging camp visited periodically for hundreds of years the same as a small village continuously occupied during the same time period? Is a spring repeatedly visited by members of many different communities the same as a shrine repeatedly visited and maintained by one community? Archaeologically, these kinds of sites could appear similar, but in terms of the behaviors that created them, they are quite different. Arguably, all are persistent places of one kind or another, and all could converge on the same archaeological site. In many archaeological contexts, it can be difficult to distinguish clearly and objectively between different kinds of places and place uses, let alone specific time frames and intensities of place use.

Defining Persistent Places

To some archaeologists, the terminology of the persistent-place model could be interpreted to mean long-term, continuous occupation or occupational stability (sensu Horne 1993), but that is not how Schlanger (1992) envisioned persistent places. Schlanger developed her model as an explanation for why some places are repeatedly reused over long time periods and other places are not. To Schlanger (1992:92), a persistent place is "a place that is used repeatedly during the long-term occupation of a region." Schlanger (1992:92) envisions persistent places as the foci of "repeated abandonments and reoccupations," not as the continuous, uninterrupted occupations that the term seems to imply.

Schlanger (1992:97) emphasized that persistent places "are neither strictly sites (that is, concentrations of cultural materials) nor simply features of a landscape. Instead they represent the conjunction of particular human behaviors on a particular landscape." Persistent places are components of systemic landscapes. They do not have to be residentially occupied to be persistent; they merely have to be used. Nor do such places have to serve a singular function. Their function can change over time, including serving as seasonal or long-term residential locales at some times and camps or resource areas at other times.

Schlanger hypothesized that persistent places form as a result of cultural or environmental attributes of places or both. Schlanger (1992:97) identified three different sets of characteristics linked to their formation: (1) places with unique environmental qualities or attributes (the presence of springs, open marshland, good farmland, or vantage points), (2) places with existing facilities (such as hearths, shelters, or storage) that can be reused, and (3) places with existing cultural materials, such as stockpiled raw materials or ground stone tools that can be reincorporated into systemic context through processes of reclamation, recycling, and reuse.

An alternate reading of Schlanger's (1992) model suggests that persistent places emerge for two reasons. As nodes in systemic landscape networks, persistent places offer abundant resources, high connectivity to other places, or both. Some places have an *abundance of resources*, whether naturally occurring or culturally provisioned (see Kuhn 1995, 2004), and other places are connective, offering *enhanced access to resources*. Theoretically, users of abundantly accommodated places should get more product—such as raw or recyclable materials, water, arable land, economic plants, and reusable tools and facilities—at a lower expense. Place users should spend less—in energy, time, material, or some other currency—to provision themselves at places that are abundantly accommodated, as opposed to those that are not. All other things being equal, a least-effort place user would favor the use of places with abundant resources over the use of places where few resources are immediately available. Connective places—such as canyon mouths, ecological edges, corridor intersections, or mountain passes—enhance access to other useful places or resource zones. All other things being equal, a least-effort place user would favor the use of places that are highly connected to other useful places.

Importantly, Schlanger suggested that functional shifts are likely to occur in the formation of persistent places. Schlanger's (1992:107) persistent-place model is basically a "settlement shift model" that anticipates functional shifts in place use as a settlement system moves and reorganizes across a landscape. Specifically, the settlement-shift model anticipates that "persistent places should be used as camps for hunting, collecting, and possibly some farming in an area at a distance from residential bases" (Schlanger 1992:107). Following Binford (1982), Schlanger suggested that over the course of major settlement change, logistically used camps, which Schlanger equated archaeologically with limited-activity or special-purpose loci, are likely to remain in use as special-purpose camps. Seasonal and habitational loci, however, she suggested will shift in function as settlement systems shift across landscapes. According to Schlanger's view, persistent places tend to form at former residential places that later become peripheral, short-term camps in logistically organized, mixed, foraging-and-farming economies. That is partly because people know about them and their attributes but also because they may retain facilities or accommodations—such as tools, raw materials, and abandoned features—that remain beneficial to short-term place use.

Network Models of Persistent Places

Schlanger (1992) presents a compelling and interesting case for persistent-place formation in the Dolores region, but it is likely that a variety of additional factors could lead to persistent-place formation in other contexts, some of which involve settlement shifts and some of which do not. Further, factors that contribute to persistent-place formation likely vary according to environmental characteristics, such as distributions of resources and physiographic landscape structure, as well as by cultural characteristics, such as subsistence strategies and social organization. Below, we reformulate persistent places as nodes in systemic landscape networks and argue that they can form according to a variety of different scenarios. Like Schlanger (1992), we define persistent places according to very basic archaeological criteria: the presence or absence of temporally diagnostic materials.

As in wayfinding (Golledge 2003), place use may be satisficing rather than optimizing. People may not require the optimal place for a given task and instead use places that are good enough to satisfy their anticipated needs. At least in the short term, places are parts of existing knowledge systems or cognized landscape networks. As such, places function not only in terms of what they can objectively "do" or "provide" but in terms of how people think about them and think to use them. As landscape elements, places are "good to think" and are cognitively constructed according to the subjective perception of landscape attributes and individual or household-level wants and needs (Whittlesey 2004a). One obvious reason why people reuse places is simply because they know about them and recognize them as elements of cognized landscapes (Ashmore 2002). People know where places are in space, how to get to them, how to get to other places from them, and how to make use of them (Heilen 2005a). Below, the persistent-place model is integrated with a landscape-network model, and three different kinds of persistent places are operationally defined and discussed: persistent-place Types I–III.

Type I Persistent Places

A *Type I persistent place* is a place that is repeatedly reused, but not necessarily occupied or inhabited, for most or all of the life span of the systemic landscape network in which it participates. Such a place can accumulate a high number of connections to other places or activities because of long-term participation in an evolving landscape network. As more places in a landscape network are added and lost, new connections may preferentially attach to more persistent places, increasing their connectivity and furthering their persistence.

The physical geometry of landscape networks and the availability of resources at any particular place likely constrain the use of any particular place, however. For instance, a place that was established early but has depleted resources and is distant from other emerging places may be more likely to be abandoned in the long term. In contrast, a place that is central to many places or that has abundant or renewable resources may be more likely to be reused and, hence, persistent. A potential corollary of this model is that places that are used continuously and intensively, such as some "permanent" residential locales, may need to be abandoned because of environmental degradation or resource depletion on time scales that preclude or diminish persistent-place formation. Counterintuitively, places that are used repeatedly and redundantly, but not necessarily continuously or intensively, could be more likely to be used over long time scales.

For Type I persistent places, the functions, use intensity, and importance of persistent places can shift through time, but participation in an overarching behavioral system is assumed to be continuous. We might expect that at any point in time, place function and use intensity will vary, in part, according to *when* a place entered a landscape network, *how* it functioned in the past, and *how* it relates to other places. Presumably, the formation of Type I persistent places is influenced by culture history to a greater degree than the formation of Type II persistent places.

Type II Persistent Places

A *Type* II *persistent place* is a place that is reused across time as a part of different, disjunctive and unrelated, landscape networks. Type II persistent places emerge repeatedly in different landscape networks because of the intrinsic or provisioned properties of locales rather than network structures related to a particular behavioral system. As discussed above, the spatial configuration of physiographic and ecological landscape attributes may focus activities in some areas instead of others. The spatial configuration of a landscape has the capacity to exert hierarchical controls on the topology of systemic landscape networks (Heilen 2005a). In other words, if key resources are concentrated in some locales as opposed to others, a landscape network will be structured in such a way as to enhance access to those resources. Major confluences in drainage systems; major landscape constrictions, such as canyons or passes; or edges separating multiple ecological zones may provide greater access to fundamental resources, such as surface water, transportation routes, or diverse plant and animal foods (Schlanger 1992; Vanderpot and Altschul 2007). The distribution of such basic resources is extrinsic to (exists independently of) a particular behavioral system and instead stems mostly from how the physical landscape is structured.

Type II persistent places may form independently of culture history. A similar concept as the one described above is Horne's (1993) concept of *locational stability*. Locations that are repeatedly reused because of their environmental attributes, such as springs, are locationally stable. By contrast, locations that are used continuously for long time periods, as in uninterrupted residential use, are *occupationally stable*. Importantly, Horne (1993:43) (*emphasis added*) observed that an "occupationally unstable area may present a shifting scene of people and activities against a background of *continuity of location*." Of course, a site's use history can reflect both locational stability and occupational stability during different periods of its use, which is a situation that obtained for Mescal Wash.

Type III Persistent Places

A *Type III persistent place* is a place that is used as part of multiple, long-lived, contemporaneous networks. Type III persistent places participate synchronically or diachronically in multiple, intersecting, contemporaneous landscape networks. Type III persistent places are expected to occur most often near the geographic limits of behavioral systems or landscape networks. The use of such places may occur according to a variety of different modes, involving behaviors such as scheduling and avoidance, ethnic coresidence, competition, or aggression (Downum and Stone 2000; Stone and Downum 1999; Reid and Whittlesey 1997, 1999). Persistent places of this type are parts of multiple co-occurring systems and have broad spatial reach or connectivity but do not necessarily possess the longevity implied by Type I and Type II persistent places. Type III persistent places constitute weak (but not insignificant) connections between distinct landscape networks or network components. As such, Type III persistent places allow the temporary formation of giant regional or meta-regional landscape networks by connecting multiple smaller landscape networks. Though easily separated into smaller networks by the elimination of a few Type III persistent places, giant networks could funnel the transmission of matter, energy, and information across vast spaces, connecting behavioral systems that crosscut major cultural and geographic boundaries. Insofar as current archaeological traditions approximate behavioral systems, Type III persistent places may form temporary but important nodes of cultural transmission and exchange.

Mescal Wash as a Persistent Place

Exactly how people think of particular places changes over time. That places remain parts of cognitive landscapes, however, allows them to be differentially available for use, reuse, and abandonment processes (Crumley 1999). We can expect that Type I persistent places have this kind of continually cognized quality over the long term. Type II and Type III persistent places, by contrast, are not necessarily parts of the same knowledge systems or cognized landscape networks. Instead, Type II persistent places may be places that are repeatedly recreated or forgotten because they are good enough for a variety of activities. If we do not assume social or phylogenetic continuity in place use or cognition, Type II persistent places are reused over the long term, not because they are part of an existing, cognized network of places, but because they are broadly satisficing. Because some places contain attributes such as reliable water sources, landscape connectivity, or visibility, these places may have a general functionality that is useful to agents in many different temporally discontinuous landscape networks. More than likely, the specific, historical reasons for recurrent place formation will vary over time.

As will be shown in this chapter, Mescal Wash functioned as a Type I, Type II, and Type III persistent place, making it especially unique, even among persistent places. Mescal Wash has evidence of use throughout much of the Formative period, appearing to be a place that was repeatedly reused by people affiliated with the Hohokam ceramic tradition. At a broader temporal scale, Mescal Wash has evidence of use during the Archaic, Formative, and historical periods, indicating that the locale repeatedly attracted users who participated in a variety of disparate land-use systems. Further, the geographic distribution and landscape connectivity of Formative period ceramic traditions (discussed below) suggest that Mescal Wash occurred at the edge of three separate ceramic traditions and could have functioned as a Type III persistent place, operating as a kind of edge place that connected multiple cultural groups in southeastern Arizona.

Operational Definitions

Processes of site formation, reuse, and abandonment can be studied at a variety of behavioral, temporal, and spatial scales (Fish and Fish 1993). They are also complex processes that can occur according to a variety of different trajectories. Archaeologists increasingly recognize the value of understanding reuse and abandonment across multiple scales, from features to individual sites, to regions (Tomka and Stevenson 1993). Further, abandonment and reuse processes often involve changes in function over time (Nelson and Hegmon 2001; Schlanger 1992). Large-scale abandonments, for instance, are often framed as evidence of collapses or disasters, but in many cases, "abandoned settlements are the outcome of a land-use strategy, not the product of failure" (Nelson and Hegmon 2001:213).

Archaeologists may be interested in studying reuse and abandonment processes at relatively fine scales, but archaeological data are often only available at much coarser scales. We might want to study reuse and abandonment at the scale of seasons, years, or human generations, but in many cases, we have only fuzzy temporal markers that allow us to study reuse and abandonment at the scale of centuries or millennia. For the Dolores study area in the Anasazi region (Robinson et al. 1986), Schlanger (1992) operationally defined persistent places as multicomponent sites. Because of the relatively coarse nature of the settlement data available for her study, Schlanger was only able to identify early and late components. Thus, Schlanger's persistent places are sites with both pre- and post-A.D. 900 temporal components. Out of a total of 377 identified prehistoric sites, Schlanger identified 31 multicomponent sites, or persistent places (8.2 percent).

Because of the complicated nature of the archaeological record and the infancy of methods and theory for inferring systemic places, landscapes, and the relationships among them, we also advocate a conservative approach to inferring the chronology of place use. Like Schlanger's (1992), the approach taken in this chapter gives individual traits or attributes equal weight and does not grade the importance or weight of different archaeological elements. That is not to say that factors such as abundance and context are unimportant but merely that the recording of these kinds of site attributes is so variable in the current data set as to render them meaningless or methodologically unwieldy at the scale of the current analysis. The basic assumption of this chapter is this: the presence of materials dating to a particular phase or period signifies the occurrence of at least one place in that location at some time during the specified interval.

Persistent places are defined in this chapter as *repeatedly* reoccupied. Here, we operationally define persistent places as sites that minimally possess three or more temporally contiguous components (e.g., Rillito, Rincon, and Tanque Verde). Sites that have only two temporally contiguous components are labelled as "reused" (rather than persistent) places. Sites that have one or more contiguous temporal components but lack the next contiguous component in a temporal sequence are identified as "abandoned" during the phase or period from which they lack evidence of use. A place that was abandoned during a previous period or phase but used again during a subsequent one is defined for that period as "recycled."

The definitions of *reuse*, *abandonment*, and *persistent-place formation* as used herein are at the temporal scale of the phase or period. Again, particular site functions, such as habitation, are not required or assumed in order to determine reuse or abandonment. Rather, we only require the presence or absence of temporally diagnostic materials. Other authors conceptualize reuse and abandonment according to more specific criteria. For instance, Fish and Fish (1993:99) defined abandonment exclusively in terms of substantial residential use, as "the absence or near absence of evidence of habitation of appreciable magnitude or duration in a locus of previous occupation." Because we are not requiring that places be inhabited residentially in order to be used, it is necessary to relax the definition of abandonment, as well. Still, it should be noted that the definition of *reuse* used here is not as broad as the one posited for the spiritual or cognitive reuse of archaeological sites by modern Native American groups (see, for example, Colwell-Chanthaphonh and Ferguson [2006]). In this chapter's approach, we require material archaeological evidence for site use or reuse to be identified. Operationally, abandonment is identified for a period or phase if there is material evidence of site use during the preceding period or phase but no material evidence for site use during the period or phase in question.

Sites that recur in different noncontiguous time periods are conceptualized as "recycled," rather than reused. For the Tucson Basin Hohokam network, we define *reused*, *abandoned*, *recycled*, and *persistent places* at the level of the phase and according to the presence or absence of temporally diagnostic Hohokam ceramic types. At a much coarser scale, in order to evaluate the formation of Type II persistent places, we define *reused*, *abandoned*, *recycled*, and *persistent places* at the level of the period and according to the presence or absence of artifacts or components diagnostic of the Archaic, Formative, and historical periods.

Caveats and Methodological Concerns

The following analyses are based largely on AZSITE data. These data were accessed in 2005, and additional sites and projects have been added to the database since that time. The study area covers 120 USGS 7.5-minute quadrangles, or approximately 19,631 km^2, and includes 9,869 sites distributed in several major watersheds. The study area includes project areas from 2,965 projects. Together, the surveyed areas cover a total of 2,762 km^2, or 14 percent of the study area (Figure 68). If we remove historical-period sites recorded from historical maps, there are 5,676 archaeologically discovered sites in the study area, amounting to an average discovery rate of 2.05 sites per square kilometer (Figure 69). Most projects are confined to valley bottoms. Projects are rare in upland zones. Large projects occur in most watersheds, but the most intensive investigation is centered in the Tucson Basin.

AZSITE data are the result of many different investigations conducted at different times by different personnel, using survey and recording techniques designed to address differing research goals. The data used for this study were entered into AZSITE by many different people with different backgrounds and different relationships to the data. Inconsistencies in AZSITE data result from problems that can occur at virtually any location along the data chain. Attempts are made in this study to control for and minimize problems with AZSITE data by carefully constructing logical and standardized analytical categories. The only way to completely correct for problems with AZSITE data is to resurvey, reexcavate, rerecord, and reenter all the data according to standardized, quality-controlled methods. Obviously, correcting many problems with AZSITE data is not feasible.

It seems a pity that the tremendous archaeological and behavioral variation confronted by archaeological inquiry should be compounded by uncontrolled variation introduced into the data by archaeologists. Aside from data corrupted by transcription errors, the data in AZSITE are the site data that investigators officially report to the Arizona Site Files Office, and ultimately, AZSITE data are the official data against which other sites are compared. Because of archaeologist-introduced variation in the site data, we must approach the problem of using AZSITE data carefully and with limited assumptions, acknowledging the fact that "the behavior of the archaeologist" could be a major influence on a lot of patterning, or lack thereof, in the current data set (Mathers et al. 2005; Schiffer 1987).

AZSITE data can be wrong or misleading in many different ways. Site sizes, shapes, and locations can be recorded according to different methods, and a wide range of mistakes can be made in how they are entered onto site cards and maps. Site attributes can be briefly summarized or highly detailed. Entries of diagnostic artifacts and features can range from exhaustive to minimally informative and may take place according to different typologies and assumptions.

Our informal impression is that many investigators who attempt to use AZSITE data for research purposes quickly become suspicious of the reliability of the data. A common refrain is that archaeologists using AZSITE will need to refer to the original site cards in order to rectify known problems. Such recourse is laudable but does not eliminate sources of error and inconsistency that originate elsewhere in the data chain. Further, the need to recheck and supplement the data using primary materials eliminates much of the usefulness of having a database. For analyses involving large study areas, the amount of labor and time involved in adequately "correcting" AZSITE data can be a task of monumental proportions.

In our case, we are interested in evaluating Mescal Wash in terms of broadly scaled archaeological variability. We want to know whether Mescal Wash, as a persistent place, is different from other sites in several adjoining watersheds. How rare are persistent places? Does this distinction contribute to the overall significance or interpretation of Mescal Wash?

One of the biggest problems with AZSITE data is a lack of consistency in entering relevant data, such as the presence or absence of ceramic types, feature types, and site components. As a result, the number of sites with any particular type—whether it be an artifact, feature, or component type—will almost always be an underestimation. Dredging AZSITE data for a particular category of site—such as all sites with Rillito, Rincon, and Tanque Verde phase ceramics—may result in a majority of the targeted sites, but it will almost always result in fewer cases than have been discovered archaeologically. Attempting to correct for these kinds of problems ad hoc by selectively adding known cases has the potential to corrupt the data further than they already are and to distort patterns that necessarily are already distorted. This analysis does not purport to reveal all the recorded sites that have a common attribute, such as possessing a certain set of ceramic types. Such a situation is not possible without more-consistent recording, reporting, and entering of data into AZSITE.

Another problem is that this analysis is based on the AZSITE data set as of October 2005 and will not include site data entered into AZSITE after that date. There may be sites from large, important projects, such as in areas of San Pedro Valley, that have yet to be entered into AZSITE. There are also some areas, such as the San Xavier reach of the southern Tucson Basin (Doelle and Wallace 1986), that have been selectively removed from the database because of cultural sensitivity and competing jurisdictions. These are real factors that potentially complicate analysis and interpretation of the data set, but again, these problems cannot pragmatically be controlled for by attempting to correct the data by going back to thousands of site cards and project reports or hounding investigators for

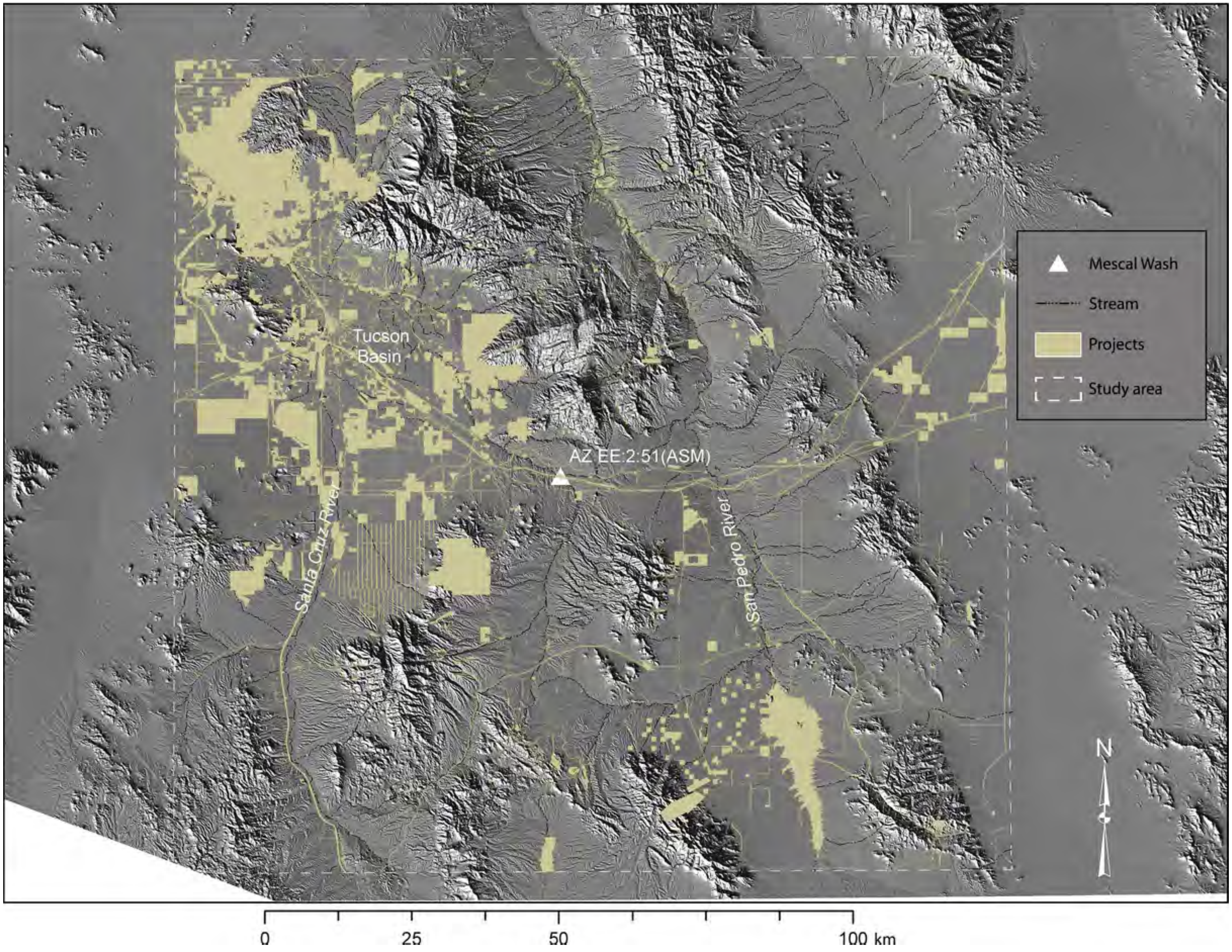

Figure 68. Map showing the locations of projects recorded in the Arizona Archaeological Site and Survey Database as of October 2005.

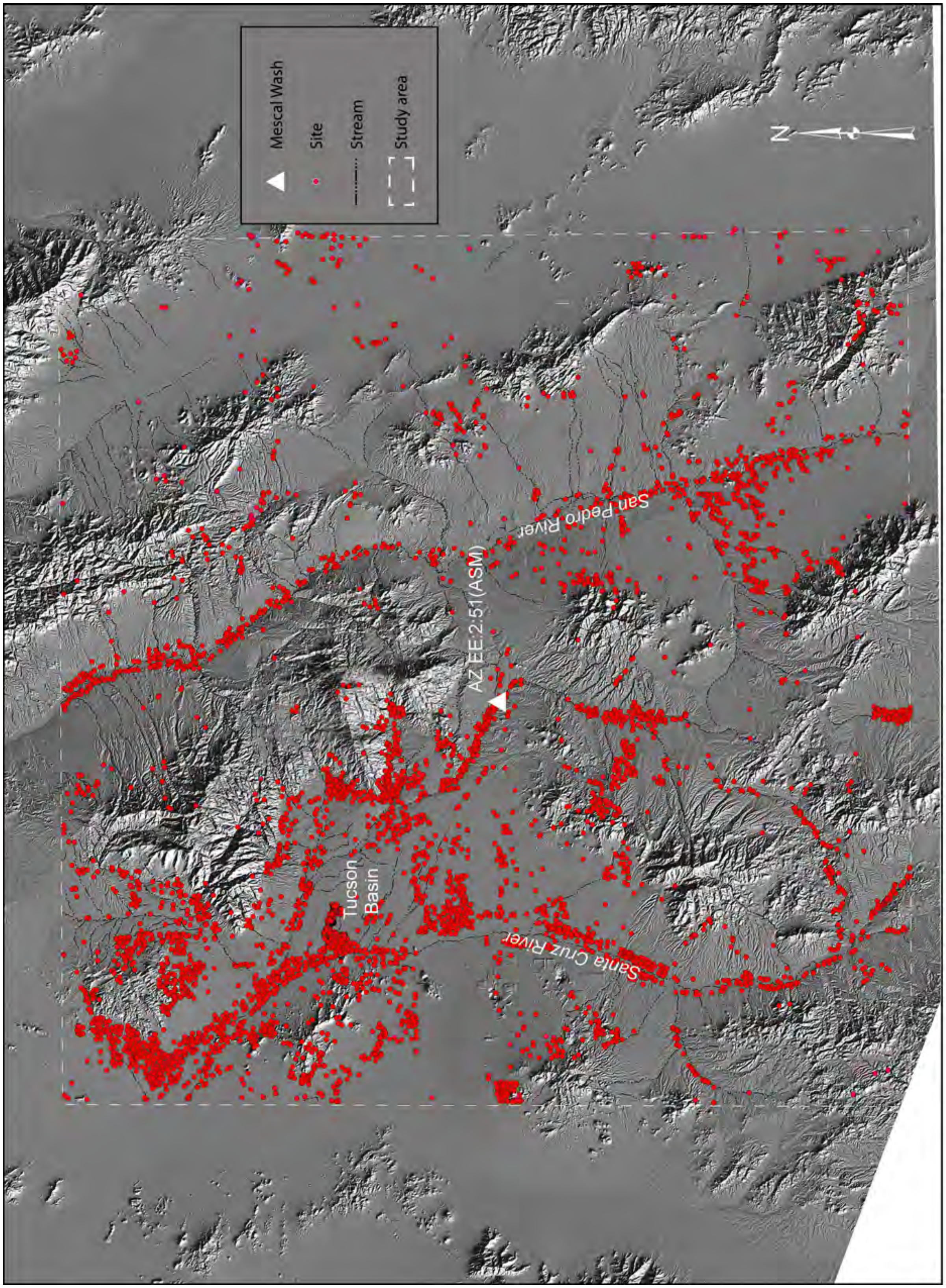

Figure 69. Map showing the locations of sites recorded in the Arizona Archaeological Site and Survey Database as of October 2005, excluding transportation-corridor sites and sites recorded from historical maps.

data that were not entered and reconstructing the database. Investigators intimately familiar with research in the study area will inevitably notice cases where a certain site type is not represented, although they know it to be. We apologize in advance for these shortcomings.

Nonetheless, there are some interpretable and interesting patterns in the data that can be used to shed some light on persistent-place formation. Observed patterns in the data are based on careful consideration of the actual, official, digital site data. Far more could probably be learned were the data more consistently recorded, reported, and entered. The disadvantage of the data set is that the data are inconsistent and coarse-grained, and there are a lot of missing cases. The advantage of the data set is that it covers many sites, over a large area, from many different projects.

Fields in AZSITE for entering diagnostic information, such as feature-description text, site-description text, component-description text, diagnostic-artifact lists, and phase lists, were extensively queried in Microsoft Access, to develop as large a number of phase or period components as possible with the current data. Developing and running the queries was time-consuming and laborious, but not as much so as would have been the case had each and every site record been individually reviewed by hand.

Only 4,033 (71.1 percent) of the 5,676 sites had sufficient data entered into AZSITE to assign temporal periods. In total, 963 sites (16.9 percent) had data sufficient to assign Hohokam phases. The 963 sites were used to assess growth and change in the Tucson Hohokam network and its relationship to Type I persistent-place formation. The 4,033 sites with data on temporal periods were used to estimate the formation of Type II persistent places. All sites with available data on Formative period ceramic traditions (n = 1,435) were used to evaluate Mescal Wash as a Type III persistent place.

A Formal, Quantitative Model of Persistent-Place Formation

In order to develop a frame of reference against which to compare our results, we present below a simple, formal model of persistent-place formation. The model is based only on counts of reused, newly formed, and abandoned sites for archaeologically defined intervals. In constructing the model, relative frequencies are assumed to approximate independent probabilities.

In formulating a neutral model to study persistent-place formation in southeastern Arizona, we are constrained by characteristics of the available site data. Because of problems in how sites are discovered, recorded, and reported, we limit assumptions about the type or intensity of place use. As discussed above, no attempt is made to quantify place-use intensity—in terms of systemic context variables, such as amounts of time or energy or numbers of interactions, activities, or people involved in place use, or in terms of archaeological context variables, such as feature or artifact abundance and diversity. Particular site functions, also, are not required. We are not arguing that variables such as use intensity, population size, or site function are unimportant. We merely caution that estimation of these variables based on the current data set is problematic and would likely add additional layers of uncertainty and subjectivity to the analysis.

Although some interesting patterns could relate to site size (Bentley and Maschner 2003; Brown and Witschey 2003; Brown et al. 2005; Fletcher 1995; Laxton and Cavanagh 1995), we do not at this time attempt to incorporate considerations of site size into the model. As discussed above, sites sizes are recorded according to a wide variety of largely subjective methods, and many sites that were recorded early in the history of cultural resource management in the region have no reported size or footprint. As a result, individual sites are treated as points, rather than polygons, in order to avoid assumptions about site size or shape. Given that archaeological sites are not perfect registers of systemic places and given the potential incongruence among places, landscapes, and Cartesian space, the modeling of sites as points with no real size or shape is reasonable. The centroid of each site polygon is used to represent each site.

Rather than abundance, feature or artifact density, or absolute size, only the presence or absence of temporally diagnostic artifacts, such as a painted sherd, a soldered-metal can, or a projectile point, is used to infer the chronology of place use. The presence of a temporally diagnostic artifact is used to infer that a systemic place converged on that location during the identified phase or period. The absence of temporally diagnostic artifacts is used to infer that a systemic place did not converge on that location during a given phase or period. Certainly, there are cases in which the presence of temporally diagnostic artifacts could represent the curation of heirlooms or the collection of curios rather than use during the period in which the artifact was made. These cases, however, are difficult to extract from the current data set and are probably overwhelmed by cases in which an artifact has not traveled far from its original location of storage, loss, or discard. Sites that have no temporally diagnostic materials entered in AZSITE were removed from the analysis. Future refinement of this model would benefit from the addition of variables that could inform on the character of place use, such as use intensity, site function, or site size.

A Neutral Model of Persistent-Place Formation

The formal model developed here specifies that place persistence is dependent on probabilities of place reuse and the original founding set of reusable places (S). The probability ($p_{(i-j)}$) that a place will be sequentially reused in *i* to the *j*th phases or periods is the product of reuse probabilities (r) for each preceding phase or period (Equation 1). The number of persistent places (PP) in any particular phase or period is the product of S and $p_{(i-j)}$ (Equation 2).

Equation 1. $p_{(i-j)} = r_i * r_{(i+1)} \ldots * r_j$

Equation 2. $PP = S * p_{(i-j)}$

For the purpose of this analysis, $(i-j)$ is calculated as the proportion of sites that are reused from the previous phase or period. Multiplying these proportions together for a specific set of sequential phases or periods yields the probability of persistence for a given period. For instance, if 20 percent of Cañada del Oro phase sites ($r_i = 0.2$) were reused during the Rillito phase, and 30 percent of sites in the Rillito phase were reused ($r_j = 0.3$) in the subsequent Rincon phase of the Tucson Basin Hohokam, then the probability that use of a place would persist from the Cañada del Oro phase into the Rincon phase is the product of those two reuse proportions: 0.2 × 0.3, or 0.06. If there were 100 sites with Cañada del Oro phase components, then we would predict that there should be on the order of 6 places that were used persistently from the Cañada del Oro phase through the Rincon phase of the Tucson Basin Hohokam. If there were instead significantly more than 6 persistent places for this period, then we might infer that there was a strong tendency to preferentially reuse Cañada del Oro phase sites in subsequent periods. Conversely, if there were significantly fewer than 6 persistent places for this period, then we might infer that there was a strong tendency to abandon use of places from the Cañada del Oro phase.

An obvious, and perhaps trivial, expectation of the model is that the number of persistent places cannot exceed the founding set of places. There cannot be more places with Cañada del Oro, Rillito, and Rincon phase uses than there are Cañada del Oro places. If the founding set of sites is small, we can only expect to have a small or smaller number of persistent places. Conversely, we can expect to have a relatively large number of persistent places when the founding set of places is large and increasing, as long as reuse occurred at appreciable rates. As will be shown below, persistent-place formation can substantially increase even when both site formation and site reuse are decreasing and abandonment is increasing.

Another expectation of the model is that unless places are always reused ($p_{(i-j)} = 1$), the more persistent a place is, the rarer it is among its contemporaries. As the number of contributing phases or periods increases, reuse probabilities are multiplied. As more phases or periods accumulate, probabilities of persistence get smaller and smaller. As a consequence, we should generally expect to have fewer places that were reused repeatedly over the course of five phases than places that were repeatedly reused over the course of three phases.

The Effects of Network Growth on Persistent-Place Formation

As stated above, persistent-place formation is a function of both reuse and previous settlement patterns. As an illustration, this is simulated here according to four different models of landscape-network growth: exponential growth, geometric growth, no growth, and constant additive growth (Figure 70). For each model, the simulation begins with 200 sites, reuse rates are set for each phase as 50 percent, and phases are held constant at 100 years in duration. Persistent places emerge in the third phase, per our definitional requirements—or, in this case, at 300 years. For the no-growth model, the network remains static in size (n = 200) throughout the duration of the simulation. For the geometric-growth model, the network doubles in size every 100 years. For the exponential-growth model, an intrinsic growth rate of 0.8 percent is set, such that sites = $100 * e^{(\text{year} * 0.008)}$. For the constant-additive-growth model, the network grows by a constant 200 sites every 100 years, or 2 sites per year.

When reuse probabilities are held constant, the simulations show that persistent-place formation follows the same form as network growth. In other words, graphing the number of persistent places according to time yields the same graphed shape as is obtained when graphing all sites according to time for a given growth model. However, an interesting outcome of these simple simulations is that for the exponential-growth, geometric-growth, and no-growth models, the proportion of sites that are persistently used is virtually constant. In other words, even though some of these simulated networks are growing rapidly while one is not growing at all, the proportion of sites that are persistent remains constant in each network when reuse rates are also held constant (Figure 71). The difference between the models is that the proportion is smaller for faster-growing networks. Only in the case of the additive-growth model does the proportion of sites that are used persistently increase through time. Therefore, we may expect that for many networks, a small and relatively constant percentage of sites are used persistently, and the faster these networks grow, the smaller that percentage is. For the constant-growth model, the proportion of persistent places increases

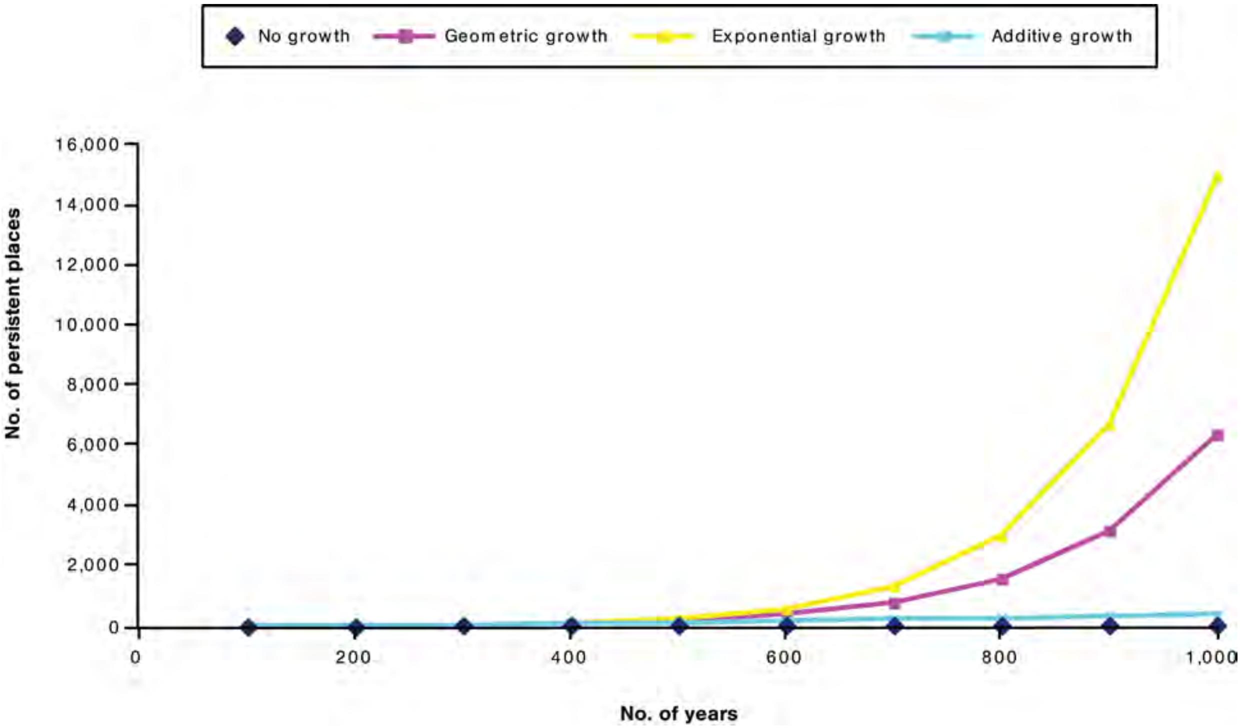

Figure 70. Chart of simulated growth in the number of persistent places through time, depending on the rate of settlement expansion.

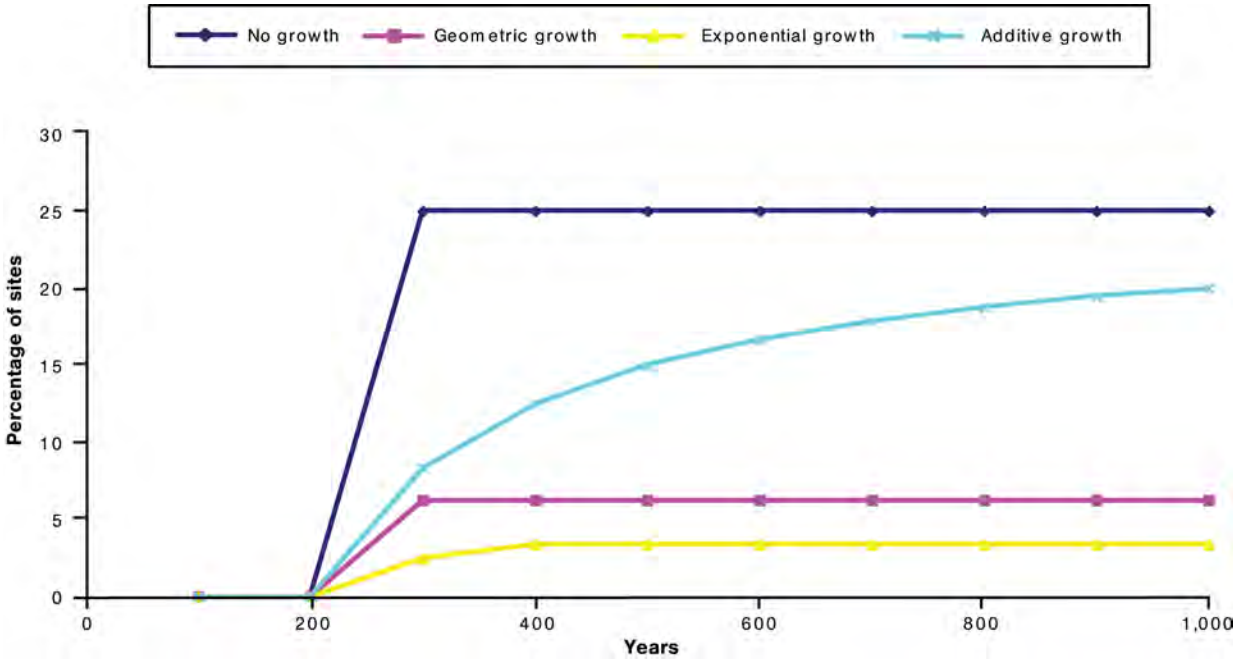

Figure 71. Chart of the proportion of sites that are persistent places, according to time and the rate of settlement expansion.

monotonically but at a predictable, decreasing rate. If we allow reuse rates to vary randomly between 10 percent and 100 percent, then persistent-place formation also varies wildly, despite predictable, continuous growth trends or states of no growth. Still, persistent-place formation is generally highest for exponentially growing networks and lowest for networks of static size.

Quantifying Persistent-Place Formation in the Study Area

At the level of Hohokam phase, place persistence is uncommon. For 963 sites with Tucson Basin or Phoenix Basin Hohokam phase ceramics represented, 76 (or 7.89 percent) are persistent places (Table 43). Interestingly, this figure is remarkably similar to the percentage of sites in the Dolores region that Schlanger identified as persistent places (8.2 percent). At the level of archaeological period, place persistence is even more uncommon in our study area. For 4,033 sites with Archaic period, Formative period, or historical-period components represented, only 59 (or 1.46 percent) have all three components (Table 44). The persistence of places, like Mescal Wash, that are persistent at the levels of both phase and period is exceedingly rare. Of 4,033 sites with Archaic period, Formative period, and historical-period components, only 7 (or 0.17 percent) are persistent places at the levels of both phase and period (Table 45). In other words, on the order of 1 out of every 576 sites has this rare quality[1].

Persistent-Place Formation and the Tucson Basin Hohokam Network

In this section, we investigate persistent place formation in terms of the Tucson Basin Hohokam network. The Hohokam are focused on here because the most temporally reliable, consistent, and finely resolved ceramic data are available in AZSITE for the study area for the Tucson Basin tradition, as opposed to other local traditions in southeastern Arizona. Also, many more cases with Hohokam ceramics have been documented than for any other ceramic tradition. By focusing on the Tucson Hohokam network, we can examine change over time in a particular landscape network.

For heuristic purposes, the Tucson Basin network is modeled as initiated by ceramic phases affiliated with the Phoenix Basin Hohokam: Vahki, Sweetwater, and Snaketown. These are followed by phases associated with the Tucson Basin Hohokam tradition: Cañada del Oro, Rillito, Rincon, and Tanque Verde. Pantano Polychrome, Tucson Polychrome, and Gila Polychrome are used together as a proxy for the terminal Late Classic period of the Tucson Basin Hohokam network. For heuristic purposes, we arrange phases in sequence, although significant portions of different phases may overlap in time. Sites with two contiguous phases could in fact be roughly contemporaneous rather than sequential. In order to partially overcome this problem, most temporal trends are evaluated using the end dates for different phases, which permits evaluation of what has "accumulated" by a certain time and deflates the effects of sequentially segregating potentially overlapping phases. Dean's (1991) Tucson and Phoenix Basin chronologies are used to track change over time, and median dates are used for cases in which phase boundaries are fuzzy.

By ignoring sites with local Early Agricultural period components, this approach may oversimplify the emergence of the Tucson Basin Hohokam network. For some time, archaeologists have argued whether the Tucson Basin was an empty niche or Hohokam farmers displaced or incorporated existing populations (Di Peso 1956, 1979; Doyel 1984; Grebinger 1976; Greenleaf 1975; Haury 1950; Hayden 1970; Wilcox 1979; Zahniser 1966). Large, pre-Hohokam, Early Agricultural period settlements have more recently been discovered in the Tucson Basin. New evidence has suggested that forager-farmer lifeways appeared substantially earlier than the Hohokam attributes (Mabry 1998, 2001). Nonetheless, the exact modes of interaction and change that occurred with the introduction of Hohokam-affiliated lifeways has yet to be fully explored (Whittlesey 2004b).

The pre-Hohokam occurrence of agriculture in southeastern Arizona seems to indicate continuity between early foraging systems and the emergence of more-agricultural lifeways. Tortolita phase settlement probably contributed to the formation of Hohokam persistent places, but it is also likely that Late Archaic period settlement took advantage of some of the best-watered habitats, those that were most suitable to riverine agricultural technologies. Doelle

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[1] The reader is asked to recall that these calculations are based solely on AZSITE data and are not corrected for missing cases. Phases or periods are assigned, however, at the levels of artifacts and features as well as identified components and, in this sense, maximize the size of the sample permitted by the existing data. The number of particular cases for any segment of the analysis likely underestimates the absolute number and probably also underestimates relative proportions, as well. More-accurate estimates, however, cannot be achieved without going back to thousands of site cards and hundreds of reports and carefully standardizing and reentering the data for over 5,000 sites.

Table 43. Sites Identified as Type I Persistent Places of the Tucson Basin Hohokam, Based on the AZSITE Data as of October 2005

Site No.	Arizona Archaeological Site and Survey Database Identification No.	Site Name	No. of Contiguous Phases in the Arizona Archaeological Site and Survey Database Data
AZ AA:12:20 (ASM)	73570		3
AZ AA:12:31 (ASM)	73579	El Rancho Chaparral	5
AZ AA:12:51 (ASM)	73589		3
AZ AA:12:57 (ASM)	73272	Los Morteros	3
AZ AA:12:99 (ASM)	73605		4
AZ AA:12:103 (ASM)	73607		3
AZ AA:12:149 (ASM)	72826		3
AZ AA:12:314 (ASM)	73637		3
AZ AA:12:368 (ASM)	73354		3
AZ AA:12:503 (ASM)	73656	Costello-King site	3
AZ AA:16:3 (ASM)	76868	West Branch site	5
AZ AA:16:6 (ASM)	76971	Tumamoc Hill	4
AZ AA:16:30 (ASM)	4786		4
AZ AA:16:36 (ASM)	76950		3
AZ AA:16:49 (ASM)	76958	Dakota Wash site	5
AZ AA:16:53 (ASM)	76962		3
AZ AA:16:356 (ASM)	4753		3
AZ BB:10:20 (ASM)	63618		3
AZ BB:11:1 (ASM)	63619	Bayless Ranch Ruin	3
AZ BB:11:2 (ASM)	63620	Redington Ruin	3
AZ BB:13:1 (ASM)	67258	Zanardelli site	3
AZ BB:13:9 (ASM)	67262		6
AZ BB:13:15 (ASM)	72034	Valencia site	3
AZ BB:13:19 (ASM)	67267		3
AZ BB:13:55 (ASM)	67330	Espinoza site	4
AZ BB:13:90 (ASM)	67378		3
AZ BB:13:92 (ASM)	67380		3
AZ BB:13:95 (ASM)	67385		3
AZ BB:13:96 (ASM)	67387		3
AZ BB:13:103 (ASM)	67396		3
AZ BB:13:120 (ASM)	67427	Spence site	4
AZ BB:13:123 (ASM)	67452	EmKay Ranch site	4
AZ BB:13:126 (ASM)	67455		3
AZ BB:13:126-A (ASM)	67456		3
AZ BB:13:126-L (ASM)	67460		3
AZ BB:13:398 (ASM)	67946	Houghton Road site	5
AZ BB:13:402 (ASM)	67958		3
AZ BB:13:404 (ASM)	67864		3
AZ BB:13:425 (ASM)	5427	Stone Pipe site	3
AZ BB:13:535 (ASM)	77581		4
AZ BB:13:544 (ASM)	22992		3
AZ BB:13:566 (ASM)	73238		4
AZ BB:14:25 (ASM)	67413	New Pantano	3
AZ BB:14:48 (ASM)	67366	Converse site	3
AZ BB:14:51 (ASM)	67381		4
AZ BB:14:52 (ASM)	67384		3

Site No.	Arizona Archaeological Site and Survey Database Identification No.	Site Name	No. of Contiguous Phases in the Arizona Archaeological Site and Survey Database Data
AZ BB:14:77 (ASM)	67439		3
AZ BB:14:161 (ASM)	67325	Davidson Canyon site	3
AZ BB:14:240 (ASM)	67598		3
AZ BB:14:505 (ASM)	5490		3
AZ BB:14:528 (ASM)	76575		3
AZ BB:14:537 (ASM)	76598		3
AZ BB:14:583 (ASM)	63827		3
AZ BB:14:595 (ASM)	63839		3
AZ BB:14:620 (ASM)	22734		3
AZ BB:5:26 (ASM)	68165	Indian Town Ruin	3
AZ BB:5:47 (ASM)	71601	Twenty Nine Wash	3
AZ BB:6:63 (ASM)	63479		4
AZ BB:9:14 (ASM)	66994	Hardy site	6
AZ BB:9:32 (ASM)	67011	Bear Canyon Ruin	3
AZ BB:9:33 (ASM)	67012	University Indian Ruin	3
AZ BB:9:45 (ASM)	67020		3
AZ BB:9:68 (ASM)	67038	Bead Mountain Puebli	3
AZ BB:9:88 (ASM)	5688	Honeybee Village	3
AZ BB:9:94 (ASM)	67055	Cim site	3
AZ BB:9:117 (ASM)	67077	Torgerson’s House site	3
AZ BB:9:213 (ASM)	65498		3
AZ DD:4:1 (ASM)	66237		3
AZ DD:4:68 (ASM)	63997		5
AZ DD:4:84 (ASM)	66288		4
AZ DD:4:138 (ASM)	66342		3
AZ DD:4:182 (ASM)	66377		3
AZ DD:8:156 (ASM)	64273		3
AZ EE:1:46 (ASM)	75169		3
AZ EE:4:1 (BLM)	68313	Curtis Knolls	4
AZ EE:9:3 (ASM)	90658	Tortolita site	4

Table 44. Sites Identified as Type II Persistent Places, Based on the AZSITE Data as of October 2005

Site No.	Arizona Archaeological Site and Survey Database Identification No.	Site Name	Watershed
AZ AA:12:57 (ASM)	73272	Los Morteros	Tortolita Fan
AZ AA:12:90 (ASM)	73597	Wetlands site	middle Santa Cruz Valley
AZ AA:12:91 (ASM)	73596	Los Pozos	middle Santa Cruz Valley
AZ AA:12:821 (ASM)	84883		Tortolita Fan
AZ AA:16:3 (ASM)	76868	West Branch site	middle Santa Cruz Valley
AZ AA:16:6 (ASM)	76971	Tumamoc Hill	middle Santa Cruz Valley
AZ AA:16:166 (ASM)	76892		middle Santa Cruz Valley
AZ AA:16:187 (ASM)	76913	Buff’s Quarry	middle Santa Cruz Valley
AZ BB:13:6 (ASM)	63765	San Augustin	middle Santa Cruz Valley
AZ BB:13:14 (ASM)	72932		upper Santa Cruz Valley
AZ BB:13:17 (ASM)	82004	Julian Wash site	middle Santa Cruz Valley

continued on next page

Site No.	Arizona Archaeological Site and Survey Database Identification No.	Site Name	Watershed
AZ BB:13:56 (ASM)	72943	Warner's Mill	middle Santa Cruz Valley
AZ BB:13:68 (ASM)	67348	Tanque Verde Wash site	middle Santa Cruz Valley
AZ BB:13:158 (ASM)	67503		middle Santa Cruz Valley
AZ BB:13:425 (ASM)	5427	Stone Pipe site	middle Santa Cruz Valley
AZ BB:13:558 (ASM)	73230		upper Santa Cruz Valley
AZ BB:14:2 (ASM)	67261	Pithouse Village	middle Santa Cruz Valley
AZ BB:14:26 (ASM)	67416		middle Santa Cruz Valley
AZ BB:14:43 (ASM)	67353		middle Santa Cruz Valley
AZ BB:14:48 (ASM)	67366	Converse site	middle Santa Cruz Valley
AZ BB:14:79 (ASM)	67410		middle Santa Cruz Valley
AZ BB:14:81 (ASM)	67409		middle Santa Cruz Valley
AZ BB:14:126 (ASM)	67528		middle Santa Cruz Valley
AZ BB:14:127 (ASM)	67529		middle Santa Cruz Valley
AZ BB:14:163 (ASM)	67538		middle Santa Cruz Valley
AZ BB:14:168 (ASM)	67545		middle Santa Cruz Valley
AZ BB:14:208 (ASM)	67669		middle Santa Cruz Valley
AZ BB:14:209 (ASM)	67676		middle Santa Cruz Valley
AZ BB:14:274 (ASM)	67674		middle Santa Cruz Valley
AZ BB:14:316 (ASM)	67745		middle Santa Cruz Valley
AZ BB:14:377 (ASM)	67852	Juniper Basin site	middle Santa Cruz Valley
AZ BB:14:465 (ASM)	63810		middle Santa Cruz Valley
AZ BB:14:467 (ASM)	68009	Hope Camp	middle Santa Cruz Valley
AZ BB:14:529 (ASM)	76576		Cienega Creek valley
AZ BB:14:601 (ASM)	63842		Cienega Creek valley
AZ BB:14:647 (ASM)	84873		middle Santa Cruz Valley
AZ BB:14:681 (ASM)	85089		upper Santa Cruz Valley
AZ BB:5:142 (ASM)	77080		lower Gila River valley
AZ BB:9:14 (ASM)	66994	Hardy site	middle Santa Cruz Valley
AZ BB:9:32 (ASM)	67011	Bear Canyon Ruin	middle Santa Cruz Valley
AZ BB:9:121 (ASM)	67081		Tortolita Fan
AZ BB:9:147 (ASM)	67103		middle Santa Cruz Valley
AZ BB:9:242 (ASM)	67191	Bear Canyon E	middle Santa Cruz Valley
AZ BB:9:280 (ASM)	5719	Casitas Del Solar	middle Santa Cruz Valley
AZ CC:9:26 (ASM)	85979		Sulphur Springs Valley
AZ DD:4:51 (ASM)	63984		upper Santa Cruz Valley
AZ DD:4:59 (ASM)	63991		upper Santa Cruz Valley
AZ EE:1:32 (ASM)	6580	Continental site	upper Santa Cruz Valley
AZ EE:1:205 (ASM)	64075		upper Santa Cruz Valley
AZ EE:1:254 (ASM)	64101		upper Santa Cruz Valley
AZ EE:2:171 (ASM)	82012		Cienega Creek valley
AZ EE:2:245 (ASM)	76655		Cienega Creek valley
AZ EE:3:48 (ASM)	77113	Cottonwood Wash Rock Pile site	middle San Pedro Valley
AZ EE:4:19 (BLM)	69750	Levin Lagoons	middle San Pedro Valley
AZ EE:4:30 (ASM)	68315	Cottonwood Oasis	middle San Pedro Valley
AZ EE:8:106 (ASM)	86700		middle San Pedro Valley
AZ EE:8:111 (ASM)	86705		middle San Pedro Valley
AZ EE:8:127 (ASM)	86590	Judy site	middle San Pedro Valley
AZ EE:8:234 (ASM)	6679		middle San Pedro Valley

Table 45. Sites Identified as Type I and Type II Persistent Places, Based on the Arizona Archaeological Site and Survey Database Data as of October 2005

Arizona Archaeological Site and Survey Database Identification No.	Site No.	Site Name	Watershed
5427	AZ BB:13:425 (ASM)	Stone Pipe site	middle Santa Cruz Valley
66994	AZ BB:9:14 (ASM)	Hardy site	middle Santa Cruz Valley
67011	AZ BB:9:32 (ASM)	Bear Canyon Ruin	middle Santa Cruz Valley
67366	AZ BB:14:48 (ASM)	Converse site	middle Santa Cruz Valley
73272	AZ AA:12:57 (ASM)	Los Morteros	Tortolita Fan
76868	AZ AA:16:3 (ASM)	West Branch site	middle Santa Cruz Valley
76971	AZ AA:16:6 (ASM)	Tumamoc Hill	middle Santa Cruz Valley

and Swartz (1997:3) argued that "information from three sites—Romero, Hodges, and Valencia . . . [suggests] that occupation initiated in the Tortolita phase continued on and subsequently developed into ballcourt villages." Other Tortolita phase sites, such as the Triangle Road site (AZ BB:9:87 [ASM]), did not continue to be used but were still located in the general vicinities of sites that formed into persistent places (Wellman 1997). This analysis does not actively incorporate Early Formative period elements, mostly because early diagnostic types used to identify phases and periods are almost nonexistent in the AZSITE database. For only three sites is Tortolita Red listed as a diagnostic type in the AZSITE database, for instance. The Tortolita phase is mentioned in the site-remarks section for an additional three sites, but because of considerable ambiguity, site remarks were not used to generate presence/absence data for ceramic types. Many more Early Formative period sites have been discovered in the study area than are listed in AZSITE (Doelle and Swartz 1997; Stevens 2001).

Fish and Fish (1994:87) noted that "residential sites associated with the earliest regional ceramics (by about A.D. 200 to 300) in many parts of the Southwest are not the first farming villages, but this temporal threshold marks a change in the visibility of cultivators and undoubtedly in key aspects of behavior other than pottery use." The appearance of Hohokam ceramic types in the Tucson Basin may also signal the advent of significant behavioral change related to the adoption of some Hohokam lifeways and technologies. Distinctly Hohokam attributes did appear in the Tucson Basin and became fundamental components of the ensuing culture history. We rely on Hohokam ceramic types to model development and change in a Hohokam network, because the ceramic types have been recognized for decades, the chronology has been developed and repeatedly evaluated, Hohokam archaeology represents a certain degree of technological and possibly cultural continuity, these ceramic types are products of potentially coherent technological and stylistic traditions, and they are more likely than other ceramic types to have been accurately and consistently entered into AZSITE. By modeling the Hohokam network in this way, we can chart general patterns and quantitatively track general trends. Given the nature of the AZSITE data (discussed above), the specific details of those patterns, such as the precise participation of particular sites in network development and change, are likely to be inaccurate and should be subjected to future revision. Future studies could also model the interaction of local and intrusive elements in the initiation of agriculturally based prehistoric networks in southeastern Arizona and test how local and intrusive elements ultimately contributed to the formation of persistent places.

Development and Change in the Tucson Basin Hohokam Network

An intriguing property of the evolving Tucson Basin landscape network is the rate of site formation. As investigators have long observed, the Tucson Basin Hohokam network grew almost exponentially during the pre-Classic period. During the following Classic period, the network appears to have collapsed. In absolute numbers of sites, the size of the network peaked during the Rincon phase and declined rapidly during the subsequent Tanque Verde and Tucson phases (Figure 72). This pattern in network growth is apparent at a broad spatial scale but is also replicated at the level of individual watersheds.

Geographically, a large portion of the absolute extent of the network was achieved early, and intervening spaces were filled in as it grew. As the network began to collapse during the Late Classic period, some new areas were colonized, and many sites were abandoned. At the same time, the absolute geographic extent of the network was largely maintained or even expanded. In the Late Classic period, settlement shifted away from a Tucson Basin focus and began to concentrate along the lower San Pedro Valley. Late Classic period Hohokam places in the Tucson Basin are almost entirely reused or persistent places. Most new Late Classic period places in the study area were formed in the Lower San Pedro Valley.

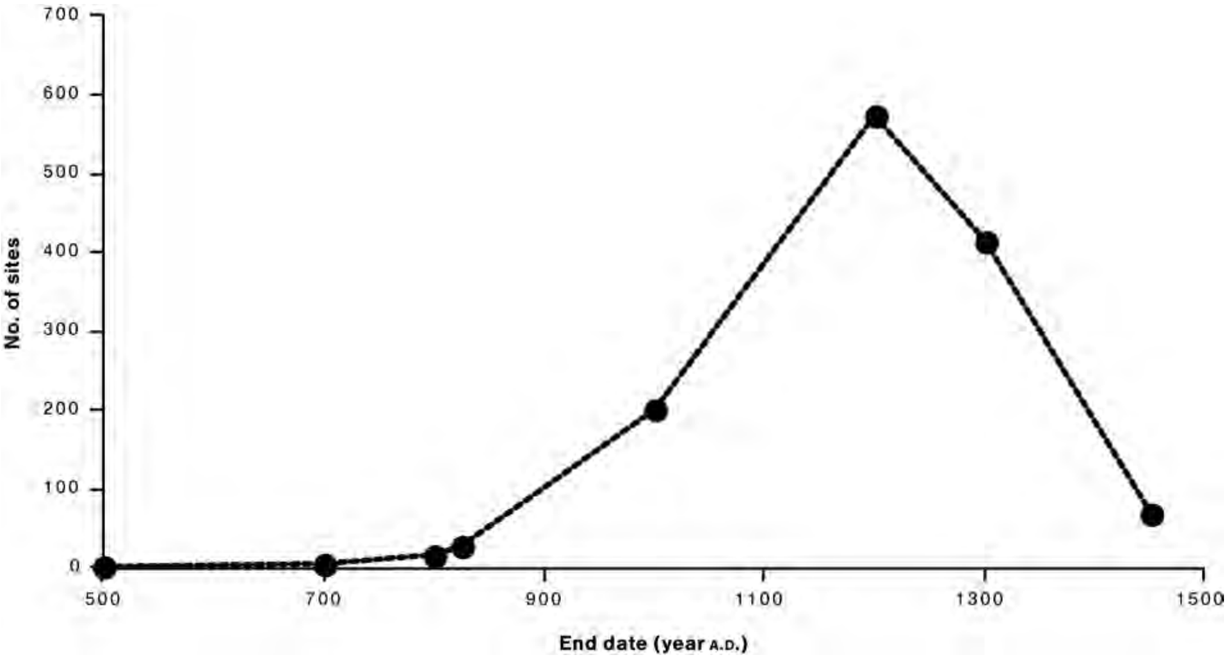

Figure 72. Chart of the numbers of sites in the study area with Hohokam phase-level components, according to time.

Patterns of Hohokam reuse and abandonment in the study area reveal complex shifts in settlement at a variety of scales (Figures 73–75). Through time, processes of reuse and abandonment appear to shift in social, temporal, and spatial scales. Colonial and Sedentary patterns of reuse and abandonment suggest frequent household-level movement. Tanque Verde phase patterns suggest less-frequent shifts of whole settlements or communities (Figure 76). Tucson phase patterns suggest regional abandonment and relocation of one or more local populations (Figure 77).

Land-use patterns suggest that abandonment was a functional component of Hohokam settlement strategies and that processes of abandonment and reuse were integrated ways of using a changing landscape. The Cañada del Oro, Rillito, and Rincon phases represent a high degree of continuity in place use. Over two-thirds of Cañada del Oro phase places were reused during the Rillito phase. Over 71 percent of Rillito phase places were reused during the Rincon phase. Still, other places were abandoned, and many new places were formed (Figure 78). During the Rillito and Rincon phases, many new sites were established in the same areas where many sites were abandoned. Patterns of Colonial and Sedentary period reuse and abandonment suggest fine-scale settlement shifts. Colonial and Sedentary period settlement shifts could have involved the household-level movement of a farmstead or hamlet from one location to another, nearby location. Archaeological patterns of abandonment and reuse during the Colonial and Sedentary periods could represent relatively frequent, possibly planned movements throughout the landscape by households in order to exploit the short-term potential of different agricultural fields and other relatively predictable resources.

Colonial and Sedentary period settlement patterns suggest relatively continuous use of landscapes entailing the dispersion of primary producers. Stone (1996) argued, for instance, that land pressure and the need for agricultural intensification may cause dispersion of households and small groups of households, because farmers are most effective when close to their fields. Favorable, predictable climate during this period may have also enabled dispersed settlement as populations grew. Cultivation may have shifted between different fields with changing local conditions but covered roughly the same general areas through time.

During the Tanque Verde phase, new sites were formed around the peripheries of the Tucson Basin (see Figure 76). Sites were formed in the northern Tucson Basin as well as to the south and southeast of it. Settlement foci appear to have shifted away from areas where many sites were abandoned into adjacent areas where new sites formed. The Marana community, for instance, was formed in the northern Tucson Basin. To the south, in Santa Cruz Valley, the area between Continental Ranch and Pima Mine Road was largely abandoned by the Tanque Verde phase, and new sites, like Continental Ranch, formed to the south (Doelle et al. 1985; Fish, Fish, and Madsen, eds. 1992b; Wallace and Holmlund 1984; Jones 1998). Similarly, reused sites were typically in areas adjacent to, but not overlapping with, areas where new sites were forming. This pattern could represent settlement fissioning or the wholesale movement of communities across the landscape. Reused places may have

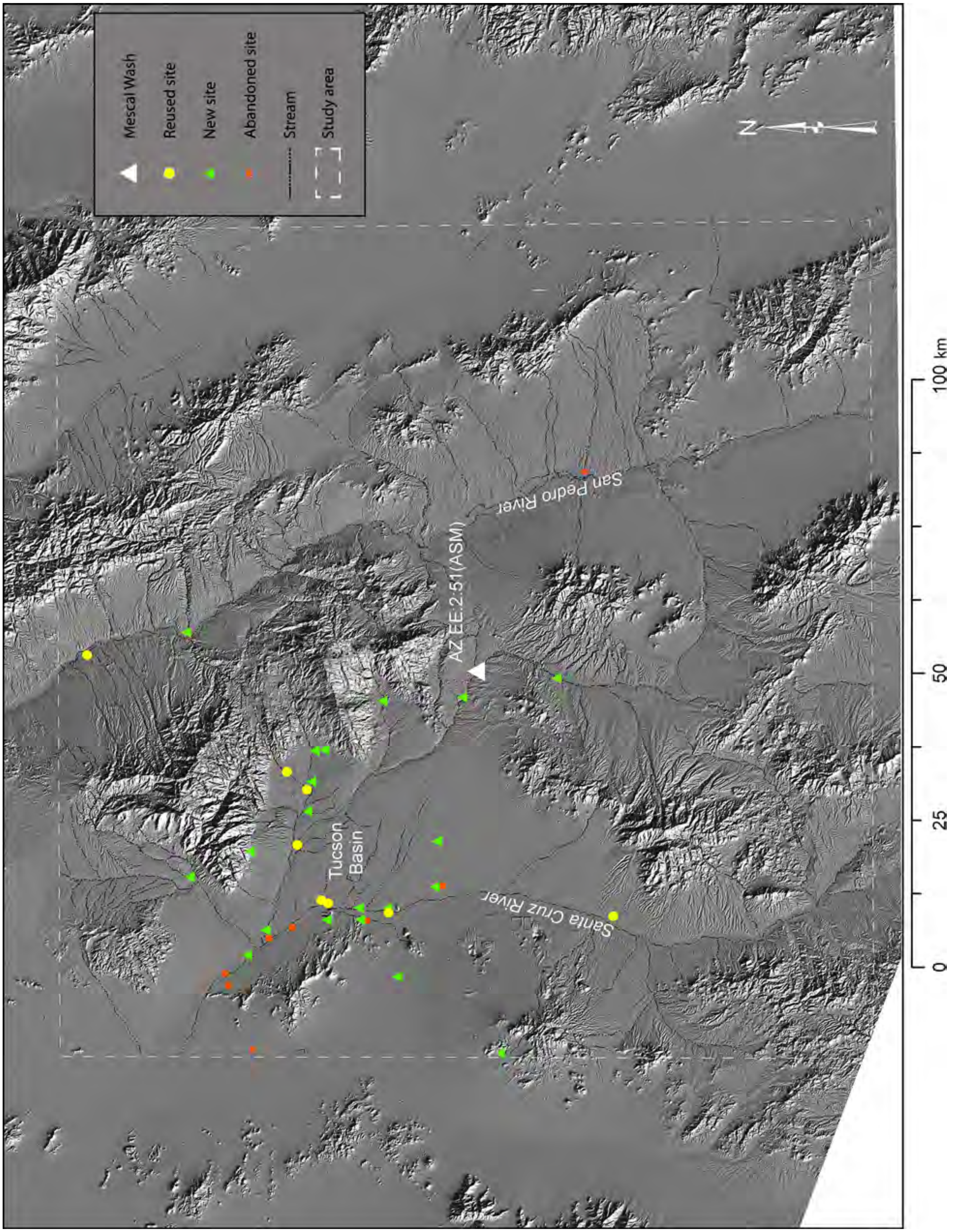

Figure 73. Map showing the locations of new, reused, and abandoned sites during the Cañada del Oro phase of the Tucson Basin Hohokam.

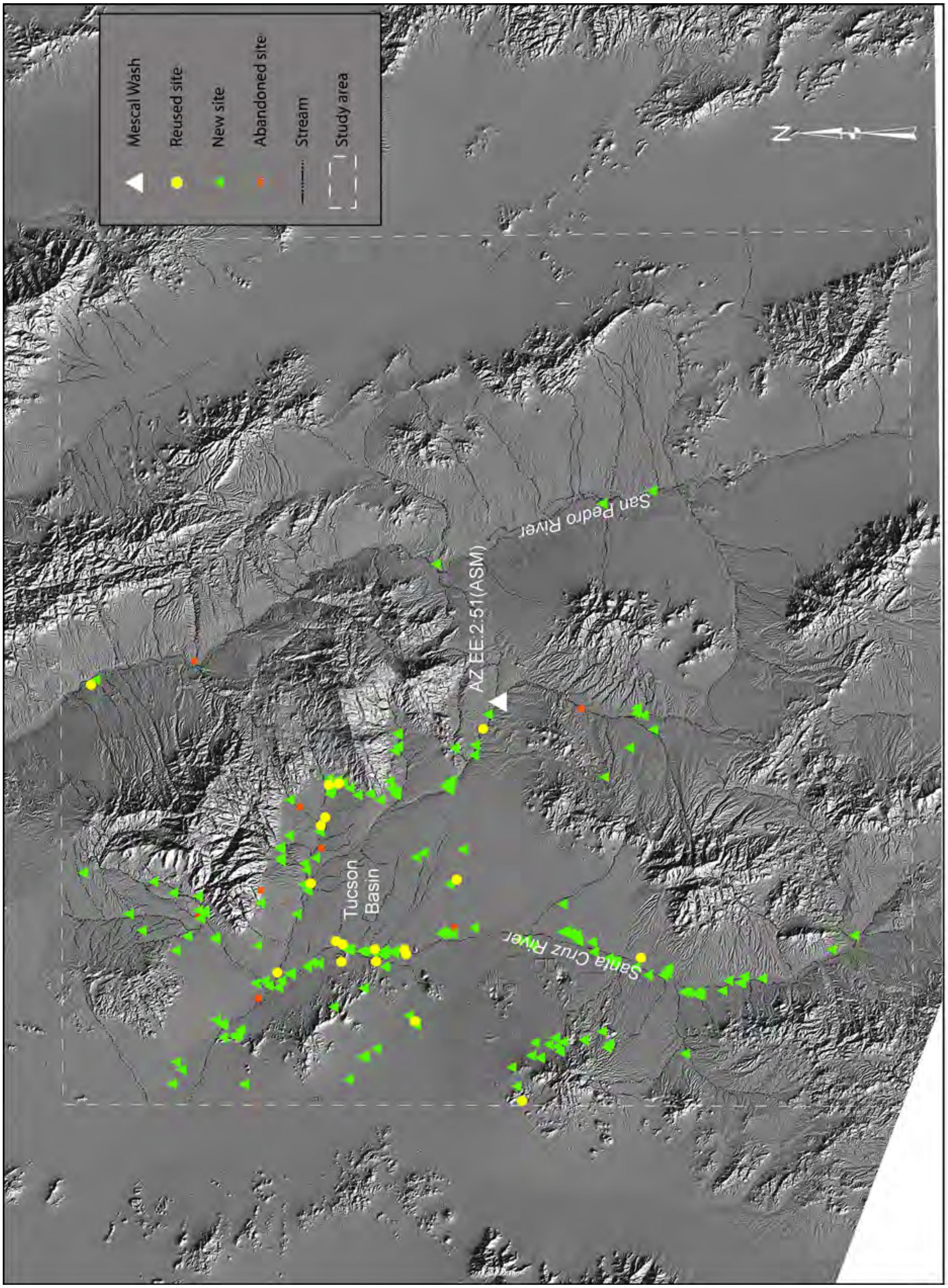

Figure 74. Map showing the locations of new, reused, and abandoned sites during the Rillito phase of the Tucson Basin Hohokam.

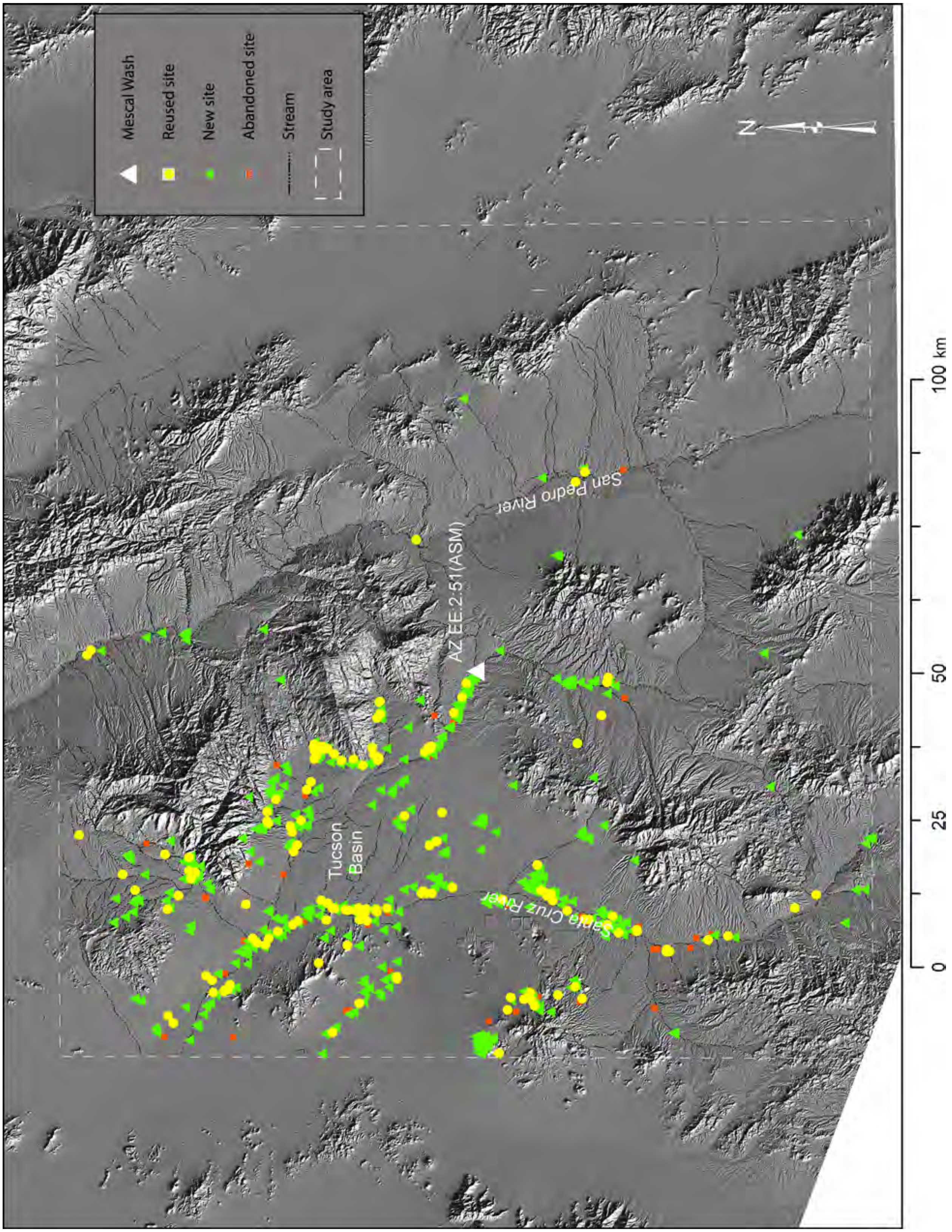

Figure 75. Map showing the locations of new, reused, and abandoned sites during the Rincon phase of the Tucson Basin Hohokam.

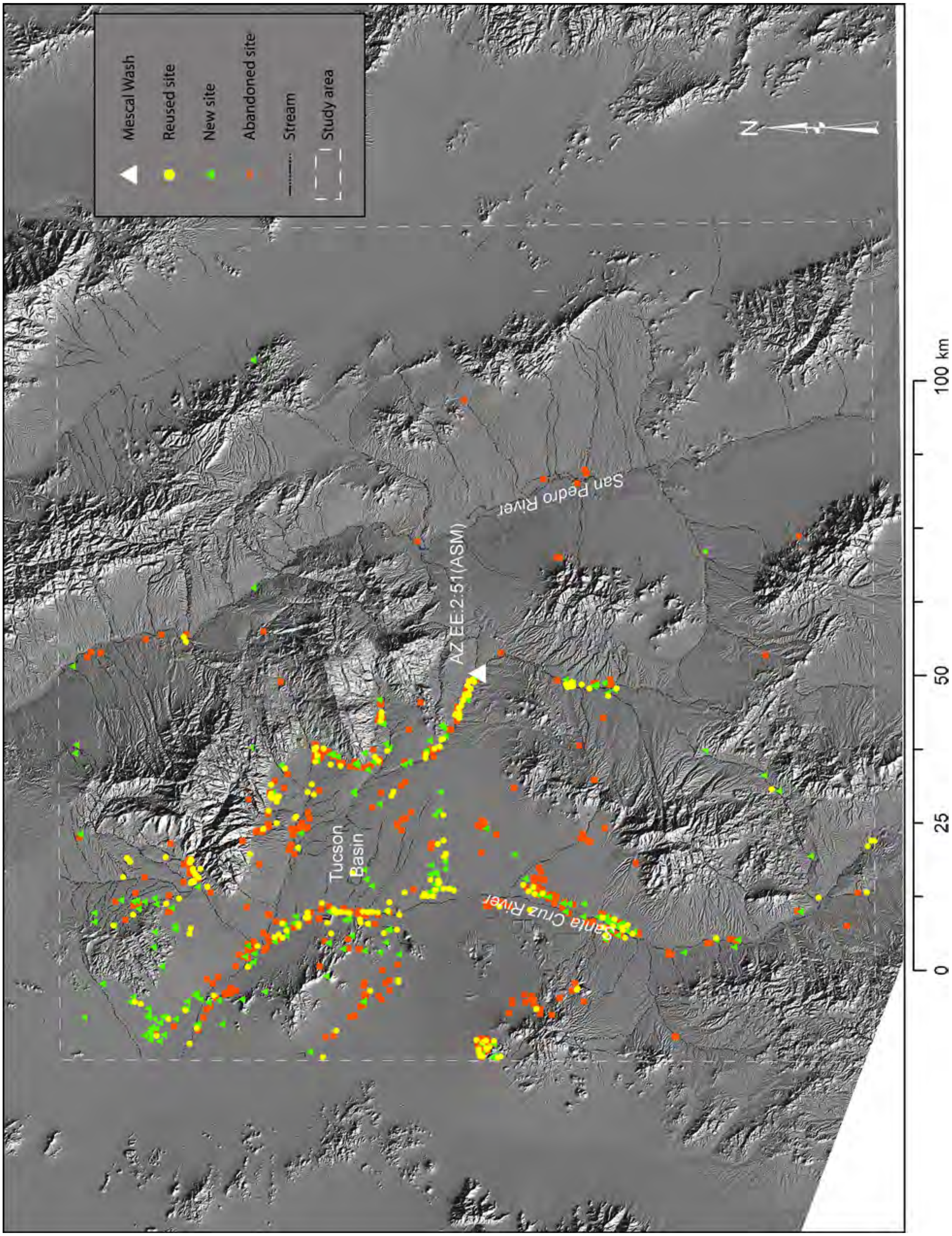

Figure 76. Map showing the locations of new, reused, and abandoned sites during the Tanque Verde phase of the Tucson Basin Hohokam.

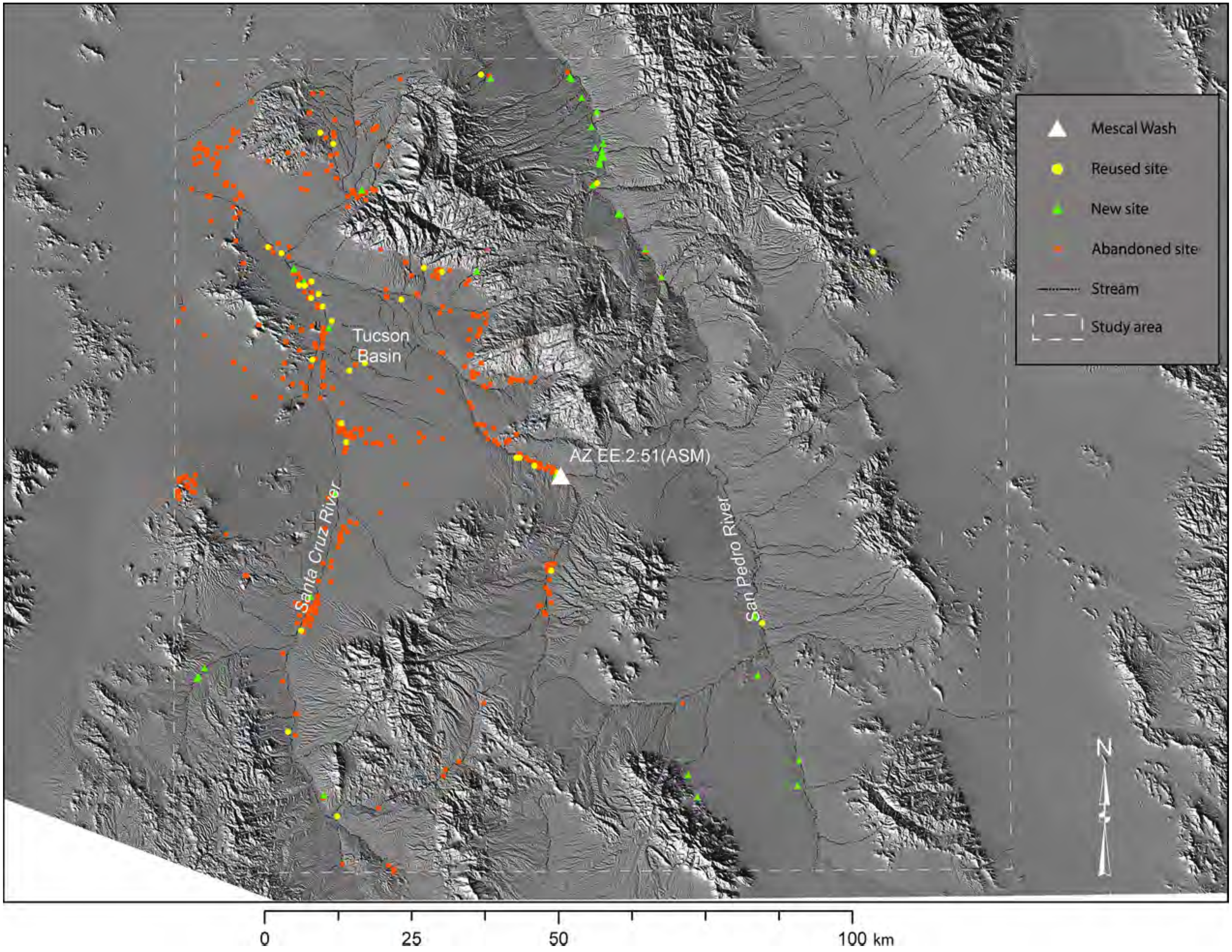

Figure 77. Map showing the locations of new, reused, and abandoned sites during the Tucson phase of the Tucson Basin Hohokam.

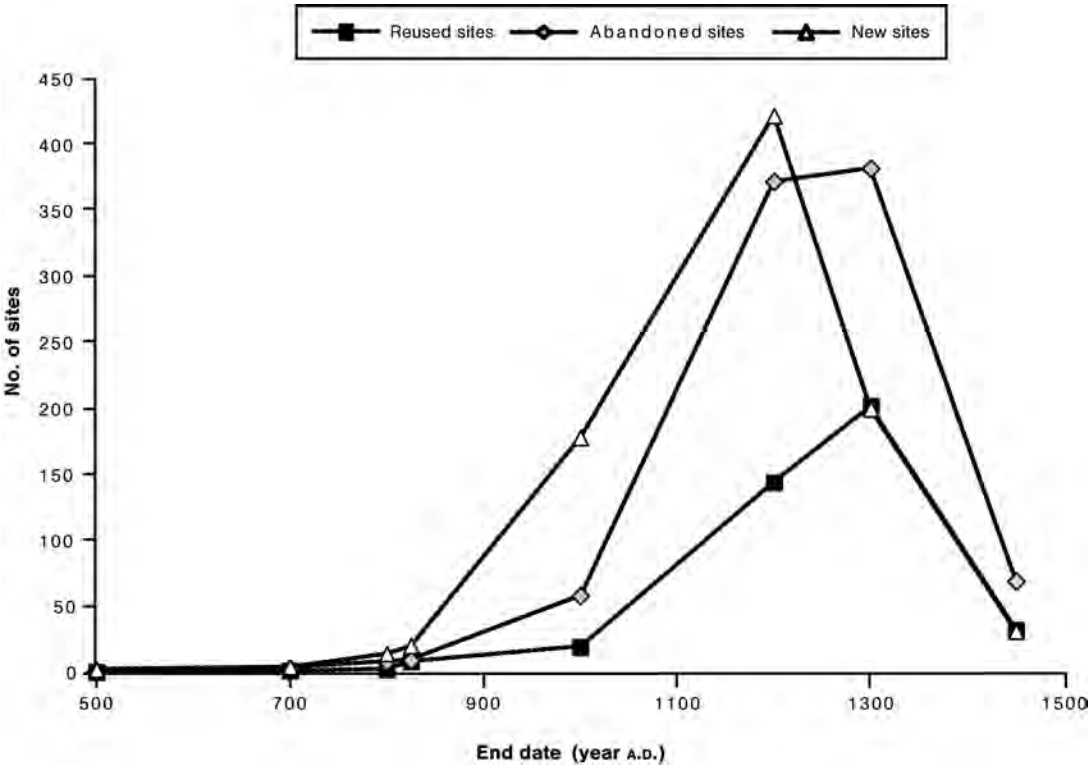

Figure 78. Chart of the numbers of new, reused, and abandoned places of the Tucson Basin Hohokam, according to time.

functioned as resources in areas that were used logistically or less intensively.

During the Tanque Verde phase, both site formation and abandonment were high. Overall, the absolute size of the Tanque Verde phase network represents a decrease from its pre-Classic period apogee. Tanque Verde phase settlement shifts are coincident with emerging patterns of settlement agglomeration, new forms of aboveground compound architecture, platform mounds, and changing reliance on agricultural technologies. The Marana community, for instance, appears to have invested heavily in extensive rock-pile fields associated with agave cultivation, far away from typical floodwater-farming areas, and Tanque Verde phase settlements appear to have expanded into areas peripheral to pre-Classic period settlement (Fish, Fish, and Madsen, eds. 1992b).

By the Tucson phase, the scale of abandonment increased to include much of the former extent of the Tucson Basin Hohokam network (see Figure 77). The vast majority of Tucson Hohokam sites were abandoned, and new sites were formed, primarily in lower San Pedro Valley. Site reuse necessarily occurred in the former heartland of the Hohokam network, and it was also necessarily the locus of persistent-place formation. Late Classic period reuse appears also to have preferentially targeted areas that were used historically and prehistorically for canal irrigation (Fish and Fish 1994).

Applying the Neutral Model of Persistent-Place Formation to the Hohokam Network

Using only reuse probabilities and the founding set of places, the neutral persistent-place model presented above closely predicted the number of persistent places (F-ratio = 768.29; $df = 1$; $r^2 = 0.99$; $p < .001$; correlation coefficient = 0.99495) (Table 46). Interestingly, Rillito and Rincon phase persistent places were underpredicted by the model, and Tanque Verde and Tucson phase persistent places were slightly overpredicted. The differences between observed and expected values for each phase were not statistically significant ($\chi^2 = 0.716$; $df = 5$; $p < 1$), but it probably was not an accident that pre-Classic and Classic period persistent places varied in terms of whether they were overpredicted or underpredicted. There were slightly fewer Classic period persistent places than predicted by the model and a few more pre-Classic period persistent places than predicted (Figure 79). The biggest difference between model predictions and observed values occurred for the Rincon phase. There were three to four more Rincon phase persistent places than predicted. Possibly, either the probability of persistence for Rincon phase places was underestimated or the founding set of Cañada del Oro places is larger than was observed.

Table 46. Observed and Expected Numbers of Type I Persistent Places, with Related Metrics

Phase	End Date (A.D.)	Probability of Reuse (First Phase)	Probability of Reuse (Second Phase)	Probability of Persistence	Observed Founding Set	Estimated Founding Set	No. of Observed Persistent Places	No. of Estimated Persistent Places
Snaketown	800	0.50	0.40	0.20	2	—	—	0.4
Cañada del Oro	825	0.40	0.50	0.20	5	5.0	1	1.0
Rillito	1000	0.50	0.68	0.34	16	20.6	7	5.4
Rincon	1200	0.68	0.71	0.48	28	35.1	17	13.5
Tanque Verde	1300	0.71	0.35	0.25	202	195.3	49	50.7
Tucson	1450	0.35	0.08	0.03	574	514.7	14	15.6

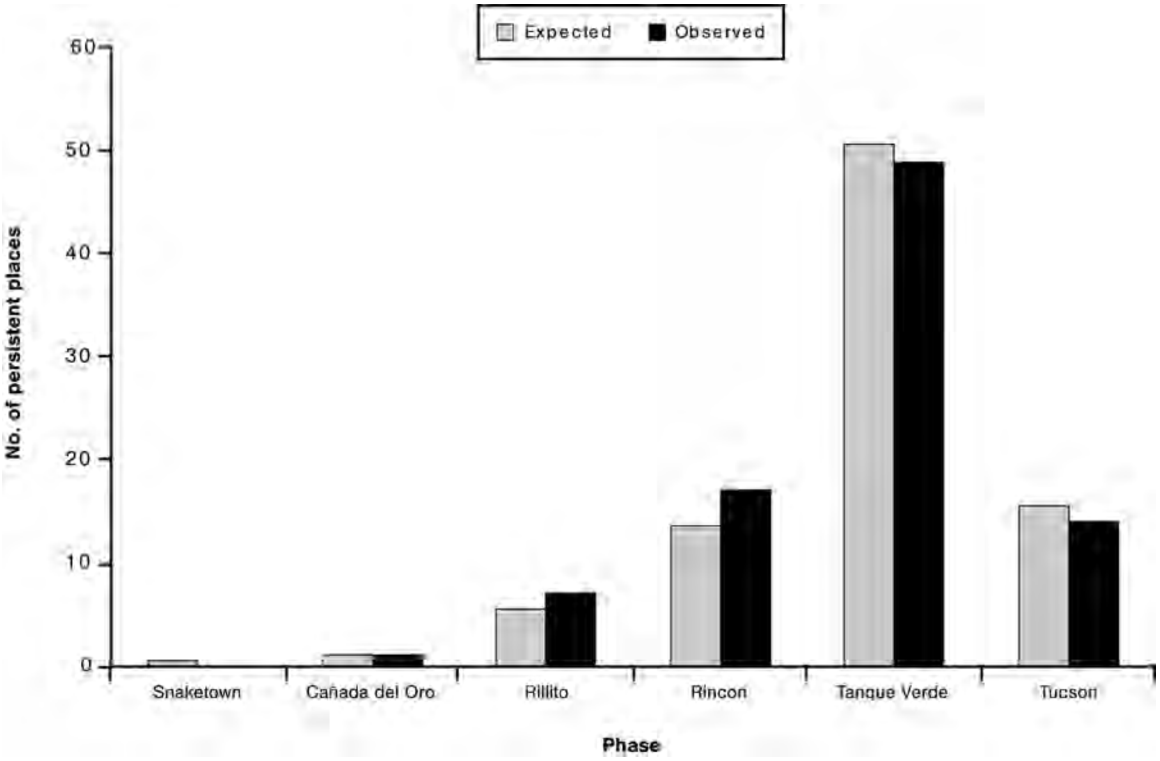

Figure 79. Chart of the observed vs. expected numbers of Type I persistent places, per phase.

A parsimonious explanation for differences between observed values and model predictions may be that Rillito and Rincon phase sites are more visible than earlier and later sites. In combination with their large numbers, discovery of Snaketown and Cañada del Oro phase components may be partially dependent on the discovery of Rillito or Rincon phase components. Similarly, elevated discovery of Rillito and Rincon phase components would lead to overestimation of the number of Classic period persistent places. The model predicted a steeper increase between pre-Classic and Classic period persistent-place formation than was inferred from the archaeological data.

Overall, however, the neutral model predictions and the observed values were a close match. If we use the observed number of persistent places and the probability of persistence to estimate the founding set of places, we find that the model predicted at least 4 more Snaketown places, 7 more Cañada del Oro places, 7 fewer Rillito places, and 59 fewer Rincon places than were observed. Some of the discrepancy could have resulted from data-entry omissions but could also have resulted from variation in the archaeological visibility of different phases. Percentage-wise, Snaketown and Cañada del Oro sites were observed or entered less often than we might have expected, and Rillito and Rincon phase sites were observed or entered somewhat more often. An alternative, behavior-based interpretation of these patterns would be that continuity in place use shifted through time, and the greatest continuity in place use occurred during the Middle Formative period.

The Persistent-Place Paradox

By examining patterns of reuse and abandonment, we can track persistent-place formation across both time and space. In the case of the Hohokam sequence, the probability of persistence peaks during the Rincon phase. A place established during the Cañada del Oro phase has an almost 50 percent chance of persisting into the Rincon phase. The probability of persistence begins to decline by the Tanque Verde phase and drops even further by the Tucson phase. A Rillito phase place had an approximately 25 percent chance of persisting into the Tanque Verde phase. A Rincon phase place had less than a 3 percent chance of persisting into the Tucson phase. Paradoxically, persistent-place formation was low and constant during the pre-Classic period and increased dramatically during the Classic period (Figure 80).

During the pre-Classic period, the percentage of persistent places was constant and low. New places were formed at high rates (Figures 81 and 82). The proportion of reused places to abandoned places was on the rise. During the Rillito and Rincon phases, the proportion was well above 1. During the Classic period, those patterns were almost entirely reversed. Few new places were formed. The proportion of reused places to abandoned places plummeted. Yet, the proportion of persistent places increased!

Apparently conflicting measures of continuity in place use are predicted by the neutral model presented above. Recall that the number of persistent places is dependent on both the probability of persistence *and* the founding set of places. The number of places increases almost exponentially during the pre-Classic period, leaving a large set of places available for reuse during the Classic period, even as large numbers of sites are abandoned. For instance, there were over 7 times more Rillito phase sites than Cañada del Oro phase sites, and there were 2.8 times more Rincon phase sites than there were Rillito phase sites. During the Rincon phase, there were more sites available than there had been in any previous or subsequent phase (n = 574). Even though reuse and place formation plummeted during the Classic period, and abandonment skyrocketed, the founding set of places was extraordinarily large. Moreover, those places extended over a large area, leaving many locations available for reuse rather than outright colonization.

Although the Classic period collapse implies a fundamental discontinuity across the pre-Classic to Classic period transition (Wilcox and Sternberg 1983), site reuse for the study area was proportionally at an all-time high. During both the Tanque Verde and Tucson phases, almost half of all places were being reused, and half were new. Similarly, proportions of persistent places increased rapidly during the Classic period, when, arguably, previously existing networks were reorganizing or falling apart. The pre-Classic period Tucson Basin landscape network grew rapidly, yet during each phase, persistent places remained at or below 3.5 percent of all contemporaneous places. During the Classic period, that percentage increased rapidly, such that by the end of the Classic period, over 20 percent of Late Classic period Hohokam sites were persistent places. How could this be?

Wilcox and Sternberg (1983:242); cf. Wallace and Holmlund (1984) argued that Classic period "site distributions suggest an increase in the scale of this local [Tucson Basin] system during the early Classic, thus possibly benefiting from the collapse of the Hohokam regional system." Evidence from other regions also suggests regional shifts in affiliations or connections (Hegmon et al. 1998). In terms of ceramics, pre-Classic period sites in the eastern Papaguería tend to be affiliated with the Phoenix Basin Hohokam, a presence that increased in intensity during the Sedentary period. A decided shift in geographic focus occurred during the Classic period, when sites in the eastern Papaguería are more often affiliated with the Tucson Basin Hohokam (Ahlstrom et al. 2001; Heilen and O'Mack 2006). Drastic changes implying fundamental reorganization also occurred in the Phoenix Basin (Bayman 2001; Redman 1992; Rice 1998).

The high percentage of persistent places during the Classic period is somewhat of a paradox. If the absolute number of sites is decreasing, and sites are being abandoned at unprecedentedly high rates, why does the percentage of persistent places increase during the Classic period? If the Hohokam landscape network is reorganizing or collapsing, why should the number of persistent places increase? More than two-thirds of Rincon phase sites (n = 372, or 64.8 percent) were abandoned by the Tanque Verde phase. Over 90 percent of Tanque Verde sites (n = 382, or 92.3 percent) were abandoned by the Tucson phase. If the Hohokam collapse was completed during the Classic period, 100 percent of Tucson phase sites were presumably abandoned by the end of the period, but despite increasing abandonment, persistent-place formation increased.

One potential explanation for this paradox, similar to the explanation posited by Schlanger (1992) for Anasazi sites, is that persistent-place formation is, in some cases, a function of settlement change as opposed to settlement stasis. As a region or portion of a region is abandoned, and residential activity is focused on new areas, former residential sites are reused for other purposes, such as logistic camps or sources of recyclable tools and raw materials. Abandonment at the scale of regions or subregions could, in some cases, result in frequent but lower intensity reuse of places in areas undergoing residential abandonment.

During the pre-Classic period, the formation of new sites always exceeded the number of reused sites by a factor of at least 2.5 (Figure 83), suggesting that in a growing network, although site reuse was high in absolute numbers, site formation was considerably higher. As the network reorganized, proportionally fewer places were being formed, and proportionally more were being reused. In both the

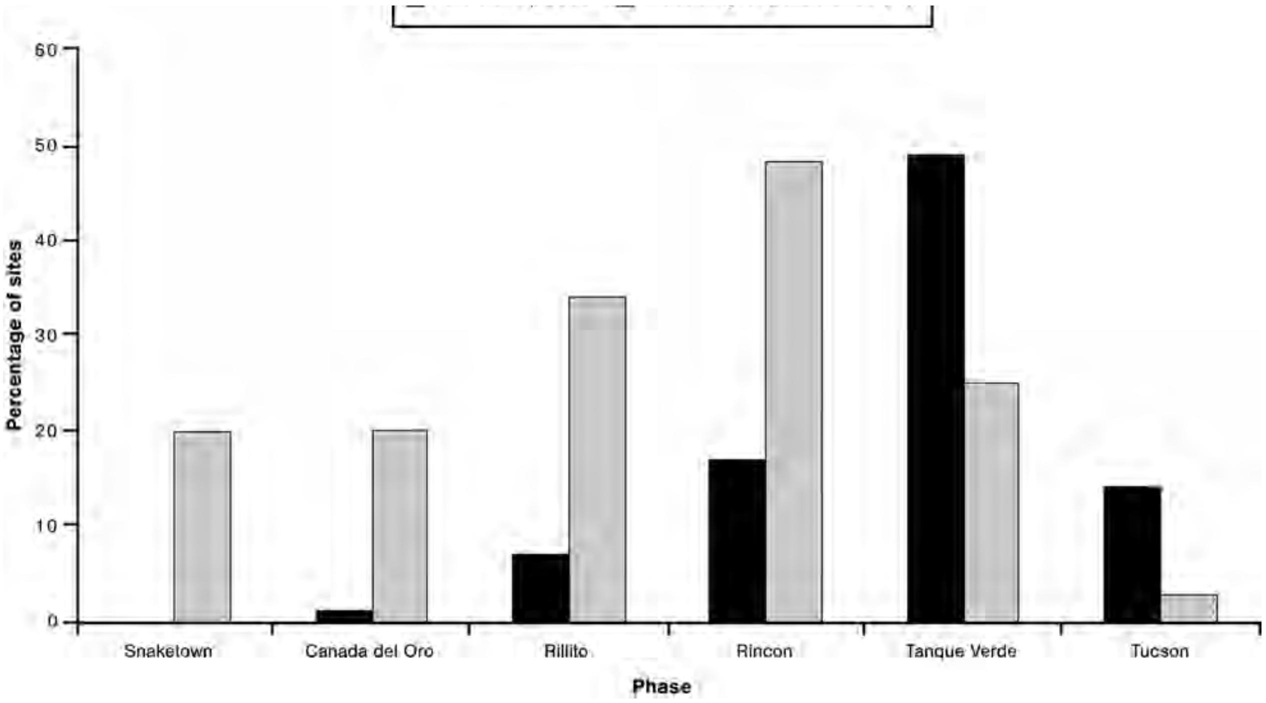

Figure 80. Comparison chart of the observed number of Type I persistent places and the probability of persistence, per phase.

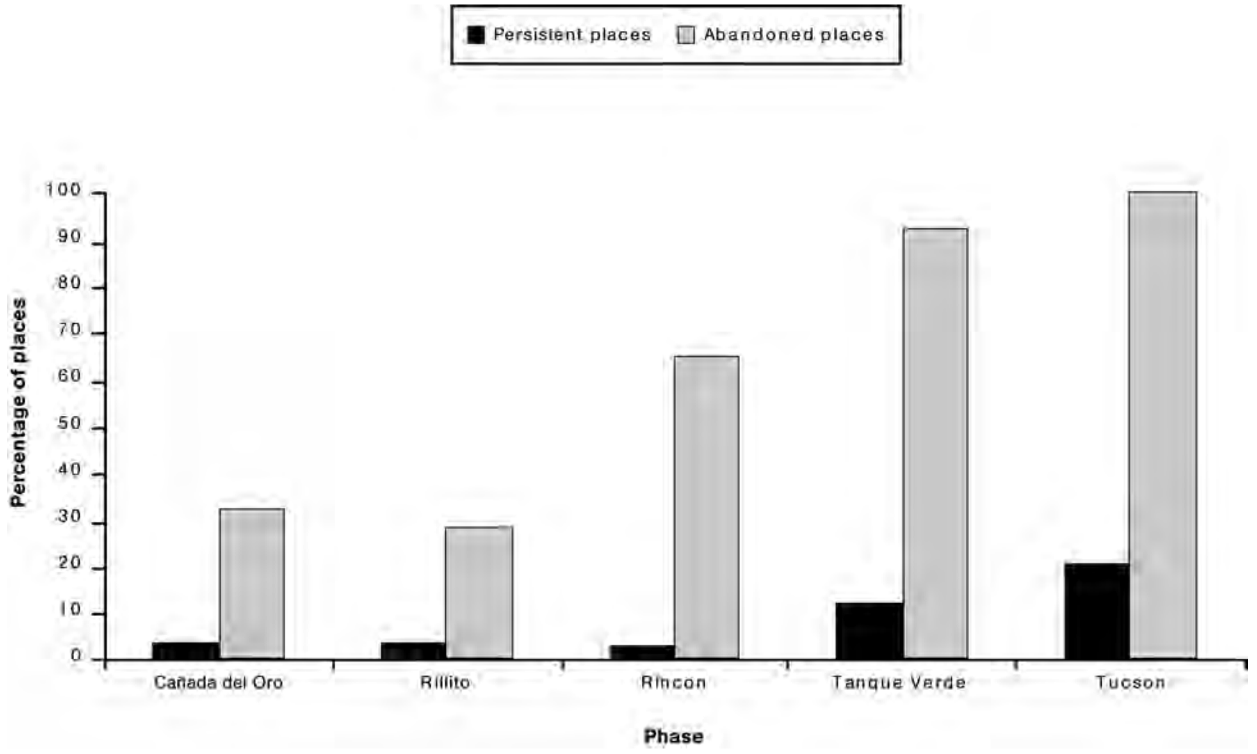

Figure 81. Comparison chart of the percentages of places that are persistent vs. those that are abandoned, per phase.

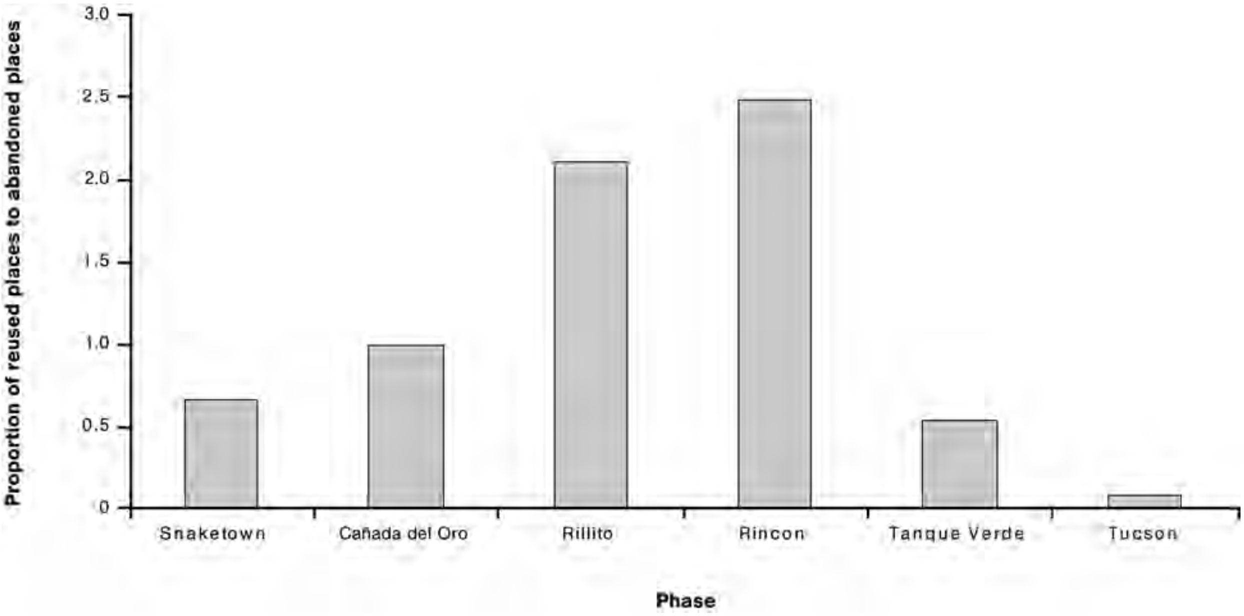

Figure 82. Chart of the proportion of reused to abandoned places, per phase.

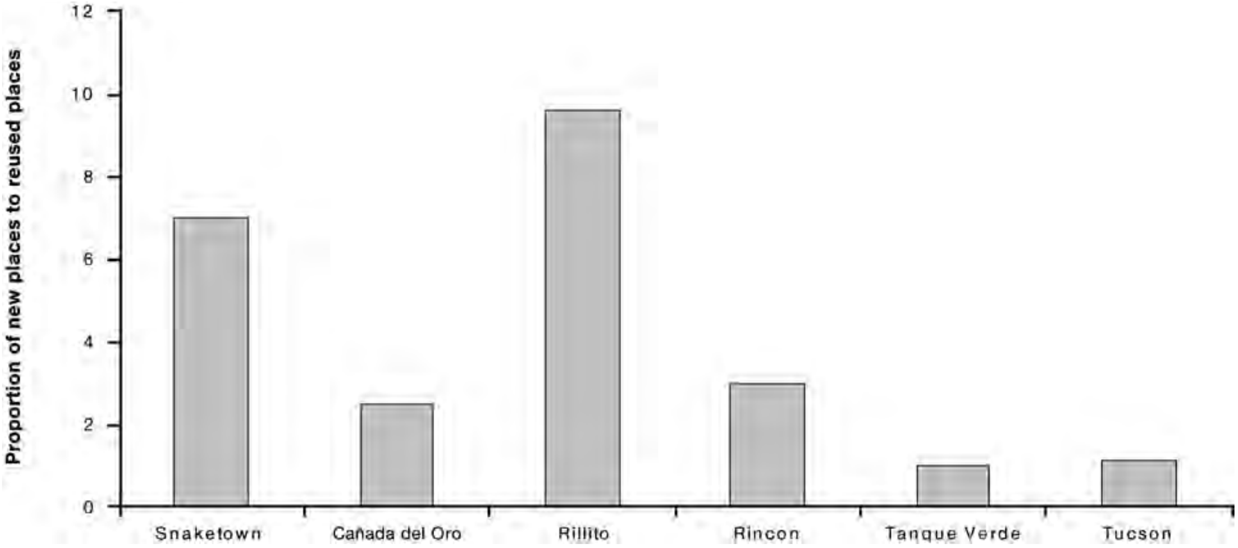

Figure 83. Chart of the proportion of new to reused places, per phase.

Tanque Verde and Tucson phases, there was approximately one new place for every reused place.[2]

For the Late Classic period, the overarching pattern appears to be that sites in middle and upper Santa Cruz Valley, the Cienega Creek valley, and the Tortolita Fan—essentially the western half of the study area—were almost entirely reused sites. As a consequence, almost all Tucson phase persistent places are in this zone. By contrast, most of the newly formed Late Classic period sites are in the middle and lower San Pedro Valley. Oddly enough, 33 of 36 places reused during the Late Classic period are in the western half of the study area, and 27 of 34 newly formed Late Classic period places are in the eastern half of the study area. During the Late Classic period, places that were part of the collapsing Tucson Basin Hohokam network were reused, and new places were formed in areas that had formerly been at the periphery of the Tucson Basin Hohokam network.

Discovery Bias

Interpreting patterns in persistent-place formation for the Tucson Basin Hohokam network is complicated by the effects of discovery bias. To evaluate the effects of discovery bias, information on investigation types in AZSITE was used to categorize sites according to whether they were subjected to only surface-survey investigations or investigated using some kind of subsurface investigative method, including test excavations or data recovery. Of the 963 sites in the Hohokam sample, 844 (87.6 percent) were investigated at the surface only, and 105 (10.9 percent) were investigated through testing or data recovery. No information on investigative methods was reported in AZSITE for an additional 14 sites (1.5 percent). Plotting the percentage of site components discovered via subsurface investigations against the end date for each archaeological phase reveals a clear pattern of discovery bias (Figure 84). The earliest components were often discovered as a result of subsurface investigation, and later components were discovered much more often as a result of surface investigation.

Understandably, discovery bias also plays a pronounced role in the identification of persistent places. Over 20 percent of sites investigated with subsurface methods were determined to be persistent places, whereas only 6 percent of sites investigated at the surface only were determined to be persistent places (Table 47). Clearly, persistent places are severely underestimated as a result of surface investigations, and later sites are much more commonly represented than earlier sites, purely as a result of discovery bias ($\chi^2 = 30.95$; $df = 2$; $p < .0001$). Percentage deviations from the expected values suggest that the number of persistent places discovered through subsurface investigation is 167 percent higher than we would expect, and the number of persistent places discovered through surface investigations is 20 percent lower than would be expected based on the chi-square distribution. Obviously, this suggests that there are proportionally more Snaketown and Cañada del Oro phase site components than have been reported, the Hohokam landscape network did not grow as quickly as is suggested by the data, and persistent-places were likely to have been substantially more common than is suggested by the AZSITE data.

Other investigators have observed that chronological distributions of archaeological sites often exhibit an exponential or power-law increase through time, a pattern routinely interpreted as reflecting a similar increase in population and land-use intensity. An alternative explanation for such rapidly increasing chronological distributions is that rather than reflecting population growth and settlement expansion, such distributions instead reflect decay in an archaeological signal through time, such that the earliest site components are infrequent, not because population levels were low, but because the signal for earlier components has degraded, and such site components either have been destroyed or are difficult to recognize archaeologically (Surovell and Brantingham 2007; Surovell et al. 2009). There appears to be at least some potential for correcting chronological distributions based on discovery bias; so, it may be possible in the future to adjust the chronological distributions discussed in this chapter to develop a more realistic model of persistent-place formation. In all likelihood, an adjusted distribution of sites according to the categories under discussion would show that reuse rates were lower than calculated, and rates of persistent-place formation were higher. Similarly, it would probably also

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[2] This suggests the mathematical possibility that during the Classic period, the reuse of a site was accompanied by the formation of a “sister” site. Tucson phase sites do occasionally occur in pairs, but at variable distances from each other. In the lower San Pedro Valley portion of the study area, a number of Late Classic period sites appear to be paired (AZ BB:6:13 [ASM] and AZ BB:6:49 [ASM]; AZ BB:6:73 [ASM] and AZ BB:6:68 [ASM]; AZ BB:11:63 [ASM] and AZ BB:11:62 [ASM]; AZ BB:11:10 [ASM] and AZ BB:11:36 [ASM]), but they are all classified as newly formed. Conceivably, paired sites could represent functionally interdependent or related places. Alternatively, paired sites could represent distinct archaeological manifestations of a single systemic entity, such as a large, dispersed village. With the exception of possibly paired sites, Late Classic period sites along lower San Pedro Valley appear to be relatively evenly spaced along the upper terraces of the San Pedro River, between 2.8 and 3.8 km apart. In the western half of the study area, in Santa Cruz Valley and the Tortolita Fan, there are also a number of apparently paired sites (AZ BB:5:26 [ASM] and AZ BB:9:82 [ASM], AZ AA:12:31 [ASM] and AZ AA:12:38 [ASM]; AZ BB:9:32 [ASM] and AZ BB:9:50 [ASM], AZ BB:13:64 [ASM] and AZ BB:13:46 [ASM], AZ BB:13:120 [ASM] and AZ BB:13:1 [ASM]). These apparently paired sites are located 2.5–3.3 km apart. A series of sites along the Santa Cruz River, immediately north of Tumamoc Hill, are also similarly spaced, and several could be interpreted as pairs of sites.

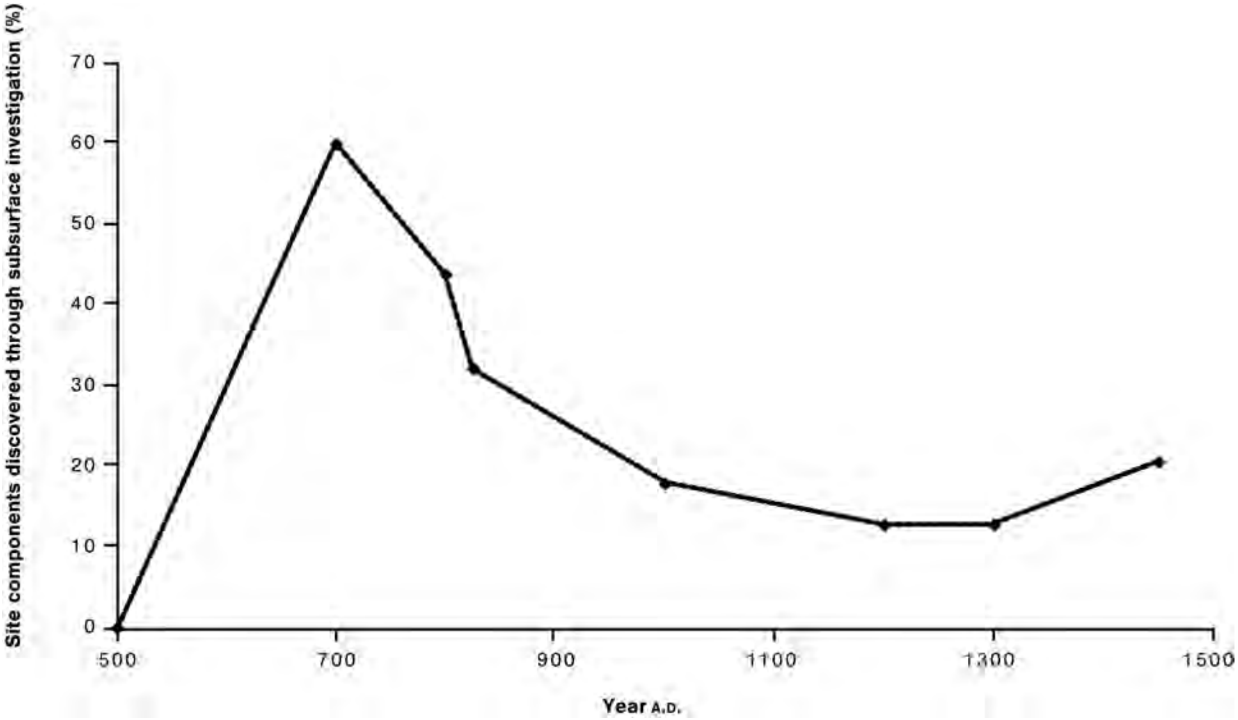

Figure 84. Chart of the percentage of site components discovered as a result of subsurface investigations, according to time.

Table 47. Numbers of Places Identified as Persistent and Not Persistent, by Investigative Method

Investigative Method	Not Persistent	Persistent	Total
Surface only	791	53	844
Subsurface	82	23	105
Not reported	14	—	14
Total	887	76	963

show that the Hohokam landscape network did not grow as rapidly during the pre-Classic period as the numbers of recorded temporal components would suggest and that sites were more common early in the sequence than has been documented.

Summary of Findings

In summary, Type I persistent-place formation is predicted well by a neutral model of persistent-place formation. The network of places in the study area appears to grow exponentially during the pre-Classic period and shrink rapidly during the Classic period. The rate of growth, however, may be substantially lower than calculated using the AZSITE data, as a result of discovery bias. By the Classic period, abandonment outpaced reuse or place formation, but reuse and persistent-place formation increased. Spatially, these patterns appear to correspond to settlement shifts that increased in geographic scale through time, and they suggest that reuse and abandonment were integrated, multi-scalar processes. Type I persistent-place formation reinforces the point that persistent-place formation may often occur in the context of settlement change, rather than stasis. In the case of the Tucson Hohokam network, place use probably was continuous, in the sense that denizens cognized landscapes as sets of related, potentially useful places. The elevated reuse of places during the Classic period suggests that existing pre-Classic period sites were on the radar of the Classic period Hohokam and remained parts of their cognized landscape, despite social and economic reorganization.

Type II Persistent-Place Formation

The formal model developed above for predicting the number of persistent places can be applied at the scale of periods. Sites used during the Archaic, Formative, and historical periods are conceptualized here as Type II persistent places, because it is more likely that persistence at the scale of the period results from Type II landscape interactions as opposed to Type I landscape interactions. Other finer-scale data, analyzed at the level of individual deposits, features, and sites, will likely have to be marshalled to argue for continuity or discontinuity in place use at the scale of archaeological periods.

In order to compare spatial variation in persistent-place formation at the scale of periods, the presence or absence of Archaic period, Formative period, or historical-period components was calculated for 5,676 sites throughout the study area. In total, 4,033 sites had at least one of the three components. Each site was classified in terms of the watershed in which it occurred: Avra Valley/Altar Valley, the Cienega Creek valley, the lower Gila River valley, lower San Pedro Valley, lower Santa Cruz Valley, middle San Pedro Valley, middle Santa Cruz Valley, Sasabe, Sulphur Springs Valley, the Tortolita Fan, upper Santa Cruz Valley, and Whitewater Draw (Figures 85–87; Table 48). Comparisons of site reuse and persistent-place formation were made between watersheds. Only a few sites in the Sasabe and lower Gila River watersheds have been recorded within the study area. Because of small sample sizes, those sites were removed from the analysis.

As with Type I persistent places, the estimated number of Type II persistent places is highly correlated (correlation coefficient = .9918) to the observed number of persistent places. Nonetheless, the *estimated* number of persistent places is nearly always smaller than the *observed* number of persistent places (Table 49). When three outliers are removed—middle Santa Cruz Valley, Avra Valley/Altar Valley, and the Cienega Creek valley—there are typically 1.7 ± 0.04 more persistent places than estimated ($r^2 = 1.00$; $p < .001$)[3]. Why should this be?

A parsimonious explanation for consistent underestimation of the number of Type II persistent places is that the number of Archaic period places (A) is underestimated. If reuse probabilities are accurate for Archaic and Formative period sites, then dividing the observed number of persistent places by the probability of persistence provides an estimate of how many Archaic period places should have been observed (A_E). If we divide the observed number of Archaic period components by the expected number and multiply by 100, we obtain an estimate of the discovery rate of Archaic period sites. Following this line of reasoning, the average discovery rate of Archaic period components is around 44 percent (Table 50).

Following this line of reasoning, we can estimate that Archaic period sites in the Cienega Creek valley are discovered at the highest rate (71 percent). Archaic period sites in middle San Pedro Valley, the Tortolita Fan, and upper Santa Cruz Valley watersheds are discovered at roughly equivalent rates, around 60 percent. Archaic period sites in middle Santa Cruz Valley (45 percent) are discovered at low rates, and Archaic period sites in the Sulphur Springs Valley and lower Gila River valley watersheds are discovered at the lowest rates. In watersheds where either no persistent places or one persistent place has been observed, the number of Archaic period sites is not estimated, and the discovery rate of Archaic period sites is not evaluated. If Archaic period components are discovered at low rates, and the number of Archaic period places is underestimated, then the probability of reuse could be overestimated. An alternative, behavior-based interpretation of the differences between observed and expected numbers of sites is that Archaic period places were preferentially and heavily reused in later periods, because of factors such as the presence of water sources or abundant natural resources or because they occurred in landscape funnels.

The Differential Discovery of Archaeological Components

Frequencies and relative proportions of sites with Archaic period (A), Formative period (F), or historical-period (H) components share a variety of interesting quantitative

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[3] Avra Valley/Altar Valley is an outlier, because there were no observed persistent places, when our estimates told us there should be at least 1 or 2. Middle Santa Cruz Valley is an outlier, because there were proportionally more observed persistent places than in other watersheds (n = 35). There were 19 or 20 more persistent places than expected in middle Santa Cruz Valley. The Cienega Creek valley is an outlier, because the number of persistent place was 1 fewer than it should have been. There are a variety of reasons that could be invoked to explain these outliers, many of which may have to do with methodology and the nature of the sample, rather than major differences between watersheds. In cases like Avra Valley/Altar Valley and the Cienega Creek valley, 1 or 2 missing cases could simply result from failure to enter all temporal components into AZSITE. The Avra and Altar Valleys are not completely encompassed by the study area; so, an inadequate or environmentally biased sample could also account for the Avra Valley/Altar Valley discrepancy. Missing cases probably also played a role in middle Santa Cruz Valley, but the discrepancy between observed and estimated numbers of persistent places could also relate to the intensity of investigation in the Tucson Basin. Some of the largest, most intensive excavations in the study area have been conducted in the Tucson Basin, and many sites may have been investigated numerous times. There is probably a greater likelihood that more components will be recognized in areas of more intensive, repeated investigations than in areas with less frequent, more circumspect investigations.

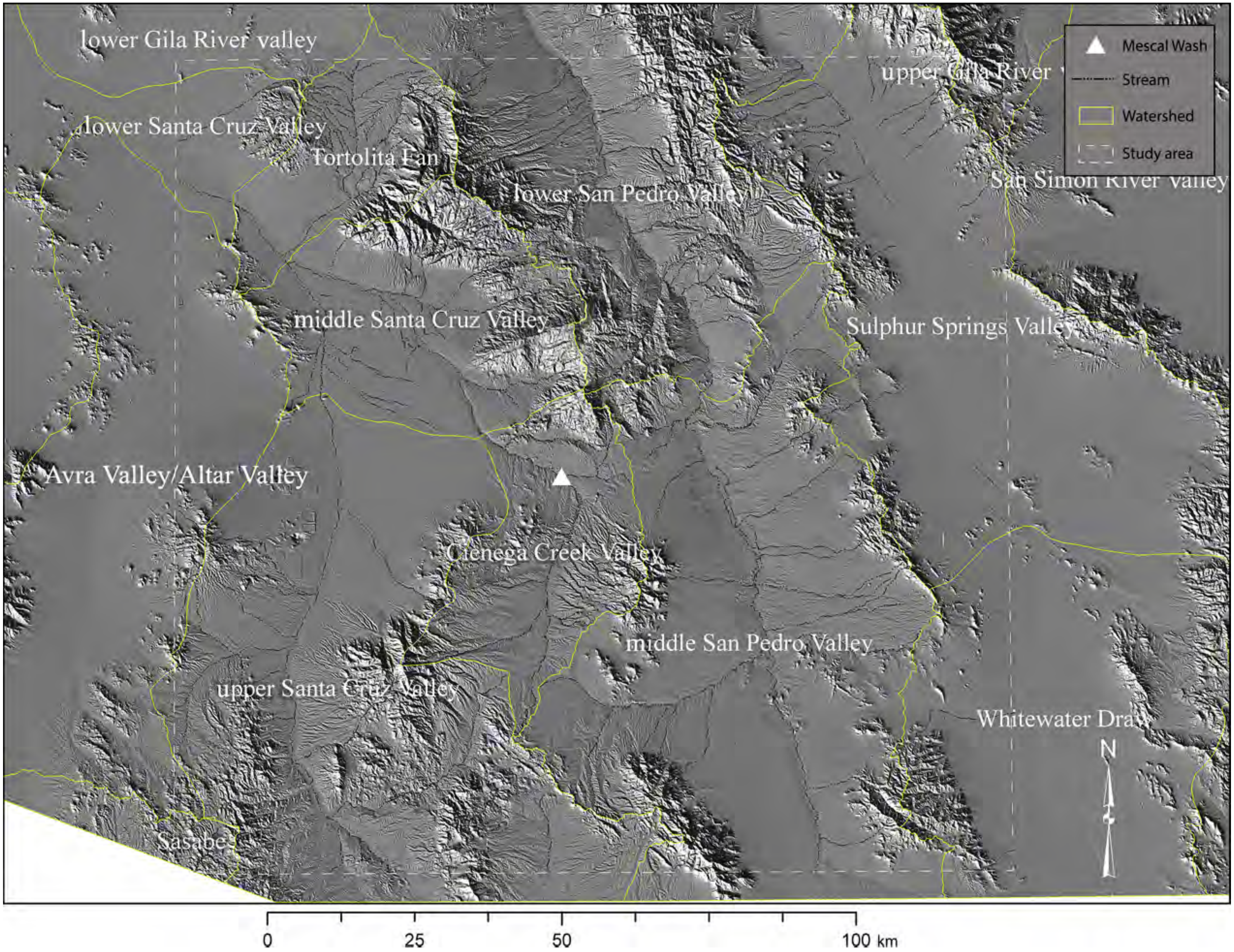

Figure 85. Map showing the locations of the watershed boundaries used to evaluate Type II persistent-place formation across the study area.

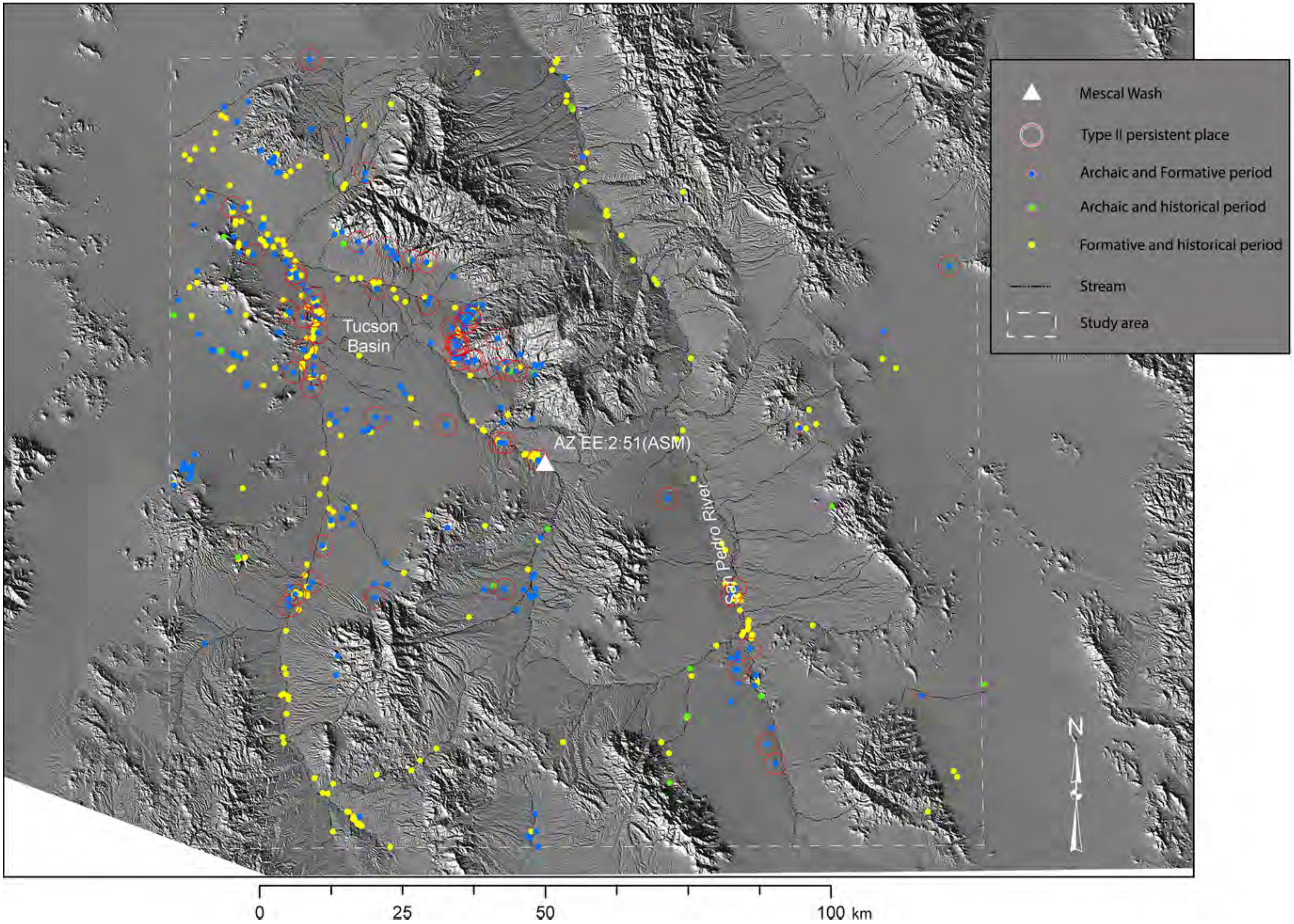

Figure 86. Map showing the locations of sites that were used during multiple temporal periods.

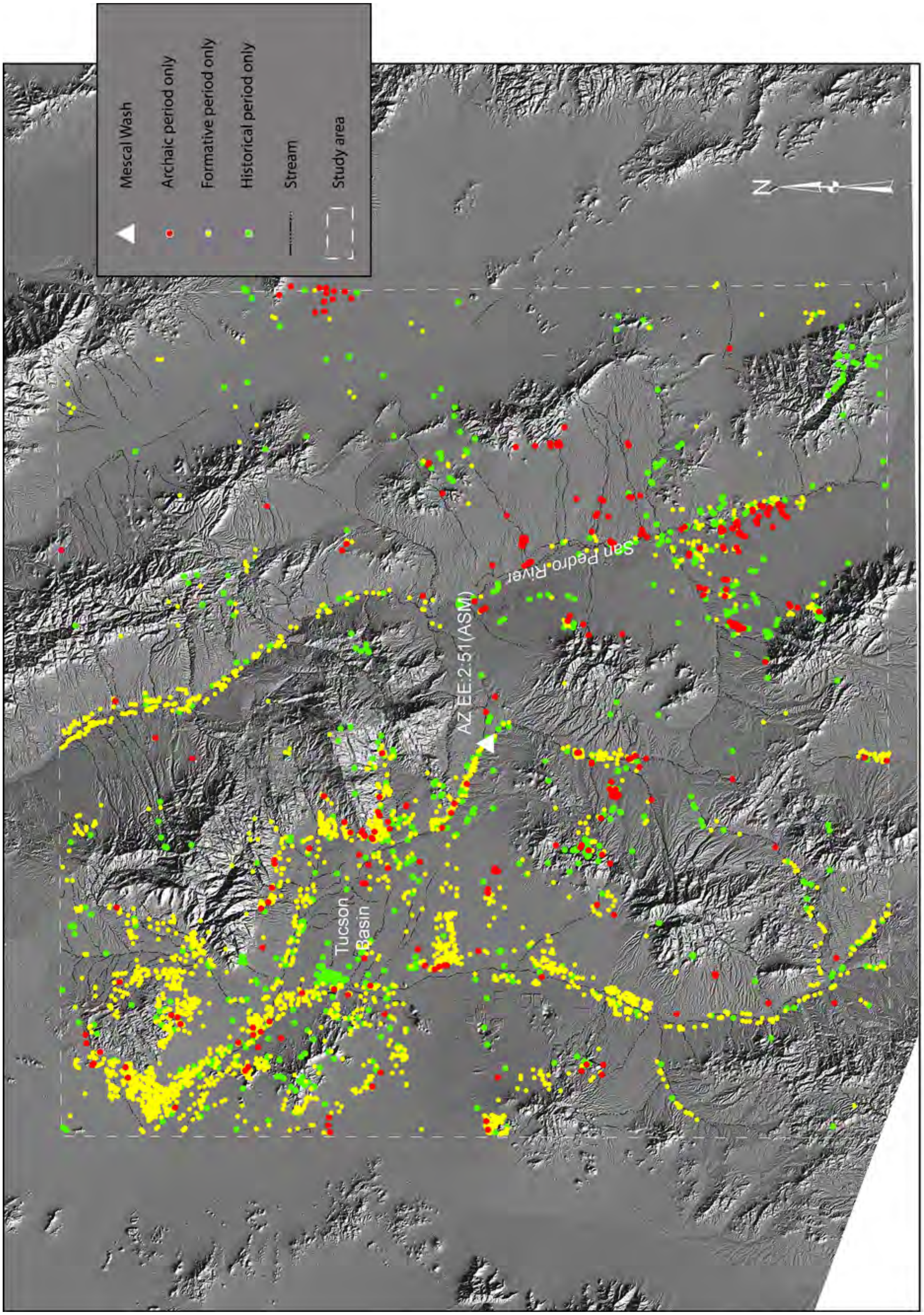

Figure 87. Map showing the locations of sites that were unique to the Archaic, Formative, or historical period.

Table 48. Sites with Archaic Period, Formative Period, or Historical-Period Components

Watershed	Archaic Period Only	Formative Period Only	Historical Period Only	Archaic and Formative Periods	Formative and Historical Periods	Archaic and Historical Periods	Persistent Place	Archaic Period Total	Formative Period Total	Historical-Period Total
Avra Valley/Altar Valley	8	148	34	25	11	3	—	36	184	48
Cienega Creek valley	29	114	83	18	24	2	4	49	156	109
Lower Gila River valley	—	2	5	1	1	—	1	1	4	6
Lower San Pedro Valley	7	198	41	2	21	1	—	10	221	63
Lower Santa Cruz Valley	8	447	19	6	10	1	—	15	463	30
Middle San Pedro Valley	124	116	163	18	38	5	7	147	172	206
Middle Santa Cruz Valley	40	496	232	97	107	6	35	143	700	345
Sasabe	—	1	1	—	—	—	—	—	1	1
Sulphur Springs Valley	14	21	27	2	5	—	1	16	28	32
Tortolita Fan	13	413	62	24	36	—	3	37	473	98
Upper Santa Cruz Valley	35	473	102	37	73	1	8	73	583	176
Whitewater Draw	1	14	21	1	3	1	—	3	18	25
Total	279	2,443	790	231	329	20	59	530	3,003	1,139

Table 49. Observed and Expected Numbers of Type II Persistent Places, with Related Metrics

Watershed	Probability of Archaic Period Site Reuse	Probability of Formative Period Site Reuse	Probability of Persistence	No. of Observed Archaic Period Sites	No. of Expected Type II Persistent Places	No. of Observed Type II Persistent Places
Avra Valley/Altar Valley	0.69	0.06	0.04	36	1.5	—
Cienega Creek valley	0.37	0.16	0.06	49	2.8	4
Lower Gila River valley	1.00	0.33	0.33	1	0.3	1
Lower San Pedro Valley	0.20	0.10	0.02	10	0.2	—
Lower Santa Cruz Valley	0.40	0.02	0.01	15	0.1	—
Middle San Pedro Valley	0.12	0.23	0.03	147	4.1	7
Middle Santa Cruz Valley	0.68	0.16	0.11	143	15.6	35
Sasabe	0.00	0.00	0.00	—	0.0	—
Sulphur Springs Valley	0.13	0.19	0.02	16	0.4	1
Tortolita Fan	0.65	0.08	0.05	37	1.8	3
Upper Santa Cruz Valley	0.51	0.13	0.06	73	4.7	8
Whitewater Draw	0.33	0.17	0.06	3	0.2	—
Total/Average	0.44	0.11	0.05	530	25.8	59

Table 50. Estimated Discovery Rates of Archaic Period Site Components Relative to Later Components

Watershed	No. of Observed Archaic Period Sites	No. of Expected Archaic Period Sites	Estimated Discovery Rate of Archaic Period Sites
Avra Valley/Altar Valley	36	—	
Cienega Creek valley	49	69.0	71.1
Lower Gila River valley	1	3.0	33.3
Lower San Pedro Valley	10	—	
Lower Santa Cruz Valley	15	—	
Middle San Pedro Valley	147	248.2	59.2
Middle Santa Cruz Valley	143	320.7	44.6
Sasabe	—	—	
Sulphur Springs Valley	16	43.2	37.0
Tortolita Fan	37	60.4	61.3
Upper Santa Cruz Valley	73	124.3	58.7
Whitewater Draw	3	—	
Total/Average	530	1,211.3	43.8

relationships at the watershed level. Most of these relationships hold for a subset of the investigated watersheds. Although there are a number of regularities in which watersheds participate in which relationships, different empirically derived relationships consisted of different sets of watersheds. Possibly, different combinations of environmental- and cultural-formation processes as well as methodological bias account for differential participation in the identified empirical relationships.

For instance, in a number of watersheds, the discovery of Archaic period and historical-period components increases exponentially with the discovery of Formative period components (Figure 88). One implication of these relationships is that discovery of both Archaic period and historical-period components is often a consequence of discovering a Formative period component. The middle San Pedro Valley is frequently an outlier in these relationships and appears to have undergone a somewhat different

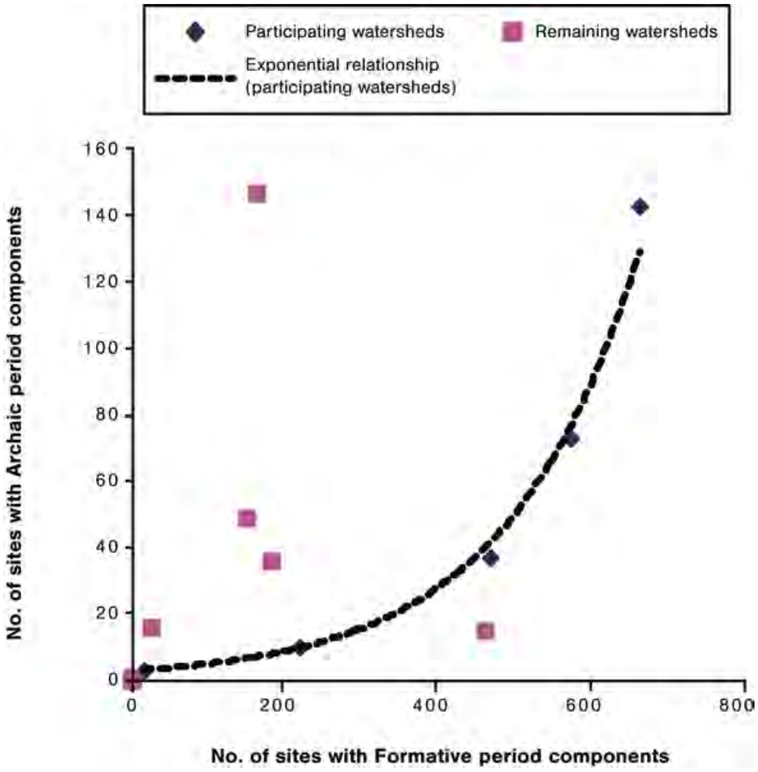

Figure 88. Chart of the relationship between the number of sites with Formative period components and the number of sites with Archaic period components, per watershed.

culture history and a different regime of formation processes than other nearby watersheds.

Because of the abundance of ceramic sherds in archaeological contexts in southeastern Arizona, Formative period materials are often highly visible components of archaeological landscapes. Archaic period components, by contrast, are often identified by the presence of relatively rare projectile point types or by inferences about flaked stone technology. Historical-period components are typically discovered by a number of attributes that suggest a site component is neither prehistoric nor modern, including diagnostic metal or glass artifacts. Though sometimes highly visible or intrusive, historical-period components are not often given as much consideration as prehistoric components during archaeological investigations.

For five watersheds—lower San Pedro Valley, middle Santa Cruz Valley, the Tortolita Fan, upper Santa Cruz Valley, and Whitewater draw—the number of Archaic period components increases exponentially with the number of Formative period components ($A = 2.6593e^{0.0058F}$; $r^2 = 0.9973$). According to this relationship, there are a lot fewer sites with Archaic period components and a lot more sites with Formative period components in lower Santa Cruz Valley than would be expected. There are a lot fewer sites with Formative period components and a lot more sites with Archaic period components in Avra Valley/Altar Valley, Sulphur Springs Valley, the Cienega Creek valley, and middle San Pedro Valley than this relationship would indicate.

A similar empirical relationship between sites with historical-period components and sites with Formative period components occurs for seven watersheds—Avra Valley/Altar Valley, lower San Pedro Valley, middle Santa Cruz Valley, Sulphur Springs Valley, the Tortolita Fan, upper Santa Cruz Valley, and Whitewater Draw ($H = 25.633e^{0.0035F}$; $r^2 = 0.9973$) (Figure 89). Notice that the watersheds in the graphed relationship, along with two additional watersheds—Avra Valley/Altar Valley and Whitewater Draw—are the same watersheds as in the relationship between sites with Archaic period components and sites with Formative period components. Both relationships suggest that as the number of sites with Formative period components increases, sites with Archaic period components and sites with historical-period components also increase, but at different intrinsic growth rates. These two empirical relationships intersect at 1,016 sites with Formative period components, when sites with Archaic period components and sites with historical-period components would equal 1,014. These two equations imply that although most observations of the archaeological landscape are swamped by sites with Formative period components, more-even proportions of different-aged components will

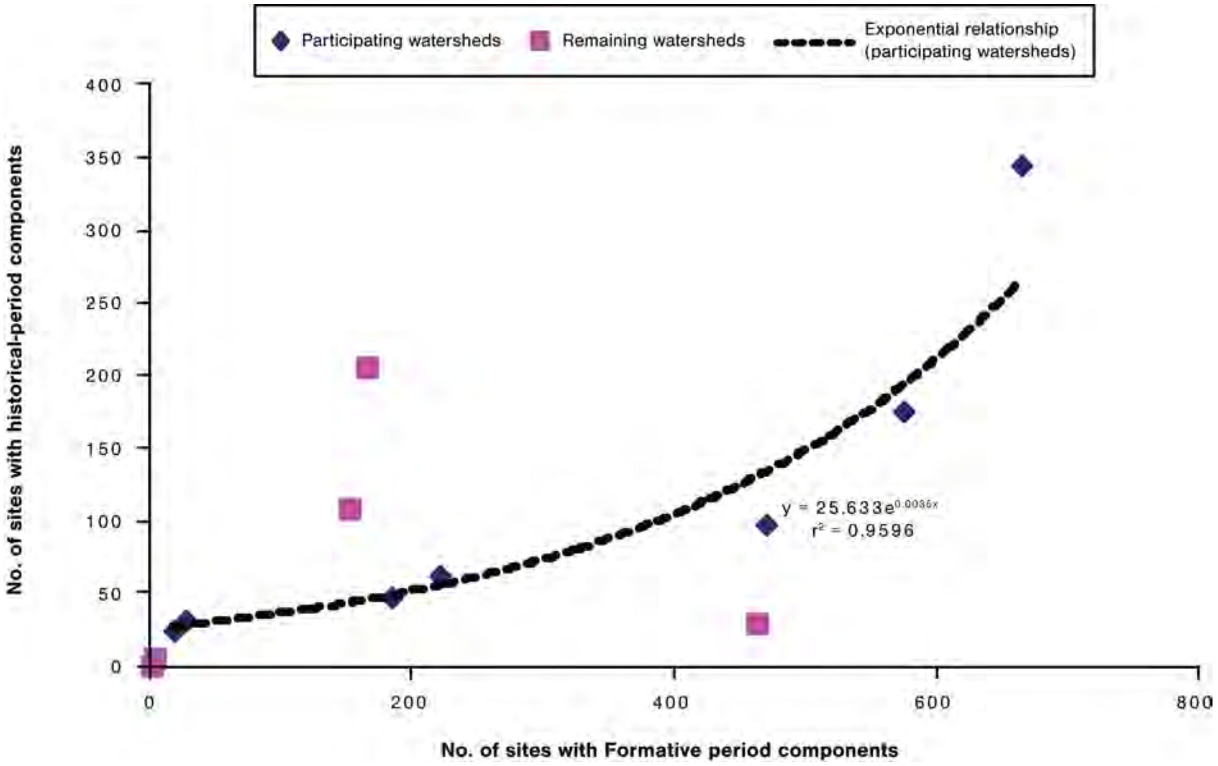

Figure 89. Chart of the relationship between the number of sites with historical-period components and the number of sites with Archaic period components, per watershed.

be obtained as the number of Formative period components increases.

Similar exponential relationships are obtained for the number of sites with both Archaic and Formative period components (A_F) and for the number of sites with both historical-period and Formative period components (H_F): $A_F = 1.6352e^{0.0058F}$ ($r^2 = 0.9877$) and $H_F = 3.624e^{0.0051F}$ ($r^2 = 0.9853$). These relationships have similar exponents but different constants, suggesting that the two relationships will only intercept at an exceptionally large number of sites with Formative period components (F = 50,460,876). Together, these relationships suggest that sites with Archaic period components and sites with historical-period components tend to be discovered as a consequence of Formative period component discovery but that Archaic period components are discovered more often along with Formative period components than historical-period components are. Thus, as is not entirely unexpected, there is greater locational continuity between Archaic and Formative period sites than between Formative period and historical-period sites, or alternatively, the discovery of sites with Archaic period components is biased by the discovery of sites with Formative period components to a greater degree than is the discovery of sites with historical-period components.

Because relative proportions of A, F, and H could vary between watersheds, another way to evaluate bias in the discovery of A and H is to monitor the proportions A_F/A and H_F/H with respect to each other and with respect to F. Oddly, there is an apparent polynomial relationship for most watersheds, such that $H_F/H = -7.7689\,(A_F/A)^2 + 8.3339\,(A_F/A) - 1.7868$; $r^2 = 0.9519$ (Figure 90). The relationship does not obtain for Sulphur Springs Valley, middle San Pedro Valley, and lower San Pedro Valley. For each of these outliers, A_F/A is less than H_F/H, implying that the discovery of A in these watersheds is not as much a consequence of the discovery of F as it is in other watersheds. Potentially, there is more continuity in place use between F and H in these watersheds than there is between A and F. In the remaining watersheds, A_F/A is always greater than H_F/H, implying the reverse. H_F/H increases with A_F/A in Whitewater Draw, the Cienega Creek valley, and lower Santa Cruz Valley. H_F/H decreases as A_F/A increases in the Tortolita Fan, middle Santa Cruz Valley, and Avra Valley/Altar Valley.

Most informative, A_F/A increases linearly with F in the upper, middle, and lower Santa Cruz Valley and middle and lower San Pedro Valley, implying broad similarities in the relationship between A and F discovery across these two major valley systems ($A_F/A = 0.001F - 0.0464$; $r^2 = 0.9787$). All the watersheds that do not participate in the relationship are above the relationship, implying a greater continuity in A and F place use in valley systems peripheral to the Santa Cruz River and San Pedro River

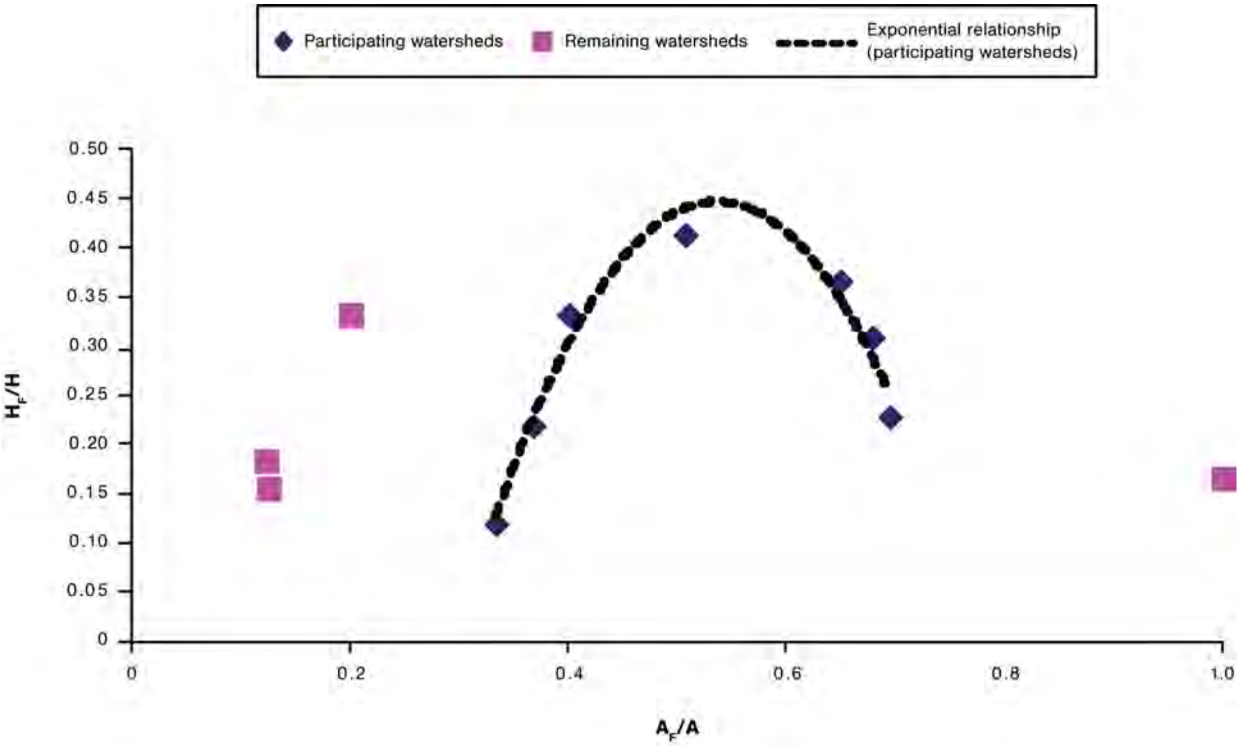

Figure 90. Chart of the relationship between the proportion of historical-period sites that were also used during the Formative period (HF/H) and the proportion of Archaic period sites reused during the Formative period (AF/A), per watershed.

valley systems, variation in depositional factors associated with upland and lowland depositional systems, or an even greater bias in the discovery of Archaic period components (Figure 91).

Similar relationships obtain for H_F/H and F, except according to different sets of watersheds. Two relationships with identical slopes are obtained between H_F/H and F. H_F/H increases with F at exactly half the rate of the above relationship. Sulphur Springs Valley, the Cienega Creek valley, Avra Valley/Altar Valley, upper Santa Cruz Valley, and the Tortolita Fan fall along the relationship $H_F/H = 0.0005\ F + 0.1449$; $r^2 = 0.9995$. Whitewater Draw, middle San Pedro Valley, and lower Santa Cruz Valley fall along the similar relationship, $H_F/H = 0.0005\ F + 0.1087$; $r^2 = 0.9990$. Lower San Pedro Valley is well above either relationship, and middle Santa Cruz Valley is well below either relationship.

Taken together, the above relationships imply that both Archaic period and historical-period components are often discovered as a consequence of discovering Formative period components. Further, Archaic period components are more likely than historical-period components to be discovered as a consequence of discovering a Formative period component.

Continuity and Discontinuity in Place Use over Time and across Watersheds

The above relationships could also imply that, in general, there was more continuity in place use between the Archaic and Formative periods. There may have been less continuity in place use in Sulphur Springs Valley ($A_F/A = 0.125$), lower San Pedro Valley ($A_F/A = 0.20$), and middle San Pedro Valley ($A_F/A = 0.122$). There may be more continuity in place use in Avra Valley/Altar Valley ($A_F/A = 0.694$), middle Santa Cruz Valley ($A_F/A = 0.678$), and the Tortolita Fan ($A_F/A = 0.649$). Oddly enough, each of these groups of three watersheds is geographically contiguous. This spatial pattern could be taken to have resulted from a general east–west settlement shift between the Archaic and Formative periods. Archaic period land use occurred throughout the study area but may have had more of an upland-lowland orientation, with more frequent movement throughout the study area between major environmental zones. Formative period land use, though not exclusive to any particular area, may have had more of a lowland focus concomitant with greater reliance on agriculture. Some of

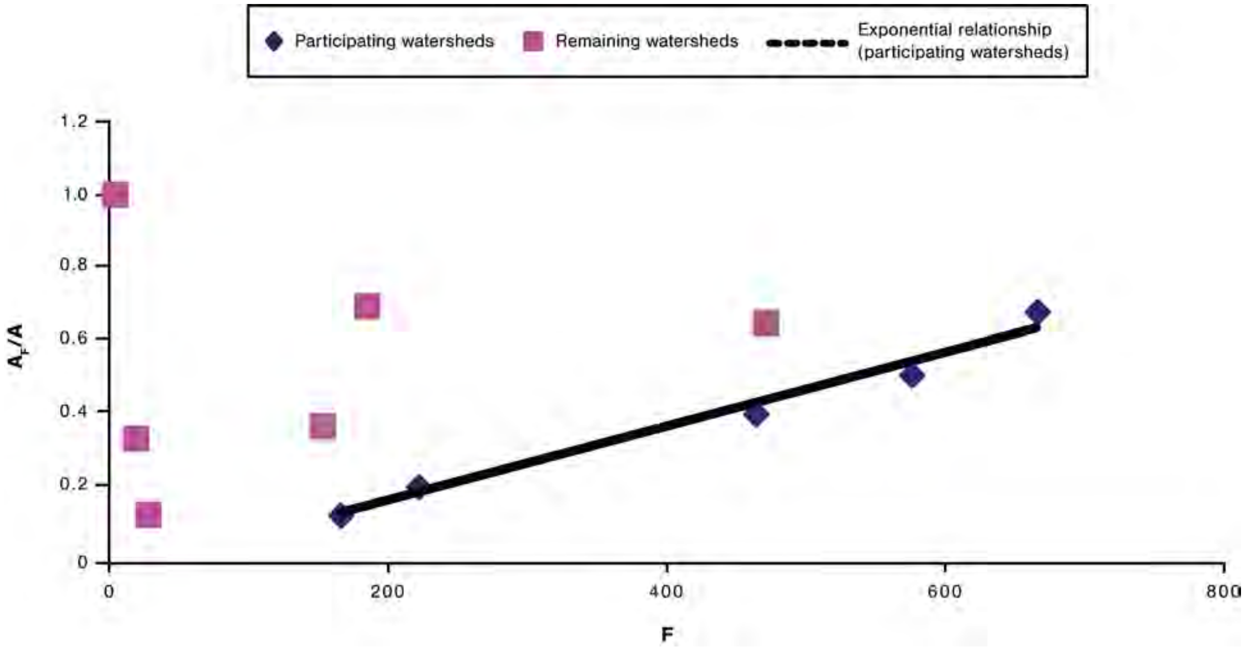

Figure 91. Chart of the relationship between the number of sites with Formative period components (F) and the proportion of Archaic period sites reused during the Formative period (AF/A), per watershed.

the best agricultural lands may have been concentrated in Santa Cruz Valley and in more restricted areas of San Pedro Valley. Well-watered places in the vicinity of the Tucson Basin tended to be reused for agriculture. In San Pedro and Sulphur Springs Valleys, places involved in foraging or farming systems may have been locationally distinctive. Grasslands associated with foraging systems may have been locationally distinct from canyon bottoms used agriculturally (Altschul 1997). Grass-seed subsistence systems commonly implemented in San Pedro Valley persisted over long time frames and may have required environmental settings different from those later used for agriculture or other uses (Vanderpot 1997; see also Altschul et al. n.d.). In other words, environmental resources that are spatially redundant in the Tucson Basin area may be more discrete in the San Pedro River area. In this sense, variation between watersheds in the apparent continuity of place use suggests variation in behavioral responses controlled by the interaction of landscape-resource structure, physiography, and subsistence technology.

These empirical trends have a bearing on the interpretation of Type II persistent-place formation. At their most basic level, they imply that there should be more sites with Archaic period or historical-period components than have been discovered by traditional survey methods. Until survey methods rectify discovery biases, sites with Formative period components will continue to dominate our understandings of archaeological site locations and relationships among Archaic period, Formative period, and historical-period site components. As a result of these biases, Type II persistent places are probably rarer than their discovery would cause us to believe. Discovery bias suggests that with current methods, we are likely to underestimate the relative number of Archaic period and historical-period places and overestimate the relative number of Formative period places. As a result, the *relative* number of Type II persistent places derived from AZSITE records could be an overestimation. At the same time, there does appear to have been variation among watersheds and among archaeological periods in the continuity of place use. Archaic period sites appear to have been more often reused in later periods in some watersheds, particularly those where agriculture was important, but less often reused in other watersheds where the focus of settlement may have targeted different sets of resources in different archaeological periods.

Location, Location, Location: Mescal Wash as a Type III Persistent Place

Mescal Wash exists within close proximity to diverse habitats along the transition between two major biomes, the Sonoran and Chihuahuan Deserts. Mescal Wash also occurs at a “cultural transition zone between prehistoric agriculturalists to the west, considered to be part of the Hohokam culture, and those to the north and east, recognized as Mogollon” (Vanderpot 2001b:10). Based on the distribution of ceramic wares (see below), Mescal Wash appears to have been located along a material-culture boundary between Mogollon traditions to the east, Hohokam traditions to the west, and Sonoran traditions to the south.

Ecological edges have a variety of effects on species interactions, including the ability to generate novel interactions between species (Fagan et al. 1999). Often, ecological edges are areas of enhanced biodiversity because they combine structural and functional components of several ecological units that normally cover discrete areas. Ecological edges also provide more immediate access to the multiple habitats they border or create. Common kinds of ecological edges are land/water interfaces, marsh/woodland interfaces, and forest/grassland interfaces. Biogeographically, Mescal Wash occurs at an ecological edge between Sonoran desertscrub and Chihuahuan grasslands, as well as at the interface of wetland and non-wetland habitats.

Turner et al. (2003) argued that cultural edges perform functions analogous to ecological edges. To Turner et al. (2003:452), cultural edges "promote exchanges and transferences of many types of goods, technologies, and knowledge amongst peoples." Turner et al. (2003) also suggested that ecological and cultural edges often, but not always, converge on the same space. Interactions and exchanges occurring along cultural edges are argued to enhance a people's flexibility and resilience by providing a wider range of strategic options with which to respond to changing circumstances.

As boundaries, borders, and frontiers can perform many different functions ranging from integrative or creative to exclusive and conflicted. Borders and frontiers are not the same but are aspects along a continuum of boundary types. Borders are typically static or restrictive, whereas frontiers are typically more porous or fluid. A boundary, such as a material-culture boundary discovered archaeologically, could represent either a border or a frontier and may exist somewhere along a continuum between borders and frontiers. Once material-culture boundaries are identified, particularly interesting questions include (1) What kinds of demographic, political, or economic processes occur along a cultural boundary? (2) How does a material-culture boundary correspond to other kinds of boundaries in the region? (3) Are borderlands inhabited by distinct groups that integrate technological, ecological, and cultural behaviors from multiple bordering groups? (4) Do boundaries reify or exaggerate cultural differences? (5) Are boundaries static and restrictive or more porous and fluid? (6) How are boundaries marked or identified? (7) How do boundaries change over time (Parker 2002, 2006)?

Landscape Structure and Connectivity

Landscapes are generally not homogeneous. More often, landscapes are heterogeneous in the spatial and temporal distributions of critical resources. Traveling through, stopping at, avoiding, or occupying different areas within landscapes carries associated costs and benefits (Binford 1983). A basic variable that fundamentally influences landscape connectivity and resource structure is topography (Dorner et al. 2002; Forman 1995). An obvious consequence of heterogeneous topography is that rough terrain can impose substantial energetic costs on movement (Minetti et al. 1993). According to a cost-benefit model of landscape movement, agents should avoid land surfaces that are costly to traverse in favor of land surfaces that are easy to traverse, unless the benefits of resources or opportunities available along a potential travel route are perceived to outweigh the costs of access.

Because of its basic influence on the costs of movement, the physiographic configurations or spatial structures of heterogeneous landscapes can focus or direct how landscapes are used. In the southern Basin and Range Province, broad alluvial valleys are separated by high northwest–southeast-trending mountain ranges (Damon et al. 1984; Morrison 1985). In such areas, human travel may be concentrated in desert valleys and a lot of north–south movement may tend to follow major valley systems. San Pedro Valley, for instance, has long been considered a corridor for the north–south movement of people, artifacts, and information. East–west movement may tend to take advantage of mountain passes and less common east–west-trending drainage systems. The lower Cienega Creek valley is also considered a corridor for the east–west movement of people, artifacts, and information between Santa Cruz and San Pedro Valleys.

When feasible, drainage systems form common corridors that concentrate resources and connect different areas of landscapes. In the desert Southwest, life forms tend to be more populous near drainage systems, because of the availability of water. People and other animals will sometimes use drainage systems as corridors. In some areas, drainage systems may be used to access upland areas, presumably to reduce the costs of obtaining upland resources. Schlanger (1992), for instance, interpreted the role of Anasazi persistent places in terms of their proximity to major upland drainages and the access routes those drainages provide. Altschul and Jones (1990:207) similarly observed that in middle San Pedro Valley, canyon mouths were favored habitation locations, a pattern that "began at least by the Archaic and lasted through the Protohistoric period."

The physiographic configuration of landscapes has the capacity to structure or exert hierarchical controls over the exchange of energy, matter, and information (Heilen 2005a). Because of the "shape" of a landscape, some areas may be highly connective with respect to other places. Depending in part on relief, as well as vegetation type, water, and other factors, some landscape areas focus the exchange of matter, energy, and information by acting as landscape funnels. Drainages, for instance, may often function as corridors of movement. Hypothetically, places like

Mescal Wash funnel the circulation of matter and energy across landscapes because they offer a least-cost solution to the circulation of matter and energy.

Vanderpot and Altschul (2007) hypothesized that the "combination of resource diversity, abundance, and accessibility was probably a major factor contributing to the longevity of the Mescal Wash site." In addition to being an abundantly accommodated place, it will be shown, Mescal Wash is also a physiographically connective place. Activities spread across landscapes are concentrated in places like Mescal Wash because of the physiographic structure of the surrounding landscape. The lower Cienega Creek valley is a corridor that connects Santa Cruz Valley to middle San Pedro Valley (and points farther east). Both prehistorically and historically, travel between major valley systems made preferential use of the lower Cienega Creek valley, and it remains an important east–west transportation corridor today. Mescal Wash is along that corridor, at the confluence of two major washes (Mescal Wash and Cienega Creek), in an area where diverse and abundant resources are immediately accessible.

Connectivity and Cost Surfaces

One way to model landscape connectivity at a purely physiographic level is to model least-cost landscape surfaces. There are many different ways to model cost surfaces involving different kinds of currencies—such as energy expenditure—as well as different ways to measure cost currencies (Anderson and Gillam 2000; Bell and Lock 2000; Ericson and Goldstein 1980; Krist 2001; van Leusen 2002; Verhagen et al. 1999). One of the simplest approaches to modeling cost surfaces is to use slope as a proxy for the cost of moving through a landscape. All other things being equal, self-propelled agents moving across topographically complex landscapes will avoid areas of high slope and favor areas of low slope because with the latter, less energy is expended in moving the same horizontal distance. People generally will not make travel decisions only with respect to topography, however. Instead, travelers take many other variables into account, including visibility, locations of food and water resources, and hazardous or high-friction areas, such as rough terrain, deep sand, dense vegetation, or enemy territory. Nonetheless, least-cost pathways derived from simple variables like slope can serve as valuable independent framed of reference for understanding the relationship of place use to landscape connectivity without making too many assumptions about the variables influencing travel routes.

In order to estimate major least-cost pathways throughout the study area, isotropic least-cost surfaces for the study area were computed in a GIS with respect to two sites, one in the northern Tucson Basin and one in the southern middle San Pedro Valley. Cost distances representing the accumulated cost of traveling to or from a point of interest were computed for travel to and from a site near the northwestern corner of the study area (AZ AA:12:51 [ASM], a prehistoric sherd scatter in the northern Tucson Basin recorded by McConville in 1955) and a second site near the southeastern corner of the study area (AZ EE:12:2 [ASM], an artifact scatter in San Pedro Valley, near Hereford, Arizona). Least-cost paths were then calculated to these two sites from a series of 14 sites positioned evenly around the perimeter of the study area and in strategic locations within major drainages. The exact sites chosen for the model do not matter as much as their general locations.

The resulting pathways confirm the hypothesis that Mescal Wash is in an area of high landscape connectivity (Figure 92). As suspected, the lower Cienega Creek valley connects the eastern and western halves of the study area according to a simple cost-surface model. In fact, the distribution of sites potentially connected via Mescal Wash describes a large, bow-tie shape that identifies Mescal Wash as the constricted portion of a giant landscape funnel.

As can be seen in Figure 92, some pathways do not pass through Mescal Wash. Routes in Santa Cruz Valley and points west do not travel through Mescal Wash. Similarly, points near Redington, in lower San Pedro Valley, are connected to the northern Tucson Basin by least-cost pathways that travel down the lower San Pedro River to Lookout Mountain, up Putnam Wash, and down drainages between the Tortolita and Santa Catalina Mountains. Least-cost surfaces based on other measures of cost could certainly direct least-cost pathways between the northern Tucson Basin and Redington through Redington Pass, but that does not occur with simple least-cost surfaces based on percent slope.

At the level of major valleys, Mescal Wash is a location of high landscape connectivity for east–west travel between the middle San Pedro River (as well as valleys farther west) and the middle Santa Cruz River. Least-cost pathways between the northern Tucson Basin and the middle San Pedro River, upper portions of the lower San Pedro River near Cascabel, and valleys to the west, including points near Bonita, Wilcox, Sulphur Spring, and Gleeson, all pass through the lower Cienega Creek valley.

Although Mescal Wash would seem to have close connections to the upper Cienega Creek valley in terms of watersheds and drainage systems, it is not necessarily a highly connective locale for travel between the upper Cienega Creek valley and the Tucson Basin or for local travel between places in the southern portion of the study area. Pathways between sites near Smith Canyon, in the upper Cienega Creek valley, and the Tucson Basin avoid The Narrows and do not pass through Mescal Wash. Instead, pathways between the Tucson Basin and the upper Cienega Creek valley exit the upper Cienega Creek valley through Davidson Canyon. Likewise, pathways between points south of Murray Springs, in middle San Pedro Valley, and

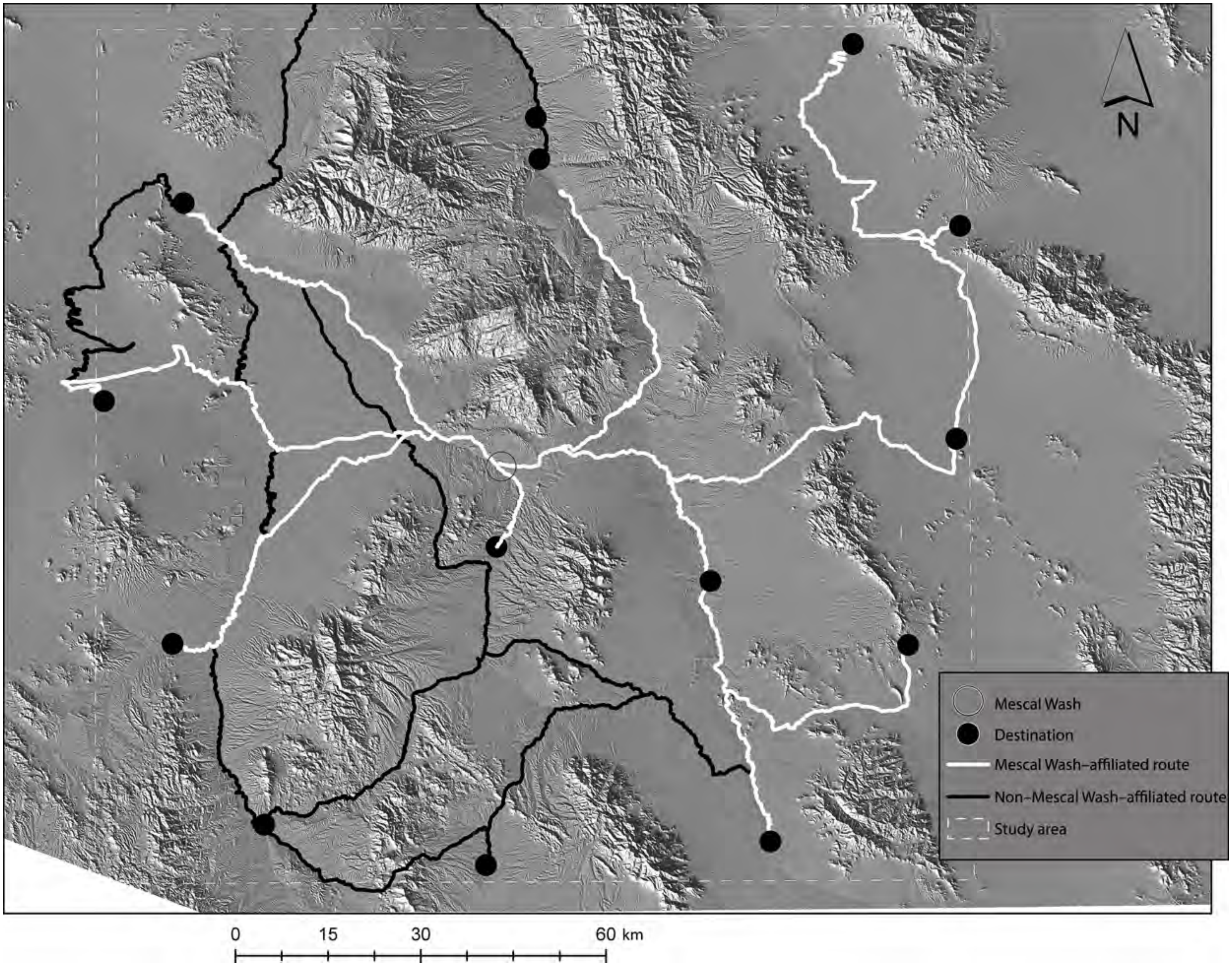

Figure 92. Map showing the locations of least-cost paths connecting different portions of the study area, according to whether or not they pass through Mescal Wash.

the upper Cienega Creek valley, the Sonoita Creek valley, or Nogales head west at a point south of Murray Springs and access the upper Cienega Creek valley between the Whetstone and Mustang Mountains.

Interestingly, results of the simple isotropic cost-surface model described above are consistent with an archaeological model of landscape connectivity, which is described below. It will be shown that Mescal Wash is along a kind of frontier zone between several different ceramic aspects.

Mescal Wash and the Organization of Ceramic Traditions

GIS data supporting the hypothesis that Mescal Wash is a connective place in terms of broad physiographic landscape configuration were presented above. Principally, Mescal Wash is at the focal point of pathways that connect the Tucson Basin with middle San Pedro Valley as well as valleys farther east. Mescal Wash is not a focal point for pathways between the Tucson Basin and the upper Cienega Creek valley, the Sonoita Creek valley, or upper Santa Cruz Valley. We now turn to assessing the landscape connectivity of Mescal Wash by assessing the co-occurrence of the Tucson Basin Hohokam ceramic tradition and other ceramic traditions in the study area.

Another way to assess the connectivity of a landscape is to assess how places are connected to each other. One way to assess the connectivity of places is by examining patterns in the co-occurrence of ceramic traditions and major ceramic wares at archaeological sites. A ceramic tradition is “a characteristic manner, method, or style of making pottery that persisted through time and was restricted in geographic space” (Whittlesey and Heckman 2000a:20). Ceramic traditions differ from ceramic horizons in that “traditions are restricted in space but have considerable time depth” (Whittlesey and Heckman 2000a:20). In contrast, ceramic horizons are more restricted in time depth but are geographically widespread.

Ceramic traditions are particularly useful theoretical constructs for southeastern Arizona. Many ceramic types that are not part of the Hohokam cultural sequence have poorly defined date ranges and limited internal subdivisions. Sites represented by non-Hohokam ceramic traditions cannot be evaluated at the same level of temporal detail as Hohokam sites, and it can be difficult to resolve temporal relationships between non-Hohokam ceramic types. The Babocomari ceramic tradition (ca A.D. 700–1450), for instance, encompasses the entire Tucson Basin Hohokam ceramic sequence, although many Babocomari sherds may date to the Late Formative period. Other local ceramic traditions have time ranges that roughly correspond to the Hohokam pre-Classic period or the Hohokam Classic period.

Heckman et al. (2000) defined a number of important ceramic traditions and other ceramic groups for southeastern Arizona. Sites with diagnostic ceramics can be assigned to any of five ceramic traditions defined for southeastern Arizona: (1) the Babocomari tradition (ca A.D. 700–1450), (2) the Dragoon tradition (ca A.D. 700–1100), (3) the San Simon tradition (ca. A.D. 650–1200), (4) the Trincheras tradition (ca. A.D. 700–1150), and (5) the Tucson Basin tradition (ca. A.D. 700–1300). A number of other ceramic types found in the region can be grouped as (1) Hohokam Buff Ware (ca. A.D. 300–1450), (2) Mimbres Mogollon wares (ca. A.D. 700–1150), (3) Roosevelt Red Ware (ca. A.D. 1200–1450), and (4) Chihuahuan Polychromes (ca. A.D. 1000s–1200/1250). A number of these traditions and wares—the Dragoon tradition, the San Simon tradition, the Trincheras tradition, and Mimbres Mogollon pottery—date to roughly the same period, ca. A.D. 650/700–1100/1200. Chihuahuan Polychromes date to near the end of this period. Roosevelt Red Ware overlaps with the latter portions of the Babocomari tradition, the Tucson Basin tradition, and the Hohokam Buff Ware sequence and corresponds roughly to the Hohokam Classic period.

The cultural affiliations of some of these ceramic traditions are obscure. A number appear to be influenced by Hohokam and Mogollon traditions. Heuristically, we refer to the Tucson Basin tradition and Hohokam Buff Ware as Hohokam and the remaining ceramic traditions and groupings as non-Hohokam. In order to evaluate potential relationships between ceramic traditions, the geographic distribution of a ceramic tradition can be theoretically modeled as a rough correlate for an aggregated landscape network. By extension, sites where artifacts representing different ceramic traditions co-occur can be conceptualized as places where two or more landscape networks overlapped, connected, or intersected. Examining these kinds of sites allows us to hypothesize how different landscape networks or network components are related and to see where places like Mescal Wash are situated with respect to broadly scaled relationships among ceramic traditions.

Results

Patterns in the co-occurrence of ceramic artifacts from different ceramic traditions and wares suggest that as a landscape network, the Tucson Basin Hohokam tradition is the dominant partner in relationships with other landscape networks. At individual sites, non-Hohokam ceramic traditions tend to occur independently of other non-Hohokam ceramic traditions or co-occur with Hohokam traditions (Tables 51 and 52). Non-Hohokam ceramic traditions co-occur with other non-Hohokam ceramic traditions less often than they co-occur with the Tucson Basin tradition. Different non-Hohokam Middle Formative period ceramic traditions did not co-occur with each other at 81 of 94 sites with non-Hohokam Middle Formative period

Table 51. Numbers of Sites at Which Ceramic Artifacts from Different Traditions and of Different Ware Types Have Co-occurred

Ware Type/ Tradition	Ware Type/Tradition									Total
	Babocomari	Dragoon	San Simon	Trincheras	Tucson Basin	Buff Ware	Mimbres	Roosevelt	Chihuahuan	
Babocomari	—	—	—	3	11	2	1	5	—	22
Buff Ware	2	6	11	7	87	—	3	12	2	130
Chihuahuan	—	—	—	1	2	2	—	1	—	6
Dragoon	—	—	9	1	11	6	3	2	—	32
Mimbres	1	3	2	—	6	3	—	1	—	16
Roosevelt	5	2	4	3	39	12	1	—	1	67
San Simon	—	9	—	3	16	11	2	4	—	45
Trincheras	3	1	3	—	16	7	—	3	1	34
Tucson Basin	11	11	16	16	—	87	6	39	2	188
Total	22	32	45	34	188	130	16	67	6	540

Table 52. Numbers and Proportions of Sites at Which Ceramic Artifacts from Different Traditions and of Different Ware Types Have Co-occurred with Tucson Tradition Ceramic Artifacts

Tradition/Ware Type	Sites with Component (S)	Connections (C)	Tucson Connections (T)	C / S	T / C	T / S
Babocomari	21	22	11	1.05	0.50	0.52
Dragoon	25	32	11	1.28	0.34	0.44
San Simon	29	45	16	1.55	0.36	0.55
Trincheras	35	34	16	0.97	0.47	0.46
Tucson Basin	795	188	—	0.24	—	—
Buff Ware	124	130	87	1.05	0.67	0.70
Mimbres	17	16	6	0.94	0.38	0.35
Roosevelt	86	67	39	0.78	0.58	0.45
Chihuahuan	4	6	2	1.50	0.33	0.50
Total	1,136	540	188	0.48	0.35	0.17

ceramic traditions. The San Simon and Dragoon traditions are the two non-Hohokam Middle Formative period ceramic traditions that co-occur with some frequency. Of the 13 sites that expressed two or more Middle Formative period traditions (13.8 percent), the most frequent are the San Simon tradition (n = 11) and the Dragoon tradition (n = 10). Tucson Basin tradition ceramics were found at 9 of those sites. Tucson Basin and Dragoon tradition ceramics were found at 11 sites. Tucson Basin and San Simon tradition ceramics were found at 16 sites.

Four out of five (81.5 percent) Tucson Basin tradition sites are associated only with the Tucson Basin tradition. For other ceramic traditions and groupings, around one out of two sites tended to co-occur with Tucson Basin tradition ceramics. This suggests that ceramic traditions and groupings in southeastern Arizona have the strongest connection to the Tucson Basin tradition and are not as strongly connected to each other. Between 45 and 55 percent of sites with Babocomari tradition, Chihuahuan Polychromes, Dragoon tradition, Roosevelt Red Ware, and Trincheras tradition ceramics also had Tucson Basin tradition ceramics. Buff wares co-occurred with Tucson Basin tradition ceramics at 70 percent of sites with buff wares.

The strong association of buff wares with the Tucson Basin tradition ceramics reinforces the idea that the Phoenix Basin and the Hohokam networks shared strong social, ceremonial, or economic relationships (Wilcox 1979). It would be interesting to determine if and when Phoenix Basin groups had satellite settlements in southeastern Arizona or whether Phoenix Basin groups did not have as much of a physical presence in southeastern Arizona as a ceremonial or technological presence. From this analysis, we can postulate that Middle Formative period ceramic exchange occurred often between the Tucson landscape network and other local landscape networks but less often *between* non-Hohokam landscape networks in the study area. This suggests the possibility that the Tucson Hohokam network oriented and structured the exchange of painted ceramic vessels and perhaps dominated or directed some ceremonial or economic relationships in the study area. At the same time, the fact that non–Tucson Basin tradition–affiliated sites tend to be in some ways exclusive to one of several other non–Tucson Basin traditions suggests that other groups were independently active in the same area but interacted to a lesser degree with other local groups.

In this sense, the Tucson network may have orchestrated spoke-and-wheel relationships with other local networks. The Babocomari and Trincheras traditions, for instance, substantially overlap geographically but rarely co-occur at individual sites. Both traditions often co-occur with the Tucson Basin tradition. The Dragoon and San Simon traditions also overlap substantially and co-occur to a somewhat greater degree but still individually co-occur much more often with Tucson Basin tradition ceramics. The San Simon and Dragoon traditions could represent a kind of east–west distribution of landscape networks that connected the Tucson Basin Hohokam with the upland Mogollon.

Given the limited chronological control of non-Hohokam ceramic traditions, some of these patterns could result from temporal discontinuities in place use, but that cannot be determined conclusively with the available evidence. In either case, patterns of co-occurrence indicate patterns of continuity or discontinuity in place use, patterns that may indicate some long-term interactions among people, places, and landscapes.

The distribution of ceramic traditions in southeastern Arizona reinforces the suspicion that Mescal Wash is betwixt and between varieties of different cultural traditions. Mescal Wash is along the boundary between the Dragoon and Babocomari traditions and near the edge of the denser core of the Tucson Basin tradition. As has also been noted, Mescal Wash is near the transition between the Sonoran and Chihuahuan Desert ecozones and is along a prominent east–west route, the lower Cienega Creek valley, connecting Santa Cruz and San Pedro Valleys. Not as much is known archaeologically, however, about the prehistory of this area of southeastern Arizona as is known about more intensively studied areas, such as the Tucson Basin.

No doubt, archaeological patterns in ceramic distributions are influenced by a preponderance of ceramic evidence from the Tucson Basin tradition and, as such, are more likely to express a Tucson Basin Hohokam landscape signature at the expense of other independent traditions. At this time, it is premature to firmly associate the various inhabitants of Mescal Wash with a known archaeological culture, although a preponderance of Hohokam-affiliated ceramics suggests a stronger affiliation with the Hohokam instead of other groups (Garraty and Heckman 2016). The ceramic types recovered at Mescal Wash suggest that Formative period users of Mescal Wash had interactions with or were bearers of the Dragoon, San Simon, Tucson Basin, Babocomari, and Trincheras traditions, though perhaps to varying degrees.

Were the inhabitants of Mescal Wash a culturally distinct group? Were inhabitants of Mescal Wash interacting simultaneously or at different times with bearers of all these material-culture traditions? Were bearers of these separate traditions occupying the same place at the same or different times? Were interactions friendly or hostile? Garraty and Heckman (2016) have suggested that different households and groupings of households at Mescal Wash probably held different cultural affiliations and that painted ceramic wares were used in social gatherings to mark cultural affiliations and signal cooperation or competition among households according to ethnic affiliations. Given what we know about the position of Mescal Wash within the larger landscape, that seems plausible, particularly considering that Mescal Wash appears to have been located at the geographic intersection of multiple ceramic traditions, as will be shown below.

Defining Ceramic Aspects

Apparent associations between different ceramic traditions in southeastern Arizona and their geographic distributions allow us to define three separate ceramic aspects: a Hohokam aspect, a Sonoran aspect, and a Mogollon aspect. Here, we define a ceramic aspect as a set of ceramic traditions that are both geographically overlapping and interacting. Geographically, the study area can be divided into three zones that, during the Middle and Late Formative periods, were filled with distinct combinations of ceramic traditions. The northeastern half of the study area—containing areas of the Tucson Basin, middle and lower San Pedro Valley, the lower Cienega Creek valley, Sulphur Springs Valley, and Whitewater Draw—is dominated by San Simon, Dragoon, and Mimbres traditions. The southern and southwestern portions of the study area—containing areas of upper Santa Cruz Valley, Avra Valley/Altar Valley, the upper Cienega Creek valley, the Sonoita Creek valley, and middle to upper San Pedro Valley—are dominated by Babocomari and Trincheras traditions. Mescal Wash is along the boundary between these two major zones of the study area (Figure 93).

Mogollon aspect and Sonoran aspect landscape networks appear to share connections with Hohokam aspect landscape networks but are largely exclusive from each other. Approximately half of sites with Mogollon aspect ceramic traditions and half of sites with Sonoran aspect ceramic traditions also have Hohokam aspect ceramic traditions, but only a small percentage of sites hosted both Mogollon aspect and Sonoran aspect ceramic traditions. Of 59 sites with Mogollon aspect ceramic traditions (Dragoon, San Simon, and Mimbres) and 53 sites with Sonoran aspect ceramic traditions (Babocomari and Trincheras), only 4 sites (3.7 percent of 108 sites) have both Mogollon aspect and Sonoran aspect traditions. Sonoran aspect ceramic traditions co-occurred with Hohokam aspect ceramic traditions at 27 of 53 sites (50.9 percent) with Sonoran aspect ceramics. Mogollon aspect ceramic traditions co-occurred

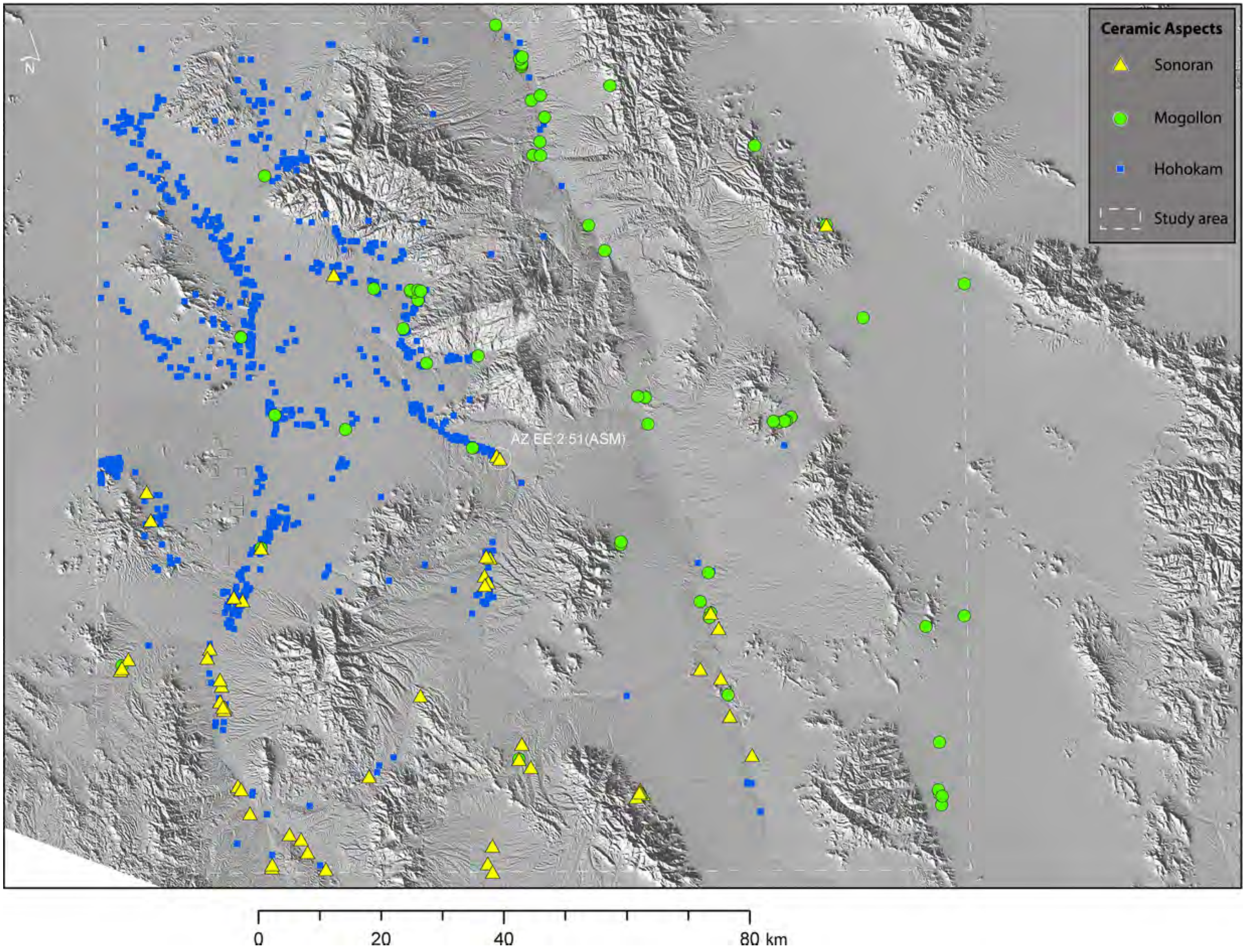

Figure 93. Map showing the distributions of sites with Hohokam-, Mogollon-, and Sonoran-affiliated ceramic artifacts.

with Hohokam aspect ceramic traditions at 32 of 59 sites (54.2 percent) with Mogollon aspect ceramics.

Previously, other authors have described middle Santa Cruz Valley south of the Tucson Basin as a frontier zone between the Hohokam to the north, the Trincheras to the south, and the Papaguería to the west (Whittlesey 1996; Whittlesey and Ciolek-Torrello 1992). Similarly, evidence from the upper Cienega Creek valley has suggested the combined presence of Trincheras, Mogollon, and Hohokam populations (Ferg et al. 1985). From the evidence developed in this chapter, it now appears that Mescal Wash existed at a material-culture boundary between multiple ceramic traditions, which may signal its position along a frontier zone or border between Hohokam-, Mogollon-, and Sonoran-affiliated groups.

Late Formative Period Connections

Roosevelt Red Ware ceramics have been linked to the Salado culture, a Late Formative period phenomenon hypothesized to have emerged "from a combined Mogollon-Anasazi base" (Haury 1945; Whittlesey and Heckman 2000b:111). Sites with Roosevelt Red Ware ceramics (ca. A.D. 1200–1450) share similarly exclusive or dualistic connections with Hohokam aspect traditions. Roosevelt Red Ware ceramics co-occurred with Hohokam aspect traditions at exactly half (n = 43) of 86 sites with Roosevelt Red Ware. Because 39 of these sites have Tucson Basin tradition ceramic artifacts and 12 have buff ware ceramic artifacts, the Tucson landscape network appears to have been the Hohokam component most strongly connected to local components of the emerging Salado landscape network. The four most frequent ceramic types at 86 sites with Roosevelt Red Wares are Gila Polychrome (n = 62, or 72.1 percent), Tanque Verde Red-on-brown (n = 26, or 30.2 percent), Rincon Red-on-brown (n = 16, or 18.6 percent) and Gila Plain (n = 13, or 15.1 percent). This suggests some continuity between Tucson Basin Hohokam place use and local components of the Salado landscape network. The Salado landscape network may have resulted from reorganization of settlement strategies that involved disintegration and reorganization of existing settlement networks and the selective reuse or abandonment of existing Hohokam and non-Hohokam places.

Mescal Wash and Ceramic Aspects

In terms of identified ceramic types, Mescal Wash appears to be affiliated most with both the Hohokam aspect (Tucson Basin tradition and buff wares) and the Mogollon aspect ceramic traditions, but may also have interacted with Sonoran aspect traditions. Mescal Wash had a few Snaketown Red-on-buff and Dos Cabezas Red-on-brown ceramics, many Gila Butte Red-on-buff, Santa Cruz Red-on-buff, Cañada del Oro Red-on-brown, Rillito Red-on-brown, Galiuro Red-on-brown, and Cerros Red-on-brown ceramics, and some Rincon Red-on-brown, Tres Alamos Red-on-white, Sacaton Red-on-buff, and Mimbres Black-on-white ceramics (see Volume 2, Chapter 3). Unique architectural elements (i.e., recessed-hearth-type pit structures) at Mescal Wash share some of the greatest technological similarities with architectural elements at Tres Alamos, Gleeson, and Texas Canyon, sites that all fall within a certain zone of the Mogollon aspect ceramic traditions (see Volume 2, Chapter 1).

Although archaeologists have long resolved the issue that pots do not equal people, the distribution of ceramic traditions and aspects can help us identify who the users of Mescal Wash were. In terms of identified technological similarities, the Middle Formative period inhabitants of Mescal Wash shared the greatest affinities with Mogollon-affiliated groups to the west and Hohokam to the east. They may have shared less of a relationship with groups affiliated with Sonoran traditions, but given their proximity, some interaction, whether violent or peaceful, cannot be entirely ruled out.

The distribution of ceramic aspects suggests the possibility that, during the Middle Formative period, Mescal Wash was at the frontier between three major landscape network components—Hohokam, Sonora, and Mogollon. Frontiers, as kinds of cultural ecological edges, could have been zones of enhanced interaction and behavioral cross-fertilization where intermediate techno-ecological behaviors and strategies took place and unique mixes of cultural traits are likely to be found. Mescal Wash and other nearby places could have served as nodes that connected landscape-network components into a giant network component. That is not to say that the Middle Formative period inhabitants of Mescal Wash were not part of a distinct local group or tradition but that their distinctiveness could have been founded in part on their unique cultural-ecological position at a frontier or transition zone.

During the historical period, for instance, the Kohatk occupied a position between Tohono O'Odham, Akimel O'Odham, and Hispanic-American landscape networks (Heilen 2005b, 2006). The Kohatk, who were fundamentally O'Odham, performed techno-ecological behaviors and settlement strategies that were intermediate between Tohono and Akimel O'Odham, occupied a geographic distribution that was betwixt and between Tohono and Akimel O'Odham heartlands, and facilitated the exchange of goods and services over large areas. As a result, the Kohatk displayed an admixture of cultural traits that is hard to identify clearly with either group (Dobyns 1974; Ezell 1955; Hackenberg 1964, 1974; Whittlesey et al. 1994). Part of that admixture was likely related to shared connections with multiple groups.

In some cases, violent confrontations are more likely to occur along cultural, political, or economic boundaries (see Downum and Stone 2000). Conversely, syncretism and productive exchanges could be the norm along other boundaries. The lower Cienega Creek valley was likely an important transportation corridor (J. Jefferson Reid, personal communication 2006) during both history and prehistory and now appears to have been involved in the formation of an important material-culture boundary. The fact that Sonoran and Mogollon ceramic aspects rarely co-occur suggests that the boundary might have been restrictive, although similarities in design motifs would suggest more fluid exchanges of stylistic information. Given the potentially restrictive nature of the boundary between Sonoran and Mogollon aspects, the lower Cienega Creek valley may have been a zone of intraregional negotiation and conflict during the Middle Formative period. It would be interesting to determine at the level of sites in the lower and upper Cienega Creek valley whether there is evidence of violence, ethnic co-residence, exchange, or opposition. During the Late Formative period, the position of Mescal Wash with respect to landscape networks appears to have been in a state of flux as large-scale abandonment occurred throughout the region and settlement shifted into new areas. By the Late Formative B period, Mescal Wash appears to have been at the western edge of an emerging Saladoan network, which may have made it a kind of base camp that was connected to newly formed sites in lower San Pedro Valley and to reused sites in the Tucson Basin. Despite reorganization, Hohokam places used in former phases appear to have played a prominent role in settlement reorganization, probably in the context of settlement shift and in a manner similar to the shifting use of sites inferred by Schlanger (1992) for the Dolores region.

Combining the results of cultural- and physiographic-connectivity analyses suggests that Middle Formative period routes between middle San Pedro Valley and the Tucson Basin could have varied according to cultural affiliation. Groups involved with Sonoran aspect traditions may have favored the use of the upper Cienega Creek valley, upper Santa Cruz Valley, the Sonoita Creek valley, and Davidson Canyon to perform exchanges or interactions with people or places in the Tucson Basin. In contrast, groups involved with Mogollon aspect traditions may have used the lower Cienega Creek valley and perhaps Redington Pass to perform exchanges or interactions with people or places in the Tucson Basin.

Discussion

Landscape networks are potentially useful models for site-level data, because at their most basic level, network models specify that systemic landscapes are composed of nodes connected by links (Heilen 2005a). As network nodes, places are related to other places through the exchange of matter, energy, and information. This is not to say that the places themselves exchanged matter, energy, and information; the people using them did. The presence of a temporally diagnostic artifact type at a site can be interpreted to mean that at least one place existed in that general location at some point during the identified phase or period. The patterns revealed by the above analyses are based primarily on the presence or absence of temporally diagnostic artifacts. As a result, they should be interpreted cautiously.

It is certainly possible for nodes to vary in terms of the number of links to other nodes, the directionality of exchange, kinds or magnitudes of exchanges, or kinds or magnitudes of nodes. In order to model persistent-place formation, we have chosen to limit assumptions about site size, feature or artifact counts, and site functions, not because these variables are irrelevant, but because they are so inconsistently recorded and reported. Similarly, we limit the analysis of Type I persistent places to the Tucson Basin Hohokam network, not because the network is all important to the prehistory of the study area, but because data on non-Hohokam-affiliated artifact types are severely limited in comparison to Hohokam-affiliated artifact types.

Place Formation, Reuse, and Abandonment

Abandonment is often more of a process than an event (Whittlesey and Deaver 2004). Both site content and function can change over time as sites are abandoned. In his investigations of pastoral-site reuse and abandonment, Tomka (1993) found that artifacts at permanently abandoned places are more often broken than artifacts at their seasonally or episodically occupied counterparts. Similarly, the number of artifacts decreases with abandonment length, even at sites that were intended to be reused at some point. The kinds of artifacts tend to change with abandonment, as well. In both seasonally abandoned and episodically abandoned sites, expedient and improvised artifacts constitute a total of around 41 percent of artifacts, and craft and industrial artifacts constitute the remaining 59 percent. At permanently abandoned sites, 70 percent of artifacts are expedient or improvised, and only 30 percent are craft or industrially manufactured artifacts, suggesting that many still-usable items were selectively removed from abandoned sites, or new artifacts were manufactured on the spot for short-term uses. Tomka (1993:21) argued that changes in artifact frequencies result from delayed curation, rather than scavenging, that "takes place not in the context of seasonal abandonment and reoccupation, but during intermittent visits embedded in the trips criss-crossing the region."

The kinds of place formation, reuse, and abandonment investigated in the above analyses are necessarily formulated at coarse scales and do not approximate many of the fine-scale processes that must be involved in the operation of settlement networks. Nonetheless, they provide an illustration of how some processes of place formation, reuse, and abandonment interact within networked settlement systems. They also give us an impression of the variable scales at which processes of place formation, reuse, and abandonment can occur.

Ceramic Types as Proxies for Behavior or Affiliation

Because of stylistic, technological, and temporal variation, ceramic types are "good to think" in the interpretation of archaeological contexts with ceramic artifacts. Yet are the ways we think about them appropriate to understanding behavioral variation and change? Ceramic types allow us to obtain some temporal resolution and thus to investigate change over time. Often ceramic types are affiliated with geographic zones. Sometimes, raw materials used in ceramic production can be tied to specific geologic deposits or source areas. For ceramic traditions, we can model variation in space and the potential connections between network components during broad periods of time. These spatial and temporal patterns allow us to get an idea of some of the factors involved in the formation of persistent places, as well as to improve our understanding of how different ceramic traditions are related to each other. Mescal Wash is located at the intersection of major ceramic traditions and so can be understood as a kind of boundary or edge place, a place that exists at the transition between major cultural, ecological, and technological regimes. The people, traditions, and activities occurring at Mescal Wash are kinds of negotiation in place use, negotiation formulated at the scale of places, ceramic traditions, and a giant landscape-network component.

Mechanisms of Ceramic-Artifact Dispersal

At Snaketown, over 1.5 million potsherds were analyzed, but approximately 100 of them (0.0067 percent) were labeled by Haury (1965) as intrusive or extralocal. Still, those few extralocal sherds were crucial to correlating the Hohokam, Mogollon, and Anasazi chronologies, almost outweighing the analytical importance of their much more abundant, local counterparts (Haury 1965).

Evidently, most sherds do not travel far (Abbott 2000), but a rare few might travel great distances. The mechanisms by which they travel are often unclear. What the presence of a ceramic type means in any particular place is often assumed but largely untested. Do pots move with the people that produced them? Do they change hands, and if so, how often? Do individual sherds sometimes travel independently of pots, as curios or keepsakes? Does the presence of a pot mean the presence of a people, the presence of a relationship, or something else (Abbott 2000; Doyel 1988; Schiffer 1987; Whittlesey 2004b)?

Linkages between Trincheras and Hohokam archaeological cultures have been posited because of similarities in ceramic designs and the co-occurrence of Hohokam and Trincheras design elements at some sites. A potential organizational factor driving linkages between Hohokam and Trincheras sites was shell exchange, in which Trincheras were on the supply side of the exchange, and Hohokam were the on the demand side (Lindauer and Zaslow 1994; McGuire and Villalpando 1989). One must ask, of course, what the Hohokam provided in return—cotton? Likewise, stylistic evidence suggests interaction or exchange of information between Trincheras and Mogollon ceramic producers. Yet the distribution of ceramic aspects and patterns of co-occurrence suggest fairly frequent interactions between Hohokam and Mogollon or Sonoran aspects but rare interactions between Sonoran and Mogollon aspects. Again, these patterns are for a particular kind of material technology and may inform on particular ceremonial or economic systems but may not hold for entire communities or groups. Other kinds of things could be exchanged between the groups, and evidently they were.

We must recognize that the dependency on ceramic artifacts to interpret broad-scale archaeological patterns ultimately requires that hypothesized networks are networks along which the products of particular material technologies were exchanged between places and activities. We do not assume the mechanisms by which particular ceramic types got from place to place, but it is hard to entirely erase or suspend the association of ceramic types with particular activities or groups. Multiple mechanisms could have been responsible for generating similar archaeological patterns. In evaluating high percentages of painted pottery at Postclassic period Mimbres sites, Hegmon et al. (1998:151) concluded that some nonlocal sherds "could have moved through wide-ranging exchange networks, they could have been brought in by people from other regions who moved into the area, and local people might have traveled widely and brought nonlocal goods home." In addition, they postulated that "people living in the area made local versions of types associated with other areas" (Hegmon et al. 1998:152). Whittlesey (1998b) has argued that many of the attributes that archaeologists associate with a coherent Hohokam lifeway may have been individually and differentially incorporated by phylogenetically distinct local groups. The appearance of a particular Hohokam-affiliated trait does not necessarily mean the presence of the Hohokam or the Hohokam "culture." Instead, such an occurrence more parsimoniously signifies a relationship within a network along which that particular trait was exchanged.

It is certainly possible that different kinds of technologies, such as weapons systems, grinding technologies, or clothing technologies, are distributed over different networks that have different geographic extents, share different connections between places and with other landscape networks, change over different time scales, and have affiliations with different sets of cultural or ethnic groups. For instance, plain ware ceramics in the Phoenix Basin may have been relatively restricted in space and confined to small, local exchange networks. As a consequence, they are used to infer membership in local irrigation cooperatives (Abbott 2000). In contrast, large bifaces made on Tiger Chert from Wyoming have been found at several widely spaced Salado sites in Arizona and suggest some form of interaction or exchange that transcended environmental divisions, archaeological cultures, or regions (Whittaker et al. 1988). Other tool technologies could easily fill the gap in these scales between local and extraregional. It is also possible that information networks along which stylistic motifs were exchanged varied from the economic networks along which pots were exchanged, as well as from technological networks along which pot-making technologies were exchanged.

Painted Pottery and Use Context

Most ceramic types used to model landscape networks in this chapter are painted types. Because plain wares are less easily placed in time or affiliated with particular groups or areas and are not differentiated to any great extent in the AZSITE database, plain ware ceramics are largely overlooked in this analysis. Given their ubiquity at archaeological sites, plain ware ceramics obviously play a significant role in container, storage, and cooking technology in the Southwest. Technological and morphological attributes of plain ware vessels could inform just as much or more on group affiliations and interactions (Heckman 2002).

A lot of places at which many mundane prehistoric activities occurred—involving interactions with plain ware ceramic items as well as flaked stone, ground stone, and other technologies—are not incorporated into the present analysis in the same way as more studied, temporally diagnostic artifacts are. This is a deficiency that cannot be rectified by the present analysis, but it likely has a profound effect on how persistent places are modeled. There may be persistent places, such as quarries, religious sites, and vantage points, that were repeatedly reused but were not used in such a way as to result in the deposition of temporally diagnostic artifacts.

Painted pottery may have more often been used in special circumstances, such as in the performance of ceremonies, at social gatherings, or in the context of more formal interactions. Further, if painted pottery was used and valued differently from how unpainted types were used, painted and unpainted pottery types may have been deposited at different rates and according to different circumstances. Painted pottery could have more to do with special kinds of social, ceremonial, or economic interactions that were not as "day-to-day" as may be indicated by more utilitarian wares (Whittlesey 2004b). Reconstructed networks based on painted-pottery types may be indicative of ceremonial or social networks rather than networks that directly register fundamental development and change in a people or a way of life. A conservative way to think about the networks we have modeled is as networks of painted-ceramic technologies and not as direct proxies for the movement and interaction of cultures or ethnic groups. If these patterns are reinforced by patterns in other material technologies and indices of behavior, then their correspondence to coherent behavioral units, such as communities or ethnic groups, is more plausible.

For archaeologists, painted-ceramic types may seem useful in determining cultural or ethnic types, but networks of painted-ceramic types could be ceremonial or technological overlays that do not closely correspond to more fundamental cultural subdivisions in a human substrate (Whittlesey 1998a, 2004b). Altschul et al. (1999:91), for instance, observed that Gila Polychrome occurs at both platform-mound sites and sites with Anasazi-like architecture in lower San Pedro Valley. They hypothesized that "the platform mounds participated in a regional, socioreligious system that included many of the major river valleys of the Sonoran Desert and the transition zone. The communities lying immediately to the south may have accepted parts of the ideology without also accepting the concomitant social structure."

Nonetheless, when ceramic traditions are modeled as networks, we can potentially understand the connectivity of the Tucson Hohokam landscape network in subtler ways. Connections between the different landscape groups are not absolute, meaning that they do not necessitate a one-to-one correspondence between artifact types, geographic distributions, and cultural units. Rather, the strong connection between the Phoenix Basin landscape network and the Tucson Hohokam network could indicate a donor relationship between the Phoenix and Tucson Basins in terms of ceremony and worldview.

O'Odham parent and daughter villages share long-lasting ceremonial and exchange relationships, despite more fluid interactions and exchanges at the individual or household levels (Heilen 2005b, 2006; Hoover 1935). Interactions between different communities could, in a sense, encode the phylogeny of village or community formation and the common ties shared between individuals, households, and communities. If some Hohokam from the Phoenix area immigrated into the Tucson Basin, where they at one time founded agricultural colonies, regardless of whether they filled an empty niche or displaced or mixed with indigenous communities (Di Peso 1956; Doyel 1977; Grebinger 1976; Greenleaf 1975; Haury 1950; Hayden 1970; Zahniser 1966), the resulting Tucson Basin communities may have retained ceremonial relationships with parent communities of the Phoenix region. The potential for ceremonial relationships as an organizing principle of Hohokam interactions does not mean that interactions between Hohokam and their neighbors involved only ideas and rituals. A lot of community, household, and personal items—such as food, clothing, and containers, and even personnel—can be exchanged in the context of ceremony (Underhill 1938, 1939).

Similarly, the Tucson Basin Hohokam may have directed ceremonial and other exchanges with other groups. The connectivity of the Tucson Basin Hohokam tradition with other local traditions suggests that the Tucson Hohokam were the central partners in relationships involving the exchange or use of painted pottery. The odd fact that Hohokam ceramic types have been found regularly at half of sites with non-Hohokam ceramic types suggests some kind of possibly dualistic organizing principle behind Hohokam regional interactions. At the same time, it suggests the participation of multiple distinct groups in the performance and organization of ceremony and ritual, relationships that may have also involved some important economic exchanges of valued trade items.

“Stacking Up” Intervals and Persistent-Place Formation

Examining Classic period Mimbres land use, Nelson (1993:30) argued that in “[a]reas that have not been intensively occupied, occupations rarely ‘stack-up’ over time.” Nelson’s adage implies that phenomena such as persistent places should occur most often in intensively occupied areas and should be rare in intermittently occupied areas. To Nelson (1991), the lack of large, complex, multicomponent sites implies intermittent, non-intensive use of an area. Nelson and Schlanger’s perspectives on how components “stack up” form an interesting contrast. Nelson’s perspective implies that redundancy is a function of use intensity, whereas Schlanger’s perspective implies that redundancy over the long term is related to settlement change or spatial flux in the intensity of land use. Nelson’s perspective links persistence to large, complex, multicomponent occupations, and Schlanger’s involves components that vary from each other, not just in terms of time, but also in terms of function.

At individual sites, recognition of these signatures is not well developed and is often a matter of interpretation. The West Branch site, a persistent place of the Tucson Basin Hohokam tradition, has been interpreted by some as a component of a long-lived, 600-year-old, continuously occupied community. Finer-scale analysis of site structure and chronological data reveals that West Branch was more likely was repeatedly reoccupied on a short-term, intermittent basis, perhaps as part of a dynamic, persistent settlement system. The persistence of West Branch was partly a function of its repeated, reoccurring use, not its continuous, “permanent” use (Whittlesey, ed. 2004).

We must remember that the persistent-place models built in this analysis were constructed using one material dimension: the “stacking-up” of diagnostic types over time. We do not also require that persistent places be large and complex or that they have particular functions. Large and complex sites are more likely to have more diverse contents and possibly contain greater evidence of multiple components. On the other hand, intense, continuous occupation of places could cause local resource depletion and militate against the formation of persistent places. The models presented here simply require that available chronological evidence imply place use in three or more contiguous phases or periods. That is reuse at the level of the archaeological interval, not reuse at the scale of more behaviorally relevant, systemic intervals. Change in temporally diagnostic materials could be related to fundamental changes in the internal timing of a behavioral system, but that is mere speculation.

Conclusions: What Have We Learned?

Persistent places are rare but regularly occurring components of systemic landscapes. The formation of persistent places is likely a multidimensional phenomenon influenced by a variety of cultural and environmental variables. As a general rule, the probability of persistence decays with time but is also sensitive to behavioral and environmental change.

Persistent-place formation differs according to the scale of persistence. At the scale of Hohokam phases, persistent-place formation is driven by the internal dynamics of an evolving settlement system. At the scale of archaeological periods, persistent-place formation is linked to the physiographic structures of landscapes and the supracultural availability of limiting resources. At any scale, persistent-place formation is the result of mutually causal interactions between culture and environment. The influence of environmental variables on persistent-place formation likely increases when multiple diachronic behavioral systems are implicated and thus may have a more profound effect on the formation of Type II persistent places.

Places that are persistent at multiple scales, like Mescal Wash, are especially rare. Mescal Wash was a unique place that persisted in a way that could only have resulted from a unique and enduring mixture of broadly scaled environmental and cultural phenomena. Although the above analysis identifies fairly large sets of Type I and Type II persistent places, we cannot expect too many sites to be equivalent to Mescal Wash. Mescal Wash was a persistent place of Types I–III that occurred in a location that was highly connective physiographically, culturally, and ecologically. There simply are not that many opportunities for such a convergence of attributes.

During the Formative period, Mescal Wash was located at the intersection of three major material-culture boundaries. The interactions and geographic extent of these material-culture areas correspond to the physiographic connectivity of the surrounding landscape. Places like Mescal Wash may be especially important in identifying and assessing the development and interaction of borderland processes. The technological and ecological behaviors performed at Mescal Wash may be intimately connected to its role as a kind of edge or boundary place and may be fundamental to interpreting its formation over time. How Mescal Wash was used at different times, for how long, and by which groups are especially intriguing questions that beg to be answered and that have been addressed in numerous analytical studies (Vanderpot and Heilen 2010).

Although some general patterns and processes may be common to all persistent places, there are probably a number of interesting dimensions of variability that can only be developed by closely examining individual sites like Mescal Wash or West Branch (Whittlesey, ed. 2004). Understanding of persistent-place formation may also be enhanced by examining persistent-place formation from a pan-regional perspective. Because of different culture histories, different technological systems, different cosmologies, and different environments, the factors involved in persistent-place formation likely differed for Anasazi, Hohokam, Patayan, and Chihuahuan places. Persistent-place formation, also, could be substantially different in Mesopotamia or the Roman Empire than in the U.S. Southwest. But then again, maybe not. Because of the unique convergence of cultural, physiographic, and ecological attributes at Mescal Wash, the closest counterparts to Mescal Wash may not be found locally but may be widely dispersed, in other areas of the globe.

CHAPTER 9

Summary and Conclusions

Jeffrey H. Altschul and Rein Vanderpot

In this final chapter, we provide a summary of the project results, particularly how our findings articulate with questions posed in the project's original research design (Altschul et al. 2000). To provide a regional context, we begin with a discussion of archaeological investigations along the San Pedro River that have laid the groundwork for our research approach to Mescal Wash. Next, we summarize the Mescal Wash settlement history and chronology. The research design is also revisited, by looking at the site's ancient community from the perspectives of ethnic identity, households, and the concept of a persistent place. In the conclusions, we take a last look at the site and provide recommendations for future work.

Setting the Stage: The San Pedro Valley

In cultural resource management (CRM), archaeologists excavate sites that will be disturbed or destroyed by land-disturbing activities covered by legal statutes or regulations. Often, those sites are not ones that archaeologists would choose to excavate. But every so often, a project arises in which the site in question is exactly the one that an archaeologist would choose if he or she were selecting a site to excavate, to address a longstanding research problem. Such was the case with the Mescal Wash site.

In 1987, SRI began work at Fort Huachuca, in southeastern Arizona. Fort Huachuca lies within the middle portion of the San Pedro Valley. Long famed for early-human sites, such as Lehner Ranch and Murray Springs (Haynes and Huckell 2007), the later parts of prehistory and protohistory in the middle San Pedro Valley were only poorly known in the late 1980s, particularly when compared to the lower reaches of the San Pedro River. Yet there were inklings that the region was rich in archaeology. Charles Di Peso's excavations at Babocomari Village (AZ EE:7:1 [ASM]) (Di Peso 1951), as well as Quibari (AZ EE:4:11 [ASM]) and Gaybanipitea (AZ EE:8:15 [ASM]) (Di Peso 1953), followed by David Kayser's (1968) survey of the proposed Charleston Dam and Reservoir, demonstrated a dense and complex archaeological record for the entire span of prehistory, well into the historical period.

Between 1987 and 1995, SRI conducted a series of projects at Fort Huachuca that significantly filled in the archaeological record of the middle San Pedro Valley. SRI developed both surface and subsurface predictive models of site location that were tested with data derived from surveys of more than 40,000 acres on the installation (Altschul and Jones 1990; Vanderpot 1994a, 1994b, 1997). In the process, SRI recorded more than 250 sites, tested 9 sites (Altschul et al. 1993; Majewski et al. 1997; Vanderpot and Majewski 1998), analyzed material from data recovery at the Garden Canyon site (AZ EE:11:13 [ASM]) (Shelley and Altschul 1996), developed a handbook about southeastern Arizona prehistoric ceramic types (Heckman et al. 2000), and synthesized the work in comprehensive management plans for the installation (Van West et al. 1997) and Garden Canyon (Van West et al. 1998). Subsequently, between 2001 and 2006, Desert Archaeology, Inc., surveyed approximately 13,400 acres of the installation, large portions of which overlapped with the area covered by SRI (Cook 2001, 2004a, 2004b, 2004c, 2004d, 2005a, 2005b, 2005c, 2006a, 2006b).

At the same time that SRI was working at Fort Huachuca, others were working in different parts of the lower and middle San Pedro Valley. Archaeology Southwest (formerly the Center for Desert Archaeology) recorded more than 500 sites in the lower San Pedro Valley (Clark and Lyons 2012; Clark et al. 2014; Elson and Clark 2007), and Deni Seymour returned once again to the enigmatic protohistoric period that had so intrigued Di Peso, with work, primarily on Sobaipuri sites, in the region between the areas covered by Archaeology Southwest and SRI (Seymour 1989, 1993, 1996, 1997). What was missing from the record was the upper San Pedro Valley—the portion of the valley in Sonora, Mexico. In 1990, fewer than 15 sites had been recorded in the upper San Pedro Valley. Carl Sauer and Donald Brand (1930) had recorded 6 sites in 1930; Di Peso and his colleagues at the Amerind Foundation added another three sites in the 1950s; and Beatriz Braniff (1992) recorded four sites in the 1960s.

In 1991, Altschul initiated discussions with César A. Quijada of the Instituto Nacional de Antropología e Historia (INAH). Together, they established the joint SRI-INAH San Pedro Archaeological Project (SPAP) in 1992. SPAP began with a series of theoretical papers outlining prospects and strategies for conducting work in Sonora (Altschul 1994, 1996, 1997; Altschul and Quijada 1995; Quijada 1993, 1994a, 1994b, 1997). While gaining permission for access to areas in Sonora, SPAP conducted a series of small projects on the U.S. side of the border (Towner 1994; Towner and Altschul 1993a). Then, after a cursory reconnaissance of the upper San Pedro Valley, Altschul and Quijada turned their attention to the Late Classic period Villa Verde site complex (AZ EE:16:3 [SON]).

Located about 25 km south of Naco, Sonora, Villa Verde is a complex of three Late Classic period occupations. Cursorily recorded by Braniff and Quijada in the late 1970s (Braniff 1992; Braniff and Quijada 1977), Villa Verde was not subjected to systematic documentation until the SPAP conducted a mapping and surface-collection project at the site in 1996 and 1997 (Altschul et al. 1998). The main site component at the Villa Verde complex (Villa Verde III) consists of cobble-reinforced adobe-walled compounds, rubble mounds, trash mounds, and assorted surface features that cover an area roughly 200 m east–west by 100 m north–south. Villa Verde I is a smaller extension of the site and consists of roughly the same features and materials as seen on the other side of the wash, and Villa Verde II, a volcanic knob overlooking the site, is replete with petroglyphs. Altschul et al. (1998:83) estimated that the total site contains more than 200 rooms, mostly arranged around irregularly shaped compounds surrounded by rubble mounds, some of which reach 2 m in height. The decorated ceramics at Villa Verde were dominated by Santa Cruz Polychrome (72 percent), followed by Chihuahuan polychromes—Ramos, Babicora, and Villa Ahumada—that constituted 8 percent of the assemblage; Gila Polychrome was poorly represented (4 percent), and Babocomari Polychrome and Tucson Basin ceramic types were completely absent. Comparing the architecture and ceramics from Villa Verde with those from other Late Classic period sites in the middle and lower San Pedro Valley led Altschul et al. (1998:91) to conclude that during the Late Classic period,

> the San Pedro River [was] clearly not a conduit fostering north–south exchanges. The occupants of the river valley were not looking to their neighbors up or down the drainage for help, inspiration, or aid, but instead over the mountains to the east and west. How these cultural currents maintained themselves against the natural physiography of the land, and how they switched 90 degrees by the time Spaniards arrived are questions that first brought Charles Di Peso to this valley and keep us here today.

The sites Altschul and his colleagues used for comparison in the middle San Pedro Valley—the Garden Canyon site (AZ EE:11:13 [ASM]) and Babocomari Village (AZ EE:7:1 [ASM])—are located at some distance from the San Pedro River. Larger Formative period sites that are more comparable to Villa Verde exist on the river, and so, the SPAP next turned its attention to those sites. Pot Town (AZ EE:8:48 [ASM]), located approximately 4 km north of Charleston, Arizona, is one of the largest and most complex Middle Formative period occupations in the riverine zone. Although locals had known of the site, Pot Town, as it was commonly called, was not recorded by archaeologists until 1968, as part of the Charleston Reservoir survey (Kayser 1968). Surface-artifact analysis and mapping at the site by the SPAP revealed a Middle Formative period component consisting of more than 30 trash mounds and a large area of rock-pile features. The trash mounds were concentrated on a relatively small bench overlooking the San Pedro Valley to the east. An oval depression surrounded by trash mounds was located in the southern part of the site and may be a ballcourt (Altschul et al. 2014:302). The rock-pile fields at Pot Town are north and west of the trash mounds and have been interpreted as small plant-processing locales.

After the work at Pot Town was complete, the SPAP moved just upstream, to map and analyze the surface artifacts at Frogsville (AZ EE:8:113 [ASM]). Pot Town was abandoned at the end of the Middle Formative period, at about the same time that Frogsville (AZ EE:8:113 [ASM]) was established. We speculated (see Altschul et al. 2014:304) that the two events were linked, with the population from Pot Town moving upstream to establish Frogsville. Much as Pot Town is one of the largest Middle Formative period occupations on the middle San Pedro River, Frogsville is one of the largest Late Formative period village sites in the area. It is situated on an open terrace about 500 m west of the river, overlooking a relatively wide section of floodplain. Water from the river could easily be diverted to that point to irrigate nearby fields. Frogsville is a large, sprawling site, measuring 300 m north–south by 220 m east–west. The cultural deposits lie on a terrace that slopes toward the floodplain, which now is heavily dissected by rills and arroyos. Many cultural features, including pit houses, roasting pits, hearths, and burials, are exposed in the sidewalls of the entrenched washes. Based on the size and intensity of the surface deposit and exposed features, Towner (1994) inferred that between 100 and 200 pit houses exist at the site, and Altschul (1997:64) estimated that Frogsville had a momentary population of at least 50 and upwards of 100 inhabitants.

To gain a better understanding of the dating of the sites, the SPAP systematically analyzed a sample of ceramics from two trash mounds at Pot Town and performed a grab-bag-sample analysis of surface ceramics at Frogsville. Diagnostic ceramics found at Pot Town included Cascabel, Deep Well, and Benson Red-on-brown of the Dragoon series ceramics (representing more than 60 percent of the decorated sherds); Dos Cabezas, Pinaleño, Galiuro, and Encinas Red-on-brown from the San Simon series (about 20 percent); Gila Butte, Santa Cruz, and Sacaton Red-on-buff from the Gila series (about 18 percent); and several red-on-brown sherds that resembled Tucson Basin–series ceramics. Red ware was abundant and highly variable, resembling defined types such as San Francisco Red, Dragoon Red, San Francisco Red (Peppersauce variety), and Rincon Red. A sand-tempered, fire-clouded plain ware with variable forming and finishing techniques was the dominant utilitarian ware observed on the surface of the site.

At Frogsville, the ceramics fit well within what Heckman (2000) defined as the Babocomari tradition. According to Heckman (in Altschul et al. 2014:303),

> the Babocomari tradition has its origins in a pottery decorated with a single pigment on a light slipped or unslipped background (bichrome) and reached its florescence with Di Peso's (1951:123–130) Babocomari Polychrome. Contrary to conventional wisdom, Babocomari ceramics are not all micaceous. In fact, they exhibit a continuum from absolutely no mica to highly micaceous. The paste color varies from a tan, orangish brown to a light, creamy gray and is frequently fire clouded. The most distinctive characteristics of the Babocomari ceramics are the chalky texture and the light, soft paste. The pigment used to paint the vessels is often fugitive and can rub off easily. In fact, it appears that a significant number of designs may have been obliterated during the use life of a vessel.

The mixed ceramic assemblage at Pot Town fits the pattern observed at other Middle Formative period sites in the middle San Pedro Valley, such as Walnut Gulch (Cook 2007), Soldier Creek (Vanderpot 1994a), and Garden Canyon (Jones 1996). Similarly, the coalescence of pottery into a single ceramic tradition at Frogsville is consistent with ceramics observed at other sites in the middle San Pedro Valley dating to the Late Formative period. Altschul et al. (2014:304) suggested that those ceramic trends may signal a "change from a multi-ethnic community on the fringe of the Hohokam system to a cohesive local cultural system that emerged in the Late Formative."

By the time the SPAP had completed its mapping and surface-collection projects at Villa Verde, Pot Town, and Frogsville, it was clear to Altschul that to gain a firmer understanding of the dynamics of the Formative period in the San Pedro Valley, we needed more data from excavations. Differences in architecture and ceramics gleaned from surface observations had revealed a complex cultural situation, but those data alone could not tell us everything. Initially, Altschul and Quijada wanted to excavate at Villa Verde. Financing such a major excavation was beyond the reach of SRI's financial capabilities, and Altschul and Quijada therefore investigated securing grant funding for the project. The SPAP faced other problems, as well, most importantly securing a permit from INAH's Consejo de Arqueologia. The Consejo had no experience with a private, for-profit CRM company doing academic research and was skeptical, believing that our real purpose was to use the archaeology for commercial gain. After several failed attempts to secure a permit, the SPAP turned its attention north of the border.

In 1998, the area of the San Pedro Valley between the Arizona towns of Fairbanks on the south and Cascabel on the north was poorly known. With the exception of the Amerind Foundation excavation at Tres Alamos (Tuthill 1947), there had been very limited survey and almost no excavations. The work of the SPAP south of Fairbanks and work by Archaeology Southwest north of Cascabel made it clear that the two parts of the river valley were culturally distinct during the Formative period. But what happened in the middle? The excavations at Tres Alamos were intriguing. They yielded distinctive forms of architecture and a material culture that was not characteristic of the areas of the valley to the north or south. By 1998, the excavations at Tres Alamos were already 50 years old, and although they met the professional standards of the day, the field and analytic techniques, as well as the reporting, certainly fell far short of those required in CRM.

The Mescal Wash Site

It was in this context that Altschul learned that ADOT planned to build an interchange on I-10 that would disturb or destroy large portions of the Mescal Wash site. Located about 15 km due west of the San Pedro Valley and 25 km southwest of Tres Alamos, the Mescal Wash site had all the surface attributes to indicate that it could provide valuable data on the issue of Formative period dynamics. For the year or so between learning of the upcoming project and the issuance of the Request for Proposals (RFP), the SPAP visited the site about a dozen times. We surveyed the flanks of Mescal Wash and Cienega Creek adjacent to the sites, as well upstream and downstream from the site for several kilometers. By the time the RFP was issued, we knew that the site was long lived and that although other habitation sites were located nearby, none had the size or longevity of Mescal Wash. Based on that information, we settled on the concept of *persistent place* as the centerpiece of SRI's research design.

Sarah Schlanger (1992) articulated the concept in an article on Anasazi settlement systems in 1992, arguing that a persistent place was not simply a location that had been used by humans for long periods of time but one in which the residue of past occupations attracted later occupations and reoriented how people thought of and used the site in those later occupations. The persistent-place concept intrigued us, because the archaeology at Mescal Wash did not suggest one continuous occupation but appeared to represent a series of discrete occupations by very different people, at different times, for different reasons. The natural setting of the Mescal Wash site on a terrace overlooking the confluence of Cienega Creek and Mescal Wash—a well-watered area—would have been attractive to hunters, gatherers, and farmers alike. The site's position at the pass between the San Pedro Valley and the Tucson Basin and at the break between the lower and middle San Pedro Valley would have made the site a node in any settlement system. Moreover, the site was located along the boundary between two very different ecological zones: the Chihuahuan Desert grasslands and the Sonoran Desert. How that focal point changed in nature between occupations should thus be able to shed light on the various Formative period cultures that surrounded the site and occupied it from time to time. In the data recovery plan (Altschul et al. 2000:14), we stated,

> Our basic task is to determine who the people were who lived at Mescal Wash at different points in its history. As noted in the RFP, we need to understand the cultural character of the population through time and to compare and contrast it with neighboring populations. Did the people living at Mescal Wash belong to a group that can be identified according to traditional labels, such as Hohokam or Mogollon? Did they represent an indigenous population with no adequate archaeological label? Or were they a mixed community, with coresiding members of different cultural groups? And again, did the social and cultural composition of the community change through time? In our model for the Mescal Wash site, social and cultural factors assume great importance in accounting for change. We assume that the relatively insular Archaic and pre-Classic period communities were replaced by a larger community whose social and cultural boundaries were greater and more fluid. Indeed, the late-prehistoric community may have been coresident and culturally mixed.

In the more than a decade and a half of investigations that have followed, we have accomplished much. First and foremost, we have conducted the most intensive data recovery project in this portion of southeastern Arizona to date, including the documentation and excavation of numerous structures and other features and analysis of unsurpassed numbers of artifacts and samples. Whatever else, scholars years from now will be using the results of the Mescal Wash data recovery in investigations of the complex and changing cultural dynamics that characterized the Late Archaic and Formative periods in the region. Second, we have been able to incorporate the data from the Mescal Wash site into the larger research programs initiated by the SPAP and others, to address issues of cultural continuity, cultural diversification, cultural ambiguity, and cultural ethnogenesis. Many of these topics have been discussed in other chapters of this volume. Here, we summarize the results and our interpretations.

Mescal Wash Settlement History

The Mescal Wash site covered an area of nearly 1 km^2 at the confluence of Mescal Wash and Cienega Creek traversed by I-10 and the UPRR line. SRI conducted phased data recovery at the site in 2000 and 2001. During the investigations, SRI identified eight loci (Loci A–H), and most of the excavations focused on Loci A, C, and D. At the end of fieldwork, the total feature inventory numbered 2,314 archaeological features, of which 423 features (not counting intramural subfeatures, 14 multiple features or feature conglomerates, and 37 extramural features that were not truly excavated but probed only to look for burials) were excavated. The excavated features were 97 structures and 326 extramural features (including 48 burials) (see Volume 1, Table 10). Numerous artifacts and ecofacts, as well as copious paleobotanical, radiocarbon, and AM samples, were collected and analyzed. Concomitant with the archaeological investigations, two additional field studies were conducted: a modern-plant study to help calibrate paleobotanical research (see Volume 2, Appendix 9A) and a geomorphological study of the Cienega Creek and Mescal Wash alluvium (see Chapters 2 and 3 of this volume). The first study highlighted the wealth and abundance of edible plant species in and near the project area. The second study showed that the availability of agricultural land that could be easily watered throughout much of prehistory explains the placement, use intensity, and temporal span of the Mescal Wash site. Situated in close proximity to diverse habitats along the transition zone between two major biomes, the Sonoran and Chihuahuan Deserts, the Mescal Wash site was optimally placed to collect a wide range of wild-plant foods, hunt across different ecological zones, and farm along Cienega Creek and Mescal Wash. Agriculture played a significant role from the Late Archaic period times, but the abundant wild-plant resources of the surrounding grassland were equally important (see Chapter 6 in this volume).

The investigations showed that the site witnessed habitation spanning nearly 3,000 years. Travelers, hunters, gatherers, farmers, pioneers, and colonists—in different configurations and at different times—all made their mark on and contributed to the local landscape in distinctive ways. As determined from radiocarbon and AM dates, the Mescal Wash site was intermittently occupied between about 1200 B.C. and A.D. 1450, a time span corresponding to the Late Archaic and Formative periods. Middle Archaic period dart points recovered from the site suggested earlier use, but no protohistoric or early-historical-period artifacts or features were identified. As expected, there was a rhythm and pulsation to the occupations. Some were transient, such as the hunter-gatherers of the Middle Archaic period and probably also the Late Archaic period occupants who added farming to their subsistence universe. AM-contemporaneity studies (see Volume 2, Chapter 2) formed a primary component of the individual locus chronologies by providing high-resolution sequences of feature abandonment during the Middle and Late Formative periods. Within the excavated part of the site, early activities, particularly residential, were restricted to Locus D and possibly Locus C, and there was no recognizable evidence of activities on the upper terraces, farther north and west, prior to A.D. 750. Most, if not all, inhabitants of the investigated area continued to live in the slightly lower portions of the site, close to Cienega Creek, until around roughly A.D. 900. Between A.D. 900 and 1000, residential, and possibly other, activities expanded out from Locus D, and new settlements were established to the north and west, in Loci A and C. The overall intensity of activity within the investigated area peaked between A.D. 900 and 1150, as indicated by the large number of structures dated to that period, and then dropped to almost nothing over the next 2 centuries. Finally, a small Late Formative period group resided in Locus D between roughly A.D. 1300 and 1450, representing the last recognizable prehistoric settlement within the investigated area. The AM-contemporaneity study indicated that there were coeval households within all three investigated loci by as early as A.D. 850–900, if not earlier. Given their proximity, residents of those areas almost certainly interacted with each other,

The earliest, and also the latest, features were found in Locus D. In that locus, SRI excavated a series of small, circular pole-and-brush structures and associated bell-shaped storage pits dating to the Late Archaic and Early Formative periods. The focus of the settlement had clearly been on the farmland along Cienega Creek. Only a small portion of this early component was located within the project area; additional early features probably were located in the western portion of the locus, closer to Cienega Creek.

The Formative period occupations were more permanent. In the Middle Formative A period, between A.D. 750 and 950, the site reached its population peak, and Locus D was developed to such a degree that clustering and superimposition of structures were the norms. The structures varied in size, shape, and orientation, but most were reminiscent of Hohokam houses-in-pits. These dense feature clusters and conglomerates of superimposed houses signified either continuous, long-term habitation or repeated, short-term occupation over several centuries. The dramatic overbuilding suggested a densely occupied, discrete hamlet or perhaps a village. Perennial flow, steady alluviation, and availability of pockets of land suitable for farming made Cienega Creek well suited for agricultural production, especially prior to A.D. 1100. During the Middle Formative B period (A.D. 950–1150), population decreased, and the site consisted of a series of dispersed farmsteads. After about A.D. 1100, the occupation shifted northward from Locus D, along Cienega Creek, to portions of the site along Mescal Wash. That shift—from the Cienega Creek side to the Mescal Wash side—occurred at the time prior to A.D. 1100 when increased rainfall and moisture made Mescal Wash a better place to farm. Instead of being contained in a single occupation center, the population was then dispersed across several discrete hamlets or farmsteads. Locus D showed little evidence of occupation during that period; in contrast, Locus A and most of Locus C were solely occupied during that time. In Locus A, houses were found isolated, rather than in clusters. In Locus C, they were clustered, but not as densely as in Locus D. As in the previous period, many of the houses were identical to Hohokam houses found in the Tucson Basin and elsewhere. However, six examples of what appeared to be a local architecture were found—pit structures characterized by a large, circular, recessed area in the floor adjoining the entrance. The hearth was located in the center of that sunken area, and postholes suggested that the recess had its own special roof. One of the recessed-hearth structures contained a series of parallel grooves in the floor outside the recessed area, suggesting a raised floor. Given that this structure (located in Locus C) was the largest excavated at the site and the only one with an east-facing entryway, it may have had a communal function. The recessed-hearth architectural style was not a "flash in the pan" that occurred simultaneously across the site but, rather, a longer-lived variation that had a minor presence through much of the Middle Formative period. The co-occurrence of this style with more-traditional Hohokam-style structures may indicate some level of ethnic coresidence. It is interesting to note that site layout always remained informal, lacking a ballcourt or platform mound, and none of the structures were arranged in courtyards or enclosed by compound walls.

That community continued through the end of the Middle Formative period, after which most people appear to have resettled elsewhere; in particular, they may have moved several kilometers downstream to what would later become the Pantano Town site (AZ BB:14:25 [ASM]), the prehistoric component of which was a large habitation site occupied predominantly during the Late Formative A period. Small farmsteads, such as the Marsh Station Road site (AZ EE:2:44 [ASM]), extended up to the confluence of Cienega Creek and Mescal Wash but did not extend as far as the Mescal Wash site. No evidence of occupation during the Late Formative A period was found, likely because a lack of sufficient water flow in the adjacent creek bed forced the local farmers to a more favorable setting downstream. During the Late Formative B period, people returned to the site itself. A small number of widely spaced adobe-walled houses with raised floors and narrow, stepped entryways were established. Thus, with its focus once more on the arable land along Cienega Creek, the occupational cycle of the site was completed. Independent families of migrant farmers lived among the earlier ruins, a pattern reminiscent of the one established by early agriculturalists, who occupied the site on and off for at least a millennium prior to A.D. 750.

Sometime after A.D. 1450 and before the arrival of the Spanish, the prehistoric populations of southern Arizona were replaced by Upper Piman peoples who farmed along the Santa Cruz and San Pedro Rivers (Ravesloot and Whittlesey 1987; Seymour 1989). The large settlements and productive farmlands of these riverine oases attracted Spanish missionaries, soldiers, and colonists. Bands of Chiricahua Apache made their homes there, and Western Apache bands routinely traveled through the region. Historical documents show that Cienega Creek was known as “Ciénega de los Pimas” (Marsh of the Pimas) during the Spanish period (Dobyns 1981:18). At that time, the site area was a stopover point for travelers between Tucson and the San Pedro River and was used regularly as a camping and watering stop for soldiers, settlers, and Apaches alike. In particular, the point where the creek turns to the west near the southern foothills of the Rincon Mountains was often used as a camping and watering stop (Dobyns 1981:18). Wagon roads and the Butterfield Overland Mail line followed, as did more recent transportation corridors (I-10 and the railroad), as well as various communication lines and energy conduits.

Addressing the Research Questions

Mescal Wash was located at an ecological and cultural crossroads. It is close to diverse plant and animal habitats along the transition between the Sonoran and Chihuahuan Deserts. The site was also on a cultural boundary between prehistoric agriculturalists—Hohokam to the west and Mogollon to the north and east, as well as Sonoran groups. A true crossroads for travelers, the site is at a pass connecting the Tucson Basin/Santa Cruz Valley and the middle San Pedro Valley, and Cienega Creek was a corridor linking it with Sonora. Long neglected by archaeologists until recent years, southeastern Arizona’s prehistoric “hinterland” populations have been overshadowed by major cultural developments (and archaeological investigations) in the surrounding “heartland” areas. The excavations at the long-lived Mescal Wash site have provided a much-needed opportunity to study the complex interplay among those various cultures and to evaluate the prevalent concept of southeastern Arizona as a hinterland between heartlands.

Given the site’s longevity, the project’s research design (Altschul et al. 2000:5–14) focused on the ancient community at Mescal Wash and, in particular, the concept of the site as a persistent place. We developed a historic context centered on “archaeology of place,” asking questions about what promoted community development and change. As rephrased in Chapter 1 of this volume, that context is a nested concept ranging from single settlements to regions—or from the Mescal Wash community to its environment, its economy, its demography, and, finally, its regional landscape. As a community, Mescal Wash was not a single place through time but many places to many people (Vanderpot and Altschul 2007:51). Such a notion brings up many questions, most having to do with ethnicity. What drew people repeatedly from different backgrounds to this location? Did the people living at Mescal Wash belong to a group that can be identified according to traditional labels, such as Hohokam or Mogollon? Did they represent an indigenous population with no adequate archaeological label? Or were they a mixed community of coresiding members of different cultural groups? Basically, these questions are about ethnic identity, community structure, and persistent places and are discussed in the following sections, as excerpted from Volume 2, Chapter 2, and Chapters 4 and 8 of this volume.

Cultural Affiliation: The Ceramic Evidence

The site’s ceramics represented a wide spectrum of traditions from the surrounding regions—Hohokam (Tucson and Phoenix Basin), Mogollon (Dragoon, San Simon, and Mimbres), Salado, and Trincheras. The collection provides insight, not just into cultural affiliation but also into the community history and social composition of Mescal Wash and how it changed over time. The earliest pottery consisted of plain wares used for cooking, storage, serving, and transport. The Middle Formative B period saw increased use of painted serving vessels, perhaps indicating a greater emphasis on communal feasting and the use of decoration to express cultural affiliation. In the Late Formative B period, painted pottery decreased in importance and was mostly limited to Roosevelt Red Ware. It has been argued that in the San Pedro Valley, this pottery was manufactured by families who originated in northern Arizona’s Kayenta/Tusayan region and exchanged it throughout southeastern Arizona (Clark and Lyons 2003). Thus, Late Formative B period people of Mescal Wash may have been migrants from the north. Alternatively, they were locals who established affiliation with the ancestral Pueblo tradition to express ritual connection or a shared religious ideology.

The main focus of the ceramic study addressed three hypotheses regarding the Middle Formative period painted ceramics that were first offered in the project's research design (Altschul et al. 2000:13): (1) they indicate settlement by migrants from other areas of the greater Southwest, (2) they were trade items acquired through exchange or other economic mechanisms, and (3) they represent locally made imitations of foreign styles that expressed social affiliations or social relationships with peoples, cultural practices, or traditions in other "regional communities" of the Southwest.

The first hypothesis has different groups moving permanently or seasonally to the site to, for example, procure resources in the nearby Chihuahuan grasslands, which differed from those available in their desert homelands (in the case of Hohokam people). Given the predominance of pottery associated with the Hohokam and Dragoon traditions, most of these migrants arrived from the Phoenix Basin, the Tucson Basin, and the San Pedro Valley. More precisely, because Hohokam pottery outnumbered Mogollon pottery by four to one, most of the hypothesized immigrants were Hohokam. Vessel form and function were telling. Nearly all Dragoon and San Simon wares were bowls likely used to serve or process food. In contrast, the Hohokam pottery included serving vessels (bowls) as well as vessels (jars and some bowls) used for storage, cooking, and transport. Assuming domestic vessels were less likely traded from afar, then the Hohokam-style vessels were not obtained through trade but were brought to the site by Hohokam migrants or manufactured locally by migrant Hohokam potters in the styles of their homelands. This would mean that the site was inhabited by Hohokam peoples who migrated from the Tucson Basin and/or Phoenix Basin. The Tucson Basin vessels were large and small, but most of the Phoenix Basin pots were small vessels, which is consistent with long-distance and large-scale trade. Phoenix is much farther—200 vs. 30 km—from the site than Tucson, and transporting large vessels over long distances is cumbersome. This suggests that either (1) the buff wares entered Mescal Wash via merchants through large scale trade or (2) migrants from the Phoenix Basin brought only small vessels with them, obtaining larger ones after they arrived. Importantly, although most features with ceramics at Mescal Wash contained a mix of different regional wares, certain different regional wares were more prevalent in some features than in others. Given the absence of any clear "local" tradition at the site, the hypothesized migrants used the native-style pottery of their homelands when making new vessels. Another line of evidence is that Dragoon wares matched or outnumbered the Hohokam-style wares in several structures in Locus C. This would suggest that the site was occupied not just by Hohokam migrants but also by "Dragoon people" from the San Pedro Valley and that both inhabited the site, simultaneously or separately, but within a short time frame.

The second hypothesis—trade or exchange—is likely true to some extent but, again, forms only part of the picture. The Hohokam ballcourt system provided a venue for merchants to move large amounts of (small) buff ware vessels over a large area. But the sheer volume of nonlocal painted pottery at the site would have involved an enormous trade investment. Moreover, the ballcourt system did not reach to the site area. It is unlikely that pottery exchange in the Southwest could have occurred on a sufficiently large scale to supply such a large volume of painted pots to the Mescal Wash population, especially in the absence of a formalized and regional exchange network. On the one hand, these data are consistent with the idea that the majority of painted-pottery vessels were made locally, possibly as local imitations of nonlocal-style vessels. On the other hand, the prevalence of small vessels among the buff wares implies long-distance exchange. Clearly, the collection might be a mix of locally made and imported painted wares.

The final hypothesis suggests that local imitation was responsible for the painted pottery at the site. Possibly, local potters manufactured pottery using foreign styles—mainly Hohokam (especially Phoenix Basin)—as tokens of identity, affiliation, or ritual performance. These potters may have been non-Hohokam, but just as likely, they may have been migrants who manufactured pottery in the styles of their Hohokam homelands for the same reasons. Either scenario would explain the large volume of painted pottery at the site.

In sum, each of the three hypotheses—migration, exchange, and local imitation—may explain the presence of the different foreign pottery styles at the site. Likely, a mix of all three scenarios occurred. Although local imitation best explains the large volume of pottery at the site, we should not exclude trade and migration. In the end, we suspect that most of the painted pots were locally made imitations of foreign styles and/or were made at the site by potters trained in the traditions of their homelands. Also, it is likely that migrants from the Hohokam region or the San Pedro Valley and farther away lived together at the site. Elsewhere, we have suggested that Mescal Wash was a shared place where different groups came together for communal cookouts and celebrations. Located at an important crossroads for travelers, it may even have been a trade center.

Households and Community Organization

Mescal Wash functioned as a mixed forager-farmer *ranchería* during much of its long history. As stated in the original research design (Altschul et al. 2000), we were particularly interested in knowing the size of the population at Mescal Wash at different points in time. Did the residents of

Mescal Wash represent a largely independent and isolated group or were they seasonal visitors from larger, more permanent communities in surrounding regions? Was there a change in domestic group composition over the course of the site's occupation? Is there any evidence of agricultural intensification in the form of increased households? Such questions are best addressed by the study of household and community organization—the evaluation of domestic-group size and composition, activity organization, occupational duration and intensity, and stages in the cycle of domestic groups. A second good line of inquiry focuses on Mescal Wash's location at the crossroads of major southwestern cultures, such as the Hohokam and Mogollon. Who were the people that lived at Mescal Wash, and did they change over time? Can the residents of Mescal Wash be identified as Hohokam or Mogollon, or did they represent a distinctive indigenous population or a mixed community of coresident members of different cultural groups? Here, we summarize the findings of the study on community development and organization presented in Chapter 4 of this volume—in particular, those relating to household size, occupation intensity, population size, and ethnic identity.

Household Size

Households at Mescal Wash were largely average in size, and most were housed in single structures. Hohokam-style courtyard groups with angled or facing entryways were extremely rare; clusters of houses with parallel entryways were slightly more common. Households composed of paired houses were also very rare, and in the few cases that were present, pairs of similar-sized houses and pairs comprising one big house and one small house were equally common. Many of the smaller structures, often with formal hearths, were isolated, suggesting use by subhousehold units representing short-term residence by task groups smaller than households. Such small, isolated, and independent households may have consisted of only one or two individuals each. Conventional-sized households were present throughout the Early to Late Formative periods. They increased slightly in numbers by the Middle Formative B period and were most common in the Late Formative period. For the most part, there was a pattern of replacement of larger households by smaller ones over the course of the Middle Formative period. The presence of a large, possibly communal house (Feature 379 in Locus C) with a rare east-facing entry suggests some level of community integration in the Middle Formative B period.

Occupation and Reoccupation

Mescal Wash evidences intense and concentrated occupation. Time depth in occupation and reoccupation by individual households suggests a concept of land tenure. For the most part, occupation was by small to average-sized and independent households. In contrast to the Hohokam courtyard group, which reflects a pattern of multigenerational use and ownership by a distinct corporate group, the pattern at Mescal Wash suggests multiple shifting, intermittent, short-term occupations by unrelated households. That is supported by the almost random distribution of extramural pits in residential areas and in abandoned houses. Households and smaller task groups came and stayed for a few years but then moved on. The eastern portion of Locus D witnessed intense occupation and reoccupation, as shown by numerous superimposed structures and the reuse of house pits from the Early Formative period through the Middle Formative A period. That occupation may have had roots in the Late Archaic period, given the presence there of bell-shaped pits dating to that time. By the Middle Formative B period, occupation began a gradual shift northward, and most structures were built in Loci A and C. That new pattern of occupation was very different from preceding times; there was much less superpositioning of structures and reuse of house pits. Although there was some evidence of replacement of households, for the most part, new houses were constructed without reference to older ones, suggesting occupation by new, unrelated households.

Population Size

Calculating population size is difficult for the same reason that it is difficult to know the total number of households at the site during a given point in time: we do not know the entire extent of occupation during each time, because the entire site was not excavated. This is especially true for the beginning and end periods of occupation. After an apparent hiatus during the Late Formative A period, the site was reoccupied in the Late Formative B period as a dispersed series of only a few structures that was very unlike the nucleated settlements found in the Tucson Basin or the San Pedro Valley. It remains unclear whether that Late Formative B period settlement was smaller than its predecessors or was only used for a brief period of time—it was certainly sparse and not overbuilt. Although many houses were built during the entire 400-year span of the Middle Formative period, only a handful appear to have been occupied at any single time. For example, the sample for the household study contained 86 Formative period structures; if we divide the 400-year Formative period span by 20 years (the span of a single generation) and divide the 86 structures in our sample by that quotient (20), only a few more than 4 houses may have been present at any time—a number comparable to the number of excavated Late Formative period houses (most of which may have been contemporaneous). This suggests the presence of farmsteads or small hamlets occupied by 20–25 people at the most, but rarely or never a true village (i.e., 20 or more houses occupied simultaneously and a population of 100 or more people). If anything, the small number of households at Mescal Wash suggests that agricultural intensification never occurred in this area.

Ethnicity

The household analysis sheds some light on the issue of who the people that lived at Mescal Wash were and whether ethnic affiliation at the site changed over time. The dominant architectural forms at Mescal Wash—variations on the house-in-pit style—clearly reflect a Hohokam connection, if not actual settlement by Hohokam people from the Tucson Basin or other areas. Significantly, the possible communal house, the largest structure excavated at the site, is of a Hohokam Sacaton phase style, not Mogollon. Mogollon-style pit houses have been excavated in Loci A and G by WestLand (Deaver 2010), and a Late Archaic/Early Formative period structure in Locus D looks Mogollon, also. The recessed-hearth pattern found at the site and the parallel floor grooves found in Feature 379 appear to represent a local variant of the raised-house-floor pattern found in many Hohokam settlements in the Phoenix Basin and surrounding upland areas. Whether that variation represents an indigenous interpretation of a Hohokam style by local groups or the building houses by actual Hohokam people in the way they knew remains unknown; however, the first option is more plausible, in which case at least three ethnic groups may have lived together at the site during the Middle Formative B period. Interestingly, most of the Late Formative B period houses also contained parallel rows of postholes across their floors, suggesting that they also had raised floors—a pattern not noted for that time period in the Phoenix Basin.

Whereas the architectural style suggests a dominant Hohokam influence, if not actual settlement by Hohokam migrants, the household arrangements suggest a Mogollon presence. Pairs of large and small houses and larger courtyard groups are rare at Mescal Wash; most households were housed in isolated structures. The presence of parallel rows of houses with entryways facing in a common direction is suggestive of Mogollon settlements. The dominant north- and south-facing pattern at Mescal Wash, however, contrasts with the dominant east-facing arrangement in Mogollon settlements. Possibly, the paucity of Hohokam-style arrangements reflects small group size—environmental constraints limited occupation long enough for small households to grow into larger ones. Alternatively, the residents of Mescal Wash may have been influenced enough by Hohokam culture to build Hohokam-style houses but not sufficiently imbued in Hohokam culture to organize their households in a typical Hohokam arrangement.

Mescal Wash as a Persistent Place

Because Mescal Wash was the scene of repeated occupation over a period of at least 3,000 years by various different cultural groups, the project research design (Altschul et al. 2000:5–14) identified longevity as a key attribute. We saw the site as an example of what Schlanger (1992:97) labeled "persistent places"—places that were repeatedly used during long-term occupations of regions. Schlanger suggested that persistent places emerge as a result of three particular qualities: environmental attributes, preexisting cultural features, or exploitable cultural tools, such as ground stone. In Chapter 8 of this volume, Heilen explored the issue by first asking a series of interrelated questions, such as *How do persistent place form? How rare are persistent places? What kinds of sites become persistent places? How are persistent places distributed in time and space?* and *How does Mescal Wash compare to other persistent places?*

Chapter 8 first discussed the formation of persistent places in southeastern Arizona, focusing on the Hohokam and developing a model to estimate the expected number of persistent places in the region. Despite strong evidence of discontinuity in subsistence, settlement, and social organization between the pre-Classic and Classic periods, a clear continuity in place use was evident between those periods. Classic period persistent-place formation appears to have been tied to broad-scale shifts in settlement pattern and regional abandonment. The model showed that during the Classic period, persistent-place formation increased at the same time that the Hohokam network collapsed. The elevated proportions of Classic period persistent places were expected, given the extraordinarily large founding set of places on which they were based. Because the Hohokam network was rapidly expanding during the Middle Formative period, a very large number of sites were available for reuse during the Classic (i.e., Late Formative) period, even though abandonment was happening at a huge scale at the same time.

Building on Schlanger's argument, there are three kinds of persistent places, in terms of relationship to the settlement networks in which they participated. Type I persistent places are nodes that endure for most of the lifespan of a particular settlement system. Type II persistent places are nodes that recur or reappear across time in different landscape networks. Type III persistent places are places that simultaneously participate in two or more contemporaneous landscape networks (and thus share attributes with both Type I and II persistent places). The formation of persistent places is influenced by a variety of cultural and environmental variables; sites are most likely to be persistent places when they occur at ecological as well as cultural edges. Persistent-place formation differs according to the scale of persistence. At the scale of archaeological periods, persistent-place formation is linked to the physiographic structure of landscapes and the supracultural availability of limiting resources (Type I). At the scale of archaeological phases, persistent-place formation is driven by the internal dynamics of an evolving settlement system (Type II). Persistent places at the level of phase (Type I) are uncommon, persistent places at the level of period (Type II) are rare, and persistent places at both the level of phase and period (Type I and II) are exceedingly rare.

At different times, Mescal Wash functioned as all three types, making it especially unique. Among other things, the study showed that all three major ceramic traditions in the area—Hohokam, Mogollon, and Sonoran—intersected, extraordinarily enough, at Mescal Wash. The site was a recurrent place in the Tucson Basin Hohokam network, used repeatedly for habitation and resource exploitation. Cost-surface modeling and least-cost-path estimation showed a convergence at Mescal Wash for travel through the region. Mescal Wash functioned as an edge or frontier place that was important to multiple contemporaneous groups participating in different cultural traditions of southeastern Arizona, southwestern New Mexico, and northern Mexico.

Mescal Wash was a special place that persisted in a way that can only result from a unique and enduring mixture of environmental and cultural phenomena. Although the region includes fairly large sets of Type I and II persistent places, we cannot expect many sites like Mescal Wash. The site occurred in a location that was highly connective physiographically, culturally, and ecologically—there just are not that many opportunities for such a convergence of those attributes. The closest counterparts to Mescal Wash may not be found locally but widely dispersed in other areas of the world.

Conclusions

Situated on the shortest prehistoric travel route between the Tucson Basin and the middle San Pedro Valley, Mescal Wash was a gateway between desert and grasslands—between Hohokam and Mogollon. Located at an ecological as well as cultural edge, the site was optimally placed to become persistent on all possible levels. That persistence does not always mean intensive occupation is evident from the site's makeup. To be sure, Locus D had many hundreds, if not thousands, of features, including numerous superimposed houses, but most of them were built over an approximately 200-year span around the Middle Formative A period. That was the time when agricultural potential was at its peak along adjacent Cienega Creek. It was also the time that the site's population peaked, but even then, it may never or rarely have been a village. Settlement was always loose, with few formal house arrangements. Households got smaller over time, suggesting that resources were limited or erratic. The amount of arable land likely was rarely large enough to support large populations. People stayed for a while, moved on, and came back only if conditions were favorable. Perhaps there were some agreements about land tenure, such as who would farm where, but people never were village-farmers as was common in the Hohokam area. Maize agriculture was important from the Late Archaic period on, but so were the gathering and processing of wild grasslands resources.

Mescal Wash was located at a cultural crossroads among Hohokam, Mogollon, and Sonoran ethnic groups. But who were the people living at the site? Does the variability in architectural styles, ceramics, and burial practices mean that local people borrowed cultural concepts from other groups in surrounding areas? Or did outside groups actually move to the site? Through the ceramic and household analyses, we have made some progress in answering these questions. The site's ceramics suggest three possible scenarios for the different foreign pottery styles: migration, exchange, and local imitation. A mix of all three scenarios likely occurred, a mix that changed through time. The large volume of "foreign" pottery at the site is best explained by local imitation and/or by local manufacture, with migrants making pottery in the styles of their homelands. A large proportion of the ceramics are (or look like) Tucson Basin Hohokam wares, which is not surprising, given that Tucson is only 30 km from the site. It is reasonable to assume that Hohokam people often made the short trip to the site, which must have had some fame for being the nearest major settlement in the grasslands. It is likely that they were attracted by the availability of abundant and varied grasslands resources, such as wild cereals and agave. They may even just have come to mingle with members of other ethnic groups, exchanging goods and information. Hohokam people may also have come from the Phoenix Basin area, which is 200 km away—linked to the site by following the Santa Cruz River or, more likely, the San Pedro River. Given the greater distance, we would expect that fewer people made that journey. It is noteworthy that most of the Phoenix Basin Hohokam buff wares are small bowls, which are stackable and relatively easy to transport. These bowls do not look locally made, and their presence at the site suggests trade or exchange. Because it is located at an important crossroads for travelers, it is easy to see Mescal Wash as a kind of trade center. Itinerant merchants may have brought their pottery from the Phoenix Basin and exchanged it for grasslands resources, such as easy-to-transport cakes baked from the flour of wild cereals.

The site's architecture sheds additional light on the issue of ethnicity. The dominant architectural forms at Mescal Wash are houses-in-pits built in the Hohokam style, indicating influence of or actual settlement by Hohokam people. Like what the ceramics show, it was probably a mix of both. Hohokam came from the Tucson Basin, bringing pottery along, and stayed at the site for a while, building houses in their native style. Additionally, local people may have started imitating Hohokam architecture, similar to what they did with pottery. Other architectural forms include Mogollon-style pit houses and pit structures with recessed-hearth areas. The Mogollon-style houses are few, but—along with the San Simon and Mimbres pottery—they do suggest the presence of that ethnic group at the site. Houses with recessed hearths are unique to this part of southwestern Arizona. They are rare also, found at just a handful of sites in the region. Although reminiscent of Hohokam houses with raised floors, they are a distinctive local stylistic expression that we tentatively termed "Dragoon," in analogy with the red-on-brown local Dragoon-style pottery. It is that Dragoon tradition that most closely resembles a local culture or ethnic group. In that respect, it is significant that the largest house at Mescal Wash had a recessed hearth area as well parallel floor grooves for a raised floor. It also was one of the very few houses with an east-facing entrance. This "big" house may have functioned as a community building used in ceremonies and other special gatherings. The community may have been bound together by coordinating farming efforts, communal hunting drives, and shared celebrations. Mescal Wash was not just a persistent place but just as much a shared place for different ethnic groups with ties to different areas. As a shared place, exchange of goods (such as grasslands products for pottery) would have been one reason people came together. From the features and ceramics, we know that people came together for communal cookouts that involved *hornos* and for feasting that involved painted serving vessels.

Viewed within a regional economic and settlement context, Mescal Wash fits the norm of forager-farmer and *rancher*ía settlement throughout much of southern Arizona's prehistory. The region was characterized by relatively small, dispersed settlements, which endured for long periods in favored places. During Archaic period times, settlements were typically small, dispersed occupations with considerable residential mobility, although some locations hosted larger and more-permanent settlements, such as Mescal Wash. Most Formative period communities stayed dispersed, supported by a mixed foraging-farming strategy, as had been used previously. Through time, dependence on cultivated-plant products and residential permanence increased, but wild-plant products and game always remained important. In Chapter 6, we stressed the importance of grasslands resources to the inhabitants of southeastern Arizona's Chihuahuan Desert. That emphasis on native resources, combined with the relative sparseness of arable land, prevented the development of the large, nucleated settlements so common in the Hohokam area.

SRI's work at Mescal Wash is done, and so is that of other investigators who have worked at the site. But researching the site and its materials is far from over—much more can be done. Four CRM firms have conducted excavations at the site, and vast quantities of materials and samples have been collected. But not everything has been analyzed, and the analyses that *have* been completed still need to be combined into an integrated whole. This and other reports on Mescal Wash form only the beginning of that research. Students can access and work with a treasure trove of data from one of the most important and unique archaeological sites in southeastern Arizona. Avenues for further research have been outlined in previous chapters and need not be repeated here. One future study stands out as of foremost importance: a ceramic-provenance analysis using chemical or petrographic methods. More than anything, knowing which ceramics were made locally and which were imported (and from where they came) will help resolve the issue of ethnicity. The continuing research potential of Mescal Wash, large areas of which remain unexcavated, makes the site persistent even to this day.

APPENDIX A

Pedon Descriptions

Profile 1, Trench 43, Locus B

Classification: loamy-skeletal, mixed, thermic Typic Calciargids
Geomorphic setting: Cienega Creek–Mescal Wash Qi2 terrace, elevation 1,105 m (3,625 feet) above mean sea level (AMSL), 2 percent slope
Parent material: mixed late Pleistocene alluvium
Described by: Jeff Homburg
Date: July 13, 2000

A 0–8 cm. Yellowish brown to dark yellowish brown (10YR 4.5/4) sandy loam, dark yellowish brown (10YR 3.5/4, moist); weak medium subangular blocks; soft, very friable, nonsticky, nonplastic; common very fine and fine roots; common very fine tubular pores; 2 percent subangular and subrounded gravel; noneffervescent; mildly alkaline; clear smooth boundary.

ABt 8–22 cm. Yellowish brown to dark yellowish brown (10YR 4.5/4) sandy loam, dark yellowish brown (10YR 3.5/4, moist); weak to moderate medium subangular blocks; moderately hard, firm, slightly sticky, slightly plastic; few very fine, fine, and medium roots; common very fine and fine tubular pores; 3 percent subangular and subrounded gravel; noneffervescent; mildly alkaline; abrupt smooth boundary.

Btk1 22–54 cm. Strong brown (7.5YR 4/6) loam, strong brown (7.5YR 3.5/6, moist); strong fine and coarse subangular blocks; rigid, rigid, moderately sticky, moderately plastic; patchy thin thick clay films on ped faces; few very fine and fine roots; few very fine and fine tubular pores; 5 percent subangular and subrounded gravel; slightly effervescent, with calcium-carbonate masses; moderately alkaline; clear smooth boundary.

Btk2 54–101 cm. Brown (7.5YR 5/4) sandy loam, light brown (10YR 6/4, moist); weak to moderate medium subangular blocks; patchy thin clay films on ped faces; hard, very firm, slightly sticky, slightly plastic; few very fine and fine roots; few fine and very fine tubular pores; slightly effervescent, with calcium-carbonate masses; mildly alkaline; clear smooth boundary.

2Ck 101–150+ cm. Brown (7.5YR 5/4) sandy loam, brown to dark brown (7.5YR 4/4, moist); weak to moderate medium subangular blocks; soft, very friable, nonsticky, nonplastic; few very fine and fine roots; few very fine and fine tubular pores; moderately effervescent, with common fine calcium-carbonate threads in the matrix; moderately alkaline.

Profile 2, Trench 246, Locus B (2–3 m South of Soil Trench 1)

Classification: loamy-skeletal, mixed, thermic Typic Haplargids
Geomorphic setting: Cienega Creek–Mescal Wash Qi2 terrace, elevation 1,105 m (3,625 feet) AMSL, 2 percent slope
Parent material: mixed late Pleistocene alluvium
Described by: Jeff Homburg and Robbie Heckman
Date: July 13, 2000

A 0–6 cm. Yellowish brown (10YR 5/4) loam, dark yellowish brown (10YR 4/4, moist); weak fine and medium subangular blocks; soft, very friable, slightly sticky, slightly plastic; common very fine and fine roots; common very fine tubular pores; noneffervescent; mildly alkaline; clear smooth boundary.

ABt 6–27 cm. Brown (7.5YR 4.5/4) loam, dark brown (7.5YR 3.5/4, moist); weak to moderate fine and medium subangular blocks; soft, very friable, slightly sticky, slightly plastic; few very fine, fine, and medium roots; common very fine and fine tubular pores; noneffervescent; mildly alkaline; abrupt smooth boundary.

Bt1 27–54 cm. Strong brown (7.5YR 5/6) clay loam, strong brown (7.5YR 4/6, moist); strong fine and medium subangular blocks and prisms; rigid, rigid, slightly sticky, slightly plastic; common moderately thick clay films on ped faces; few very fine and fine roots; many very fine and fine tubular pores; 20 percent subangular and subrounded gravel; noneffervescent; mildly alkaline; clear smooth boundary.

Bt2 54–78 cm. Brown to dark brown (7.5YR 4/4) clay loam, dark brown (7.5YR 3/4, moist); moderate medium subangular blocks; common moderately thick clay films on ped faces; hard, very firm, slightly sticky, slightly plastic; few very fine and fine roots; many fine and very fine tubular pores; noneffervescent; mildly alkaline; gradual smooth boundary.

BCt 78–89 cm. Brown to dark brown (7.5YR 4/4) clay loam, dark brown (7.5YR 4/3, moist); weak to moderate fine and medium subangular blocks; slightly hard, firm, slightly sticky, slightly plastic; few fine and very fine roots; many very fine and fine tubular pores; slightly effervescent; moderately alkaline; clear smooth boundary.

2Ck 89–140+ cm. Brown to dark brown (7.5YR 4/2) loamy sand, dark brown (7.5YR 3/2, moist); weak to moderate fine and medium subangular blocks; soft, very friable, nonsticky, nonplastic; few very fine and fine roots; common very fine and fine tubular pores; strongly effervescent, with common fine calcium-carbonate threads in the matrix; moderately alkaline.

Profile 3, Trench 234, Locus C

Classification: loamy-skeletal, mixed, thermic Typic Haplocalcids

Geomorphic setting: Cienega Creek–Mescal Wash Qi2 terrace, elevation 1,105 m (3,625 feet) AMSL, 2 percent slope

Parent material: mixed late Pleistocene to Holocene alluvium

Described by: Jeff Homburg and Robbie Heckman

Date: July 12, 2000

Fill 0–49 cm. Dark yellowish brown (10YR 4/4) extremely gravelly loamy sand, dark yellowish brown (10YR 3.5/4, moist); massive; soft, very friable, nonsticky, nonplastic; common very fine, fine, and medium roots; common very fine tubular pores; 75 percent angular and subangular gravel; slightly effervescent; mildly alkaline; very abrupt smooth boundary.

Bw 49–70 cm. Yellowish brown to dark yellowish brown (10YR 4.5/4) sandy loam to loam, dark yellowish brown (10YR 3.5/4, moist); weak to moderate medium and coarse subangular blocks; soft to slightly hard, friable, slightly sticky, slightly plastic; common very fine and few fine to coarse roots; few very fine and few fine tubular pores; 5 percent subrounded and rounded gravel; slightly effervescent; moderately alkaline; clear smooth boundary.

Bk1 70–104 cm. Yellowish brown (10YR 5/4) sandy loam, dark yellowish brown (10YR 4/4, moist); moderate to strong medium and coarse subangular blocks; moderately hard, friable, slightly sticky, slightly plastic; few very fine, fine, and medium roots; few fine and very fine tubular pores; 5 percent subrounded and rounded gravel; slightly effervescent, with calcium-carbonate coatings on sides and bottoms of rock fragments and threads in the matrix; moderately alkaline; clear smooth boundary.

Bk2 104–124 cm. Light yellowish brown to yellowish brown (10YR 5.5/4) sandy loam, dark yellowish brown (10YR 4/4, moist); moderate medium and coarse subangular blocks; hard, friable to firm, slightly sticky, slightly plastic; few very fine and fine roots; few fine and very fine tubular pores; 7 percent subrounded and rounded gravel; strongly effervescent, with calcium carbonate on sides and bottoms of rock fragments and threads in the matrix; moderately alkaline; gradual smooth boundary.

Bk3 124–151 cm. Light yellowish brown (10YR 6/4) sandy loam, yellowish brown (10YR 5/4.5, moist); weak to moderate coarse and very coarse subangular blocks; hard, firm, slightly sticky, slightly plastic; few fine and very fine roots; few very fine and fine tubular pores; 5 percent subrounded and rounded gravel; strongly effervescent, with common fine to coarse, soft to hard masses of calcium carbonate; moderately alkaline; clear smooth boundary.

2BCk 151–175+ cm. Yellowish brown (7.5YR 5/4) sandy loam to loamy sand, dark yellowish brown (7.5YR 4/4, moist); weak medium and coarse subangular blocks; extremely hard to rigid, rigid, nonsticky, nonplastic; many thin clay films on ped faces; few very fine roots; few very fine and fine tubular pores; very strongly effervescent, with common fine, soft masses and hard nodules of calcium carbonate; moderately alkaline; gradual smooth boundary.

Profile 4, Trench 237, Locus C

Classification: loamy-skeletal, mixed, thermic Typic Calciargids

Geomorphic setting: Cienega Creek–Mescal Wash alluvial terrace, elevation 1,105 m (3,625 feet) AMSL, 2 percent slope

Parent material: mixed late Pleistocene alluvium

Described by: Jeff Homburg

Date: July 13, 2000

A 0–9 cm. Yellowish brown (10YR 5/4) loam, brown (10YR 4/3, moist); weak to moderate fine and medium granules and weak to moderate medium subangular blocks; slightly hard, friable, slightly sticky, slightly plastic; common very fine and fine roots; common very fine and fine tubular pores; less than 1 percent subangular and subrounded gravel and cobbles; slightly effervescent; mildly alkaline; clear smooth boundary.

BAt 9–32 cm. Brown to dark yellowish brown (10YR 4.5/4) loam, dark brown to dark yellowish brown (10YR 3.5/4, moist); moderate medium and coarse subangular blocks; slightly hard, friable, slightly sticky, slightly plastic; few very fine, fine, and medium roots; few very fine and fine tubular pores; less than 1 percent subangular and subrounded gravel and cobbles; slightly effervescent; moderately alkaline; clear smooth boundary.

Btk1 32–45 cm. Brown (7.5YR 5/4) clay loam, brown to dark brown (7.5YR 4/4, moist); moderate medium and coarse subangular blocks; moderately hard, firm, moderately sticky, moderately plastic; patchy thin clay films on ped faces; few very fine and fine roots; few fine and very fine tubular pores; less than 1 percent subangular and subrounded gravel and cobbles; strongly effervescent, with few fine to medium calcium-carbonate threads; moderately alkaline; clear smooth boundary.

Btk2 45–54 cm. Brown (7.5YR 5/4) clay loam, brown to dark brown (7.5YR 4/4, moist); moderate medium and coarse subangular blocks; hard, firm to very firm, moderately sticky, moderately plastic; patchy thin clay films on ped faces; few very fine and fine roots; few fine and very fine tubular pores; less than 1 percent subangular and subrounded gravel and cobbles; strongly effervescent, with common fine to coarse, soft to hard masses of calcium carbonate; moderately alkaline; clear smooth boundary.

Btk3 54–84 cm. Brown (7.5YR 5/4) sandy loam, brown to dark brown (7.5YR 4/4, moist); weak to moderate coarse and very coarse subangular blocks; moderately hard, very firm, slightly sticky, slightly plastic; patchy thin clay films on ped faces; few fine and very fine roots; many very fine and few fine tubular pores; less than 1 percent subangular and subrounded gravel and cobbles; strongly effervescent, with common fine to coarse, soft to hard masses of calcium carbonate; moderately alkaline; gradual smooth boundary.

BCtk 84–101 cm. Brown (7.5YR 5/4) sandy loam, brown to dark brown (7.5YR 4/4, moist); weak medium subangular blocks; slightly hard, friable to firm, slightly sticky, slightly plastic; many thin clay films on ped faces; few very fine and fine roots; few very fine and fine tubular pores; less than 1 percent subangular and subrounded gravel and cobbles; strongly effervescent, with common fine, soft to hard masses of calcium carbonate; moderately alkaline; gradual smooth boundary.

C 101–133 cm. Brown (7.5YR 5/4) sandy loam, brown to dark brown (7.5YR 4/4, moist); massive; soft, very friable, nonsticky, nonplastic; few very fine and fine roots; many very fine and few fine tubular pores; 5 percent subangular and subrounded gravel and cobbles; slightly effervescent; moderately alkaline; abrupt smooth boundary.

2C 133–150+ cm. Brown (7.5YR 5/4) very gravelly loam, brown to dark brown (7.5YR 4/4, moist); massive; soft, very friable, nonsticky, nonplastic; few fine and very fine roots; 50 percent subangular and subrounded gravel and cobbles; slightly effervescent; moderately alkaline.

Profile 5, Trench 615, Locus F

Classification: loamy-skeletal, mixed, thermic Typic Calciargids
Geomorphic setting: Pleistocene alluvial terrace, elevation 1,105 m (3,625 feet) AMSL, 2 percent slope
Parent material: mixed late Pleistocene alluvium
Described by: Jeff Homburg and Robby Heckman
Date: July 12, 2000

A 0–11 cm. Brown (10YR 5/3) very fine sandy loam, brown to dark brown (10YR 4/3, moist); weak very thin and thin plates at 0–1 cm and weak fine and medium granules; slightly hard, friable, slightly sticky, slightly plastic; common very fine and fine and few medium roots; common very fine and fine and few medium tubular pores; <1 percent subrounded and subangular gravel; slightly effervescent; mildly alkaline; clear smooth boundary.

BA 11–33 cm. Yellowish brown (10YR 5/4) fine sandy loam, dark yellowish brown (10YR 4/4, moist); weak to moderate fine and medium subangular blocks; slightly hard, very friable, slightly sticky, slightly plastic; few very fine to coarse roots; common very fine and fine tubular pores; <1 percent subrounded and subangular gravel; slightly effervescent; mildly alkaline; gradual smooth boundary.

Bk 33–50 cm. Yellowish brown (10YR 5/4) loam, yellowish brown (10YR 4/4, moist); moderate fine and medium subangular blocks; slightly hard, friable, slightly sticky, slightly plastic; few very fine and fine roots; many very fine and fine tubular pores; <1 percent subangular and subrounded gravel; slightly effervescent; mildly alkaline; clear smooth boundary.

Btk 50–74 cm. Brown to pale brown (10YR 5.5/4) loam, yellowish brown to dark yellowish brown (10YR 4.5/4, moist); moderate fine and medium subangular blocks; common thin clay films on ped faces; hard, firm, slightly sticky, slightly plastic; few very fine and fine roots; common very fine and fine tubular pores; slightly effervescent; mildly alkaline; clear wavy boundary.

BCk 74–87 cm. Very pale brown (10YR 7/3) fine sandy loam, pale brown (10YR 6/3, moist); weak to moderate fine and medium subangular blocks; slightly hard, firm, slightly sticky, slightly plastic; few fine and very fine roots; common very fine and fine tubular pores; slightly effervescent; moderately alkaline.

Profile 8, Soil Trench 2, Terrace of Cienega Creek, North of Interstate 10

Classification: coarse-loamy, mixed, superactive, calcareous thermic Ustic Torrifluvents
Geomorphic setting: Cienega Creek alluvial terrace (T-2), correlates to Profile 6, elevation 1,105 m (3,625 feet) AMSL, <1 percent slope
Parent material: mixed late Holocene alluvium
Described by: Jeff Homburg and Seth Gering
Date: July 25, 2001

Oi 0–4 cm. Very dark grayish brown (10YR 3/2) leaf litter of mesquite, ocotillo, creosotebush, and miscellaneous grasses, very dark brown (10YR 2/2, moist).

A 4–14 cm. Dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2, moist); weak medium granules; moderately hard, firm, slightly sticky, slightly plastic; many very fine, common fine, and few medium and coarse roots; many very fine and fine tubular and dendritic tubular pores and common medium tubular pores; strongly effervescent; abrupt smooth boundary.

C 14–35 cm. Yellowish brown (10YR 5/4) silt loam, brown (10YR 4/3, moist); massive; moderately hard, friable to firm, slightly sticky, slightly plastic; common very fine and very fine and few medium and coarse roots; common very fine and fine and few medium and coarse tubular pores; strongly effervescent; abrupt smooth boundary.

2Ab1 35–54 cm. Grayish brown to dark grayish brown (10YR 4.5/2) silt loam, very dark grayish brown (10YR 3/2, moist); moderate medium and coarse subangular blocks; moderately hard, friable to firm; slightly sticky, slightly plastic; common very fine and fine and few medium roots; common very fine and fine tubular and planar pores; 2 percent subangular fine gravel; strongly effervescent; clear smooth boundary (Cienega deposit).

2Ab2 54–71 cm. Grayish brown to dark grayish brown (10YR 4.5/2) silt loam, very dark grayish brown (10YR 3/2, moist); moderate medium and coarse subangular blocks; moderately hard, friable to firm, slightly sticky, slightly plastic; common fine and very fine, and few medium roots; common very fine and fine tubular pores; strongly effervescent, with few fine light gray (10YR 7/2, dry) threads of calcium carbonate; clear smooth boundary (Cienega deposit).

2Ab3 71–100 cm. Grayish brown (10YR 5/2) silt loam, dark grayish brown to very dark grayish brown (10YR 3.5/2, moist); weak to moderate medium and coarse subangular blocks; moderately hard, friable to firm, slightly sticky, slightly plastic; few very fine, fine, and medium roots; few very fine and fine tubular pores; strongly effervescent; abrupt smooth boundary (Cienega deposit).

2C 100–110+ cm. Brown to grayish brown (10YR 5/2.5) silt loam, dark brown to very dark grayish brown (10YR 3.5/2.5, moist); massive; slightly hard, friable, slightly sticky, slightly plastic; few very fine, fine, and medium roots; few very fine and fine tubular pores; strongly effervescent.

APPENDIX B

Soil-Stratigraphic Descriptions from Exposures along Cienega Creek and Mescal Wash

Profile 6, Southeast Bank of Mescal Wash, North of the Confluence with Cienega Creek

Classification: coarse-loamy, mixed, superactive, calcareous thermic Ustic Torrifluvents
Geomorphic setting: Mescal Wash alluvial terrace (Qy2r), elevation 1,105 m (3,625 feet) above mean sea level (AMSL), <1 percent slope
Parent material: mixed late Holocene alluvium
Described by: Jeff Homburg, Phil Pearthree, and Seth Gering
Date: May 1, 2001

Horizon	Depth (cm)	Description
A	0–5	Brown (10YR 5/3.5) sandy loam, dark brown (10YR 3/4, moist); weak medium granules; slightly hard, firm, slightly sticky, slightly plastic; many very fine, common fine, and few medium and coarse roots; many very fine and fine tubular and dendritic tubular pores and common medium tubular pores; 5 percent subangular medium gravel; strongly effervescent; abrupt smooth boundary.
AC	5–28	Brown (10YR 5/4) sandy loam, dark yellowish brown (10YR 4/4, moist); weak medium and coarse granules; slightly hard, very friable, slightly sticky, slightly plastic; common very fine and very fine and few medium and coarse roots; common very fine and fine and few medium and coarse tubular pores; 5 percent subangular coarse gravel; strongly effervescent; abrupt wavy boundary.
C	28–42	Yellowish brown (10YR 5/4) sandy loam, dark yellowish brown (10YR 4/5, moist); massive; moderately hard, firm, slightly sticky, slightly plastic; common very fine and fine and few medium and coarse roots; common very fine and fine and few medium and coarse tubular pores; 5 percent subangular medium gravel; strongly effervescent; abrupt wavy boundary (laminated at base).
Top Buried Soil		
2Ab	42–79	Brown (10YR 5/3) silt loam, dark brown to dark yellowish brown (10YR 3/3.5, moist); moderate medium and coarse subangular blocks; moderately hard, friable; slightly sticky, slightly plastic; common very fine and fine and few medium roots; common very fine and fine tubular and planar pores; 2 percent subangular fine gravel; strongly effervescent; gradual smooth boundary (Cienega deposit, charred Gramineae-stem fragments at 42–52 cm were dated to A.D. 1476–1947) (2σ range; see Table 3).
2ACb	79–102	Brown to pale brown (10YR 5.5/3) silt loam, dark brown to dark yellowish brown (10YR 3.5/3, moist); massive; moderately hard, friable, slightly sticky, slightly plastic; common fine and very fine and few medium roots; common very fine and fine tubular pores; strongly effervescent; abrupt wavy boundary. (Cienega deposit).
2C	102–108	Yellowish brown (10YR 5/4) loamy sand, dark yellowish brown (10YR 3.5/4, moist); massive; slightly hard, firm, nonsticky, nonplastic; few very fine, fine, and medium roots; few very fine and fine tubular pores; 2 percent subangular fine gravel; strongly effervescent; abrupt wavy boundary.

Horizon	Depth (cm)	Description
		Top Weak Soil
3AC	108–118	Brown (10YR 5/3) loamy sand, brown (10YR 4/3, moist); weak medium subangular blocks; very hard, friable, nonsticky, nonplastic; common very fine and fine and few medium roots; common very fine and fine tubular pores; strongly effervescent; clear smooth boundary (weak Cienega deposit).
3C	118–125	Brown (10YR 5/3) sandy loam, brown (10YR 4/3, moist); massive; very hard, friable, slightly sticky, slightly plastic; few very fine, fine, and medium roots; common very fine, fine, and medium tubular pores; strongly effervescent; abrupt wavy boundary.
		Top Buried Soil
4A	125–153	Grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2, moist); weak to moderate medium and coarse subangular blocks; very hard, extremely rigid, slightly sticky, slightly plastic; few very fine, fine, and medium roots; few very fine, fine, and medium tubular pores; 2 percent subangular fine gravel; strongly effervescent; clear smooth boundary (Cienega deposit; charred Gramineae-stem fragment at 125–135 cm was dated to A.D. 1412–1638; charred Gramineae-stem fragment at 143–153 cm was dated to A.D. 1215–1391).
4AC	153–170	Brown (10YR 5/3) sandy loam, dark brown (10YR 3.5/3, moist); massive; very hard, very friable, nonsticky, nonplastic; few very fine, fine, and medium roots; few very fine, fine, and medium tubular pores; 5 percent subangular medium gravel; strongly effervescent; abrupt wavy boundary (Cienega deposit).
4C1	170–177	Brown (10YR 4.5/3) medium gravelly loamy sand, yellowish brown to dark yellowish brown (10YR 3.5/4, moist); massive; slightly hard, very friable; nonsticky, nonplastic; few fine roots; interstitial pores; 15 percent subangular medium gravel strongly effervescent; abrupt wavy boundary.
4C2	177–183	Brown (10YR 5/3) loam to sandy loam, brown (10YR 4/3.5, moist); massive; extremely hard, firm, nonsticky, nonplastic; few fine roots; interstitial pores; 2 percent subangular fine gravel; strongly effervescent; abrupt wavy boundary.
		Top Very Weak Soil
5C1	183–198	Brown to yellowish brown (10YR 5/3.5) very gravelly loamy sand, brown to dark yellowish brown (10YR 4/3.5, moist); massive; slightly hard, very friable, nonsticky, nonplastic; few fine roots; interstitial pores; 35 percent subangular coarse gravel; strongly effervescent; clear wavy boundary.
5C2	198–205	Brown to yellowish brown (10YR 5/3.5) medium gravelly loamy sand, brown to dark yellowish brown (10YR 4/3.5, moist); massive; soft, very friable, nonsticky, nonplastic; few fine roots; interstitial pores; 25 percent subangular medium gravel; strongly effervescent; moderately alkaline.
5C3	205–210	Brown to yellowish brown (10YR 5/3.5) very gravelly loamy sand, brown to dark yellowish brown (10YR 4/3.5, moist); massive; soft, very friable, nonsticky, nonplastic; few fine roots; interstitial pores; 40 percent subangular fine and coarse gravel; strongly effervescent; clear wavy boundary.
5C4	210–214	Brown to yellowish brown (10YR 5/3.5) gravelly coarse sand, brown to dark yellowish brown (10YR 4/3.5, moist); massive; soft, very friable, nonsticky, nonplastic; few fine roots; interstitial pores; 30 percent subangular coarse gravel; strongly effervescent; clear wavy boundary.
5C5	214–221	Brown (10YR 5/3.5) fine gravelly coarse sand, brown to dark yellowish brown (10YR 4/3.5, moist); massive; soft, very friable, nonsticky, nonplastic; few fine roots; interstitial pores; 40 percent subangular gravel and cobbles; strongly effervescent; abrupt wavy boundary.
5C6	221–235	Brown (10YR 5/3.5) coarse gravelly loam to silt loam, dark yellowish brown (10YR 3/4, moist); massive; very hard, very firm, slightly sticky, slightly plastic; few fine roots; interstitial pores; 25 percent subangular coarse gravel; strongly effervescent; abrupt wavy boundary.
		Top Buried Soil
6A	235–285	Yellowish brown (10YR 5/4) sandy loam, dark yellowish brown (10YR 4/4, moist); moderate coarse subangular blocks; slightly hard, firm, slightly sticky, slightly plastic; few very fine and fine roots; few very fine and fine tubular pores; 2 percent subangular fine gravel; strongly effervescent; abrupt wavy boundary (Cienega deposit; charred Gramineae-stem fragment at 235–245 cm was dated to A.D. 1269–1420; *Celtis*-seed fragment at 275–285 cm was dated to A.D. 441–675).
7C1	235–298	Brown to yellowish brown (10YR 5/3.5) sandy loam to loamy sand, dark yellowish brown (10YR 3.5/4, moist); massive; soft, friable, nonsticky, nonplastic; few fine and very fine roots; few very fine and fine tubular pores; 2 percent subangular fine gravel; strongly effervescent; abrupt wavy boundary.

Horizon	Depth (cm)	Description
7C2	298–318	Yellowish brown to light yellowish brown (10YR 5.5/4) loamy sand, dark yellowish brown (10YR 4/4, moist); massive; moderately hard, firm, nonsticky, nonplastic; 5 percent subangular medium gravel; strongly effervescent; abrupt wavy boundary.
		Top Very Weak Soil
8C1	318–342	Yellowish brown to light yellowish brown (10YR 5.5/4) medium gravelly loamy sand, dark yellowish brown (10YR 4/4, moist); massive; soft, friable, nonsticky, nonplastic; 15 percent subangular medium gravel; violently effervescent; abrupt wavy boundary.
8C2	342–351	Yellowish brown to light yellowish brown (10YR 5.5/4) coarse gravelly loamy sand, dark yellowish brown (10YR 4/4, moist); massive; moderately hard, firm, nonsticky, nonplastic; 25 percent subangular coarse gravel; violently effervescent; abrupt wavy boundary.
8C3	351–430	Yellowish brown to light yellowish brown (10YR 5.5/4) medium gravelly loamy sand, dark yellowish brown (10YR 4/4, moist); massive; moderately hard, firm, nonsticky, nonplastic; 15 percent subangular medium gravel; violently effervescent; abrupt wavy boundary.
		Stratigraphic Boundary?
9C	430–455	Yellowish brown to light yellowish brown (10YR 5.5/4) silt loam to silty clay loam, dark yellowish brown (10YR 4/4, moist); massive; moderately hard, firm, slightly sticky, slightly plastic; violently effervescent; abrupt wavy boundary.
		Stratigraphic Boundary?
10C	455–475	Yellowish brown to light yellowish brown (10YR 5.5/4) sandy loam, dark yellowish brown (10YR 4/4, moist); massive; slightly hard, friable, nonsticky, nonplastic; few very fine and fine roots; many very fine and fine tubular pores; 5 percent subangular medium gravel; violently effervescent; abrupt wavy boundary.
		Top Buried Soil
11AC	475–490	Yellowish brown to light yellowish brown (10YR 5.5/4) sandy loam, dark yellowish brown (10YR 4/4, moist); massive; moderately hard, firm, nonsticky, nonplastic; strongly effervescent; abrupt wavy boundary.
		Stratigraphic Boundary?
12C	490–520	Yellowish brown to light yellowish brown (10YR 5.5/4) sand, dark yellowish brown (10YR 4/4, moist); massive; soft, very friable, nonsticky, nonplastic; strongly effervescent.

Profile 7, North Bank of Cienega Creek, South of the Mescal Wash Site

Classification: coarse-loamy, mixed, superactive, calcareous thermic Ustic Torrifluvents
Geomorphic setting: Cienega Creek alluvial terrace (Qy2r), elevation 1,105 m (3,625 feet) AMSL, <1 percent slope
Parent material: Mixed late Holocene alluvium
Described by: Jeff Homburg, Phil Pearthree, and Seth Gering
Date: July 13 and 24, 2001

Horizon	Depth (cm)	Description
AC	0–17	Brown (10YR 4.5/3) silt loam, dark brown (10YR 3.5/3, moist); weak fine and medium granules; soft, very friable, slightly sticky, slightly plastic; strongly effervescent; abrupt smooth boundary.
C	17–25	Brown (10YR 5/3) silt loam, brown (10YR 4/3, moist); weak fine and medium granules; soft, very friable, slightly sticky, slightly plastic; strongly effervescent; clear smooth boundary.
		Top Buried Soil
2Ab1	25–51	Brown (10YR 5/3) sandy loam, brown (10YR 4/3, moist); moderate medium and coarse subangular blocks; hard, very firm, slightly sticky, slightly plastic; strongly effervescent; abrupt wavy boundary.

Horizon	Depth (cm)	Description
2Ab2	51–65	Light brownish gray (10YR 6/2) sandy loam, grayish brown to dark grayish brown (10YR 5.5/2, moist); weak to moderate fine and medium subangular blocks; moderately hard, firm; slightly sticky, slightly plastic; strongly effervescent; clear smooth boundary.
2Ab3	65–76	Grayish brown to light brownish gray (10YR 5.5/2) silt loam, dark grayish brown (10YR 4/2, moist); weak to moderate medium and coarse subangular blocks; moderately hard, firm, slightly sticky, slightly plastic; strongly effervescent; abrupt wavy boundary (Cienega deposit; 10+ charred Gramineae-stem fragments were submitted for radiocarbon dating, but the sample was too small for accelerator mass spectrometry [AMS] analysis).
2Ab4	76–87	Grayish brown (10YR 5.5/2) silt loam, dark grayish brown (10YR 4/2, moist); weak to moderate medium and coarse subangular blocks; moderately hard, firm, slightly sticky, slightly plastic; strongly effervescent; abrupt smooth boundary (charred Gramineae-stem fragment was dated to A.D. 1304–1474).
2ACb	87–97	Brown to grayish brown (10YR 5/2.5) sandy loam, brown to dark grayish brown (10YR 4/2.5, moist); weak fine and medium subangular blocks; slightly hard, very friable, nonsticky, nonplastic; strongly effervescent; abrupt wavy boundary (contains silt drapes).
2C1	97–124	Grayish brown (10YR 5/2) very fine sandy loam, dark grayish brown (10YR 5/2, moist); massive; slightly hard, firm, nonsticky, nonplastic; strongly effervescent; clear wavy boundary.
2C2	124–130	Light brownish gray (10YR 6/2) sandy loam, grayish brown to dark grayish brown (10YR 4.5/2, moist); massive; slightly hard, friable, nonsticky, nonplastic; strongly effervescent; abrupt wavy boundary.
2C3	130–135	Brown to pale brown (10YR 5.5/3) fine sandy loam, brown (10YR 4.5/3, moist); massive; soft, very friable, nonsticky, nonplastic; strongly effervescent; abrupt wavy boundary.
2C4	135–139	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2, moist); massive; slightly hard, friable; slightly sticky, slightly plastic; strongly effervescent; abrupt wavy boundary.
2C5	139–148	Brown (10YR 5/3) very fine sandy loam, yellowish brown to dark yellowish brown (10YR 4.5/4, moist); massive; slightly hard, friable, slightly sticky, slightly plastic; strongly effervescent; abrupt smooth boundary.
Top Weak, Buried Soil		
3ACb	148–160	Pale brown (10YR 6/3) very fine sandy loam, brown (10YR 3.5/4, moist); weak fine and medium granules; slightly hard, friable, slightly sticky, slightly plastic; strongly effervescent; abrupt smooth boundary (10+ charred Gramineae-stem fragments were submitted for radiocarbon dating, but the sample was too small for AMS analysis).
3C	160–170	Brown (10YR 5/3) very fine sandy loam, brown (10YR 4/3, moist); massive; slightly hard to hard, friable, nonsticky, nonplastic; strongly effervescent; clear wavy boundary.
Stratigraphic Boundary?		
4C1	170–182	Brown (10YR 5/3) very gravelly loamy sand, brown (10YR 4/3, moist); massive; loose, very friable, nonplastic; 35 percent subangular and subrounded medium gravel; strongly effervescent; clear smooth boundary.
4C2	182–194	Yellowish brown (10YR 5/4) sandy loam, dark yellowish brown (10YR 4/4, moist); massive; loose, very friable, nonsticky, nonplastic; strongly effervescent; abrupt wavy boundary.
Top Weak, Buried Soil		
5ACb	194–203	Pale brown (10YR 6/3) very fine sandy loam, brown (10YR 4.5/3, moist); few fine brownish yellow (10YR 6/8, dry) threads and hypocoatings of iron and few fine black (10YR 2/1, dry) hypocoatings of manganese; weak fine and medium granules; slightly hard, friable, nonsticky, nonplastic; strongly effervescent; abrupt smooth boundary (charred Monocotyledon-tissue fragment was dated to A.D. 1062–1378).
5C1	203–210	Pale brown (10YR 6/3) gravelly fine sandy loam, brown (10YR 4.5/3, moist); massive; slightly hard, friable, nonsticky, nonplastic; strongly effervescent; abrupt smooth boundary.
5C2	210–230	Pale brown (10YR 6/3) gravelly fine sandy loam, brown (10YR 4.5/3, moist); massive; loose, very friable, nonsticky, nonplastic; 30 percent subangular and subrounded medium and coarse gravel; strongly effervescent; clear smooth boundary.
5C3	230–235	Pale brown (10YR 6/3) fine sand, brown (10YR 5/3, moist); massive; loose, very friable, nonsticky, nonplastic; strongly effervescent; clear smooth boundary.

Horizon	Depth (cm)	Description
5C4	235–250	Pale brown (10YR 6/3) fine sand, brown (10YR 5/3, moist); massive; loose, very friable, nonsticky, nonplastic; strongly effervescent; abrupt smooth boundary.
		Top Weak, Buried Soil
6ACb1	250–265	Grayish brown to light grayish brown (10YR 5.5/2) sandy loam, grayish brown to dark grayish brown (10YR 4.5/2, moist); common brownish yellow (10YR 6/8, dry) fine iron hypocoatings and few black (10YR 2/1, dry) manganese hypocoatings; massive; very hard, very firm, slightly sticky, slightly plastic; strongly effervescent; abrupt smooth boundary (contains some silty laminations; an unidentified-charcoal sample was dated to A.D. 1285–1447).
6ACb2	265–280	Light brownish gray (10YR 6/2) sandy loam, grayish brown to dark grayish brown (10YR 4.5/2, moist); weak to moderate medium and coarse subangular blocks; slightly hard, friable, slightly sticky, slightly plastic; strongly effervescent; abrupt smooth boundary (contains a thin small sandy lens; charred *Prosopis*-pod fragment was radiocarbon dated, but the analysis yielded a modern date).
6C	280–290	Grayish brown to light brownish gray (10YR 5.5/2) loamy sand, grayish brown to dark grayish brown (10YR 4.5/2, moist); massive; loose, very friable, nonsticky, nonplastic; strongly effervescent; abrupt smooth boundary.
		Top Weak, Buried Soil
7ACb	290–300	Pale brown (10YR 6/3) silt loam, brown to dark brown (10YR 4.5/3, moist); moderate medium and coarse subangular blocks; hard, firm, slightly sticky, slightly plastic; strongly effervescent; abrupt smooth boundary (an unidentified charcoal sample was dated to A.D. 1276–1420).
		Top Buried Soil
8Ab1	300–323	Pale brown (10YR 6/3) loam, brown to dark brown (10YR 4.5/3, moist); moderate fine and medium granules; very hard, friable, nonsticky, nonplastic; 5 percent subrounded and subangular fine and coarse gravel; strongly effervescent, common fine white (10YR 8/2, dry) masses and threads of calcium carbonate; abrupt smooth boundary.
8Ab2	323–370	Pale brown (10YR 6/3) sandy loam, brown to dark brown (10YR 4.5/3, moist); moderate fine and medium granules; slightly hard, firm, slightly sticky, slightly plastic; strongly effervescent; abrupt smooth boundary.
8C	370–465	Pale brown (10YR 6/3) sandy loam, brown to dark brown (10YR 4.5/3, moist); massive; slightly hard, firm, slightly sticky, slightly plastic; strongly effervescent.

Cienega Creek–Paleochannel Stratigraphic Section 1

Location: Western part of the paleochannel exposure, where the gravel that fills the paleochannel is thin and discontinuous on prechannel fine deposits.
Described by: Steve DeLong and Phil Pearthree
Date: April 7, 2004

Depth (cm)	Unit Characteristics
0–15	Dark brown silt and fine sand with minor clay; soft, fine to medium subangular blocky, no bedding preserved; gradual, smooth lower contact.
15–35	Light gray sand and silt; slightly hard, moderate fine to medium subangular blocky, no apparent bedding; disseminated charcoal; abrupt, wavy contact.
35–40	Gray sand, granules, and pebbles, up to the 3-cm intermediate axis; pinches out to west, crudely planar bedding; locally interfingers with the overlying unit; clear, wavy contact.
	Stratigraphic Boundary/Top Weak, Buried Soil
40–90	Light brown silty sand with some pebbles up to 1 cm, sandier near base; some crudely stratified gravel lenses and isolated gravel clasts; finer layers moderately hard, medium subangular blocky; charcoal-rich layer 70–75 cm, possibly correlative to layer in Section 2; abrupt, irregular contact.

Depth (cm)	Unit Characteristics
	Stratigraphic Boundary
90–105	Light brown weakly cemented sand with granules and pebbles up to 4 cm; crudely bedded, subangular clasts; abrupt, wavy contact.
105–125	Brown fine to coarse sand; soft, not indurated, finely crossbedded; likely sand pocked at the base of the paleochannel gravel as it spread over the unincised floodplain; abrupt, wavy contact.
	Stratigraphic Boundary
125–165	Gray to brown interbedded sand and silt layers, with few granules; alternating fine and coarse beds 3–12 cm thick, with a few thin light-colored clay beds; approximate horizontal bedding is evident; soft to hard, weak fine to medium subangular blocky; abrupt, irregular contact.
165–170	Loose coarse sand, granules, and pebbles up to 4 cm; lenticular body pinches out into finer deposits; massive, no bedding evident; abrupt, wavy contact.
170–195	Light brown fine sand and granules with rare pebbles; poorly sorted, faintly bedded, weakly indurated; soft, medium subangular blocky; red-stained layer in the lower few centimeters of the unit; abrupt, wavy contact.
195–210	Light gray fine to medium sand; moderately well sorted, faintly finely bedded; soft, medium subangular blocky; abrupt, irregular.
	Stratigraphic Boundary
210–235	Sand, granules, pebbles, and small cobbles up to 7 cm ; bedded, locally x-bedded; poorly sorted, moderately indurated; abrupt, wavy contact.
235–290	Gray to tan sand and silt; sand finely bedded, more silt lower in unit; loose to weakly indurated, local oxidation zones; abrupt, wavy.
290–305	Sand, granules, and pebbles, poorly sorted; subangular gravel, moderate to poorly indurated; abrupt, wavy contact.
305–320	Gray silt; crudely bedded, moderately indurated; moderately hard to hard, medium to coarse angular blocky to subangular blocky; locally oxidized bands; base of exposure.

Cienega Creek–Paleochannel Stratigraphic Section 2

Location: Western part of the paleochannel, where the coarse gravel fill is thick and obvious.
Described by: Steve DeLong and Phil Pearthree
Date: April 7, 2004

Depth (cm)	Unit Characteristics
0–10	Light gray silty sand; soft, weak fine to medium subangular blocky; gradual, smooth lower contact.
10–35	Dark brown silty sand; slightly hard, moderate fine to medium subangular blocky; few pebbles; clear, wavy contact.
35–50	Gravel lens; sand, granules, and pebbles up to the 3-cm intermediate axis; subangular to subrounded; some interbedding with thin silt beds; clear, wavy contact.
	Top Buried Soil
50–90	Light brown fine sand and silt; finer grained areas, slightly hard, weak fine to medium subangular blocky; coarser layers have sand matrix with granules to pebbles, poorly sorted; clear, wavy contact at 70–75 cm, dark gray to black layer with some reddish pockets, possible surface burn layer; Sample No. 040704.02 at 75 cm was collected for radiocarbon dating.
90–107	Medium to coarse sand, granules, and pebbles up to 3 cm; weak subhorizontal bedding; abrupt, clear contact.
	Stratigraphic Boundary
107–110	Thin sand and silt layers; cap is approximately 1-cm-thick gray silt, finely laminated; below is faintly bedded to massive sand; clear, smooth contact.
	Stratigraphic Boundary

Depth (cm)	Unit Characteristics
110–295	Moderately coarse gravel; sand matrix with abundant pebbles and some cobbles; crudely bedded, lots of lateral variation in grain size, sand content, and bedding; moderately indurated, forms vertical face, no fine-grained layers or evidence of even weak soil development; carbonate cementation based on strong hydrogen-chloride (HCl) reaction; abrupt, wavy contact.
	Stratigraphic Boundary/Base of Paleochannel
295–315	Thin beds of sand, silt, and fine gravel; capped with approximately 1-cm-thick gray silt, finely laminated; below, light brown fine sand with occasional granules and pebbles; local oxidized bands; massive to weak fine to medium subangular blocky; bottom is base of exposure.

Cienega Creek–Paleochannel Stratigraphic Section 3

Location: Near the middle of the paleochannel, where the gravel is fairly thin**.**
Described by: Steve DeLong and Phil Pearthree
Date: April 7, 2004

Depth (cm)	Unit Characteristics
0–15	Light brown silt; soft, weak fine to medium subangular blocky, no bedding; gradual, smooth lower contact.
15–65	Dark brown to gray, silt and fine sand; slightly hard, moderate medium to coarse subangular blocky; gradual, wavy contact.
65–85	brown sand, granules, with few pebbles, and thin silt beds <2 cm thick; coarse beds crudely bedded, fine beds moderately well bedded; loose to hard, single grain to weak fine to medium subangular blocky; abrupt, wavy contact.
	Top Weak, Buried Soil
85–110	Tan to gray fine sand and silt; alternating silt (1–10 cm thick) and sand (5–10 cm) beds, moderately bedded; soft to slightly hard, weak fine to medium subangular blocky in silt beds, single grain in sand beds; coarser layers have sand matrix with granules to pebbles, poorly sorted; clear, wavy contact.
110–145	Tan sand with minor silt; alternating fine and coarse sand and fine gravel beds with minor silt beds; subhorizontal bedding evident throughout; soft, single grain; clear, wavy contact.
	Stratigraphic Boundary
145–160	Tan fine to medium sand with minor silt; soft to loose; outcrop is poor but no bedding evident; clear, wavy contact.
160–230	Gray gravelly sand; sand, granules, pebbles, and minor cobbles, weakly to moderately indurated; crude subhorizontal bedding; silty unit above 205 cm varies up to 30 cm thick; clear, irregular contact.
230–255	Reddish brown moderately indurated sand with rare cobbles and minor thin silt interbeds; subhorizontal bedding; massive to single grain structure; radiocarbon Sample No. 040704.1 collected from silt interbed in this unit at approximately 250 cm; abrupt, wavy contact.
	Stratigraphic Boundary/Base of Paleochannel
255–270	Tan to brown silt; local oxidized bands; bedding not evident; slightly hard, massive to weak fine to medium subangular blocky; bottom is base of exposure.

Cienega Creek–Paleochannel Stratigraphic Section 4

Location: Minimum gravel thickness toward the eastern part of the paleochannel.
Described by: Steve DeLong and Phil Pearthree
Date: April 13, 2004

Depth (cm)	Unit Characteristics
0–35	Dark gray silt; hard, medium, and fine to medium subangular blocky, no bedding or laminations; gradual, wavy lower contact.
35–55	Light brown silt; slightly hard, weak fine to medium subangular blocky; crudely laminated, soil structure less pervasive than overlying horizon; abrupt, wavy contact.
Top Buried Soil	
55–60	Brown coarse sand and granules; crudely bedded, loose to slightly hard, single grain; poorly sorted; clear, wavy contact.
60–65	Light brown silt; crudely bedded, hard, moderate fine to medium subangular blocky; fine disseminated charcoal; clear, wavy contact.
65–105	Tan to brown fine to medium sand with thin silt beds; sand is well sorted, loose, single grain, no obvious bedding; silt beds have subhorizontal to wavy bedding, soft, moderate fine to medium subangular blocky; clear, wavy contact.
105–115	Tan to brown fine to medium sand; moderately well sorted, loose, single grain, no obvious bedding; abrupt, wavy contact.
Top Buried Soil	
115–180	Light brown silt and fine sand; soft, weak fine to medium subangular blocky, no obvious bedding; some beds more sandy, but silt is dominant; clear, wavy contact.
180–200	Tan to light brown fine to medium sand with some granules; soft, weak fine to medium subangular blocky, finely bedded; radiocarbon Sample No. 040604.7 collected at approximately 190 cm; gradual, wavy contact.
Stratigraphic Boundary	
200–225	Brown sand and granules up to 2 cm; massive, single grain; weak to moderate induration, gravel subangular, local manganese stain, sandier near base; abrupt wavy to irregular contact.
225–235	Brown silt, sand and granules; hard, massive, coarser in both directions laterally, no obvious bedding; abrupt, wavy contact.
235–285	Tan to light brown fine to medium sand with some granules and small pebbles; massive, soft, no bedding evident; gradual, wavy contact.
285–295	Brown sand and granules; soft, single grain, crudely bedded; abrupt, wavy contact.
Stratigraphic Boundary/Base of Paleochannel	
295–335	Brown fine to coarse sand; slightly hard to hard, moderate medium subangular blocky, no bedding, siltier lower in exposure; covered below.

Cienega Creek–Paleochannel Stratigraphic Section 5

Location: Maximum gravel thickness near the eastern margin of the paleochannel.
Described by: Steve DeLong and Phil Pearthree
Date: April 13, 2004

Depth (cm)	Unit Characteristics
0–10	Light gray silt; could not access from ladder, so viewed from distance; gradual, wavy lower contact.
10–70	Dark gray silt; slightly hard to hard, moderate fine to medium subangular blocky, no bedding evident; few pebbles and granules in fine matrix in lower part of horizon; clear, wavy contact.
Stratigraphic Boundary	
70–135	Brown to slightly reddish sand, granules, and pebbles and rare cobbles; subangular to subrounded; moderately to crudely bedded, slightly hard, single grain; very poorly sorted; variations between sandier and coarser beds; clear, wavy contact.
135–150	Brown sand, granules, and pebbles up to 2 cm; moderate subhorizontal bedding, loose, single grain; gradual, wavy contact.

Depth (cm)	Unit Characteristics
150–190	Reddish brown sand, granules, and pebbles; moderately indurated, slightly hard, single grain, moderate subhorizontal to small-scale cross beds, lowest 5 cm is less indurated; radiocarbon Sample No. 041304.1 collected at 170–178 cm; clear, wavy contact.
190–230	Pale brown medium sand to cobbles up to 10 cm; very poorly sorted subangular clasts, slightly indurated, single grain, crudely bedded, very slight calcium-carbonate coatings on clast bottoms; gradual, wavy contact.
230–285	Brown sand to cobbles with minor silt; weakly indurated, slightly hard, massive, crudely bedded; clear, irregular contact.
285–310	Slightly reddish brown fine to medium sand with minor silt; hard, weak medium subangular blocky, no bedding evident; abrupt, irregular contact.
Stratigraphic Boundary/Base of Paleochannel	
310–330	Tan to light brown silt; slightly hard to hard, moderate medium subangular blocky; no bedding evident; covered below.

APPENDIX C

Geologic Units near the Mescal Wash Site

Excerpted from Spencer et al. (2002)

Cienega Creek Deposits

Qycr - Modern river channel deposits (<100 years). This unit consists of river channel deposits. Deposits are composed primarily of sand and gravel. Along Cienega Creek, modern channels are typically entrenched several meters below adjacent young terraces. The current entrenched channel configuration began to evolve with the development of arroyos in the late 1800s, and continued to evolve through this century (Dobyns 1981; Myrick 1975). Channels have variable widths, but modern channels in much of the map area are relatively uniform within artificial dikes. Channels are extremely flood prone and are subject to deep, high velocity flow in moderate to large floods. Most modern channel banks are formed in weakly to moderately cohesive late Holocene alluvium and may be subject to severe lateral erosion during floods. Erosion is likely to be most severe on the outside banks of channel bends.

Qy3r - Historical river terrace deposits (<100 years). Terrace deposits that occupy elevations from 0.5 to 2 meters above Qycr deposits and are inset below the pre-incision historical floodplain. These surfaces are generally planar but exhibit bar and swale microtopography. Although no soil development is present, dense grasses and small mesquite trees abound. Sediments composing these deposits are poorly sorted silt, sand, pebbles and cobbles. Pebbles and cobbles are well-rounded to sub-angular. Trough crossbedding, ripple marks, and stacked channel deposits viewable in cross-section indicate deposition in a low to moderate energy braided stream environment. These deposits are prone to flooding during extreme flow events, and undercutting and rapid erosion of Qy3r surfaces is possible during lower flow events.

Qy2r - Late Holocene to early historical river terrace deposits. Deposits associated with the floodplain that existed prior to the early historical entrenchment of Cienega Creek. Qy2r deposits are associated with planar surfaces that are up to 5 m above modern Qycr deposits and are the most extensive river terraces in the valley. Qy2r sediments were deposited when Cienega Creek was a widespread, shallowly-flowing river systems and are dominated by fine grained floodplain deposits. Dense mesquite bosque and tall grass is typically present on these surfaces. These surfaces appear predominantly fine grained at the surface due in part to the input of organic matter and windblown dust deposition but are composed of interfingering coarse sandy to pebbly braided channel and fine sand to clayey river floodplain deposits. Qy2r deposits are not subject to inundation by river floods, but are subject to catastrophic bank failure due to undercutting and lateral erosion during flow events. Young tributary deposits have interfingering relationships with Qy2r deposits in the subsurface.

Qi3r - Late Pleistocene river terrace deposits. Remnant river terrace deposits along Cienega Creek. These terraces are typically 5 to 10 m above the active channel. Qi3r deposits consist of cobbles, gravels and finer-grained sediment. Qi3r surfaces commonly have loose, open lags of cobbles and gravels; surface clasts exhibit weak rock varnish. Qi3r surfaces appear light orange color aerial photos, reflecting slight reddening of surface clasts and the surface soil horizon. Qi3r soils are moderately developed, with orange to reddish brown clay loam to light clay argillic horizons and stage II calcium carbonate accumulation. Vegetation on Qi3r terraces consists of scattered mesquite, prickly pear and creosote bushes.

Qi1r – Early to middle Pleistocene river terrace deposits. Unit Qmor consists of a few high remnant river terrace deposits along Cienega Creek. These terraces are typically 30 to 40 m above the active channel. Qmor deposits consist primarily of cobbles, pebbles and finer-grained sediment. Qmor surfaces commonly have open gravel surface lags. Qmor surfaces appear red to reddish brown on color aerial photos, reflecting orange rock varnish on surface clasts and reddened soils. Soils typically contain reddish brown, clay-rich argillic horizons where surfaces are well preserved. Underlying soil carbonate development is typically stage III to IV, with abundant carbonate through at least 1 m of the soil profile; indurated petrocalcic horizons were not observed. Dominant vegetation includes mesquite and low shrubs, with some creosote.

Qor – Early Pleistocene river deposits. Unit Qor consists of very high remnant river terrace deposits along Cienega Creek. The tops of these terraces are 40 to 60 m above the active channel of Cienega Creek. Qor deposits consist of cobbles, pebbles, and a few small boulders with sand and finer-grained sediment. Qor surfaces commonly have a loose cobble and pebble lag; surface clasts exhibit moderate to strong rock varnish. Qor surfaces appear dark reddish brown in color aerial photos, reflecting reddening of surface clasts and relatively clay-rich surface soil horizon with some dark organic material. Soils typically have brown to reddish brown clay argillic horizons over indurated stage IV carbonate horizons where surfaces are well preserved. In other places, argillic horizons have been removed by erosion. Dominant vegetation includes mesquite, prickly pear cactus and creosote.

Tributary Deposits

Qyc - Late Holocene active channel deposits (<100 years). Unit Qyc consists of active channels of the larger tributary drainages composed of primarily of sand, pebbles, and cobbles. Channels are incised as much as several meters below adjacent Holocene terraces (unit Qy2). Channels are mapped where they are large enough to accurately represent at 1:24,000 scale. They generally consist of single, relatively large channels, but this unit includes some smaller branching channels in areas of channel expansions. Local relief within channels varies from minimal to more than 1 meter. Vegetation generally consists of small bushes and grasses, although the channel banks are typically lined with trees including mesquite, acacia, and palo verde.

Qy2 - Late Holocene alluvium (<~2 ka). Unit Qy2 consists of small channels, low terraces, and small alluvial fans composed of cobbles, sand, silt and clay that have been recently deposited by modern drainages. Channels generally are incised less than 2 m below adjacent terraces and fans, but locally incision may be as much as 5 m. Channel morphologies generally consist of a single-thread channel or multi-threaded channels with gravel bars adjacent to low flow channels. Downstream-branching distributary channel patterns are associated with the few small active alluvial fans in the area. In these areas, channels typically are discontinuous, with small, well-defined channels alternating with broad expansion reach where channels are very small and poorly defined. Local relief varies from fairly smooth channel bottoms to the undulating bar-and-swale topography that is characteristic of coarser deposits. Locally near Cienega Creek channels are incised several meters below young terraces. Terrace surfaces typically have planar surfaces, but small channels are also common on terraces. Soil development associated with Qy2 deposits is weak. Terrace and fan surfaces are brown, and on aerial photos they generally appear darker than surrounding areas, whereas sandy to gravelly channels appear light-colored on aerial photos. Vegetation density is variable.

Qy1 - Older Holocene alluvium (~2 to 10 ka). Unit Qy1 consists of terraces and alluvial fans found at scattered locations along drainages throughout the map area. Qy1 surfaces are slightly higher than adjacent Qy2 surfaces and generally are not subject to flood inundation. Surfaces are generally planar; local relief may be up to 1 m where gravel bars are present, but typically is much less. Qy1 surfaces typically are about 2 m above adjacent active channels, but may be higher. Surfaces typically are silty or sandy but locally have fine, unvarnished open gravel lags. Qy1 surfaces generally are lightly vegetated and appear somewhat lighter on aerial photos than Qy2 surfaces. Qy1 terrace surfaces support creosote and other small bushes, with some mesquite and palo verde trees along drainages. Qy1 soils typically are weakly developed, with some soil structure but little clay and stage I to II calcium carbonate accumulation.

Qi3 - Late Pleistocene alluvium (~10 to 100 ka). Unit Qi3 consists of moderately dissected terraces and relict alluvial fans found on the upper, middle and lower piedmont. Moderately to well developed, slightly to moderately incised tributary drainage networks are typical on Qi3 surfaces. Active channels typically are incised a few meters below Qi3 surfaces. Qi3 fans and terraces are commonly lower in elevation than adjacent Qi2 and older surfaces, but the lower margins of Qi3 deposits lap out onto more dissected Qi2 surfaces in some places. Qi3 deposits consist of pebbles, cobbles, and finer-grained sediment. Qi3 surfaces commonly have loose, open lags of pebbles and cobbles; surface clasts exhibit weak rock varnish. Qi3 surfaces appear light orange to dark orange on color aerial photos, reflecting slight reddening of surface clasts and the surface soil horizon. Qi3 soils are moderately developed, with orange to reddish brown clay loam to light clay argillic horizons and stage II calcium carbonate accumulation. Vegetation includes grasses, small shrubs, mesquite, and palo verde.

Qi2 - Middle to late Pleistocene alluvium (~100 to 500 ka). Unit Qi2 consists of moderately dissected relict alluvial fans and terraces with strong soil development found throughout the map area. Qm surfaces are drained by well-developed, moderately to deeply incised tributary channel networks; channels are typically several meters below adjacent Qi2 surfaces. Well-preserved, planar Qi2 surfaces are smooth with scattered pebble and cobble lags; surface color is reddish brown rock varnish on surface clasts is typically orange or dark brown. More eroded, rounded Qi2 surfaces are characterized by scattered cobble lags with moderate to strong varnish, broad ridge-like topography and some carbonate litter on the surface. Well-preserved Qi2 surfaces have a distinctive dark red color on color aerial photos, reflecting reddening of the surface soil and surface clasts. Soils typically contain reddened, clay loam to clay argillic horizons, with obvious clay skins and subangular to angular blocky structure. Maximum calcic horizon development is typically stage III, with abundant carbonate through at least 1 m of the soil profile. Qi2 surfaces generally support grasses, bursage, cholla, and small shrubs.

Qi1 - Middle to early Pleistocene alluvium (~500 ka to 1 Ma). Unit Qi1 consists of moderately to deeply dissected relict alluvial fans with variable soil development. Qi1 surfaces are typically 5 to 10 meters above adjacent active channels. Qi1 surfaces are drained by well-developed, deeply incised tributary channel networks. Well-preserved planar Qi1 surfaces are not common. Where they exist, they are smooth with pebble and cobble lags; rock varnish on surface clasts is typically orange to red. Well-preserved soils typically contain deep reddish brown, clay argillic horizons, with obvious clay skins and subangular blocky structure. Soil carbonate development is variable, but locally is quite strong. More eroded Qi1 surfaces are characterized by loose cobble lags with moderate to strong varnish, ridge-and-valley topography, and carbonate litter on the side slopes. On aerial photos, ridge crests on Qi1 surfaces are reddish brown, reflecting reddening of the surface soil and surface clasts, and eroded slopes are gray to white. Qi1 surfaces generally support bursage, ocotillo, and creosote.

Older Sedimentary Units

QTs – Late Miocene to early Quaternary (?) deposits. Very poorly sorted, moderately consolidated cobbles, pebbles, boulders and sand associated with alluvial fan deposits underlying the highest alluvial ridges in the valley. Ridgelines typically are 5 to 10 m above active washes. Soil development is moderate and variable, and dominated by calcium carbonate accumulation. Surfaces typically are light in color because they are covered with debris churned up from indurated petrocalcic horizons and unvarnished to lightly varnished gravel.

QTsc – Thin hillslope colluvium mantling older Tertiary alluvial deposits. This unit includes deeply dissected and highly eroded Tertiary alluvial fan and lacustrine deposits in areas where these Tertiary strata are not divided from mantling colluvium. This map unit typically forms alternating eroded ridges and arroyos, with ridgecrests typically 5 to 30 meters above adjacent active channels that are part of deeply incised tributary channel networks. Even the highest surfaces atop QTsc ridges are rounded, and original highest capping fan surfaces are not preserved. QTsc deposits are dominated by gravel ranging from boulders to pebbles. Deposits are moderately indurated and are quite resistant to erosion because of the large clast size and carbonate cementation. Also included are areas where incision is moderate to slight and underlying Tertiary strata are fine-grained and poorly resistant. In some of these areas, map unit QTsc has been outlined by aerial photograph analysis of low relief areas where a large amount of fine grained strata is apparent by its very light shades but a veneer of remobilized Pantano Formation and other Quaternary deposits is also apparent. Soils typically are cemented by carbonate accumulation on ridgecrests. Carbonate litter is common on ridgecrests and hillslopes. On aerial photos, QTsc surfaces are commonly gray to white, and support creosote, mesquite, palo verde, ocotillo, and cholla.

Twc – Conglomerate of Wakefield Canyon (Miocene to Pliocene). Lithologically diverse clasts commonly resemble exposed bedrock in the western Whetstone and eastern Empire Mountains. Generally poorly exposed, forming rounded slopes. Both plane bedded and channelized beds in the same localities are interpreted as alluvial fan deposits with channelized coarse deposits and planar overbank deposits. Clasts are typically 2 to 20 cm diameter, locally as large as 40 cm, rarely to 1 m.

Twsc – Sandy conglomerate of Wakefield Canyon (Miocene to Pliocene). Sandy pebble to cobble conglomerate, with less abundant sandstone. Generally tan to medium brown. Distinguished from conglomeratic sandstone (map unit Twcs) by >50 percent content of sandstone and granule sandstone with grains less than 1 cm diameter. Lenticular conglomerate beds 20 to 200 cm thick and 5 to 40 m long are locally common in wash bank exposures.

Twcs – Conglomeratic sandstone of Wakefield Canyon (Miocene to Pliocene). Primarily consists of strata that are dominantly sandstone but contain beds of pebble and cobble conglomerate with local boulders up to 30 cm diameter. Conglomerate commonly fills channels within finer grained beds. At one locality, channelfilling conglomerate lenses area 20–80 cm thick, 5–20 m across. Distinguished from conglomeratic sandstone (map unit Twsc) by <50 percent content of sandstone and granule sandstone with clasts less than 1 cm diameter. Locally includes sandy conglomerate and sandstone.

Twss - Sandstone of Wakefield Canyon (Miocene to Pliocene). Poorly sorted sandstone, silty sandstone, and pebbly sandstone, typically tan to pale brown and poorly to moderately consolidated. Locally includes siltstone, clay beds, and pebble-conglomerate beds. Locally, protruding sandy beds 5 to 20 cm thick alternate with 5 to 10 cm thick, recess-forming silty beds.

Txc – Pantano Formation breccia derived from Paleozoic carbonate rocks (Oligocene to Miocene). Breccia composed of sub-angular to angular limestone clasts ranging in size from pebbles to boulders (many boulders in excess of 20 m in diameter are present locally). Rare clasts of siliclastic rocks are locally present. The unit occurs as a sheet like deposit in the north where it overlies gently dipping strata of the Pantano Formation, but to the south, a narrow outcrop band of this unit crosses I-10 that may be conformable with underlying conglomerate and pebbly sandstone of the upper Pantano Formation.

Tpu - Pantano Formation, undivided (Oligocene to Miocene). A heterolithic assemblage of medium- to thick-bedded sandstone, pebbly sandstone, and pebble-cobble-boulder conglomerate, with intervals of thin- to medium-bedded sandstone and mudstone. Clasts, which range from rounded to subangular, consist chiefly of Bisbee Group sandstone and mudstone along with a distinctive coarse-grained, crystal-rich quartz porphyry. Minor volcanic clasts are also present. The base of the unit in many areas is defined as the top a distinctive crystal-rich, coarse-grained andesite lava (map unit Ta). In areas where this lava is absent or concealed, abundant clasts of the lava are common near the base of the unit. A sequence of one or two nonwelded felsic tuffs occur near the base in the easterly adjacent The Narrows 7$^1/_2$ feet Quadrangle, typically within a sequence of mudstone and thin-bedded to laminated sandstone. Also, in the easterly adjacent The Narrows 7$^1/_2$ feet Quadrangle, a distinctive, limestone boulder-megaclast breccia sheet appears to be interbedded with conglomerate near the top of this unit.

APPENDIX D

Descriptions of Soils near the Mescal Wash–Cienega Creek Confluence Area

Compiled by Jeffrey A. Homburg

Source: U.S. Department of Agriculture Natural Resources Conservation Service, Soil Survey Division, Official Soil Series Descriptions (http://www.statlab.iastate.edu/soils/osd>, accessed June, 2011)

Andrada Series

Location: Andrada, Arizona
Established Series
Rev. MLR/SJL/PDC/CEM/WWJ 09/2002

The Andrada series consists of very deep, well drained soils formed in alluvium and residuum from sandstone, shale, diorite, and conglomerate. Andrada soils are on hills and pediments and have slopes of 3–45 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 63°F.

Taxonomic Class: Loamyskeletal over fragmental, mixed, superactive, thermic Ustic Haplocalcids

Typical Pedon: Andrada extremely gravelly loam—rangeland. (Colors are for dry soil unless otherwise noted).
A: 0–8 inches; dark grayish brown (10YR 4/2) extremely gravelly loam, very dark grayish brown (10YR 3/2) moist; moderate very fine, and fine granular structure; soft, very friable, slightly sticky and slightly plastic; many very fine and fine and few medium roots; many fine interstitial and few fine and medium tubular pores; 60 percent angular gravel that is intermittently calcium-carbonate-coated white (10YR 8/1); strongly effervescent; moderately alkaline (pH 8.2); abrupt broken to wavy boundary. (5–14 inches thick)
Bk: 8–11 inches; light brownish gray (10YR 6/2) extremely gravelly loam, brown (10YR 4/3) moist; massive; slightly hard, very friable, slightly sticky and nonplastic; many very fine and a few fine roots; many interstitial pores; 75 percent gravel; violently effervescent, many very pale brown (10YR 8/2) and light gray (10YR 7/2) calcium-carbonate coatings on rock fragments; moderately alkaline (pH 8.2); abrupt irregular boundary. (1–6 inches thick)
2Ck: 11–60 inches; fragmental; highly fractured and partially weathered sandstone; common very fine roots in fractures; many thin calcium-carbonate coatings and common black stains in fractures.

Type Location: Pima County, Arizona; 2,100 feet north and 2,400 feet east of the southwestern corner of Section 27, Township 17 South, Range 16 East.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. Ustic aridic soil moisture regime.
Soil temperature: 61°–69°F.
Rock fragments: 35–85 percent angular gravel and cobble, some stones
Depth to fragmental material: 6–20 inches
Calcium-carbonate equivalent: 10–35 percent; includes part of the A horizon in some pedons
Reaction: slightly or moderately alkaline

A horizon
Hue: 10YR, 7.5YR
Value: 3–5 dry; 2–4 moist
Chroma: 2–4 dry or moist
Organic matter: Greater than 1 percent
Calcium carbonate: Strongly or violently effervescent
Rock fragments: 35–85 percent fine and medium angular gravel or channers

Bk horizon
Hue: 10YR, 2.5Y, 7.5YR
Value: 3–8 dry; 3–7 moist
Chroma: 1, 2, 3, or 4 dry; 2, 3, 4, or 6 moist
Texture: Sandy loam, loam, fine sandy loam
Rock fragments: 60–80 percent fine and medium angular gravel or channers
Some pedons contain unweathered and weathered bedrock at depths greater than 40 inches.

Competing Series: There are no competing series.

Geographic Setting: Andrada soils are on hills and pediments. Slopes range from 3 to 45 percent. The soil formed in alluvium and residuum from sedimentary rock including sandstone, shale, chert, conglomerate and diorite. Elevations are 3,500–5,400 feet. The mean annual precipitation is 12–16 inches. The mean annual air temperature is 59°–67°F. The frostfree period is 180–240 days.

Geographically Associated Soils: These are the Deloro, Oracle, Romero, Caralampi and Nolam series. Deloro soils have argillic horizons and are noncalcareous. Oracle and Romero soils do not have calcic horizons. Caralampi and Nolam soils are very deep and have argillic horizons.

Drainage and Permeability: Well drained; medium to rapid runoff; moderate permeability.

Use and Vegetation: Used mainly for livestock grazing and wildlife habitat. The vegetation consists of shrubby buckwheat, range ratany, mariola, sotol, mesquite, javelina bush, whitethorn, catclaw, sideoats, black, slender and hairy gramas, threeawn, bush muhly, wolftail, false mesquite, ocotillo, curly mesquite and cane bluestem.

Distribution and Extent: Southern Arizona. The Andrada series is moderately extensive. It is usually in complex with other soils on cretaceous sediments.

Major Land Resource Area (MLRA) Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona; Soil Survey of Pima County, Arizona, Eastern Part; 1985.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 8 inches (A horizon)
Calcic horizon: The zone from 0 to 11 inches (A, Bk horizons)

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Arizo Series

Location: Arizo, Nevada, Arizona, California, and New Mexico
Established Series
Rev. LNL/RPZ/ET 06/2005

The Arizo series consists of very deep, excessively drained soils that formed in mixed alluvium. Arizo soils are on recent alluvial fans, inset fans, fan apron, fan skirts, stream terraces, floodplains of intermittent streams and channels. Slopes are 0–15 percent. The mean annual precipitation is about 7 inches and the mean annual temperature is about 62°F.

Taxonomic Class: Sandyskeletal, mixed, thermic Typic Torriorthents

Typical Pedon: Arizo very gravelly fine sand, desert wildlife habitat. (Colors are for dry soil unless otherwise noted.)
A: 0–8 inches; light brownish gray (10YR 6/2) very gravelly fine sand, dark grayish brown (10YR 4/2) moist; weak coarse platy structure; slightly hard, very friable, nonsticky and nonplastic; few fine and medium roots; few fine vesicular and many very fine and fine interstitial pores; 35 percent pebbles; strongly effervescent; moderately alkaline (pH 8.2); abrupt wavy boundary. (0–10 inches thick)
C1: 8–36 inches; light brownish gray (10YR 6/2) extremely gravelly sand, dark grayish brown (10YR 4/2) moist; single grained; loose, nonsticky and nonplastic; few fine and medium roots; many very fine and fine interstitial pores; 60 percent pebbles, 10 percent cobbles; few very thin coats of lime on undersides of pebbles; strongly effervescent; moderately alkaline (pH 8.2); gradual wavy boundary. (12–36 inches thick)
C2: 36–62 inches; light brownish gray (10YR 6/2) extremely gravelly sand, dark grayish brown (10YR 4/2) moist; single grained; loose, nonsticky and nonplastic; few very fine and fine roots; many very fine and fine, and few medium interstitial pores; 60 percent pebbles, 20 percent cobbles, 3 percent stones; strongly effervescent; moderately alkaline (pH 8.2).

Type Location: Clark County, Nevada; about 1,000 feet east and 600 feet south of center of Section 20, Range 13 South, Range 17 East.

Range in Characteristics
Soil moisture: Usually dry, moist for short periods throughout the moisture control section during December through March. Moist above and periodically in upper part of moisture control section for 10–20 days cumulative, during July through October.

Soil temperature: 59°–71°F.
Reaction: Neutral to strongly alkaline.
Other features: Effervescent in some or all parts, with thin lime coatings on undersides of rock fragments in some pedons.
Control section: Rock fragments: 35–85 percent, mainly pebbles.

A horizon
Hue: 10YR or 7.5YR
Value: 5–8 dry; 3–6 moist.
Chroma: 2–6.

C horizon
10YR or 7.5YR
Value: 4–8 dry; 3–6 moist.
Chroma: 2–6.
Texture of fine earth: Averages coarse sand through loamy sand.
Structure: Single grained or massive.

Competing Series: These are the Dudleyville (Arizona), Jean (Nevada) and Kokan (New Mexico) series. Dudleyville soils occur within the Sonoran Desert (MLRAs 40 and 41) and are moist above and periodically in upper part of moisture control section for more than 20 days cumulative, during July through October. Jean soils have a shallow Bw horizon and have textures in the upper control section of loamy sand or loamy fine sand with less than 15 percent rock fragments. Kokan soils occur within the Chihuahuan Desert (MLRA 42) and are moist for short periods in some part mainly in July, August, and early September and are dry the rest of the year.

Geographic Setting: Arizo soils are on recent alluvial fans, inset fans, fan aprons, fan skirts, stream terraces, floodplains of intermittent streams and channels. These soils formed in alluvium from mixed rock sources. Slopes are 0–15 percent. Elevations are 750–4,600 feet. The climate is arid or semiarid with mild winters and hot dry summers. The mean annual precipitation is 2–10 inches and may range to 13 inches in Arizona where temperatures are 67°–70°F.; mean annual temperature is 57°–70°F, and the frostfree season is 200–340 days.

Geographically Associated Soils: These are the Bard, Bitter Spring, Gila, Nickel, Tonopah, and Vinton soils. Bard soils have a petrocalcic horizon. Bitter Spring soils have a gravelly sandy loam B2t horizon. Gila soils have a loamy control section. Nickel and Tonopah soils have a calcic horizon. Vinton soils have a loamy fine sand or loamy sand control section.

Drainage and Permeability: Excessively drained; negligible to medium runoff; rapid to very rapid permeability. Arizo soils with sandy loam and loam surface textures have moderate or moderately rapid over very rapid permeability.

Use and Vegetation: Source of sand and gravel, rangeland, and wildlife habitat. The present vegetation is mainly creosotebush and white bursage.

Distribution and Extent: Southern Nevada, Southern California, Arizona, and New Mexico. These soils are extensive. The central concept for the series is in MLRA 30. Use in MLRAs 40, 41, and 42 should be reevaluated.

MLRA Office Responsible: Davis, California

Series Established: Clark County (Virgin River Area), Nevada. 1971.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Particlesize control section: The zone from 10 to 40 inches.

Bernardino Series

Location: Bernardino, Arizona
Established Series
Rev. MLR/DLR/PDC/WWJ 06/2000

The Bernardino series consists of very deep, well drained soils that formed in fan alluvium from igneous and sedimentary rock. Bernardino soils are on fan terraces and have slopes of 0–30 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 62°F.

Taxonomic Class: Fine, mixed, superactive, thermic Ustic Calciargids

Typical Pedon: Bernardino gravelly clay loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–2 inches; dark brown (7.5YR 3/2) gravelly clay loam, dark brown (7.5YR 3/2) moist; weak medium platy structure parting to moderate fine granular; slightly hard, friable, moderately sticky and moderately plastic; common very fine and fine roots; many very fine irregular pores; 35 percent gravel; slightly alkaline (pH 7.5); abrupt smooth boundary. (1–3 inches thick)
Bt1: 2–9 inches; dark reddish brown (5YR 3/3) gravelly clay loam, dark reddish brown (5YR 3/4) moist; moderate fine subangular blocky structure; hard, friable, moderately sticky and moderately plastic; common very fine and fine roots; few very fine tubular and irregular pores; common

faint patchy clay films on faces of peds and lining pores; 20 percent gravel; slightly alkaline (pH 7.5); clear wavy boundary. (5–8 inches thick)

Bt2: 9–15 inches; dark reddish brown (5YR 3/4) gravelly clay, dark reddish brown (5YR 3/4) moist; moderate fine and medium subangular and angular blocky structure; hard, friable, moderately sticky and moderately plastic; few very fine and medium roots; few very fine tubular and common very fine irregular pores; common faint clay films on faces of peds and lining pores; 15 percent gravel; strongly effervescent in spots; moderately alkaline (pH 8.0); clear wavy boundary. (4–9 inches thick)

2Bk1: 15–48 inches; pinkish gray (5YR 7/2) gravelly sandy loam, reddish brown (5YR 5/3) moist; massive; very hard, friable, nonsticky and slightly plastic; few very fine and fine roots; many very fine and fine irregular pores; 30 percent gravel; common fine irregular calcium-carbonate masses; violently effervescent; moderately alkaline (pH 8.0); gradual smooth boundary. (30–40 inches thick)

2Bk2: 48–60 inches; pinkish gray (5YR 7/2) very gravelly sandy loam, reddish brown (5YR 5/3) moist; massive; very hard, friable, nonsticky and slightly plastic; many very fine and fine irregular pores; 40 percent gravel; few fine irregular calcium-carbonate masses; strongly effervescent; moderately alkaline (pH 8.0).

Type Location: Santa Cruz County, Arizona; about 2 miles southeast of Sonoita; 500 feet west and 650 feet north of the southeastern corner of Section 29, Township 20 South, Range 17 East.

Range in Characteristics

Soil Moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. Ustic aridic soil moisture regime.
Soil Temperature: 60°–70°F.
Depth to calcic horizon: 5–20 inches. Calcium-carbonate equivalent averages 15–40 percent and decreases with increasing depth
Rock Fragments: Averages less than 35 percent in the control section; can range to 80 percent in any one horizon
Organic matter: Averages 1 percent or more in the surface
Reaction: Neutral or slightly alkaline in the upper part and slightly or moderately alkaline in the lower part

A horizon
Hue: 5YR, 7.5YR, 10YR
Value: 3–6 dry; 2–5 moist
Chroma: 2, 3, or 4 dry or moist

Bt horizon
Hue: 2.5YR, 5YR, 7.5YR
Value: 3, 4, or 5 dry; 2, 3, or 4 moist
Chroma: 2–6 dry or moist
Texture: Clay loam, clay

Bk or C horizon
Hue: 2.5YR through 10YR
Value: 5–8 dry; 4–7 moist
Chroma: 2–6 dry or moist
Texture: Sandy loam, sandy clay loam, clay loam, loam, loamy sand

Competing Series: These are the Forrest and Stellar series. A potential competitor that does not yet have CEA class assigned is the Penthouse series. All these soils have a calcic horizon at depths of 20–40 inches.

Geographic Setting: Bernardino soils are on fan terraces and have slopes of 0–30 percent. These soils formed in fan alluvium from mixed sources. Elevation ranges from 3,500 to 5,500 feet. The mean annual precipitation ranges from 12 to 16 inches. The mean annual air temperature is 58°–68°F. The frost-free period is 160–250 days.

Geographically Associated Soils: These are the Bonita, McAllister, Stronghold, Tombstone and the competing Forrest and White House soils. Bonita soils are fine textured. McAllister soils are fine-loamy. Stronghold and Tombstone soils do not have argillic horizons.

Drainage and Permeability: Well drained; slow or medium runoff; slow permeability.

Use and Vegetation: Bernardino soils are used for livestock grazing and wildlife habitat. The present vegetation is sideoats grama, slender grama, purple grama, plains lovegrass, cane beardgrass, curly mesquite, tobosa, beargrass, and mesquite.

Distribution and Extent: Southern Arizona. This series is of moderate extent. MLRA 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Santa Cruz County (Santa Cruz County Area), Arizona; 1971.

Remarks

Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 2 inches (A horizon)
Argillic horizon: The zone from 2 to 15 inches (Bt1, Bt2 horizons)
Calcic horizon: The zone from 15 to 60 inches (2Bk1, 2Bk2 horizons)

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Caralampi Series

Location: Caralampi, Arizona and New Mexico
Established Series
Rev. MLR/CCC/PDC/CEM/WWJ 06/2000

The Caralampi series consists of very deep, well drained soils formed in fan and slope alluvium from granitic and volcanic rock. Caralampi soils are on fan terraces and hills. Slopes range from 1 to 50 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 62°F.

Taxonomic Class: Loamy-skeletal, mixed, superactive, thermic Ustic Haplargids

Typical Pedon: Caralampi very gravelly sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–2 inches; dark brown (7.5YR 4/4) very gravelly sandy loam, dark reddish brown (5YR 3/4) moist; weak fine granular structure; slightly hard, friable, nonsticky and nonplastic; common very fine and fine roots; common irregular pores; 40 percent gravel; slightly acid (pH 6.2); abrupt smooth boundary. (1–5 inches thick)
BAt: 2–5 inches; dark brown (7.5YR 4/2) very gravelly sandy clay loam, dark brown (7.5YR 3/2) moist; weak fine subangular blocky structure; slightly hard, friable, slightly sticky and moderately plastic; common very fine and fine roots; many irregular pores; few faint clay films in tubular pores; 55 percent gravel; slightly acid (pH 6.5); clear wavy boundary.
Bt1: 5–9 inches; dark reddish brown (5YR 3/4) very gravelly sandy clay loam, dark reddish brown (5YR 3/4) moist; weak fine and medium subangular blocky structure; slightly hard, friable, moderately sticky and moderately plastic; many very fine and fine roots; common irregular and fine tubular pores; few faint clay films on faces of peds; 50 percent gravel; slightly acid (pH 6.1); abrupt wavy boundary.
Bt2: 9–13 inches; yellowish red (5YR 4/6) very gravelly sandy clay loam, dark red (2.5YR 3/6) moist; moderate medium subangular blocky structure; hard, friable, moderately sticky and moderately plastic; many very fine and fine roots; common irregular and fine tubular pores; common faint clay films on faces of peds and in pores; 50 percent gravel; slightly acid (pH 6.1); clear wavy boundary.
Bt3: 13–23 inches; yellowish red (5YR 4/6) and reddish yellow (5YR 6/6) gravelly sandy clay loam, yellowish red (5YR 4/6) moist; weak fine and medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; common fine roots; few very fine tubular pores; common faint clay films on faces of peds; 40 percent gravel; slightly acid (pH 6.5); clear wavy boundary. (Combined thickness of the Bt horizons is 12–29 inches)
BCt1: 23–31 inches; reddish brown (5YR 5/4) very gravelly sandy loam, reddish brown (5YR 4/4) moist; common fine faint pink (5YR 7/3) and light reddish brown (5YR 6/3) features, light reddish brown (5YR 6/4) moist; massive; hard, friable, slightly sticky and slightly plastic; few very fine and fine roots; few very fine tubular pores; few faint clay films in pores; 50 percent gravel; slightly acid (pH 6.5); clear wavy boundary.
BCt2: 31–42 inches; light reddish brown (5YR 6/4) very gravelly sandy loam, reddish brown (5YR 4/4) moist; massive; hard, friable, nonsticky and slightly plastic; few very fine roots; few faint clay films in pores; 50 percent gravel; slightly acid (pH 6.5); clear wavy boundary. (Combined thickness of the BC horizons is 6–21 inches)
C: 42–60 inches; light brown (7.5YR 6/4) gravelly sandy loam, dark brown (7.5YR 4/4) moist; massive; hard, friable, nonsticky and nonplastic; 30 percent gravel; slightly acid (pH 6.5).

Type Location: Santa Cruz County, Arizona; 2.5 miles north-northwest of Nogales, Arizona; about 2,800 feet north and 1,600 feet west of the southeastern corner of Section 36, Township 23 South, Range 13 East.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–March. Driest during May and June. Ustic aridic soil moisture regime.
Soil temperature: 59°–69°F.
Rock fragments: 35–80 percent
Calcium carbonate: Noneffervescent in the upper part, may have slight to strong effervescence below 40 inches
Organic matter content: Greater than 1 percent in the upper 10 inches

A horizon
Hue: 10YR, 7.5YR, 5YR
Value: 3–5 dry; 3 or 4 moist
Chroma: 2, 3, or 4 dry or moist
Reaction: Neutral to moderately acid

Bt horizons
Hue: 5YR, 2.5YR
Value: 3–5 dry or moist
Chroma: 3, 4, or 6 dry or moist
Texture: Sandy clay loam, clay loam, sandy loam (more than 18 percent clay)
Reaction: slightly acid to slightly alkaline

BC, Bk, and C horizons
Hue: 7.5YR, 5YR
Value: 3–7 dry or moist
Chroma: 2, 3, 4, or 6 dry or moist
Texture: Sandy loam, coarse sandy loam, sandy clay loam
Reaction: Slightly acid to moderately alkaline

Competing Series: These are the Holliday, Hoppswell, Hyrhy, and Monza series. Potential competitors still classified as Ustollic are the Coxwell and Maloy series. Coxwell, Hyrhy, and Monza soils have bedrock at moderate depths. Holliday soils contain less than 18 percent clay. Hoppswell soils are moist in the soil moisture control section less than 20 days cumulative during July–September. Maloy soils contain dominantly cobble size rock fragments in the control section.

Geographic Setting: Caralampi soils are on strongly sloping to steep fan terraces and hills. Slopes range from 1 to 50 percent. Elevations range from 2,800 to 5,200 feet. These soils formed in fan and slope alluvium derived from granite, rhyolite, andesite, dacite, and related tuff, and agglomerates. The mean annual air temperature ranges from 57°–68°F. and the mean annual precipitation ranges from 12 to 16 inches. The frost-free period is 180–260 days.

Geographically Associated Soils: These are the Riveroad, Comoro, and White House soils. Riveroad and Comoro soils do not have argillic horizons. White House soils are clayey.

Drainage and Permeability: Well drained; medium to rapid runoff; moderately slow permeability.

Use and Vegetation: These soils are used for livestock grazing, wildlife habitat and urban development. Vegetation is curlymesquite, sprucetop grama, hairy grama, sideoats grama, threeawn, cane beardgrass, wolftail, and plains lovegrass. Brush species are mesquite, catclaw, mimosa, calliandra, range ratany, and a few oak and cacti.

Distribution and Extent: Southern Arizona. Caralampi soils are moderately extensive.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Santa Cruz County Area, Arizona; 1971.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 2 inches (A horizon)
Argillic horizon: The zone from 2 to 42 inches (BAt, Bt1, Bt2, Bt3, BCt1, BCt2)

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Comoro Series

Location: Comoro, Arizona and New Mexico
Established Series
Rev. CWG/JEJ/PDC/CEM/WWJ 11/2001

The Comoro series consists of very deep, well or somewhat excessively well drained soils formed in stratified alluvium. Comoro soils are on alluvial fans and flood plains and have slopes of 0–8 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 65°F.

Taxonomic Class: Coarse-loamy, mixed, superactive, calcareous, thermic Ustic Torrifluvents

Typical Pedon: Comoro sandy loam—irrigated cropland. (Colors are for dry soil unless otherwise noted.)
Ap: 0–8 inches; brown (7.5YR 5/2) sandy loam, dark brown (7.5YR 3/2) moist; weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; many fine irregular pores; slightly alkaline (pH 7.5); clear smooth boundary. (5–8 inches thick)
C1: 8–19 inches; brown (7.5YR 5/3) sandy loam, dark brown (7.5YR 3/3) moist; weak medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; many very fine and fine tubular pores; moderately alkaline (pH 8.0); clear wavy boundary. (5–12 inches thick)
C2: 19–46 inches; light brown (7.5YR 6/3) fine sandy loam, brown (7.5YR 4/3) moist; massive; slightly hard, very friable, nonsticky and nonplastic; common very fine and fine roots; many fine and very fine tubular pores; slightly effervescent; moderately alkaline (pH 8.2); clear wavy boundary. (20–40 inches thick)
C3: 46–60 inches; light brown (7.5YR 6/3) sandy loam, brown (7.5YR 4/3) moist; massive; slightly hard, very friable, nonsticky and nonplastic; common very fine and fine roots; many very fine and fine tubular pores; slightly effervescent; moderately alkaline (pH 8.0).

Type Location: Cochise County, Arizona; about 2 miles north of Elfrida; 2,500 feet east and 2,000 feet south of the northwestern corner of Section 9, Township 20 South, Range 26 East.

Range in Characteristics
Soil Moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. The epipedon is moist in some part less than 90 days (cumulative) when the soil temperature is above 41°F. in 7 out of 10 years. Ustic aridic soil moisture regime.
Soil Temperature: 59°–72°F.
Stratification: Usually thin strata of finer or coarser material
Rock Fragments: averages less than 35 percent in the control section

Organic matter: more than 1 percent in the surface that decreases irregularly with depth. Commonly dark colored to a depth of 36 inches or more.
Reaction: neutral to moderately alkaline; can range to slightly acid in the upper part

A horizon
Hue: 10YR, 7.5YR
Value: 3, 4, or 5 dry; 2 or 3 moist
Chroma: 1, 2, or 3 dry or moist
Calcium carbonate: none to strongly effervescent

C horizon
Hue: 10YR, 7.5YR
Value: 3–6 dry; 2, 3, or 4 moist
Chroma: 1–4 dry or moist
Texture: Sandy loam, coarse sandy loam, fine sandy loam, loamy sand (less than 18 percent clay)
Calcium carbonate: Slightly to violently effervescent as disseminated or as filaments. Some areas on alluvial fans, in swales, and along narrow drainageways do not effervesce.

Competing Series: This is the Ubik series. A potential competitor that does not yet have CEA class assigned is the San Jose series. San Jose soils have soil temperatures of about 58°–62°F, hue redder than 7.5YR from the influence of red sandstone and shale, and occur on the Great Plains as part of MLRA 70. Ubik soils are loam, very fine sandy loam and silt loam in the control section.

Geographic Setting: Comoro soils are on alluvial fans and flood plains. Elevations range from 2,200 to 5,200 feet. Slopes range from 0 to 8 percent. These soils formed in stratified alluvium from predominantly granite and rhyolite sources. The mean annual precipitation is 12–16 inches, occurring as summer thunderstorms and winter rain. The mean annual air temperature is 57°–70°F. Frost-free period is 160–240 days.

Geographically Associated Soils: These are the Bodecker, Elgin, McAllister, and Stronghold series and the competing Ubik series. Bodecker soils have sandy-skeletal control sections. Elgin, McAllister, and Stronghold soils are on fan terraces.

Drainage and Permeability: Well or somewhat excessively well drained; medium runoff; moderately rapid permeability.

Use and Vegetation: Used for livestock grazing and irrigated cropland. Vegetation is catclaw, mesquite, yucca, burroweed, threeawn, grama grasses, Arizona cottontop, bush muhly and annual grasses. Irrigated crops are cotton, small grains, sorghum and alfalfa.

Distribution and Extent: Southern Arizona. Comoro soils are extensive. This soil occurs in Land Resource Region (LRR) D, MLRAs 40, 41, and 42.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Santa Cruz County, Arizona; 1930.

Remarks
Formerly part of the Rucker series that included both Typic aridic and ustic aridic soil moisture regimes. The type location for Comoro was moved in 1981 to a Typic aridic area in Graham County, Arizona. The Comoro concept has a long history of use and familiarity to ranching, research and soil survey. It is extensively referenced in many documents, publications and thesis. This historical use has prompted us to structure the series as close to the original concept as possible and necessitates moving the type location to a ustic aridic (12–16 inch pz) soil moisture regime with a change in classification. Rucker soils have a limited extent and will reflect a Typic aridic (<12 inch pz) moisture regime.
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: the zone from 0 to 8 inches (Ap horizon)
Entisol feature: the absence of diagnostic subsurface horizons

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Deloro Series

Location: Deloro, Arizona
Established Series
Rev. MLR/CCC/PDC 06/2000

The Deloro series consists of shallow, well drained soils that formed in mixed alluvium dominantly from shale, schist, phyllite or sandstone. Deloro soils are on pediments, hills and mountains. Slopes range from 1 to 45 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 62°F.

Taxonomic Class: Clayey-skeletal, mixed, superactive, thermic, shallow Ustic Haplargids

Typical Pedon: Deloro extremely channery loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–2 inches; brown (7.5YR 5/4) extremely channery loam, dark reddish brown (5YR 3/4) moist; moderate fine granular structure; slightly hard, very friable, slightly sticky and slightly plastic; many fine and very fine roots; many

interstitial pores; 65 percent channers; noneffervescent; neutral (pH 7.3); clear wavy boundary. (1–4 inches thick)
Bt: 2–11 inches; reddish brown (5YR 4/3) extremely channery clay, dark reddish brown (5YR 3/4) moist; moderate fine granular structure; hard, friable, sticky and plastic; many very fine roots; many interstitial pores; common faint clay films lining pores and coating channers; 75 percent channers; noneffervescent; neutral (pH 7.2); abrupt wavy boundary. (9–16 inches thick)
2Crt: 11–60 inches; highly fractured, weathered phyllite; dark red (10R 3/6) clay coatings and common very fine roots in fractures.

Type Location: Pima County, Arizona; about 1,200 feet south and 900 feet west of the northeastern corner of Section 9, Township 17 South, Range 17 East.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–March. Driest during May and June. Ustic aridic soil moisture regime.
Soil temperature: 59°–68°F.
Depth to bedrock: 10–20 inches
Organic matter content: 1–3 percent in the surface
Rock fragments: 35–85 percent channers or gravel
Reaction: Slightly acid to mildly alkaline

A horizon
Hue: 10YR, 7.5YR, 5YR
Value: 4 or 5 dry; 3 or 4 moist
Chroma: 2, 3, or 4 dry or moist

B horizon
Hue: 2.5YR, 5YR
Value: 4, 5, or 6 dry; 3 or 4 moist
Chroma: 2, 3, 4, or 6 dry or moist
Texture: Clay loam, clay

Competing Series: There are no competing series.

Geographic Setting: Deloro soils are on pediments, hills and mountains. Slopes range from 1 to 45 percent. Deloro soils formed in alluvium from schist, shale, phyllite or sandstone. Elevations range from 3,300 to 5,400 feet. The mean annual precipitation is 12–16 inches. The mean annual air temperature is 57°–66°F. The frost-free period is about 180–240 days.

Geographically Associated Soils: These are the Andrada, Chiricahua, Mabray, Oracle, and Schrap soils. Andrada soils do not have argillic horizons and have a calcic horizon. Mabray soils are carbonatic and have a lithic contact. Schrap soils do not have argillic horizons. Chiricahua soils are clayey. Oracle soils are loamy.

Drainage and Permeability: Well drained; rapid runoff; slow permeability.

Use and Vegetation: These soils are used for livestock grazing. Vegetation is ocotillo, yucca, catclaw, agave, pricklypear, cholla, shrubby buckwheat, slender grama, tobosa, black grama, sideoats grama, hairy grama, wolftail, curlymesquite, false mesquite, plains lovegrass, and threeawn.

Distribution and Extent: Southern Arizona. These soils are moderately extensive. MLRA 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pinal County, Arizona; Soil survey of Pima County, Arizona, Eastern Part; 1985.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: the zone from 0 to 2 inches (A horizon)
Argillic horizon: the zone from 2 to 11 inches (Bt horizon)
Paralithic contact: the boundary at 11 inches (2Crt)

Diaspar Series

Location: Diaspar, Arizona
Established Series
Rev. MLR/CCC/PDC/CEM/WWJ 12/2003

The Diaspar series consists of very deep, well drained soils formed in fan alluvium from granitic and volcanic rock. Diaspar soils are on fan terraces and have slopes of 0–8 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 61°F.

Taxonomic Class: Coarseloamy, mixed, superactive, thermic Ustic Haplargids

Typical Pedon: Diaspar sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–2 inches; light brown (7.5YR 6/4) sandy loam, brown (7.5YR 4/4) moist; weak thin platy structure; loose, very friable, nonsticky and nonplastic; many very fine roots; common very fine interstitial pores; 10 percent gravel; slightly acid; abrupt smooth boundary.
BA: 2–9 inches; brown (7.5YR 5/4) gravelly sandy loam, dark brown (7.5YR 3/4) moist; weak medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; many very fine and common fine roots;

common very fine tubular pores; 30 percent gravel; slightly acid; clear wavy boundary.
Bt1: 9–21 inches; yellowish red (5YR 5/6) gravelly sandy loam, yellowish red (5YR 4/6) moist; weak medium subangular blocky structure; hard, firm, sticky and plastic; many very fine roots; common very fine tubular pores; common faint clay films lining pores and bridging sand grains; 30 percent gravel; slightly alkaline; clear wavy boundary.
Bt2: 21–28 inches; yellowish red (5YR 5/6) gravelly sandy loam, yellowish red (5YR 4/6) moist; weak medium prismatic structure; hard, firm, sticky and plastic; many very fine roots; common very fine tubular pores; 30 percent gravel; common faint clay films bridging sand grains and lining pores; moderately alkaline; clear wavy boundary.
2Bt: 28–41 inches; reddish yellow (5YR 6/6) sandy clay loam, yellowish red (5YR 4/6) moist; weak medium prismatic structure; hard, firm, sticky and plastic; common very fine roots; common very fine tubular pores, 10 percent gravel; many distinct clay films on faces of peds and lining pores; many fine iron and manganese stains and masses; slightly effervescent; moderately alkaline; clear wavy boundary.
3BCt: 41–46 inches; light yellowish brown (10YR 6/4) gravelly loam, dark yellowish brown (10YR 4/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; common very fine roots; many very fine tubular pores; few faint clay films lining pores; 30 percent gravel; moderately alkaline; clear wavy boundary.
3C: 46–60 inches; light yellowish brown (10YR 6/4) very gravelly loam, dark yellowish brown (10YR 4/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; few very fine roots; many very fine tubular pores; 50 percent gravel; slightly effervescent moderately alkaline

Type Location: Pima County, Arizona; about 550 feet north and 100 feet west of the southeastern corner of Section 35, Township 19 South, Range 8 East.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. Ustic aridic soil moisture regime.
Soil temperature: 59°–72°F.
Rock fragments: Averages 10–35 percent gravel in the particlesize control section

A and BA horizons
Hue: 7.5YR or 5YR
Value: 4–6 dry; 3–5 moist
Chroma: 3–6 dry or moist
Reaction: Moderately acid to neutral
Organic matter: Less than 1 percent

Bt horizon
Hue: 2.5YR to 7.5YR
Value: 3–6 dry; 3–5 moist
Chroma: 3–6 dry or moist
Texture: Sandy loam, loam, fine sandy loam, sandy clay loam (averages less than 18 percent clay and more than 50 percent sand)
Calcium-carbonate equivalent: 0–5 percent
Reaction: Neutral to moderately alkaline

C horizon
Hue: 5YR to 10YR
Value: 4–7 dry; 4–6 moist
Chroma: 2–6 dry or moist
Texture: Sandy loam, loam, fine sandy loam, loamy fine sand, loamy sand, sand (5–18 percent clay)
Calcium-carbonate equivalent: 0–5 percent
Buried horizons: Some pedons have a buried argillic horizon below 40 inches.

Competing Series: This is the Summerford series. Summerford soils have Ck horizons.

Geographic Setting: Diaspar soils are on gently sloping to sloping fan terraces at elevations of 3,000–5,200 feet. Slopes range from 0 to 8 percent. These soils formed in fan alluvium from rhyolite, granite, gneiss, schist, quartzite and andesite. The mean annual precipitation is 12–16 inches. The mean annual air temperature is 59°–68°F. The frost-free period is 180–240 days.

Geographically Associated Soils: These are the Courtland, Cowan, and Sasabe soils. Courtland soils are fineloamy. Cowan soils do not have argillic horizons. Sasabe soils are fine.

Drainage and Permeability: Well drained; medium runoff; moderately rapid or moderate permeability.

Use and Vegetation: Used for livestock grazing and irrigated cropland. Vegetation is sideoats grama, black grama, sand dropseed, Arizona cottontop, and cane bluestem. Common irrigated crops are cotton, corn, small grains and alfalfa.

Distribution and Extent: Southern Arizona. Diaspar soils are moderately extensive. MLRA 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona; Soil Survey of Pima County, Arizona, Eastern Part; 1985.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 2 inches (A horizon)

Argillic horizon: The zone from 9 to 53 inches (Bt1, Bt2, Bt3, 2Btk1, 2Btk2 horizons)

The type location was moved to Pima County in 2003.

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Granolite Series

Location: Granolite, Arizona
Established Series
Rev. CCC/DJB/PDC 02/2003

The Granolite series consists of shallow, well drained soils formed in slope alluvium derived from volcanic and metamorphic rock. Granolite soils are on hills, mountains or pediments with slopes of 2–65 percent. The mean annual precipitation is about 11 inches. The mean annual air temperature is about 68°F.

Taxonomic Class: Clayeyskeletal, mixed, superactive, thermic, shallow Typic Haplargids

Typical Pedon: Granolite extremely gravelly sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–2 inches; reddish brown (5YR 4/4) extremely gravelly sandy loam, dark reddish brown (5YR 3/4) moist; weak fine and medium platy structure; soft, very friable, nonsticky and nonplastic; few very fine and fine roots; common to many very fine vesicular and tubular pores; 50 percent gravel, 15 percent cobble and 1 percent stones from igneous rock; noneffervescent; neutral; abrupt smooth boundary. (1–6 inches thick)
Bt1: 2–7 inches; dark reddish brown (2.5YR 3/4) extremely gravelly sandy clay, dark reddish brown (2.5YR 2/4) moist; moderate fine and medium subangular blocky structure; hard, friable, very sticky and very plastic; few discontinuous faint clay coatings in root channels and/or pores; common fine and medium roots; few to common fine and very fine tubular pores; 55 percent gravel, 10 percent cobble from igneous rock; noneffervescent; neutral; clear wavy boundary. (4–7 inches thick)
Bt2: 7to 16 inches; weak red (10R 4/4) extremely gravelly sandy clay, dusky red (10R 3/4) moist; moderate fine and medium subangular blocky structure; very hard, firm, very sticky and very plastic; few patchy clay coatings in root channels and/or pores; many continuous faint pressure faces on vertical and horizontal faces of peds; few to common fine and medium roots; few to common very fine and fine tubular pores; 60 percent gravel and 10 percent cobble from igneous rock; noneffervescent; neutral; abrupt wavy boundary. (5–9 inches thick)
2Crtk: 16–19 inches; light gray (5YR 7/1) weathered rhyolite, light gray to gray (5YR 6/1) moist; common patchy prominent red (2.5YR 4/6) clay films on fractured rock; common patchy distinct strongly effervescent calcium-carbonate coats on fractured faces of rocks; very few to few coarse roots in fractures; gradual wavy boundary. (3–20 inches thick)
2Crk: 19–24 inches; light gray (5YR 7/1) weathered rhyolite, light gray to gray (5YR 6/1) moist; common patchy distinct strongly effervescent calcium-carbonate coats on fractured faces of rock.
2R: 24 inches; rhyolite.

Type Location: Pima County, Arizona; 2,600 feet west and 1,400 feet north of the southeastern corner of Section 20, Township 14 South, Range 10 East.

Range in Characteristics
Soil Moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–March. Driest during May and June. Typic aridic soil moisture regime.
Soil Temperature: 68°–72°F.
Depth to Bedrock: 10–20 inches
Calcium carbonate: May have coatings on bedrock and weak effervescence in the lower part of the solum.
Organic Matter: 0.5–1 percent
Rock Fragments: 35–85 percent gravel and/or cobble
Clay Content: Average 35–50 percent and less than 25 percent very coarse and coarse sand in the control section
Reaction: Neutral or slightly alkaline

A horizon
Hue: 5YR, 7.5YR
Value: 4 or 5 dry; 3 or 4 moist
Chroma: 3 or 4 dry or moist

Bt horizon
Hue: 10YR, 7.5YR, 5YR
Value: 3, 4, or 5 dry or moist
Chroma: 3, 4, or 6 dry or moist
Texture: sandy clay, clay, clay loam

Competing Series: This is the Gran (Arizona) series. Gran soils do not have calcium carbonate, rock fragments readily break to coarse and very coarse sand with slight to medium pressure, and formed in decomposed granite.

Geographic Setting: The Granolite soils are on hills, mountains or rockfloored pediments. Slope is 2–65 percent. They formed in slope alluvium, derived dominantly from rhyolite and other acid igneous rock including to a lesser extent hard granitic material. Elevation ranges from 2,000 to 3,600 feet. The mean annual precipitation is

10–13 inches. The mean annual air temperature is 67°–70°F, and the frostfree period is about 240–260 days.

Geographically Associated Soils: These are the Anklam, Lajitas and Pantano soils. Lajitas soils do not have diagnostic properties and are very shallow and shallow to a lithic contact. Pantano soils have calcic horizons. Anklam soils are loamyskeletal.

Drainage and Permeability: Well drained; rapid runoff; slow permeability.

Use and Vegetation: Used mainly for livestock grazing. Vegetation is triangle bursage, paloverde, ocotillo, limberbush, ironwood, guajilla, janusia, range ratany, spidergrass, and saguaro.

Distribution and Extent: Southern Arizona. This series is extensive.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona; Soil survey of the Tohono O'odham Nation, Arizona, Parts of Maricopa, Pima and Pinal Counties; 1993.

Remarks

Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 2 inches (A horizon)
Argillic horizon: The zone from 2 to 16 inches (Bt1, Bt2 horizon)
Paralithic contact: The boundary at 16 inches (2Crtk horizon)
Lab data: BIANREL, FY87, sample numbers 129131.

Hantz Series

Location: Hantz, Arizona, New Mexico, and Utah
Established Series
Rev. ADD/PDC/CEM/WWJ 11/2001

The Hantz series consists of very deep, well drained soils that formed in stratified mixed alluvium. Hantz soils are on flood plains, stream terraces and alluvial fans and have slopes of 0–5 percent. The mean annual precipitation is about 10 inches and the mean annual air temperature is about 62°F.

Taxonomic Class: Fine, mixed, superactive, calcareous, thermic Vertic Torrifluvents

Typical Pedon: Hantz silty clay—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–3 inches; light brownish gray (10YR 6/2) silty clay, grayish brown (10YR 5/2) moist; weak fine and medium subangular blocky structure; very hard, firm, very sticky and very plastic; few fine roots; few very fine and fine tubular pores; 5 percent angular gravel; violently effervescent; moderately alkaline (pH 8.2); abrupt smooth boundary. (2–4 inches thick)
C1: 3–22 inches; light brownish gray (10YR 6/2) silty clay, grayish brown (10YR 5/2) moist; weak medium and coarse angular blocky structure; very hard, very firm, very sticky and very plastic; few fine roots; few very fine and fine tubular pores; violently effervescent; moderately alkaline (pH 8.3); clear smooth boundary. (15–22 inches thick)
C2: 22–60 inches; light brownish gray (10YR 6/2) silty clay, grayish brown (10YR 5/2) moist; weak coarse and medium angular blocky structure; very hard, very firm, very sticky and very plastic; few medium roots; few very fine tubular pores; violently effervescent; strongly alkaline (pH 8.5).

Type Location: Yavapai County, Arizona; about 2,000 feet southeast of the junction of Middle Verde and Cornville cutoff road; NE 1/4 of Section 3, Township 14 North, Range 4 East.

Range in Characteristics

Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. Typic aridic soil moisture regime.
Soil temperature: 59°–72°F.
Soil cracking: When dry, cracks 1 cm or more wide, extend to depths of 20 inches or more and remain open for more than 240 days, cumulative, and are not closed for 60 days. Pressure faces and slickensides are common.
Rock fragments: 0–35 percent gravel
Organic matter: Less than 1 percent decreasing irregularly with depth.
Gypsum: 0–2 percent
Salinity: slightly to moderately
Sodicity: moderate to strong

A and C horizons

Hue: 5YR, 7.5YR, 10YR
Value: 4–7 dry; 3–7 moist
Chroma: 2–6 dry or moist
Texture: silty clay, silty clay loam, clay, clay loam (35–50 percent clay)
Reaction: slightly to very strongly alkaline
Calcium-carbonate equivalent: 5–15 percent

Competing Series: This is the Pecos series. Pecos soils have greater than 1 percent organic matter in the upper

20 inches of the surface, is moderately well drained and has redox features.

Geographic Setting: The Hantz soils are on alluvial fans, stream terraces, and flood plains and have slopes of 0–5 percent. Elevations are 2,000–5,500 feet. The soils formed in stratified mixed alluvium. The mean annual precipitation is 8–12 inches and is evenly divided between two periods, July through September, and December through February. The mean annual air temperature is 56°–70°F. The frostfree period is 180–280 days.

Geographically Associated Soils: These are the Anthony, Bridge and Cornville soils. Anthony soils are coarseloamy. Bridge soils have a calcic horizon. Cornville soils have argillic horizons.

Drainage and Permeability: Well drained; slow to medium runoff; slow permeability. Subject to flooding and/or sheet flow.

Use and Vegetation: Used for livestock grazing and irrigated cropland. Native vegetation is snakeweed, widely spaced creosotebush, tobosa grass, and annuals. About 90 percent of the surface is barren.

Distribution and Extent: Central and southern Arizona. The Hantz soils are of small extent. This soil occurs in LRR D, MLRAs 38, 40, and 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Beaver Creek Area, Yavapai County, Arizona; 1965.

Remarks

Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 3 inches (A horizon)
Entisol feature: The absence of diagnostic subsurface horizons
Vertic feature: Primarily cracks extending 12 inches deep or more
Fluvial feature: Irregular decrease in organic carbon in the zone from 3 to 60 inches (C1, C2 horizons)

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Keysto Series

Location: Keysto, Arizona
Established Series
Rev. DJB/WAS/PDC/CEM/WWJ 11/2001

The Keysto series consists of very deep, well drained soils formed in mixed fan alluvium and stream alluvium. Keysto soils are on alluvial fans and stream terraces with slopes of 0–8 percent. The mean annual precipitation is about 14 inches. The mean annual air temperature is about 65°F.

Taxonomic Class: Loamy-skeletal, mixed, superactive, nonacid, thermic Ustic Torrifluvents

Typical Pedon: Keysto very gravelly sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.)
C1: 0–3 inches; dark brown (7.5YR 3/2) very gravelly sandy loam, dark brown (7.5YR 3/2) moist; weak thin platy structure; soft, very friable, nonsticky and nonplastic; common very fine, fine and medium roots; common fine irregular pores; 5 percent cobble and 45 percent gravel; noneffervescent; neutral (pH 6.6); abrupt smooth boundary. (2–5 inches thick)
C2: 3–24 inches; dark brown (10YR 3/3) extremely cobbly sandy loam, very dark brown (10YR 2/2) moist; massive; soft, very friable, nonsticky and nonplastic; common very fine, fine, medium and coarse roots; common fine irregular pores; 55 percent cobble and 24 percent gravel; noneffervescent; neutral (pH 6.8); clear wavy boundary. (20–30 inches thick)
Ck: 24–60 inches; brown (10YR 4/3) extremely cobbly loamy sand, dark brown (10YR 3/3) moist; massive; soft, very friable, nonsticky and nonplastic; common very fine, fine, and few medium roots; common fine irregular pores; many distinct continuous calcium-carbonate coatings on rock fragments; 55 percent cobble and 30 percent gravel; noneffervescent in the fine earth; slightly alkaline (pH 7.4).

Type Location: Pima County, Arizona; latitude of 31° 47 minutes 33 seconds North and a longitude of 111° 39 minutes 30 seconds West. Chiuli Shaik topoquad, Sycamore Canyon road.

Range in Characteristics

Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. The epipedon is moist in some part less than 90 days (cumulative) when the soil temperature is above 41°F. in 7 out of 10 years. Ustic Aridic soil moisture regime.
Soil temperature: 61°–69°F.
Rock fragments: 35–75 percent gravel, cobble, and stones
Reaction: slightly acid to slightly alkaline
Organic matter: 1–3 percent, decreasing irregularly with depth
Depth to calcium carbonate: greater than 20 inches

C horizons

Hue: 10YR, 7.5YR
Value: 3–5 dry; 2–4 moist
Chroma: 2–4 dry or moist

Texture: sandy loam, loamy sand, fine sandy loam, coarse sand
Calcium carbonate: occurs as coatings on rock fragments

Competing Series: There are no competitors.

Geographic Setting: The Keysto soils are on alluvial fans and stream terraces. Slope ranges from 0 to 8 percent. They formed in mixed fan and stream alluvium. Elevation ranges from 3,000 to 5,200 feet. The mean annual precipitation is 12–16 inches. The mean annual air temperature ranges from 59° to 67°F. The frost-free period is about 180–250 days.

Geographically Associated Soils: These are the Cellar, Lampshire, Romero, Chiricahua, and Oracle soils. These soils have bedrock within 60 inches.

Drainage and Permeability: Well drained; medium runoff; moderately rapid permeability.

Use and Vegetation: Keysto soils are used for livestock grazing and wildlife habitat. Vegetation includes mesquite, paloverde, catclaw acacia, burroweed, cacti, sideoats grama, Arizona cottontop, spike dropseed, annual grasses and forbs.

Distribution and Extent: Southern Arizona. This series is of moderate extent. This soil occurs in LRR D, MLRAs 40 and 41. Subject to flooding.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona; Soil survey of Tohono O'odham Nation, Arizona, Parts of Maricopa, Pima and Pinal Counties; 1993.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Entisol feature: The absence of diagnostic subsurface horizons
Fluvial feature: Irregular decrease in organic carbon in the zone from 3 to 60 inches (C2, Ck horizons)

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Kimrose Series

Location: Kimrose, Arizona
Established Series
Rev. DJB/CEM/PDC/WWJ 09/2002

The Kimrose series consists of very shallow or shallow to hardpan, well drained soils formed in mixed alluvium dominantly from gneiss, schist and granite. Kimrose soils are on fan piedmonts and fan terraces with slopes of 1–20 percent. The mean annual precipitation is about 13 inches. The mean annual air temperature is about 65°F.

Taxonomic Class: Loamyskeletal, mixed, superactive, thermic, shallow Ustic Petrocalcids

Typical Pedon: Kimrose very gravelly sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–2 inches; strong brown (7.5YR 5/6) very gravelly sandy loam, dark brown (10YR 3/3) moist; weak thin platy structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; common very fine and fine interstitial and tubular pores; 35 percent gravel; strongly effervescent, 8 percent calcium-carbonate equivalent; slightly alkaline (pH 7.6); abrupt smooth boundary. (1–7 inches thick)
Bk1: 2–12 inches; strong brown (7.5YR 5/6) very gravelly sandy clay loam, brown (10YR 4/3) moist; weak medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine, fine and coarse roots; common very fine and fine interstitial and tubular pores; 40 percent gravel with few distinct continuous carbonate coatings; few medium irregular soft masses and common threads of calcium carbonate; violently effervescent, 15 percent calcium-carbonate equivalent; slightly alkaline (pH 7.8); abrupt wavy boundary. (0–18 inches thick)
Bk2: 12–20 inches; white (7.5YR 8/1) strongly cemented extremely gravelly sandy loam, white (7.5YR 8/1) moist; massive; hard, firm, nonsticky and nonplastic; few very fine and fine roots; 60 percent gravel and 10 percent cobble with few distinct continuous carbonate coatings; violently effervescent, 36 percent calcium-carbonate equivalent; moderately alkaline (pH 8.4); abrupt wavy boundary. (0–20 inches thick)
Bkm: 20–60 inches; white (7.5YR 8/1) indurated petrocalcic with a thin laminar cap; extremely hard; few very fine roots in fractures.

Type Location: Pima County, Arizona; west of the Baboquivari Mountains and south of Hiavanan Nakya on the Tohono O'odham Indian Nation; 31° 56 minutes 20 seconds north latitude and 111° 41 minutes 35 seconds west longitude.

Range in Characteristics
Soil Moisture: Intermittently moist in some part of the soil moisture control section during July through September and December through February. Driest during May and June. Ustic aridic soil moisture regime.
Soil Temperature: 65°–69°F.
Rock Fragments: 35–60 percent gravel; some pedons contain cobble

Reaction: Neutral to moderately alkaline
Depth to petrocalcic horizon: 7–20 inches
Calcium-carbonate equivalent: Greater than 15 percent
Clay content: Averages 18–35 percent in the particle size control section

<u>A horizon</u>
Hue: 7.5YR, 10YR
Value: 3–5 dry; 2–4 moist
Chroma: 1–6 dry; 2–4 moist

<u>B horizon (not present in all pedons)</u>
Hue: 7.5YR, 10YR
Value: 3–8 dry or moist
Chroma: N/ through 6 dry or moist
Texture: sandy loam, sandy clay loam, loam

<u>Bkm horizon</u>
Cementation: strongly cemented to indurated

Competing Series: These are the Missile, Monterosa, and Pedregosa series. The Missile soils have mean annual soil temperature of 61°–65°F, and contain less than 15 percent calcium carbonate in the particle size control section. Monterosa soils are dry in the soil moisture control section for longer periods due to a lower rainfall component and have moderately fine textured soil material below the hardpan at moderate depths. Pedregosa soils have 5–18 percent clay in the particlesize control section.

Geographic Setting: The Kimrose soils are on fan piedmonts and fan terraces. Slopes range from 1 to 20 percent. They form in alluvium from gneiss, schist and granite. Elevation ranges from 2,800 to 4,900 feet. The mean annual precipitation is 12–16 inches. The mean annual air temperature ranges from 59° to 67°F. The frostfree period is about 190–250 days.

Geographically Associated Soils: These are the Nolam, Whitehouse, Hathaway, Caralampi, and Selevin soils. These soils are very deep and lack a petrocalcic horizon.

Drainage and Permeability: Well drained; slow to medium runoff; moderate permeability.

Use and Vegetation: Kimrose soils are used for livestock grazing and wildlife habitat. Vegetation includes bush muhly, black grama, slender janusia, fluffgrass, spidergrass, creosotebush, littleleaf paloverde and ocotillo.

Distribution and Extent: Southern Arizona. This series is of moderate extent.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona; Soil survey of Tohono O'odham Indian Reservation, Arizona, Parts of Maricopa, Pima and Pinal Counties; 1993.

<u>Remarks</u>
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: the zone from 0 to 2 inches (A horizon)
Calcic horizon: the zone from 2 to 20 inches (Bk1, Bk2 horizons)
Petrocalcic horizon: the zone from 20 to 60 inches (Bkm horizon)

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Lampshire Series

Location: Lampshire, Arizona
Established Series
Rev. MLR/PDC/WWJ/HCD 07/2005

The Lampshire series consists of very shallow and shallow, well drained soils that formed in alluvium and colluvium from igneous rocks. Lampshire soils are on hills and mountains and have slopes of 0–90 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 62°F.

Taxonomic Class: Loamyskeletal, mixed, superactive, nonacid, thermic Lithic Ustic Torriorthents

Typical Pedon: Lampshire very cobbly loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–8 inches; grayish brown (10YR 5/2) very cobbly loam, very dark grayish brown (10YR 3/2) moist; moderate fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; many fine and few medium roots; many fine tubular pores; 20 percent gravel and 40 percent cobble; neutral (pH 7.0); abrupt irregular boundary. (4–20 inches thick)
2R: 8 inches; tuff.

Type Location: Santa Cruz County, Arizona; approximately 2 miles westnorthwest of Tubac; on the southeast slope of a low hill; 800 feet south and 500 feet west of the northeastern corner of Section 11, Township 21 South, Range 12 East.

<u>Range in Characteristics</u>
Soil Moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. Ustic aridic soil moisture regime. The epipedon is moist in some

part less than 90 days (cumulative) when the soil temperature is above 41°F. in 7 out of 10 years.
Rock Fragments: 35–70 percent cobble and gravel; mainly igneous and tuffaceous
Soil Temperature: 59°–72°F.
Depth to bedrock: 4–20 inches. Some pedons may have a layer less than 3 inches thick of weathered bedrock above the lithic contact.

<u>**A or C horizons**</u>
Hue: 7.5YR, 10YR
Value: 3, 4, or 5 dry; 2–4 moist
Chroma: 1–4 dry or moist
Organic matter: 1–2 percent
Texture: Loam, sandy loam, fine sandy loam, silt loam, coarse sandy loam (10–20 percent clay)
Reaction: Slightly acid to moderately alkaline
Calcium carbonate: Few coatings on bedrock in some pedons

Competing Series: These are the Lingua and Reduff series. Lingua and Reduff soils contain more than 20 percent clay. In addition, the Lingua soils formed in basalt and the Reduff soils have hue redder than 7.5YR.

Geographic Setting: Lampshire soils are on hills and mountains at elevations of 2,500–5,800 feet. These soils formed in alluvium and colluvium from basalt, tuff, andesite, rhyolite, dacite, granite and schist. Slopes range from 0 to 90 percent. The mean annual precipitation is 12–16 inches. The mean annual air temperature is 57°–70°F. The frostfree period is 170–250 days.

Geographically Associated Soils: These are the Caralampi, Chiricahua, Graham and Signal soils. Caralampi and Signal soils are very deep. Chiricahua and Graham soils have a finetextured argillic horizon.

Drainage and Permeability: Well drained; medium to high runoff; moderate or moderately rapid permeability.

Use and Vegetation: Lampshire soils are used for livestock grazing and wildlife habitat. Vegetation is sideoats, sprucetop, hairy and slender gramas, threeawn, canebeardgrass, plains lovegrass, bristlegrass, tanglehead, curly mesquite, black grama, ocotillo, whitethorn, range ratany, mimosa, catclaw, agave, beargrass, sotol, barrel cacti, palo verde and desert hackberry.

Distribution and Extent: Southern and Central Arizona. This series is extensive. This soil occurs in LRR D, MLRAs 38 and 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Santa Cruz County Area, Arizona; 1971.

<u>**Remarks**</u>
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 8 inches (A horizon)
Lithic contact: The boundary at 8 inches (2R horizon)

Classified according to *Keys to Soil Taxonomy*, 9th ed., 2003.

Mabray Series

Location: Mabray, Arizona
Established Series
Rev. MLR/CCC/PDC/CEM/WWJ 11/2001

The Mabray series consists of shallow and very shallow, well drained soils formed in slope alluvium from limestone. Mabray soils are on hills and mountains and have slopes of 3–70 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 61°F.

Taxonomic Class: Loamy-skeletal, carbonatic, thermic Lithic Ustic Torriorthents

Typical Pedon: Mabray very gravelly loam—rangeland. (Colors are dry soil unless otherwise noted.)
A: 0–1 inch; dark grayish brown (10YR 4/2) very gravelly loam, very dark grayish brown (10YR 3/2) moist; weak fine and medium granular structure; slightly hard, friable, slightly sticky and slightly plastic; many fine and few medium roots; common fine and very fine irregular pores; 35 percent gravel and 15 percent cobble; violently effervescent; moderately alkaline (pH 8.0); abrupt smooth boundary. (1–3 inches thick)
ACk: 1–12 inches; dark grayish brown (10YR 4/2) extremely cobbly loam, very dark grayish brown (10YR 3/2) moist; moderate fine and medium granular structure; slightly hard, friable, slightly sticky and slightly plastic; common fine and few medium roots; common fine and very fine tubular pores; 30 percent gravel and 45 percent cobble; violently effervescent; common light gray (10YR 7/2) calcium-carbonate coatings on underside of gravel and cobble; moderately alkaline (pH 8.2); abrupt irregular boundary. (3–17 inches thick)
2R: 12 inches; extremely hard, fractured limestone; common fine roots along fractures.

Type Location: Santa Cruz County, Arizona; approximately 10 miles east-southeast of Amado; 300 feet north of the Glove Mine and 1,250 feet north of the S 1/4 corner of Section 30, Township 20 South, Range 13 East.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–March. Driest during May and June. The epipedon is moist in some part more than 90 days (cumulative) when the soil temperature is above 41°F. in 7 out of 10 years. Ustic aridic soil moisture regime.
Soil temperature: 59°–72°F.
Rock fragments: 35–80 percent
Depth to bedrock: 4–20 inches
Organic matter content: 1–5 percent
Reaction: slightly to moderately alkaline
Calcium-carbonate equivalent: greater than 40 percent based on whole soil less than 20 mm
Clay content: averages more than 18 percent in the control section. Ranges from 15 to 25 percent.

A horizon
Hue: 10YR, 7.5YR
Value: 2, 3, 4, or 5 dry; 2 or 3 moist
Chroma: 1–4 dry or moist

AC or C horizon
Hue: 10YR, 7.5YR
Value: 3–8 dry; 3–7 moist
Chroma: 1–4 dry or moist
Texture: Silt loam, loam, sandy loam, fine sandy loam
Some pedons contain a layer less than 3 inches thick of weathered bedrock above the lithic contact.

Competing Series: These are no competing series.

Geographic Setting: Mabray soils are on hills and mountains. Elevations range from 3,000 to 5,500 feet. Slopes range from 3 to 70 percent. They formed in slope alluvium from calcareous sedimentary rocks that includes limestone, marble and calcareous sandstone. The mean annual precipitation ranges from 12 to 16 inches as summer thundershowers and gentle winter rain and occasional snow. The mean annual air temperature ranges from 57° to 67°F. The frost-free period is about 160–250 days.

Geographically Associated Soils: These are the Caralampi, Chiricahua, Deloro, Graham, Oracle and Romero soils. Caralampi soils are very deep. Chiricahua, Deloro, Graham and Oracle soils have argillic horizons. Romero soils have mixed mineralogy and no lithic contacts.

Drainage and Permeability: Well drained; medium to rapid runoff; moderate permeability.

Use and Vegetation: These soils are used for livestock grazing and wildlife habitat. Present vegetation is ocotillo, whitethorn, sandpaper bush, guajillo, catclaw, buckbrush, agave, sotol, beargrass, burroweed, snakeweed, some mesquite and palo verde, slim tridens, plains lovegrass, sideoats and hairy grama, black grama, New Mexico needlegrass, threeawn, fluffgrass and bullgrass.

Distribution and Extent: Southern and Central Arizona. The Mabray series is moderately extensive. This soil occurs in LRR D, MLRA 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Santa Cruz County Area, Arizona; 1971.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 1 inch (A horizon)
Lithic contact: The boundary at 12 inches (2R horizon)

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Mohave Series

Location: Mohave, Arizona, California, and New Mexico
Established Series
Rev. JEJ/PDC/CEM/WWJ 06/2000

The Mohave series consists of very deep, well drained soils formed in mixed alluvium. Mohave soils are on fan terraces, basin floors, and stream terraces and have slopes of 0–8 percent. The mean annual precipitation is about 10 inches and the mean annual air temperature is about 63°F.

Taxonomic Class: Fineloamy, mixed, superactive, thermic Typic Calciargids

Typical Pedon: Mohave sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–4 inches; light yellowish brown (10YR 6/4) sandy loam, dark yellowish brown (10YR 4/4) moist; weak medium platy structure; slightly hard, friable, slightly sticky and slightly plastic; many very fine roots; common very fine and fine tubular and common very fine irregular pores; noneffervescent; neutral (pH 7.2); clear wavy boundary. (1–7 inches thick)
Bt1: 4–11 inches; brown (7.5YR 5/4) sandy loam, dark brown (7.5YR 4/4) moist; weak medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; many very fine roots; common very fine and fine tubular and very fine irregular pores; few faint clay films lining pores and bridging mineral grains; noneffervescent; slightly alkaline (pH 7.5); clear wavy boundary. (3–8 inches thick)

Bt2: 11–28 inches; brown (7.5YR 5/4) clay loam, dark brown (7.5YR 4/4) moist; weak coarse prismatic structure parting to moderate medium subangular blocky; hard, friable, moderately sticky and moderately plastic; many very fine roots; few very fine and fine tubular and few fine irregular pores; few faint clay films on faces of peds and lining pores; noneffervescent; moderately alkaline (pH 8.0); clear wavy boundary. (8–22 inches thick)
Bt3: 28–39 inches; strong brown (7.5YR 5/6) loam, dark brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard, friable, slightly sticky and moderately plastic; few very fine roots; common fine tubular and few fine irregular pores; few faint clay films on faces of peds and lining pores; violently effervescent; moderately alkaline (pH 8.0); clear wavy boundary. (5–15 inches thick)
Btk: 39–55 inches; brown (7.5YR 5/4) clay loam, dark brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; very hard, firm, moderately sticky and moderately plastic; few very fine roots; common fine tubular pores; common distinct clay films on faces of peds and lining pores; violently effervescent, many fine calcium-carbonate accumulations as filaments and soft masses; moderately alkaline (pH 8.0); clear wavy boundary. (3–16 inches thick)
2C: 55–60 inches; reddish brown (5YR 5/4) gravelly loamy coarse sand, reddish brown (5YR 4/4) moist; massive; slightly hard, friable; common fine irregular pores; moderately alkaline (pH 8.0).

Type Location: Yavapai County, Arizona; 1,960 feet west and 1,476 feet north of the southeastern corner of Section 32, Township 10 North, Range 6 West.

Range in Characteristics

Soil moisture: Intermittently moist in some part of the soil moisture control section during December–February and for more than 20 days cumulative during July–September. Driest during May and June. Typic aridic soil moisture regime.
Soil temperature: 59°–72°F.
Rock fragments: Less than 15 percent gravel in the control section
Depth to carbonates: 6–36 inches. Some pedons are slightly or strongly effervescent in the A and B horizons
Organic matter: Less than 1 percent in the upper 15 inches
Depth to calcic horizon: 20–40 inches
Sand content: Less than 50 percent in the control section

A horizon

Hue: 10YR,7.5YR
Value: 4–7 dry; 3, 4, or 5 moist
Chroma: 2, 3, 4, or 6 dry or moist
Reaction: Neutral to moderately alkaline

B horizon

Hue: 7.5YR, 5YR
Value: 4, 5, 6, or 7 dry; 3, 4, 5, or 6 moist
Chroma: 3, 4, or 6 dry or moist
Texture: Loam, sandy clay loam, silt loam, clay loam. The Bt1 horizon is sandy loam in some pedons (averages 27–40 percent clay)
Reaction: Slightly alkaline or moderately alkaline

C horizon

Hue: 7.5YR, 5YR, N8/
Value: 5, 6, 7, or 8 dry; 3–8 moist
Chroma: 2, 3, 4, or 6 dry or moist
Texture: loam, sandy loam, loamy coarse sand, loamy fine sand, sandy clay loam (3–30 percent clay)
Rock fragments: 0–15 percent gravel, ranging to 80 percent below 40 inches in some pedons
Cementation: Weak calcium-carbonate cementation in some pedons
Reaction: Moderately alkaline or strongly alkaline

Competing Series: These are the Blackmagic, Doña Ana, Kidwell, and Nutt series. A potential competitor that does not yet have CEA class assigned is the Jagerson series. Potential competitors that are not yet reclassified as Calciargids are the Berino, Cornville, Hap, Madurez, and Tres Hermanos soils. Blackmagic soils have mean annual precipitation of 4–7 inches and receive most of the precipitation in the winter. Berino and Cornville soils have greater than 50 percent sand in the control section. Doña Ana and Tres Hermanos soils have calcic horizons at depths less than 20 inches. Hap soils average more than 15 percent gravel in the argillic horizon. Madurez soils have argillic horizons less than 10 inches thick and sola less than 25 inches thick. Jagerson and Kidwell soils are moist for less than 20 days cumulative in the summer and occur in MLRA 30.

Geographic Setting: Mohave soils are on basin floors, fan terraces, and stream terraces. Slopes range from 0 to 8 percent. They formed in mixed alluvium from acid and basic igneous rocks. Elevation is 1,800–5,000 feet. The mean annual precipitation is 7–12 inches. The mean annual air temperature is 57°–70°F. The frostfree period is 180–300 days.

Geographically Associated Soils: In addition to the competing Doña Ana and Tres Hermanos soils, are the Guest and Pinaleno soils. Guest soils are fine. Pinaleno soils are loamyskeletal.

Drainage and Permeability: Well drained; slow runoff; moderately slow permeability.

Use and Vegetation: Used for livestock grazing and irrigated cropland. The present vegetation is mesquite, paloverde, creosotebush, bursage, cactus, bush muhly, threeawn, Arizona cottontop, plains bristlegrass, sixweeks grama and Indianwheat. Irrigated areas are planted to alfalfa, cotton, citrus, vegetables and other crops.

Distribution and Extent: North-central, south-central, and southern Arizona and New Mexico. The Mohave series is extensive. MLRAs 40 and 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Middle Gila Valley Area, Arizona; 1917.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 4 inches (A horizon)
Argillic horizon: The zone from 4 to 55 inches (Bt1, Bt2, Bt3, Btk horizons)
Calcic horizon: The zone from 39 to 55 inches (Btk horizon)

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Nolam Series

Location: Nolam, Arizona and New Mexico
Established Series
Rev. HEB/CEM/PDC/WWJ 06/2000

The Nolam series consists of very deep, well drained, moderately slow permeable soils that formed in alluvial sediments derived from rhyolite and andesite on terraces and piedmonts. Slopes range from 2 to 15 percent. The mean annual precipitation is about 12 inches. The mean annual air temperature is about 66°F.

Taxonomic Class: Loamy-skeletal, mixed, superactive, thermic Ustic Calciargids

Typical Pedon: Nolam very gravelly sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–2 inches; light brown (7.5YR 6/4) very gravelly fine sandy loam, brown (7.5YR 5/4) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; few medium roots; slightly alkaline; abrupt smooth boundary. (1–4 inches thick)
Bt: 2–10 inches; red (2.5YR 4/6) very gravelly sandy clay loam, dark red (2.5YR 3/6) moist; some volumes of 5YR hue; weak medium and coarse subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common fine roots; common prominent clay films coating and bridging sand grains and gravel; slightly alkaline; clear wavy boundary. (4–20 inches thick)
Btk: 10–17 inches; dominantly reddish brown (5YR 5/4) very gravelly sandy clay loam, reddish brown (5YR 4/4) moist; some parts have 7.5YR hue, particularly in the lower part; massive; soft, friable, slightly sticky and slightly plastic; common fine roots; few distinct clay films coating and bridging sand grains and gravel; strongly effervescent; moderately alkaline; abrupt wavy boundary. (2–16 inches thick)
Bk1: 17–24 inches; dominantly pink (7.5YR 8/4) very gravelly sandy loam, pink (7.5YR 7/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; few fine roots; strongly effervescent; most gravel are separated by calcium carbonate; moderately alkaline; clear wavy boundary. (6–12 inches thick)
Bk2: 24–40 inches; mixed pink (7.5YR 8/4) and light brown (7.5YR 6/4) very gravelly sandy loam, light brown (7.5YR 6/4) and brown (7.5YR 5/4) moist; massive; slightly hard, very friable, slightly sticky and slightly plastic; few fine roots; strongly effervescent; calcium carbonate thickly coats gravel in light colored parts, thinly coats them in darker parts, light and dark parts occur in nearly vertical tongues and in irregular volumes, 1 inch to several inches across; moderately alkaline; clear wavy boundary. (10–20 inches thick)
Bk3: 40–52 inches; alternating tongues and lenses of very pale brown (10YR 7/4) and yellowish brown (7.5YR 5/4) very gravelly loamy sand, yellowish brown (10YR 5/4) and dark yellowish brown (7.5YR 4/4) moist; massive; soft, very friable, nonsticky and nonplastic; few fine roots; strongly effervescent; light colored parts commonly held together by weak carbonate cementation, darker parts have only thin carbonate coatings; moderately alkaline; clear wavy boundary. (8–20 inches thick)
Bk4: 52–71 inches; dominantly brown (7.5YR 5/4) very gravelly sand, dark brown (7.5YR 4/4) moist; few tongues and lenses of pink (7.5YR 8/4), light brown (7.5YR 6/4) moist; massive; soft, very friable, nonsticky and nonplastic; few fine roots; strongly effervescent; material weakly held together by calcium carbonate; moderately alkaline; clear wavy boundary. (10–30 inches thick)
C: 71–79 inches; brown (7.5YR 5/4) gravelly sand, dark brown (7.5YR 4/4) moist; massive and single grained; soft, loose, nonsticky and nonplastic; slightly effervescent; some gravel have very thin discontinuous calcium-carbonate coatings; moderately alkaline.

Type Location: Doña Ana County, New Mexico; 200 feet west of Soledad Canyon road, south bank of arroyo; in the NE 1/4 of Section 21, Township 23 South, Range 3 East; 106° 38 minutes 18 seconds west longitude and 32° 17 minutes 45 seconds north latitude.

Range in Characteristics
Soil Moisture: Intermittently moist in some part of the soil moisture control section during July through September and December through April. Driest during May and June. Ustic aridic soil moisture regime.

Soil temperature: 59°–69°F.
Rock fragments: more than 35 percent
Depth to calcic horizon: 20–40 inches

A horizon
Hue: 5YR, 7.5YR
Value: 3–6 dry; 3–5 moist
Chroma: 2–6 dry or moist
Texture: fine sandy loam, sandy loam

Bt and Btk horizons
Hue: 2.5YR, 5YR
Value: 3–6 dry; 3–5 moist
Chroma: 3–6 dry or moist
Texture: sandy loam, loam, sandy clay loam, clay loam (averages 18–35 percent clay)

Bk and C horizons
Hue: 2.5YR through 10YR
Value: 4–8 dry; 3–8 moist
Chroma: 2–6 dry or moist
Texture: fine sandy loam, coarse sandy loam, sandy clay loam, sandy loam, loamy sand, sand

Competing Series: This is the Beewon and Throne (T) series. A potential competitor not yet reclassified is the Alsco series. Alsco soils typically have hue of 7.5YR or yellower in the argillic. Beewon soils have 35–50 percent clay. Throne soils are moderately deep.

Geographic Setting: The Nolam soils are on fan piedmonts and fan terraces. Slopes range from 1 to 15 percent. Elevation ranges from 3,500 to 6,000 feet. The mean annual precipitation ranges from about 10 to 16 inches. The mean annual air temperature ranges from 57° to 67°F. The frost-free period is about 180–240 days.

Geographically Associated Soils: These are the Boracho, Casito, Delnorte, Monterosa, Pinaleno, Terino and Vado soils. Casito and Terino soils are shallow and have petrocalcic horizons. Pinaleno soils lack calcic horizons within 40 inches of the surface. Boracho, Delnorte and Monterosa soils have a petrocalcic horizon and lack an argillic horizon. Vado soils lack argillic and calcic horizons.

Drainage and Permeability: Well drained; medium runoff; moderate or moderately slow permeability. **Use and Vegetation:** This soil is used primarily for livestock grazing. Native vegetation includes snakeweed, range ratany, fluffgrass, prickly pear, yucca and creosotebush. In some areas there are scattered clumps of black grama and bush muhly.

Distribution and Extent: Southern New Mexico and Arizona. The series is of moderate extent. MLRAs 41 and 42.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Doña Ana County, New Mexico; 1972.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 2 inches (A horizon)
Argillic horizon: The zone from 2 to 17 inches (Bt, Btk horizons)
Calcic horizon: The zone from 24 to 52 inches (Bk2, Bk3 horizons)

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Oracle Series

Location: Oracle, Arizona
Established Series
Rev. MLR/DJB/PDC/CEM/WWJ 06/2005

The Oracle series consists of shallow, well drained soils formed in residuum and slope alluvium from granitic rock. Oracle soils are on hills and pediments. Slopes range from 5 to 45 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 64°F.

Taxonomic Class: Loamy, mixed, superactive, thermic, shallow Ustic Haplargids

Typical Pedon: Oracle gravelly coarse sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.) Surface cover of about 40 percent fine and medium gravel, 10 percent cobble and 5 percent stone.
A: 0–4 inches (0–10 cm); brown (7.5YR 4/4) gravelly coarse sandy loam, dark brown (7.5YR 3/4), moist; weak thin platy parting to weak fine granular structure; soft, very friable, slightly sticky, slightly plastic; many very fine roots; common very fine interstitial pores; 12 percent fine and 12 percent medium gravel; noneffervescent; neutral, pH 6.6; abrupt smooth boundary.
Bt1: 4–11 inches (10–28 cm); reddish brown (5YR 4/4) sandy clay loam, reddish brown (5YR 4/4), moist; strong medium and coarse subangular blocky structure; hard, firm, very sticky, very plastic; common very fine and few coarse roots; common very fine tubular pores; common continuous distinct clay films on faces of peds and rock fragments; 5 percent fine and 5 percent medium gravel; noneffervescent; neutral, pH 6.6; clear smooth boundary.
Bt2: 11–19 inches (28–48 cm); reddish brown (5YR 4/3) sandy clay loam, yellowish red (5YR 4/6), moist; moderate

fine and medium prismatic parting to strong fine and medium angular blocky structure; very hard, very firm, very sticky, very plastic; common very fine roots between peds; common very fine tubular pores; common continuous distinct clay films on faces of peds and rock fragments; 2 percent fine and 3 percent medium gravel; noneffervescent; neutral, pH 6.6; abrupt wavy boundary.
Crt: 19–60 inches (48–152 cm) weathered granite (grus) with many distinct continuous clay films on rock fragments

Type Location: Pinal County, Arizona, located at latitude 32°, 36 minutes 24.00 seconds north, longitude 110°, 48 minutes 10.00 seconds west North American Datum 83; and about 2,000 feet north and 1,600 feet west of the southwestern corner of Section 34, Township 9 South, Range 15 East; U.S. Geological Survey (USGS) Quadrangle: Oracle.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–March. Driest during May and June. Ustic aridic soil moisture regime. The epipedon is moist in some part less than 90 days (cumulative) when the soil temperature is above 41°F. in 7 out of 10 years.
Soil temperature: 59°–69°F.
Rock fragments: Averages 1–35 percent fine granitic gravel in the control section; 5–65 percent on the surface.
Depth to bedrock: 10–20 inches. Usually weathered to a depth of 60 inches or more.
Reaction: Slightly acid to moderately alkaline

A horizon
Hue: 5YR, 7.5YR, 10YR
Value: 4 or 5 dry; 2, 3, or 4 moist
Chroma: 2, 3, or 4 dry or moist

B horizon
Hue: 5YR, 7.5YR
Value: 3, 4, or 5 dry; 3 or 4 moist
Chroma: 2, 3, or 4 dry; 4–6 moist
Texture: Clay loam, loam, sandy clay loam (18–35 percent clay)

Cr horizon
Extremely weakly cemented to moderately cemented granite (grus)

Competing Series: This is the Brunkcow series. Brunkcow soils have a lithic contact below the paralithic contact.

Geographic Setting: Oracle soils are on hills and pediments. They formed in residuum and slope alluvium material weathered from coarse grained granite or granodiorite. Elevations range from 3,400 to 5,400 feet. Slope is 5–45 percent. The mean annual precipitation is 12–16 inches with summer thunderstorms and gentle winter rain. The mean annual air temperature is 57°–67°F. The frostfree period is about 180–255 days.

Geographically Associated Soils: These are the Andrada, Deloro, Lampshire and Romero series. Andrada soils have a calcic horizon. Deloro soils are clayeyskeletal. Lampshire and Romero soils do not have argillic horizons.

Drainage and Permeability: Well drained; medium to rapid runoff; moderately slow permeability.

Use and Vegetation: These soils are used for livestock grazing, wildlife habitat, mining and homesites. Vegetation is mainly beargrass, calliandra, shrubby buckwheat, sideoats grama, hairy grama, cane beardgrass, plains lovegrass and threeawn, with a scattered overstory of manzanita, juniper and Emory oak.

Distribution and Extent: Southern Arizona. The Oracle series is moderately extensive. MLRA 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: PageTrowbridge Experiment Range, Arizona; 1952.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: the zone from 0 to 4 inches (A horizon)
Argillic horizon: the zone from 4 to 19 inches (Bt1, Bt2 horizons)
Paralithic contact: the boundary at 19 inches (Crt horizon)

In October 2000, taxonomic classification was converted to the closest match found in *Soil Taxonomy*, 2nd ed., 1999. No update was made to horizon nomenclature, competing series section, etc. Other placements may be more appropriate after a complete update. The type location was moved in June 2005. The new type location is in an area consistent with the moisture regime.

Pantak Series

Location: Pantak, Arizona
Established Series
Rev. DJB/PDC 11/2000

The Pantak series consists of very shallow and shallow, well drained soils formed in mixed slope alluvium, colluvium, and residuum from igneous rock. Pantak soils are on pediments, hills and mountains with slopes of 8–60 percent. The mean annual precipitation is about 14 inches. The mean annual air temperature is about 62°F.

Taxonomic Class: Loamyskeletal, mixed, superactive, thermic Lithic Ustic Haplargids

Typical Pedon: Pantak very gravelly sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–1 inch; brown to dark brown (10YR 4/3) very gravelly sandy loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; common fine roots; common fine interstitial pores; 40 percent gravel; noneffervescent; moderately acid (pH 6.0); abrupt wavy boundary. (1–3 inches thick)
AB: 1–4 inches; brown (10YR 5/3) very gravelly sandy loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common fine and medium roots; common fine tubular pores; 45 percent gravel; noneffervescent; moderately acid (pH 6.0); abrupt wavy boundary. (2–5 inches thick)
Bt: 4–14 inches; yellowish brown (10YR 5/4) very gravelly sandy clay loam, dark yellowish brown (10YR 3/4) moist; weak fine subangular blocky structure; soft, very friable, sticky and plastic; common fine and medium roots; common fine tubular pores; common distinct continuous clay films on rock fragments; 50 percent gravel; noneffervescent; moderately acid (pH 6.0); abrupt wavy boundary. (4–16 inches thick)
R: 14 inches; andesite.

Type Location: Pima County, Arizona; latitude of 31°, 48 minutes, 50 seconds North and a longitude of 111°, 35 minutes, 00 seconds West.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. The epipedon is moist in some part less than 90 days (cumulative) when the soil temperature is above 41°F. in 7 out of 10 years. Ustic aridic soil moisture regime.
Soil temperature: 61°–69°F.
Rock fragments: 35–65 percent gravel, cobble or stones
Depth to bedrock: 4–20 inches
Clay content: ranges from 20 to 35 percent
Reaction: moderately acid to slightly alkaline
Calcium carbonate: can have carbonates in the rock fractures
Organic Matter: 1–3 percent

A horizon
Hue: 7.5YR, 10YR
Value: 4 or 5 dry; 3 or 4 moist
Chroma: 1–4 dry or moist

Bt horizon
Hue: 7.5YR, 10YR
Value: 4 or 5 dry
Chroma: 1–4 dry or moist
Texture: clay loam, sandy clay loam

Competing Series: These are the Lemitar (New Mexico) and Whitvin (Arizona) series. Lemitar soils have accumulations of calcium carbonate in the control section and are dry in the soil moisture control section for longer periods due to a lower rainfall component. Whitvin soils have hue of 2.5YR or 5YR.

Geographic Setting: The Pantak soils are on pediments, hills and mountains. Slope ranges from 8 to 60 percent. They formed in mixed slope alluvium, colluvium, and residuum from andesite and related igneous rock. Elevation ranges from 3,200 to 5,600 feet. The mean annual precipitation is 12–16 inches. The mean annual air temperature ranges from 57 to 67°F. The frostfree period is about 170–250 days.

Geographically Associated Soils: These are the Cellar, Lampshire, Romero, Chiricahua, and Oracle soils. Cellar, Lampshire, and Romero soils do not have argillic horizons. Chiricahua soils are clayey. Oracle soils are loamy.

Drainage and Permeability: Well drained; medium to rapid runoff; moderate permeability.

Use and Vegetation: Pantak soils are used for livestock grazing and wildlife habitat. Vegetation includes sideoats grama, cane bluestem, curly mesquite, Schott agave, prickly pear, snakeweed, and mesquite.

Distribution and Extent: Southern Arizona. This series is of moderate extent. Pantak is a village on the Tohono O'odham Nation. MLRA 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona; Soil survey of the Tohono O'odham Nation, Arizona, Parts of Maricopa, Pima and Pinal Counties; 1993.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 4 inches (A horizon)
Argillic horizon: The zone from 4 to 14 inches (Bt horizon)
Lithic contact: The boundary at 14 inches (R horizon)

In October 2000, taxonomic classification was converted to the closest match found in *Soil Taxonomy*, 2nd ed., 1999. No update was made to horizon nomenclature, competing series section, etc. Other placements may be more appropriate after a complete update.

Pantano Series

Location: Pantano, Arizona
Established Series
Rev. MLR/DJB/PDC/WWJ 09/2002

The Pantano series consists of shallow, well drained soils formed in slope alluvium and colluvium from metamorphic rock and limestone. Pantano soils are on hills, pediments and mountains. Slopes range from 5 to 50 percent. The mean annual precipitation is about 11 inches and the mean annual air temperature is 66°F.

Taxonomic Class: Loamyskeletal, mixed, superactive, thermic, shallow Typic Haplocalcids

Typical Pedon: Pantano extremely gravelly loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–1 inch; pale brown (10YR 6/3) extremely gravelly loam, brown (10YR 4/3) moist; weak thin platy structure; slightly hard, very friable, slightly sticky and slightly plastic; few fine roots; many fine interstitial pores; 70 percent gravel; strongly effervescent; moderately alkaline (pH 8.0); abrupt smooth boundary. (1–2 inches thick)
Bw: 1–10 inches; brown (10YR 5/3) very gravelly loam, brown (10YR 4/3) moist; moderate fine granular structure; slightly hard, very friable, slightly sticky and slightly plastic; many very fine and common fine roots; many fine interstitial pores; 40 percent gravel; violently effervescent; moderately alkaline (pH 8.0); clear wavy boundary. (4–10 inches thick)
Bk: 10–16 inches; very pale brown (10YR 8/2) and brown (10YR 5/3) extremely gravelly loam, light gray (10YR 7/2) and brown (10YR 4/3) moist; massive and weakly calcium-carbonate cemented; slightly hard, friable, slightly sticky and slightly plastic; many very fine and few fine roots; many interstitial pores; 70 percent calcium carbonate—coated gravel, coatings are violently effervescent; moderately alkaline (pH 8.4); abrupt irregular boundary. (4–8 inches thick)
2Crk: 16–60 inches; highly fractured schist; common faint patchy white (N 8/) calcium-carbonate coatings in fractures.

Type Location: Pima County, Arizona; 1,300 feet south and 25 feet east of the northwestern corner of Section 29, Township 14 South, Range 16 East.; on the east side of the road at the top of a 10foot cut.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. Typic aridic soil moisture regime.
Soil temperature: 65°–72°F.
Depth to bedrock: 10–20 inches
Rock fragments: greater than 35 percent
Depth to calcic horizon: 2–14 inches
Organic matter content: Less than 1 percent
Calcium carbonate: Averages 15–40 percent calcium-carbonate equivalent in the control section

A horizon
Hue: 10YR, 7.5YR, 5YR
Value: 5, 6, or 7 dry; 4, 5, or 6 moist
Chroma: 3 or 4 dry or moist

Bk and Bw horizons
Hue: 10YR, 7.5YR, 5YR
Value: 4–8 dry; 4, 5, 6, or 7 moist
Chroma: 2, 3, or 4 dry or moist
Texture: Loam, sandy loam (5–18 percent clay)

Some pedons have a lithic contact below the paralithic within depths of 20–40 inches.

Competing Series: There are no competing series.

Geographic Setting: Pantano soils are on hills, pediments and mountains. Elevations range from 2,200 to 3,800 feet. Slopes range from 5 to 50 percent. The soils formed in alluvium from schist, conglomerate, and other pyroclastic rocks. The mean annual air temperature is 63°–70°F. The precipitation is 10–13 inches, occurring as summer thunderstorms and gentle winter rains. The frostfree period is 220–280 days.

Geographically Associated Soils: These are the Anklam, Chimenea, Pinaleno and Tres Hermanos soils. Anklam and Chimenea soils have argillic horizons. Pinaleno and Tres Hermanos soils are very deep and have argillic horizons.

Drainage and Permeability: Well drained; medium to rapid runoff; moderate permeability.

Use and Vegetation: These soils are used for livestock grazing, wildlife habitat and urban development. Vegetation is creosotebush, brittlebush, paloverde, bursage, whitethorn, ocotillo, desert zinnia, paper daisy, pricklypear, staghorn cholla, pencil cholla, Christmas cholla and a few saguaros. Grasses mainly are bush muhly and fluffgrass.

Distribution and Extent: Southeastern Arizona. The Pantano series are not extensive.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona, Eastern Part; 1985.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:

Ochric epipedon: the zone from 0 to 1 inch (A horizon)
Calcic horizon: the zone from 10 to 16 inches (Bk horizon)
Paralithic contact: the boundary at 16 inches (2Crk horizon)

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Pinaleno Series

Location: Pinaleno, Arizona and New Mexico
Established Series
Rev. FWG/YHH/PDC/WWJ 12/2003

The Pinaleno series consists of very deep, well drained soils formed in fan alluvium from mixed rock. Pinaleno soils are on fan terraces and stream terraces. Slopes are 0–45 percent. The mean annual precipitation is about 10 inches and the mean annual air temperature is about 62°F.

Taxonomic Class: Loamyskeletal, mixed, superactive, thermic Typic Calciargids

Typical Pedon: Pinaleno very gravelly clay loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–1 inch; yellowish red (5YR 5/6) very gravelly clay loam, reddish brown (5YR 4/4) moist; weak thick platy structure; soft, very friable, slightly sticky and slightly plastic; common very fine roots; common very fine interstitial pores; 40 percent subrounded gravel and 5 percent cobble; noneffervescent; moderately alkaline; clear smooth boundary. (1–3 inches thick)
Bt: 1–5 inches; yellowish red (5YR 5/6) gravelly clay loam, reddish brown (5YR 4/4) moist; weak fine granular structure; slightly hard, very friable, sticky and plastic; common very fine roots; common very fine interstitial pores; 40 percent subrounded gravel and 5 percent cobble; noneffervescent; moderately alkaline; clear smooth boundary. (3–6 inches thick)
Btk1: 5–12 inches; yellowish red (5YR 5/6) very gravelly clay loam, reddish brown (5YR 4/4) moist; moderate medium subangular blocky structure; slightly hard, very friable, sticky and plastic; common very fine roots; common very fine tubular pores; common distinct clay films on faces of peds; 55 percent gravel; strongly effervescent; common calcium-carbonate filaments; moderately alkaline; gradual wavy boundary. (3–31 inches thick)
Btk2: 12–24 inches; light brown (7.5YR 6/4) very gravelly loam, brown (7.5YR 5/4) moist; moderate medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common very fine roots; common very fine tubular pores; few distinct clay films lining pores and on faces of peds; 35 percent gravel; violently effervescent; many soft calcium-carbonate masses; moderately alkaline; gradual wavy boundary. (12–20 inches thick)
C: 24–60 inches; light brown (7.5YR 6/4) loam, brown (7.5YR 5/4) moist; massive; soft, very friable, slightly sticky and slightly plastic; common very fine interstitial pores; violently effervescent; moderately alkaline.

Type Location: Maricopa County, Arizona; 2,400 feet west and 330 feet south of the northeastern corner of Section 1, Township 6 North, Range 8 West.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. Typic aridic soil moisture regime.
Rock fragments: Averages 35–70 percent gravel and cobble in the control section
Soil temperature: 59°–72°F.
Thickness of solum: 15–40 inches
Depth to calcic horizon: 5–40 inches

A horizon
Hue: 5YR, 7.5YR, 10YR
Value: 4–7 dry; 4–6 moist
Chroma: 2, 3, 4, or 6 dry or moist
Organic matter: Less than 1 percent

Bt horizons
Hue: 2.5YR, 5YR, 7.5YR
Value: 4–7 dry; 3–7 moist
Chroma: 4 or 6 dry or moist
Texture: Sandy clay loam, clay loam, loam (18–35 percent clay)
Calcium carbonate: Upper part noncalcareous; lower part more than 15 percent calcium-carbonate equivalent

Bk or C horizon
Hue: 7.5YR, 5YR
Value: 5–8 dry; 4–7 moist
Chroma: 2–4 dry; 2, 3, 4, or 6 moist
Texture: Sandy clay loam, loam, sandy loam, loamy sand (10–25 percent clay)
Calcium carbonate: 8–25 percent or more calcium-carbonate equivalent

Competing Series: These are the Bitter Spring and Oldwoman series. Bitter Spring soils are less than 10 inches thick to the base of the argillic horizon and average less than 15 percent clay. Oldwoman soils have durinodes.

Geographic Setting: Pinaleno soils are on fan terraces and stream terraces. Slopes range from 0 to 45 percent. Elevations range from 1,500 to 5,400 feet. They formed in mixed alluvium. The mean annual air temperature is 58°–70°F. The mean annual precipitation is 8–12 inches and falls as rain mainly in July and August and much of the remainder in December, January, and February. The frostfree period is 180–280 days.

Geographically Associated Soils: These are the Anthony, Arizo, Brazito, Continental, and Gila soils. Arizo soils are sandyskeletal. Continental, Gila, Anthony, and Brazito soils are not skeletal.

Drainage and Permeability: Well drained; slow to medium runoff; moderately slow permeability.

Use and Vegetation: Used for livestock grazing. Vegetation is a sparse cover of creosotebush, cacti, mesquite, sixweeks grama and annuals.

Distribution and Extent: Southern Arizona and southwestern New Mexico. MLRAs 40, 41, and 42. The Pinaleno soils are moderately extensive.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Eastern Maricopa–Northern Pinal Counties Area, Arizona; 1969.

Remarks

Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: the zone from 0 to 1 inch (A horizon)
Argillic horizon: the zone from 1 to 24 inches (Bt, Btk1, Btk2 horizons)
Calcic horizon: the zone from 12 to 24 inches (Btk2 horizon)

The classification was changed from loamyskeletal, mixed, superactive, thermic Typic Haplargids to loamyskeletal, mixed, superactive, thermic Typic Calciargids in 2003.

Additional Data: NSSL S77AZ009004 S60NM013009 S66NM013016 S67NM013004 S67NM013005

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Powerline Series

Location: Powerline, Arizona
Established Series
Rev. CCC/PDC/WWJ 09/2002

The Powerline series consists of moderately deep, well drained soils formed in slope alluvium. Powerline soils are on hills and have slopes of 2–40 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 63°F.

Taxonomic Class: Loamyskeletal, mixed, superactive, thermic Ustic Haplocalcids

Typical Pedon: Powerline very gravelly sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–3 inches; pale brown (10YR 6/3) very gravelly sandy loam, brown (10YR 4/3) moist; weak moderately thick platy structure; slightly hard, very friable, slightly sticky and slightly plastic; many very fine roots; common fine tubular pores; 40 percent gravel; strongly effervescent; moderately alkaline (pH 8.2); clear smooth boundary. (2–6 inches thick)
Bk1: 3–17 inches; very pale brown (10YR 7/3) gravelly loam, light yellowish brown (10YR 6/4) moist; weak medium subangular blocky structure; slightly hard, friable, sticky and plastic; many fine roots; common very fine tubular pores; few distinct calcium-carbonate coatings on gravel and lining pores; 25 percent gravel and 5 percent cobble; violently effervescent; moderately alkaline (pH 8.2); gradual wavy boundary. (12–16 inches thick)
Bk2: 17–29 inches; very pale brown (10YR 7/3) very gravelly sandy loam, light yellowish brown (10YR 6/4) moist; massive; hard, firm, slightly sticky and slightly plastic; common fine roots; common fine tubular pores; common distinct calcium-carbonate coatings on gravel and lining pores; 50 percent gravel and 5 percent cobble; violently effervescent; moderately alkaline (pH 8.2); abrupt smooth boundary. (6–18 inches thick)
2Crkq: 29–60 inches; sandy fanglomerate; thin discontinuous limesilica cemented cap on bedrock; common fine roots in fractures; many distinct calcium-carbonate coatings in fractures; strongly effervescent.

Type Location: Pima County, Arizona; 300 feet east and 1,800 feet north of the southwestern corner of Section 12, Township 17 South, Range 17 East.

Range in Characteristics

Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–March. Driest during May and June. Ustic aridic soil moisture regime.
Soil temperature: 61°–68°F.
Rock fragments: Averages 35–65 percent gravel and cobble in the control section
Depth to bedrock: 20–40 inches
Calcium-carbonate equivalent: 15–35 percent
Organic matter: greater than 1 percent

A horizon

Hue: 10YR, 7.5YR

Value: 5, 6, or 7 dry; 3, 4, 5, or 6 moist
Chroma: 2, 3, or 4 dry or moist

Bk horizon
Hue: 10YR, 7.5YR
Value: 5, 6, or 7 dry; 4, 5, 6, or 7 moist
Chroma: 2, 3, or 4 dry; 3 or 4 moist
Texture: Sandy loam, loam (10–20 percent clay)

Competing Series: These are the Chilicotal, Gallegos, Gallen, Gilland, Polar, and Tombstone series. Chilicotal, Gallegos, Gallen, Polar, and Tombstone soils are very deep. Gilland soils formed in alluvium and colluvium derived from red sandstone and calcareous shales. In addition, Gallen soils are in the PecosCanadian Plains and Valleys (MLRA 70); Polar soils are in the Central Rolling Red Plains (MLRA 78); both soils are moister in May and June.

Geographic Setting: Powerline soils are on hills. Slopes are commonly 5–30 percent but range from 2 to 40 percent. They formed in slope alluvium from calcareous sandy fanglomerate. Elevations range from 3,300 to 5,000 feet. The mean annual precipitation is 12–16 inches, occurring as summer thunderstorms and winter rain. The mean annual air temperature is 59°–66°F. The frostfree period is about 180–240 days.

Geographically Associated Soils: These are the Andrada, Arizo, and Monterosa soils. Arizo soils are sandyskeletal and very deep. Monterosa soils are shallow to a petrocalcic horizon. Andrada soils are shallow to bedrock.

Drainage and Permeability: Well drained; moderately rapid runoff; moderate permeability.

Use and Vegetation: Used mainly for livestock grazing. Vegetation is ocotillo, range ratany, sotol, black grama, banana yucca, creosotebush, sideoats grama, slim tridens, wolftail, threeawn, fluffgrass, bush muhly, whitethorn, and Mormon tea.

Distribution and Extent: Southern Arizona. The Powerline soils are of minor extent.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona; Soil survey of Pima County, Arizona, Eastern Part; 1985.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 3 inches (A horizon)
Calcic horizon: The zone from 3 to 29 inches (Bk1, Bk2 horizons)
Paralithic contact: The boundary at 29 inches (2Crkq horizon)

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Redington Series

Location: Redington, Arizona
Established Series
Rev. WAS/DJB/PDC/CEM/WWJ 11/2001

The Redington series consists of very deep, somewhat excessively drained soils formed on hills from mixed stream alluvium and fan alluvium. Slope is 3–60 percent. The mean annual precipitation is about 11 inches and the mean annual air temperature is about 67°F.

Taxonomic Class: Sandy, mixed, thermic Typic Torriorthents

Typical Pedon: Redington very gravelly fine sand rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–2 inches; brown (7.5YR 5/4) very gravelly fine sand, brown (7.5YR 4/4) moist; moderate fine granular structure; loose, nonsticky and nonplastic; few very fine and fine roots; common very fine and fine interstitial pores; 40 percent gravel; strongly effervescent; slightly alkaline (pH 7.8); abrupt smooth boundary. (2–6 inches thick)
C: 2–10 inches; brown (7.5YR 5/4) fine sand, brown (7.5YR 4/4) moist; single grain; soft, very friable, nonsticky and nonplastic; few very fine and fine roots; common very fine and fine interstitial pores; 5 percent gravel; slightly effervescent; slightly alkaline (pH 7.8); abrupt smooth boundary. (8–20 inches thick)
Cd: 10–14 inches; light brown (7.5YR 6/4) sand, brown (7.5YR 5/4) moist; massive; hard, firm, nonsticky and nonplastic; 5 percent gravel; noneffervescent; moderately alkaline (pH 8.2); abrupt smooth boundary. (3–15 inches thick)
C': 14–28 inches; light brown (7.5YR 6/4) fine sand, brown (7.5YR 5/4) moist; massive; soft, friable, nonsticky and nonplastic; 5 percent gravel; noneffervescent; slightly alkaline (pH 7.8); abrupt smooth boundary. (14–20 inches thick)
C'd: 28–40 inches; light brown (7.5YR 6/4) sand, brown (7.5YR 5/4) moist; massive; very hard, firm, nonsticky and nonplastic; 5 percent gravel; noneffervescent; strongly alkaline (pH 8.6); abrupt smooth boundary. (9–15 inches thick)
C": 40–60 inches; light brown (7.5YR 6/4) stratified gravelly coarse sand and sand; massive; loose, very friable, nonsticky and nonplastic; 30 percent gravel; strongly effervescent; moderately alkaline (pH 8.0).

Type Location: Pima County, Arizona; 850 feet west and 710 feet south of the northeastern corner of Section 2, Township 12 South, Range 18 East.

Range in Characteristics

Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. Typic aridic soil moisture regime.
Soil Temperature: 62°–72°F.
Reaction: slightly to strongly alkaline
Reaction: noneffervescent to violently effervescent
Surface rock fragments: 10–40 percent gravel and, or cobble
Rock fragments: 20–45 percent gravel, cobble and petronodes in any one horizon; averages less than 35 percent in the control section

A horizon

Hue: 10YR, 7.5YR
Value: 5–7 dry; 4 or 5 moist
Chroma: 3–6 dry or moist
Calcium-carbonate equivalent: 0–10 percent
Gypsum content: 0–5 percent

C horizon

Hue: 10YR, 7.5YR
Value: 5–7 dry; 4–6 moist
Chroma: 3–6 dry or moist
Textures: sand, loamy sand, fine sand, fine sandy loam, coarse sand (averages less than 8 percent clay) Calcium-carbonate equivalent: 0–25 percent
Gypsum content: 0–10 percent

Cd horizons

Dense sediments that are intergrades between soft sediments (C material) and soft bedrock (Cr material). These naturally compacted sediments have been subjected to a slow reduction in volume and increase in density from deep water loading in the geologic past. These materials easily break down in water and roots can penetrate when moist. They are root restrictive when dry.
Hue: 7.5YR, 5YR
Value: 5 or 6 dry; 4 or 5 moist
Chroma: 3, 4, or 6 dry or moist
Texture: fine sand, sand, coarse sand
Calcium-carbonate equivalent: 10–35 percent
Gypsum content: 5–10 percent

Competing Series: These are the Amole, Challenger, Hypoint, Livefire, Orwash, Shortbread, and Yellowrock series. These soils do not have Cd horizons. In addition, Challenger, Hypoint, Livefire, Orwash, Shortbread, and Yellowrock soils are in the Mohave Desert (MLRA 30), receive mostly winter precipitation and are usually dry from April through November.

Geographic Setting: The Redington soils are on hills and dissected relict lake beds. Slopes range from 3 to 60 percent. They formed in mixed stream alluvium and fan alluvium from prehistoric lakes and marshes. Elevation ranges from 2,200 to 4,100 feet. The mean annual precipitation in 10–12 inches. The mean annual air temperature is 60°–70°F. The frost-free period is 190–280 days.

Geographically Associated Soils: These are the Redo, Arizo, Contention, Nahda, Stagecoach, and Delnorte soils. Redo and Stagecoach soils have calcic horizons. Arizo soils are sandy-skeletal. Nahda and Delnorte soils have petrocalcic horizons. Contention soils are fine textured.

Drainage and Permeability: Somewhat excessively drained; moderate runoff; moderately rapid to rapid permeability.

Use and Vegetation: Redington soils are used for livestock grazing. Vegetation includes creosotebush, mesquite, black grama, snakeweed, annual grasses and forbs.

Distribution and Extent: Southern Arizona. This series is of small extent. This soil occurs in LRR D, MLRAs 40 and 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona; Soil survey of Pima County, Arizona, Eastern Part; 1985.

Remarks

Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 2 inches (A horizon)
Entisol feature: The absence of diagnostic subsurface horizons

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Riveroad Series

Location: Riveroad, Arizona
Established Series
Rev. CCC/PDC/CEM/WWJ 11/2001

The Riveroad series consists of very deep, well drained soils formed in stream alluvium from mixed sources. Riveroad soils are on flood plains and alluvial fans and have slopes of 0–5 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 65°F.

Taxonomic Class: Fine-silty, mixed, superactive, calcareous, thermic Ustic Torrifluvents

Typical Pedon: Riveroad clay loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–4 inches; brown (10YR 5/3) stratified clay loam, dark brown (10YR 3/3) moist; weak thick platy structure; slightly hard, friable, moderately sticky and moderately plastic; common very fine roots; common very fine irregular pores; common thin sand coatings on faces of peds; thick (4 cm) pale brown (10YR 6/3) finely stratified silt loam and very fine sandy loam layer on the surface, brown (10YR 4/3) moist; slightly alkaline (pH 7.4); abrupt smooth boundary. (2–13 inches thick)
C1: 4–21 inches; brown (10YR 4/3) clay loam, very dark brown (10YR 2/2) moist; moderate medium subangular blocky structure; hard, friable, moderately sticky and moderately plastic; common very fine roots; many very fine irregular pores; few thin very fine sand coatings on faces of peds; slightly effervescent, few fine filaments of calcium carbonate in pores; slightly alkaline (pH 7.4); clear wavy boundary. (12–20 inches thick)
C2: 21–33 inches; dark grayish brown (10YR 4/2) clay loam, very dark brown (10YR 2/2) moist; weak medium subangular blocky structure; hard, friable, moderately sticky and moderately plastic; common very fine roots; common very fine tubular pores; slightly alkaline (pH 7.4); clear wavy boundary. (6–15 inches thick)
C3: 33–60 inches; brown (7.5YR 4/4) clay loam, dark yellowish brown (10YR 3/4) moist; moderate medium subangular blocky structure; very hard, friable, moderately sticky and moderately plastic; few very fine roots; common fine tubular pores; slightly effervescent, few fine filaments of calcium carbonate in pores; common faint organic stains on faces of peds and lining pores; slightly alkaline (pH 7.4).

Type Location: Pima County, Arizona; 1,660 feet south and 200 feet east of the northwestern corner of Section 26, Township 18 South, Range 9 East.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during December-March and July–September. Driest during May and June. The epipedon is moist in some part less than 90 days (cumulative) when the soil temperature is above 41°F. in 7 out of 10 years. Ustic aridic soil moisture regime.
Soil temperature: 62°–72°F.
Rock fragments: 0–15 percent gravel
Texture: Averages less than 15 percent fine sand or coarser. Averages 5–40 percent very fine sand and l8–35 percent clay in the control section
Organic matter: 1–5 percent decreasing irregularly with depth
Reaction: Neutral to moderately alkaline
Stratification: commonly stratified with finer or coarser material throughout
Gypsum content: 0–4 percent

A and C horizons
Hue: 10YR, 7.5YR
Value: 3–6 dry; 2–5 moist
Chroma: 1–4 dry or moist
Texture: Loam, silt loam, silty clay loam, clay loam, silty clay

Competing Series: These are the Crowflats and Nillo series. Crowflats soils are dominantly silt loam and very fine sandy loam in the control section and have mean annual precipitation of 8–10 inches. Nillo soils are formed in tuff parent material from the Duff and Pruett Formations.

Geographic Setting: Riveroad soils are on flood plains and alluvial fans with slopes of 0–5 percent. They formed in stratified stream alluvium from metamorphic, sedimentary and basic and acid igneous rock. Elevation ranges from 2,200 to 4,600 feet. The mean annual precipitation is 12–16 inches, occurring as summer thunderstorms and winter rain. The mean annual air temperature is 60°–70°F. The frost-free period is about 180–280 days.

Geographically Associated Soils: These are the Bodecker, Comoro, Guest, Hayhook, Sonoita, and Ubik soils. Bodecker soils are sandy-skeletal. Hayhook, Comoro, Sonoita, and Ubik soils are coarse-loamy. Guest soils are fine.

Drainage and Permeability: Well drained; slow runoff; moderate to moderately slow permeability. This soil is subject to flooding.

Use and Vegetation: Used for livestock grazing, irrigated cropland and urban development. Vegetation is mesquite, sacaton, vine mesquite, grama grasses, cane beardgrass, and catclaw. Irrigated crops include cotton, sorghum, wheat, alfalfa, sugar beets, lettuce and small grains.

Distribution and Extent: Southern Arizona. The Riveroad soils are moderately extensive. This soil occurs in LRR D, MLRAs 40 and 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona; Soil survey of Pima County, Arizona, Eastern Part; 1985.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 4 inches (A horizon)

Entisol feature: The absence of diagnostic subsurface horizons
Fluvial feature: Irregular decrease in organic carbon in the zone from 4 to 60 inches (C1, C2, C3, C4 horizons)

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Romero Series

Location: Romero, Arizona
Established Series
Rev. MLR/DJB/PDC/WWJ/RKS/HCD 01/2005

The Romero series consists of very shallow or shallow, well drained soils that formed in slope alluvium from schist or granitic rock. Romero soils are on pediments, hills and mountains and have slopes of 5–70 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 62°F.

Taxonomic Class: Loamyskeletal, mixed, superactive, nonacid, thermic, shallow Ustic Torriorthents

Typical Pedon: Romero very gravelly sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A1: 0–2 inches; dark grayish brown (10YR 4/2) very gravelly sandy loam, very dark grayish brown (10YR 3/2) moist; weak moderately thick platy structure; slightly hard, very friable, nonsticky and nonplastic; many very fine and few fine and medium roots; many fine interstitial pores; 40 percent fine subrounded gravel; neutral (pH 7.0); abrupt smooth boundary. (1–4 inches thick)
A2: 2–10 inches; very dark grayish brown (10YR 3/2) very gravelly fine sandy loam, very dark brown (10YR 2/2) moist; moderate fine granular structure; slightly hard, very friable, nonsticky and nonplastic; many very fine and few fine and medium roots; many fine interstitial pores; 40 percent fine gravel; neutral (pH 7.0); abrupt wavy boundary. (4–16 inches thick)
2Crt1: 10–17 inches; brown (10YR 5/3) and light gray (10YR 7/2) weathered granite (grus), brown (10YR 4/3) and light brownish gray (10YR 6/2) moist; many fine and medium and coarse fractures; many very fine and few fine and medium roots in fractures; very dark grayish brown (10YR 3/2) fine sandy loam, very dark brown (10YR 2/2) moist in fractures; few faint and distinct dark reddish brown (5YR 2/2) clay films on fracture faces; diffuse wavy boundary. (4–15 inches thick)
2Crt2: 17–60 inches; light brownish gray (10YR 6/2) and very pale brown (10YR 7/4) weathered granite (grus); many fine and few medium and coarse roots in fractures; few faint dark reddish brown (5YR 3/4) clay films on fracture faces.

Type Location: Pima County, Arizona; in a road cut in a small hill on the south side of the road, about 1,495 feet west and 1,625 feet south of the northeastern corner of Section 1, Township 18 South, Range 11 East.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. Ustic aridic soil moisture regime. The epipedon is moist in some part less than 90 days (cumulative) when the soil temperature is above 41°F. in 7 out of 10 years.
Soil temperature: 59°–69°F.
Rock fragments: Averages 35–90 percent
Depth to bedrock: 4–20 inches
Reaction: Slightly acid to slightly alkaline
Organic matter content: Averages 1–5 percent

A horizon
Hue: 10YR, 7.5YR
Value: 3–6 dry; 2–6 moist
Chroma: 1–6 dry or moist
Texture: Sandy loam, fine sandy loam, loam (averages less than 18 percent clay)

Competing Series: This is the Schrap series. Schrap soils average more than 18 percent clay in the control section.

Geographic Setting: Romero soils are on pediments, hills and mountains and formed from granite, granodiorite, schist or pegmatite and gneiss. Elevations range from 3,000 to 5,600 feet. Slopes range from 0 to 70 percent, but are dominantly 10–35 percent. The mean annual precipitation ranges from 12 to 16 inches, occurring as summer thunderstorms and winter rain. The mean annual air temperature is about 57°–67°F. The frostfree period is about 180–250 days.

Geographically Associated Soils: These are the Lampshire and Oracle series. Lampshire soils have lithic contacts at depths less than 20 inches. Oracle soils have argillic horizons.

Drainage and Permeability: Well drained; medium runoff; moderately rapid permeability.

Use and Vegetation: Used for livestock grazing and wildlife habitat. Vegetation includes oak, mesquite, scattered juniper, ocotillo, catclaw, mimosa, calliandra, hackberry, range ratany, shrubby buckwheat, southwest rabbitbrush, pricklypear, cholla, beargrass and bullgrass. Some areas have manzanita, buckthorn and sumac. Grasses are sideoats grama, sand lovegrass, plains lovegrass, purple grama, wolftail, threeawn, black grama, Arizona cottontop, cane beardgrass and bush muhly.

Distribution and Extent: Southern Arizona. The Romero series is moderately extensive. MLRAs 38 and 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona; Eastern Part; 1985.

Remarks

Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 10 inches (A1, A2 horizons)
Paralithic contact: The boundary at 10 inches (2Crt1 horizon)
Entisol feature: The absence of diagnostic subsurface horizons

Classified according to *Keys to Soil Taxonomy*, 9th ed., 2003.

Sahuarita Series

Location: Sahuarita, Arizona
Established Series
Rev. CCC/DJB/PDC/WWJ 08/2002

The Sahuarita series consists of very deep, well drained soils formed in alluvium from limestone, schist, phyllite and granitic rock. Sahuarita soils are on fan terraces and basin floors have slopes of 0–8 percent. The mean annual precipitation is about 11 inches and the mean annual air temperature is about 68°F.

Taxonomic Class: Coarseloamy, mixed, superactive, thermic Typic Haplocambids

Typical Pedon: Sahuarita very gravelly fine sandy loam rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–3 inches; light yellowish brown (10YR 6/4) very gravelly fine sandy loam, dark yellowish brown (10YR 4/4) moist; weak moderately thick platy structure; soft, very friable, nonsticky and nonplastic; few fine roots; common very fine tubular pores; 45 percent gravel; strongly effervescent; moderately alkaline (pH 7.9); abrupt wavy boundary. (1–10 inches thick)
Bk: 3–19 inches; light yellowish brown (10YR 6/4) fine sandy loam, brown (10YR 4/3) moist; weak coarse prismatic structure; soft, very friable, slightly sticky and nonplastic; common fine roots; common fine tubular pores; 10 percent gravel; strongly effervescent as few faint calcium-carbonate coatings on undersides of gravel; moderately alkaline (pH 7.9); gradual smooth boundary. (10–30 inches thick)
C: 19–28 inches; light yellowish brown (10YR 6/4) fine sandy loam, dark yellowish brown (10YR 4/4) moist; massive; soft, very friable, slightly sticky and nonplastic; common fine roots; few fine tubular pores; 10 percent gravel; strongly effervescent; moderately alkaline (pH 7.9); clear wavy boundary. (9–15 inches thick)
2Btkb: 28–45 inches; brown (7.5YR 5/4) loam, brown (7.5YR 4/4) moist; weak medium prismatic structure; hard, firm, sticky and plastic; common fine roots; common fine and very fine tubular pores; common faint clay films coating sand grains and lining pores; 10 percent gravel; strongly effervescent as few faint calcium-carbonate filaments on faces of peds; moderately alkaline (pH 8.0); clear wavy boundary. (10–25 inches thick)
2Btb: 45–60 inches; brown (7.5YR 5/4) very gravelly sandy clay loam, brown (7.5YR 4/4) moist; weak medium prismatic structure; hard, friable, slightly sticky and slightly plastic; few fine roots; few fine tubular pores; many faint clay films coating sand grains and lining pores; 35 percent gravel; strongly effervescent; moderately alkaline (pH 8.0).

Type Location: Pima County, Arizona; 460 feet north and 1,060 feet west of the southeastern corner of Section 7, Township 17 South, Range 15 East.

Range in Characteristics

Soil moisture: Intermittently moist in some part of the soil moisture control section part during July–September and December–March. Driest during May and June. Typic aridic soil moisture regime.
Soil temperature: 66°–72°F.
The control section averages less than 18 percent clay
Depth to buried argillic horizon: 20–40 inches
Rock Fragments: 0–65 percent in any one horizon; averages less than 35 percent in the particlesize control section
Calcium carbonate: Slightly to strongly effervescent and less than 15 percent calcium-carbonate equivalent at depths less than 40 inches; violently effervescent and as much as 25 percent calcium-carbonate equivalent at depths of more than 40 inches

A horizon

Hue: 10YR, 7.5YR, 5YR
Value: 4–6 dry; 4 or 5 moist
Chroma: 3, 4, or 6 dry or moist
Organic matter: Less than 1 percent
Reaction: Mildly or moderately alkaline

Bk or Bw and C horizons

Hue: 10YR, 7.5YR, 5YR
Value: 5 or 6 dry; 4 or 5 moist
Chroma: 3, 4, or 6 dry or moist

Texture: Loam, very fine sandy loam, fine sandy loam, sandy loam (10–17 percent clay)
Reaction: Slightly alkaline or moderately alkaline

Buried Bt horizon
Hue: 7.5YR, 5YR
Value: 4, 5, or 6 dry; 4 or 5 moist
Chroma: 3–6 dry or moist
Texture: Loam, sandy loam, coarse sandy loam, sandy clay loam, clay loam (averages 18–35 percent clay)
Reaction: Slightly to strongly alkaline

Competing Series: These are the Agustin, Filaree, Hayhook, Lostman, Nasagold, Pajarito, and Pyxo series. All of these soils lack buried argillic horizons. In addition, Filaree, Lostman, and Nasagold soils are in the Mohave Desert (MLRA 30); Pyxo soils are in the Central California Coast Range (MLRA 15), all these soils receive mostly winter precipitation and are usually dry from April through November. Hayhook soils are noncalcareous to depths of 20 inches or more. Pyxo soils are moderately deep to sandstone bedrock.

Geographic Setting: Sahuarita soils are on fan terraces and basin floors with slopes of 0–8 percent. They formed in stratified alluvium from limestone, schist, phyllite, and granitic rock. Elevation ranges from 2,000 to 3,600 feet. The mean annual precipitation is 10–13 inches, occurring as summer thunderstorms and winter rain. The mean annual air temperature is 64°–70°F. The frostfree period is about 230–280 days.

Geographically Associated Soils: These are the Arizo, Bucklebar, Mohave, Stagecoach, and Pinaleno series. Arizo soils are sandyskeletal and are in drainageways. Bucklebar and Mohave soils have argillic horizons. Stagecoach and Pinaleno soils are loamyskeletal.

Drainage and Permeability: Well drained; slow to medium runoff; moderate or moderately rapid permeability above the buried argillic horizons and moderately slow or moderate within.

Use and Vegetation: Used mainly for livestock grazing and some homesites. Vegetation is creosotebush, bush muhly, threeawn, fluffgrass, whitestem paperflower, desert zinnia, and annual forbs and grasses.

Distribution and Extent: Southern Arizona. These soils are moderately extensive.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona, Eastern Part; 1985.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: the zone from 0 to 3 inches (A horizon)
Cambic horizon: the zone from 3 to 19 inches (Bw horizon)
Buried soil: the zone from 28 to 60 inches (2Btkb, 2Btb horizons)
In October 2000, taxonomic classification was converted to the closest match found in *Soil Taxonomy*, 2nd ed., 1999. No update was made to horizon nomenclature, competing series section, etc. Other placements may be more appropriate after a complete update.

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

Sasabe Series

Location: Sasabe, Arizona
Established Series
Rev. CCC 04/2009

The Sasabe series consists of very deep, well drained soils formed in fan alluvium from mixed sources. Sasabe soils are on fan terraces and have slopes of 0–20 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is 63°F.

Taxonomic Class: Fine, mixed, superactive, thermic Ustic Paleargids

Typical Pedon: Sasabe sandy loam rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–5 inches; strong brown (7.5YR 5/6) sandy loam, red (2.5YR 4/6) moist; weak thin and moderately thick platy structure; slightly hard, very friable, slightly sticky and slightly plastic; few fine and common very fine roots; many fine interstitial pores; noneffervescent; 10 percent gravel; slightly acid (pH 6.4); abrupt smooth boundary. (1–8 inches thick)
Bt1: 5–15 inches; yellowish red (5YR 4/6) clay loam, red (2.5YR 4/6) moist; moderate fine subangular blocky structure; hard, friable, moderately sticky and moderately plastic; many very fine roots; common fine tubular pores; few faint clay films lining pores and as stains on grains; noneffervescent; 5 percent gravel; slightly alkaline (pH 7.6); clear wavy boundary.
Bt2: 15–22 inches; red (2.5YR 4/6) clay, dark red (2.5YR 3/6) moist; moderate medium prismatic structure; very hard, firm, very sticky and very plastic; many very fine roots; many fine tubular pores; many distinct clay films lining pores, as stains on sand grains and coating faces of peds; slightly effervescent; 10 percent gravel; moderately alkaline (pH 8.0); clear wavy boundary.

Bt3: 22–31 inches; yellowish red (5YR 4/6) gravelly clay loam, dark red (2.5YR 3/6) moist; weak medium subangular blocky structure; very hard, firm, moderately sticky and moderately plastic; common very fine roots; common very fine tubular pores; common faint clay films lining pores and coating gravel; slightly effervescent; 30 percent gravel; moderately alkaline (pH 8.0); clear wavy boundary.
Bt4: 31–41 inches; yellowish red (5YR 4/6) gravelly sandy clay loam, red (2.5YR 4/6) moist; weak coarse subangular blocky structure; very hard, firm, moderately sticky and moderately plastic; common very fine roots; common very fine tubular pores; common faint clay films on faces of peds; slightly effervescent; 25 percent gravel; moderately alkaline (pH 8.0); clear wavy boundary. (Combined thickness of the Bt horizons is 20–50 inches)
2Btk: 41–60 inches; yellowish red (5YR 5/8) very gravelly sandy clay loam, yellowish red (5YR 4/6) moist; weak medium subangular blocky structure; very hard, firm, moderately sticky and moderately plastic; common very fine roots; common very fine tubular and few fine irregular pores; few faint clay films as stains on sand grains and lining pores; strongly effervescent as many fine calcium-carbonate masses and coating gravel; 40 percent gravel; moderately alkaline (pH 8.4).

Type Location: Pima County, Arizona; 1,300 feet east and 1,400 feet north of the southwestern corner of Section 6, Township 20 South, Range 9 East.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during July–October and December–February. Driest during May and June. Ustic aridic soil moisture regime.
Soil temperature: 62°–69°F.
Clay content: Averages 35–60 percent
Calcium carbonate: Noneffervescent to 10 inches or more; less than 15 percent calcium-carbonate equivalent to 40 inches or more
Organic matter: Less than 1 percent

A horizon
Hue: 10YR, 7.5YR, 5YR
Value: 3–6 dry or moist
Chroma: 3–8 dry or moist
Rock fragments: less than 50 percent gravel and cobble
Reaction: moderately acid to slightly alkaline

Bt horizon
Hue: 5YR, 2.5YR
Value: 3–5 dry or moist
Chroma: 3–8 dry or moist
Texture: clay, clay loam, sandy clay, sandy clay loam, clay
Rock fragments: 0–35 percent gravel and cobble

Btk or Bk horizon(s) (when present)
Hue: 7.5YR, 5YR
Value: 5, through 7 dry; 4–7, moist
Chroma: 4, through 8 dry or moist
Texture: loam, clay loam, sandy clay loam, sandy loam
Rock fragments: 5–50 percent gravel and less than 15 percent cobble

Competing Series: There are no competing series.

Geographic Setting: Sasabe soils are on fan terraces with slopes of 0–20 percent. They formed in stratified fan alluvium from mixed sources. Elevations range from 3,000 to 4,890 feet. The mean annual precipitation is 12–16 inches, occurring as summer thunderstorms and winter rain. The mean annual air temperature is 60°–67°F. The frost-free period is 180–240 days.

Geographically Associated Soils: These are the . . . and soils. Altar soils are loamy-skeletal and have cambic horizons. Caralampi soils are loamy-skeletal and have greater than 1 percent organic matter. Diaspar soils are coarse-loamy. Bernardino and White House soils contain greater than 1 percent organic matter.

Drainage and Permeability: Well drained; slow to medium runoff; slow or moderately permeability.

Use and Vegetation: Used for livestock grazing. Vegetation is sideoats grama, hairy grama, sprucetop grama, curlymesquite, cane beardgrass, threeawn, black grama, Rothrock grama, false mesquite, and snakeweed.

Distribution and Extent: Southern Arizona. The Sasabe soils are of minor extent. MLRA 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona, Eastern Part; 1986.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: the zone from 0 to 5 inches (A horizon)
Argillic horizon: the zone from 5 to 60 inches (Bt1, Bt2, Bt3, Bt4, 2Btk horizons)
Pale feature: an increase of 15 percent clay (absolute) at the upper boundary of the argillic horizon.

Classified according to *Soil Taxonomy*, 2nd ed., 1999,
and *Keys to Soil Taxonomy*, 10th ed., 2006.

Stagecoach Series

Location: Stagecoach, Arizona
Established Series
Rev. DRT/DLR/PDC/WWJ/RKS/HCD 06/2005

The Stagecoach series consists of very deep, well drained soils formed in mixed alluvium. Stagecoach soils are on fan terraces with slopes of 0–55 percent. The mean annual precipitation is about 11 inches and the mean annual air temperature is about 63°F.

Taxonomic Class: Loamyskeletal, mixed, superactive, thermic Typic Haplocalcids

Typical Pedon: Stagecoach very gravelly sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–1 inch; light brown (7.5YR 6/4) very gravelly sandy loam, brown (7.5YR 4/4) moist; weak thin platy structure; soft, very friable, slightly sticky and nonplastic; few very fine and fine roots; common very fine vesicular and tubular pores; 45 percent gravel; violently effervescent; moderately alkaline (pH 8.4); clear smooth boundary. (3–6 inches thick)
Bw: 1–10 inches; brown (7.5YR 5/4) gravelly sandy loam, brown (7.5YR 4/4) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and slightly plastic; common very fine and fine roots; common very fine interstitial and tubular pores; 25 percent gravel; violently effervescent; moderately alkaline (pH 8.4); clear smooth boundary. (0–10 inches thick)
Bk1: 10–24 inches; light brown (7.5YR 6/4) gravelly sandy loam, brown (7.5YR 4/4) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and slightly plastic; common very fine and fine roots; common very fine irregular and tubular pores; 25 percent gravel; violently effervescent; common faint continuous calcium-carbonate coats on rock fragments; moderately alkaline (pH 8.4); gradual wavy boundary. (10–20 inches thick)
Bk2: 24–32 inches; light brown (7.5YR 6/4) very gravelly sandy loam, brown (7.5YR 4/4) moist; massive; soft, friable, slightly sticky and slightly plastic; few very fine and fine roots; 45 percent gravel; violently effervescent; many distinct continuous calcium-carbonate coats on rock fragments and few fine rounded soft masses of calcium carbonate; 45 percent gravel; moderately alkaline (pH 8.4); gradual wavy boundary. (5–25 inches thick)
Bk3: 32–60 inches; pinkish white (7.5YR 8/2) extremely gravelly sandy loam, pink (7.5YR 7/4) moist; massive; hard, very firm, slightly sticky and slightly plastic; 60 percent gravel; violently effervescent; many distinct continuous calcium-carbonate coats on rock fragments; moderately alkaline (pH 8.4).

Type Location: Pima County, Arizona; 100 feet south and 2,500 feet east of the northwestern corner of Section 21, Township 9 South, Range 2 East. Latitude of 32°, 38 minutes, 08 seconds north and longitude of 112°, 09 minutes, 38 seconds west.

Range in Characteristics
Soil moisture: Intermittently moist in some part of the soil moisture control section during December–March and for more than 20 days cumulative during July–September. Driest during May and June. Typic aridic soil moisture regime.
Soil Temperature: 61°–72°F.
Rock Fragments: 35–85 percent
Depth to calcic: 10–25 inches
Clay content: averages less than 18 percent
Reaction: slightly to strongly alkaline

A horizon
Hue: 7.5YR, 10YR
Value: 5–8 dry; 4–7 moist
Chroma: 2–6 dry or moist

B horizon
Hue: 5YR, 7.5YR, 10YR
Value: 5–8 dry; 4–7 moist
Chroma: 2–6 dry or moist
Calcium carbonate: greater than 15 percent calcium-carbonate equivalent
Texture: sandy loam, loam, coarse sandy loam

C horizons (when present)
Some pedons contain C horizons of loamy sand with variable rock fragment content below 40 inches.

Competing Series: These are the Alemeda, Chamberino, Corazones, Dime, Nickel, Piquin, and Railroad (T) (Nevada) series. Alemeda soils have bedrock at depths of 20–40 inches. Chamberino soils average 18–27 percent clay in the control section. Piquin soils have calcic horizons at depths less than 10 inches. Chamberino, Corazones, and Piquin soils are in the Chihuahuan Desert (MLRA 42) receive mostly summer precipitation and are dry November through June. Dime, Nickel, and Railroad soils are in the Mohave Desert (MLRA 30) receive mostly winter precipitation and are usually dry from April through November.

Geographic Setting: Stagecoach soils are on fan terraces. Slope is 0–55 percent. They formed in alluvium from mixed sources. Elevation ranges from 1,800 to 5,000 feet. The mean annual precipitation ranges from 7 to 12 inches. The mean annual air temperature ranges from 59° to 70°F. The frostfree period is 200–280 days.

Geographically Associated Soils: These are the Sahuarita, Pinaleno and Palos Verdes soils. Sahuarita soils are fine-loamy. Palos Verdes and Pinaleno soils have argillic horizons.

Drainage and Permeability: Well drained; medium runoff; moderately rapid permeability.

Use and Vegetation: Used for livestock grazing and wildlife habitat. Vegetation is creosotebush, bush muhly, red grama, and Arizona cottontop.

Distribution and Extent: Southern Arizona. The series is extensive. MLRA 40.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Beaver Creek Area, Arizona; 1965.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 1 inch (A horizon)
Calcic horizon: The zone from 10 to 60 inches (Bk1, Bk2, Bk3 horizons)

The type location for Stagecoach has been moved to a more accessible area within a modern soil survey. Stagecoach soils are typical of a 10–12-inch precipitation zone within MLRA 40 of the Sonoran Desert.

Classified according to *Keys to Soil Taxonomy*, 9th ed., 2003.

Tombstone Series

Location: Tombstone, Arizona
Established Series
Rev. CLG/PDC/CEM/WWJ 09/2002

The Tombstone series consists of very deep, somewhat excessively drained soils that formed in fan alluvium. Tombstone soils are on fan and stream terraces and have slopes of 1–50 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 63°F.

Taxonomic Class: Loamyskeletal, mixed, superactive, thermic Ustic Haplocalcids

Typical Pedon: Tombstone very gravelly fine sandy loam—rangeland. (Colors are for dry soil unless otherwise noted.) Surface rocks—50–65 percent of the surface is covered with gravel and cobbles
A: 0–1 inch; grayish brown (10YR 5/2) very gravelly fine sandy loam, dark grayish brown (10YR 4/2) moist; weak thin platy structure; soft, very friable, nonsticky and nonplastic; few fine roots; few fine tubular pores; 52 percent gravel; strongly effervescent, 13 percent calcium-carbonate equivalent; moderately alkaline (pH 8.2); abrupt smooth boundary.
Bk1: 1–5 inches; dark grayish brown (10YR 4/2) gravelly fine sandy loam, very dark grayish brown (10YR 3/2) moist; massive; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; common fine tubular pores; many distinct calcium-carbonate coatings on rock fragments; 21 percent gravel; violently effervescent, 17 percent calcium-carbonate equivalent; moderately alkaline (pH 8.2); abrupt smooth boundary.
Bk2: 5–13 inches; pinkish white (7.5YR 8/2) gravelly sandy loam, pinkish gray (7.5YR 6/2) moist; massive; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; common very fine and fine tubular pores; many distinct calcium-carbonate coatings on rock fragments; 21 percent gravel; violently effervescent, 22 percent calcium-carbonate equivalent; moderately alkaline (pH 8.2); clear smooth boundary.
Bk3: 13–27 inches; pinkish gray (7.5YR 7/2) very gravelly sandy loam, pinkish gray (7.5YR 6/2) moist; massive; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; few very fine and fine tubular pores; many distinct calcium-carbonate coatings on rock fragments; 47 percent gravel; violently effervescent, 19 percent calcium-carbonate equivalent; moderately alkaline (pH 8.2); gradual smooth boundary.
Bk4: 27–60 inches; pinkish gray (7.5YR 6/2) very gravelly loamy sand, brown (7.5YR 4/2) moist; massive; soft, very friable, nonsticky and nonplastic; few fine roots; common very fine and fine irregular and tubular pores; few prominent calcium-carbonate coatings on rock fragments; 38 percent gravel; strongly effervescent, 6 percent calcium-carbonate equivalent; moderately alkaline (pH 8.0).

Type Location: Cochise County, Arizona; located at a latitude of 32°, 44 minutes, 13 seconds North and a longitude of 109°, 59 minutes, 50 seconds West; about 1,310 feet west and 2,275 feet north of the southeastern corner of Section 33, Township 19 South, Range 23 East.

Range in Characteristics
Soil Moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. Ustic aridic soil moisture regime. The epipedon is moist in some part less than 90 days (cumulative) when the soil temperature is above 41°F. in 7 out of 10 years.
Rock Fragments: Averages 35–70 percent in the particle-size control section, but ranges from 15 to 90 percent in any one horizon

Soil Temperature: 59°–70°F.
Depth to calcic horizon: 1–20 inches. Is weakly cemented in some pedons
Calcium-carbonate equivalent: Averages 20–35 percent, but ranges from 5 to 40 percent in any one horizon

A horizon
Hue: 7.5YR, 10YR
Value: 4–7 dry; 2–5 moist
Chroma: 2–4 dry or moist

Bk horizon
Hue: 7.5YR, 10YR
Value: 3–8 dry or moist
Chroma: 2, 3, or 4 dry; 1–4 moist
Texture: Sandy loam, loam, coarse sandy loam, fine sandy loam (5–18 percent clay); can range to include loamy sand and loamy coarse sand below 30 inches.

Competing Series: These are the Chilicotal, Gallen, Polar, and Powerline series. Chilicotal soils have 15–27 percent clay in the control section. Gallen soils have gypsum accumulations. Polar soils have mean annual precipitation of 16–24 inches. In addition, Gallen soils are in the PecosCanadian Plains and Valleys (MLRA 70); Polar soils are in the Central Rolling Red Plains (MLRA 78); both soils are moister in May and June. Powerline soils have bedrock at depths of 20–40 inches.

Geographic Setting: Tombstone soils are in the Sonoran and Chihuahuan deserts on fan terraces and stream terraces and have slopes of 1–50 percent. These soils formed in fan alluvium from mixed sources. Elevations range from 3,000 to 5,300 feet. The mean annual precipitation is 12–16 inches. The mean annual air temperature is 57°–68°F. The frostfree period is 160–250 days.

Geographically Associated Soils: These are the Elgin, Pedregosa and Stronghold soils. Elgin soils have argillic horizons. Pedregosa soils are very shallow and shallow to a petrocalcic horizon. Stronghold soils are coarseloamy.

Drainage and Permeability: Somewhat excessively drained; slow runoff; moderately rapid permeability.

Use and Vegetation: Tombstone soils are used for livestock grazing and wildlife habitat. Some areas are used for watershed research. The present vegetation is threeawn, black grama, sideoats grama, tarbush, whitethorn, and creosotebush.

Distribution and Extent: Central Arizona portion of the Upper Sonoran desert and southeastern Arizona portion of the Chihuahuan Desert. This series is not extensive. MLRAs 38 and 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County, Arizona; Soil survey of Pima County, Arizona, Eastern Part; 1985.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 1 inch (A horizon)
Calcic horizon: The zone from 1 to 60 inches (Bk1, Bk2, Bk3, Bk4 horizons)

The type location was moved to the DouglasTombstone Area in April 2000.

Classified according to *Soil Taxonomy*, 2nd ed., 1999.

White House Series

Location: White House, Arizona and New Mexico
Established Series
Rev. MLR/JEJ/PDC/CEM/WWJ/RKS/DWD 01/2005

The White House series consists of very deep, well drained soils that formed in fan alluvium from mixed sources. White House soils are on fan terraces and have slopes of 0–35 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 62°F.

Taxonomic Class: Fine, mixed, superactive, thermic Ustic Haplargids

Typical Pedon: White House gravelly loam—rangeland. (Colors are for dry soil unless otherwise noted.)
A: 0–3 inches; brown (7.5YR 5/4) gravelly loam, dark brown (7.5YR 3/2) moist; weak thin platy structure parting to moderate fine granular; slightly hard, friable, nonsticky and slightly plastic; many very fine and fine roots; common fine irregular pores; 15 percent gravel; moderately acid (pH 5.6); clear smooth boundary. (2–8 inches thick)
Bt1: 3–9 inches; reddish brown (5YR 5/4) clay loam, dark reddish brown (5YR 3/4) moist; weak medium subangular blocky structure; hard, friable, moderately sticky and moderately plastic; common fine and very fine roots; few fine and very fine tubular pores; few faint clay films on faces of peds; 2 percent fine gravel; slightly acid (pH 6.2) clear smooth boundary. (5–18 inches thick)
Bt2: 9–22 inches; reddish brown (5YR 4/4) clay, dark reddish brown (5YR 3/4) moist; moderate medium and coarse prismatic structure; hard, firm, moderately sticky and moderately plastic; common fine and very fine roots; few very fine irregular and tubular pores; many distinct clay films on faces of peds; 2 percent fine gravel; neutral (pH 7.0); clear wavy boundary. (9–26 inches thick)

Btk1: 22–26 inches; dark red (2.5YR 3/6) clay, dark red (2.5YR 3/6) moist; moderate medium and coarse subangular and angular blocky structure; hard, firm, moderately sticky and moderately plastic; common fine roots; few fine tubular pores; many distinct clay films on faces of peds; common pressure faces; common medium slickensides; 2 percent gravel; 9 percent calcium-carbonate equivalent; strongly effervescent; moderately alkaline (pH 8.0); clear wavy boundary. (3–10 inches thick)
Btk2: 26–39 inches; mixed red (2.5YR 4/6) and pink (5YR 7/4) clay loam, dark red (2.5YR 3/6) and light reddish brown (5YR 6/4) moist; weak medium subangular blocky structure; hard, friable, sticky and plastic; few fine roots; few very fine and fine tubular pores; common faint clay films on faces of peds; 5 percent gravel; common medium irregular calcium-carbonate masses; 10 percent calcium-carbonate equivalent; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary. (6–15 inches thick)
Bk1: 39–49 inches; mixed yellowish red (5YR 5/6) and pink (5YR 7/4) sandy clay loam, yellowish red (5YR 4/6) and light reddish brown (5YR 6/3) moist; massive; hard, friable, slightly sticky and moderately plastic; few very fine tubular and irregular pores; 10 percent medium and coarse gravel; few fine and medium calcium-carbonate masses; 2 percent calcium-carbonate equivalent; slightly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary. (8–12 inches thick)
Bk2: 49–60 inches; mixed yellowish red (5YR 5/8) and pink (5YR 7/3) very gravelly sandy clay loam, yellowish red (5YR 4/6) and light reddish brown (5YR 6/3) moist; massive; hard, friable, moderately sticky and moderately plastic; few very fine irregular pores; 35 percent medium and coarse gravel; few fine calcium-carbonate masses; 2 percent calcium-carbonate equivalent; slightly effervescent; moderately alkaline (pH 8.0).

Type Location: Santa Cruz County, Arizona; 1.3 miles east southeast of Highway 83 and .1 mile south of the El Paso Natural Gas pipeline in the San Ignacio Del Babocomari Grant, 3 miles south and 4.5 miles east of Sonoita in Section 11, Township 21 South, Range 17 East.

Range in Characteristics
Soil Moisture: Intermittently moist in some part of the soil moisture control section during July–September and December–February. Driest during May and June. Ustic aridic soil moisture regime.
Soil Temperature: 59°–70°F.
Rock Fragments: Averages less than 35 percent in the control section
Organic matter: Averages 1 percent or more in the surface
Reaction: moderately acid through moderately alkaline
A horizon
Hue: 2.5YR, 5YR, 7.5YR
Value: 3–6 dry or moist
Chroma: 2–6 dry or moist

Bt horizons
Hue: 2.5YR, 5YR, 7.5YR
Value: 3–6 dry or moist
Chroma: 2–8 dry or moist
Texture: Clay loam, clay, sandy clay loam, sandy clay (averages more than 35 percent clay)

B, Bk, or C horizons
Hue: 2.5YR through 10YR
Value: 3–8 dry; 3–7 moist
Chroma: 2–8 dry or moist
Texture: Sandy clay loam, clay loam, clay
Some pedons contain thin layers of coarse sandy loam, loamy sand, or loamy coarse sand at depths greater than 25 inches.

Competing Series: There are no competing series.

Geographic Setting: White House soils are on fan terraces and have slopes of 0–35 percent. These soils formed in fan alluvium from mixed sources. Elevations range from 3,000 to 5,400 feet. The mean annual precipitation is 12–16 inches. The mean annual air temperature is 57°–67°F. The frostfree period is 160–250 days.

Geographically Associated Soils: These are the Forrest and Bernardino soils. In addition is the Caralampi soil. Caralampi soils are loamyskeletal. Forrest and Bernardino soils have calcic horizons.

Drainage and Permeability: Well drained; slow or medium runoff; slow or very slow permeability.

Use and Vegetation: White House soils are used for livestock grazing and wildlife habitat. A few areas are used for homesites and other urban uses. Present vegetation is grama grasses, plains lovegrass, wolftail, curly mesquite, tobosa, and mesquite.

Distribution and Extent: Southern Arizona. This series is extensive. MLRAs 38 and 41.

MLRA Office Responsible: Phoenix, Arizona

Series Established: Pima County (Tucson Area), Arizona; 1931.

Remarks
Diagnostic horizons and features recognized in this pedon are as follows:
Ochric epipedon: The zone from 0 to 3 inches (A horizon)
Argillic horizon: The zone from 3 to 39 inches (Bt1, Bt2, Btk1, Btk2 horizons)

Classified according to *Keys to Soil Taxonomy*, 9th ed., 2003.

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