CULTURAL RESOURCE

TECHNICAL SERIES 2015-3

NMDOT

LA 159879: A Late Archaic/Early Agricultural Period Site in the Mimbres Bolson, Near Deming, Luna County, New Mexico

Office of Archaeological Studies Museum of New Mexico
Archaeology Notes 456

NMDOT Project CN G3721; G3731
NMCRIS Activity No. 132231

NEW MEXICO DEPARTMENT
OF TRANSPORTATION

NMCRIS Activity No.: 132231

MUSEUM OF NEW MEXICO
~
OFFICE OF ARCHAEOLOGICAL STUDIES

LA 159879: A Late Archaic/Early Agricultural Period Site in the Mimbres Bolson, Near Deming, Luna County, New Mexico

BY

Nancy J. Akins, Matthew J. Barbour, Robert Dello-Russo, and Stephen C. Lentz

WITH CONTRIBUTIONS BY

Jeffrey L. Boyer
Pamela J. McBride
James L. Moore
Donald E. Tatum
Karen Wening

Robert Dello-Russo, Ph.D.
Principal Investigator

NMCRIS Activity No. 132231
NMDOT Project CN G3721 and G3731
MNM Project No. 41.928 [US 180]
State Permit No. SE-303

ARCHAEOLOGY NOTES 456

SANTA FE 2015 NEW MEXICO

NMCRIS INVESTIGATION ABSTRACT FORM (NIAF)

1. NMCRIS Activity No.: 132231	**2a. Lead (Sponsoring) Agency**: US Department of Transportation, Federal Highway Administration	**2b. Other Permitting Agency(ies):**	**3. Lead Agency Report No.:**

4. Title of Report: LA 159879: A Late Archaic/Early Agricultural Period Site in the Mimbres Bolson, Near Deming, Luna County, New Mexico **Author(s):** Nancy J. Akins, Matthew J. Barbour, Robert Dello-Russo, and Stephen C. Lentz	**5. Type of Report** ☐ **Negative** ☒ **Positive**

6. Investigation Type

☐ Research Design ☐ Survey/Inventory ☐ Test Excavation ☒ Excavation ☐ Collections/Non-Field Study
☐ Overview/Lit Review ☐ Monitoring ☐ Ethnographic study ☐ Site specific visit ☐ Other

7. Description of Undertaking (what does the project entail?): Between March 21 and April 15, 2011, data recovery was performed at LA 159879, an archaeological site located slightly north of the City of Deming near the intersection of NM 26 and US 180 and between Milepost 163 and Milepost 164, in Luna County, New Mexico. The project was performed by the Department of Cultural Affairs, Office of Archaeological Studies (OAS) at the request of Mr. Blake Roxlau and Ms. Janet McVickar of the New Mexico Department of Transportation (NMDOT) in preparation of highway construction widening.	**8. Dates of Investigation:** March 21, 2011, to April 15, 2011 **9. Report Date**: February 2, 2015
10. Performing Agency/Consultant: **Principal Investigator:** Robert Dello-Russo **Field Supervisor**: Matthew J. Barbour and Stephen C. Lentz **Field Personnel Names**: Richard Montoya, Isaac Coan, Donald E. Tatum, Mary Weahkee, Gavin Bird, Vernon Foster	**11. Performing Agency/Consultant Report No.:** Office of Archaeological Studies/Museum of New Mexico/Department of Cultural Affairs **12. Applicable Cultural Resource Permit No.:** State Permit No. SE-303
13. Client/Customer (project proponent): **Contact:** Laurel Wallace, Cultural Resources Coordinator **Address:** NMDOT P.O. Box 1149, Santa Fe NM 87504 **Phone:** 505-827-9899	**14. Client/Customer Project No.:** NMDOT Project CN G3721 and G3731

15. Land Ownership Status *(<u>Must</u> be indicated on project map)*:

Land Owner	Acres Surveyed	Acres in APE
NM Department of Transportation	0	4.58
TOTALS	**0**	**4.58**

16 Records Search(es):

Date(s) of ARMS File Review	**Name of Reviewer(s) Matthew Barbour**	**5/4/2011**
Date(s) of NR/SR File Review	**Name of Reviewer(s)**	
Date(s) of Other Agency File Review	**Name of Reviewer(s)**	**Agency**

17. Survey Data:

a. Source Graphics ☐ NAD 27 ☒ NAD 83 Note: NAD 83 is the NMCRIS standard

X USGS 7.5’ (1:24,000) topo map ☐ Other topo map, Scale:

☒ GPS Unit Accuracy ☒<1.0m ☐ 1-10m ☐ 10-100m ☐ >100m

b. USGS 7.5' Topographic Map Name USGS Quad Code

USGS 7.5' Topographic Map Name	USGS Quad Code
Deming West, NM Quadrangle	32107-C7

c. County(ies): Luna County

17. Survey Data (continued):

d. Nearest City or Town: Deming, New Mexico

e. Legal Description:

Township (N/S)	Range (E/W)	Section	¼ ¼ ¼
23N	9E	22	, , .
			, , .
			, , .
			, , .
			, , .
			, , .
			, , .
			, , .
			, , .

Projected legal description? ☐ **Yes** ☒ **No** ☐ **Unplatted**

f. Other Description (e.g. well pad footages, mile markers, plats, land grant name, etc.):
Between mile markers 163 and 164 of US 180 just north of Deming, New Mexico**.**

18. Survey Field Methods:

Intensity: ☐ 100% coverage ☐ <100% coverage

Configuration: ☐ block survey units ☐ linear survey units (l x w): ☐ other survey units (specify):

Scope: ☐ non-selective (all sites recorded) ☐ selective/thematic (selected sites recorded)

Coverage Method: ☐ systematic pedestrian coverage ☐ other method (describe)

Survey Interval (m): **Crew Size:** **Fieldwork Dates:**

Survey Person Hours: **Recording Person Hours:** **Total Hours:**

Additional Narrative:

19. Environmental Setting (NRCS soil designation; vegetative community; elevation; etc.):
Located approximately 0.5 miles north of the Mimbres River, LA 159879 is situated within the northern reaches of the Mimbres Bolson or Deming flood plain. Here, the Mimbres River is an intermittent wash, an unreliable stream in an otherwise moisture-deprived area. Both alluvial and eolian soils occur in the general area. Depth of these soils varies, but all are coarse-textured and are susceptible to erosion. The area is dominated by Chihuahua Desert vegetation, including mesquite, yucca, salt bush, and dropseed grasses. The area receives moisture from a bimodal precipitation pattern of winter rains with the occasional snowfall and summer thunderstorms. Winter moisture occurs as gentle showers, whereas summer precipitation can be intense events, occurring sporadically throughout the basin. As a result heavy rains can transform the basin into a series of shallow playas and the Mimbres River can swell into a raging torrent. Despite the likelihood of heavy precipitation events, the average annual rainfall for the area is between 8 and 12 inches per year.

20.

a. Percent Ground Visibility: **b. Condition of Survey Area (grazed, bladed, undisturbed, etc.):**

21. CULTURAL RESOURCE FINDINGS ☒ **Yes, see next report section**
☐ **No, Discuss Why:**

22. Required Attachments (check all appropriate boxes): All of the information below is included in the attached report. ☒ **USGS 7.5 Topographic Map with sites, isolates, and survey area clearly drawn** ☐ **Copy of NMCRIS Mapserver Map Check** ☐ **LA Site Forms - new sites (*<u>with sketch map & topographic map</u>*)** ☒ **LA Site Forms (update) - previously recorded & un-relocated sites (*<u>first 2 pages minimum</u>*)** ☐ **Historic Cultural Property Inventory Forms** ☐ **List and Description of isolates, if applicable** ☐ **List and Description of Collections, if applicable**	**23. Other Attachments:** ☐ **Photographs and Log** ☐ **Other Attachments** ***(Describe)*:**

24. I certify the information provided above is correct and accurate and meets all applicable agency standards.

Principal Investigator/Responsible Archaeologist:

Signature **Date 1-26-15** **Title (if not PI):**

25. Reviewing Agency: **Reviewer's Name/Date** **Accepted ( ) Rejected ( )** **Tribal Consultation (if applicable):** ☐ **Yes** ☐ **No**	**26. SHPO** **Reviewer's Name/Date:** **HPD Log #:** **SHPO File Location:** **Date sent to ARMS:**

CULTURAL RESOURCE FINDINGS

[fill in appropriate section(s)]

1. NMCRIS Activity No.: 132231	**2. Lead (Sponsoring) Agency:** US Department of Transportation, Federal Highway Administration	**3. Lead Agency Report No.:**

SURVEY RESULTS:
Sites discovered and registered: 0
Sites discovered and NOT registered: 0
Previously recorded sites revisited (*site update form required*): 1
Previously recorded sites not relocated *(site update form required):* 0
TOTAL SITES VISITED:
Total isolates recorded: 0
Non-selective isolate recording? ☐
HCPI properties discovered and registered: 0
HCPI properties discovered and NOT registered: 0
Previously recorded HCPI properties revisited: 0
Previously recorded HCPI properties not relocated 0
TOTAL HCPI PROPERTIES (visited & recorded, including acequias): 0

MANAGEMENT SUMMARY:

IF REPORT IS NEGATIVE YOU ARE DONE AT THIS POINT.

SURVEY LA NUMBER LOG
Sites Discovered:

LA No.	Field/Agency No.	Eligible? (Y/N, applicable criteria)

Previously recorded revisited sites:

LA No.	Field/Agency No.	Eligible? (Y/N, applicable criteria)
159879		Eligible criterion d

MONITORING LA NUMBER LOG *(site form required)*

Sites Discovered (*site form required*) **:** **Previously recorded sites *(Site update form required):***

LA No.	Field/Agency No.	LA No.	Field/Agency No.

Areas outside known nearby site boundaries monitored? Yes ☐, No ☐ If no explain why:

TESTING & EXCAVATION LA NUMBER LOG (*site form required*)

Tested LA number(s)	Excavated LA number(s)
	159879

ADMINISTRATIVE SUMMARY

Between March 21 and April 15, 2011, data recovery efforts were completed at LA 159879, an archaeological site located just north of the city of Deming near the intersection of NM 26 and US 180 and between Milepost 163 and Milepost 164 of US 180, in Luna County, New Mexico. The project was performed by the Department of Cultural Affairs' Office of Archaeological Studies (OAS) at the request of Mr. Blake Roxlau and Ms. Janet McVickar of the New Mexico Department of Transportation (NMDOT), in preparation for highway construction to widen US 180.

Data-recovery efforts were undertaken on 100 percent of the site within the Area of Potential Effect (APE), which extended 38 m east of the right-of-way fence. Specific treatments for archaeological resources followed field methods discussed in a data recovery plan (DRP) developed by DMG Four Corners Research, Inc. (Greenwald et al. 2009). These efforts resulted in the documentation of 25 features, 21 of which were thermal and residential features, and the collection of 2,091 artifacts and samples including diagnostic projectile points. Analytical results suggest that the occupants of this Late Archaic/Early Agricultural–period base camp exploited both wild and domestic plant species growing along the floodplain of the Mimbres River. Evidence for early corn and cotton were found in association with several features at the site including phytoliths, pollen, and carbonized kernel fragments. The most accurate radiocarbon dates for the corn remains are 758–429 cal BC (2 sigma). Cotton pollen was identified beneath a ground stone artifact associated with an ephemeral structure; the most accurate dates recovered for the structure were between 897 and 774 cal BC (2 sigma). This indirect date for cotton is consistent with early cotton dates in southeast Arizona and may currently be the oldest evidence of domesticated cotton in New Mexico.

Based on the data-recovery results, LA 159879 remains recommended as "eligible" for inclusion on the *National Register of Historic Places* (NRHP) under Criterion 'd.' However, since no intact archaeological materials or features remain in the location designated for road modification activities, OAS recommended that the client proceed with its activities within the areas treated during the OAS data recovery program. If future construction activities are expanded to include areas outside the APE, further work at LA 159879 may be necessary.

NMCRIS Activity No. 132231
NMDOT Project CN G3721 and G3731
MNM Project 41.928 [US 180]
State Permit No. SE-303

Frontispiece: Florida Mountains, southeast of Deming.

ACKNOWLEDGMENTS

We would like to thank Laurel Wallace, Janet McVickar, and the New Mexico Department of Transportation for their continued support of archaeological research in New Mexico; Susan Smith for the early cotton references; the residents of Deming, New Mexico, and Dollarhide Construction for their continuing interest in archaeology; and the volunteers and OAS field personnel whose hard work made this report possible.

CONTENTS

FIGURES LIST

TABLES LIST

1 Introduction

LA 159879 was first recorded in 2008, for proposed NMDOT work along US 180, between mileposts 122 and 165 (Harris et al. 2008), and found to extend into the project Area of Potential Effect (APE). LA 159879 is located partially within the US 180 east right-of-way, extending further east onto privately owned land located toward the Mimbres River floodplain (Appendix 5: Figs. A5.1, A5.2). The site was originally described in 2008 as a large prehistoric artifact and fire-cracked rock scatter with the potential to inform on settlement patterns and subsistence strategies during the Late Archaic or Early Agricultural period (ca. 900 BC–AD 400) (Harris et al. 2008). Consultation with the New Mexico Historic Preservation Division determined that LA 159879 was eligible under Criterion 'd' (HPD Log No. 86402, signed May 4, 2009).

A research design and data recovery plan (DRP) for the proposed widening of US 180 from a two-lane to a four-lane highway was prepared by DMG Four Corners Research, Inc. (Greenwald et al. 2009) and approved by HPD. Because the NMDOT contract with DMG Four Corners Research had expired and the project needed to move forward, Mr. Blake Roxlau and Ms. Janet McVickar of NMDOT requested that the Office of Archaeological Studies (OAS) conduct the data recovery program. The DMG Four Corners Research DRP and field methods were re-approved by the New Mexico Cultural Properties Review Committee (CPRC) on March 11, 2011.

Between March 21 and April 15, 2011, OAS archaeologists performed archaeological excavations at LA 159879 in the area north of the intersection of NM 26 and US 180 between Milepost 163 and Milepost 164 of US 180, in Luna County, New Mexico (Fig. 1.1; Appendix 5, Fig. A5.1). The site measures 324.6 m northwest–southeast and 102 m northeast–southwest, encompassing an area of roughly 23,069 sq m. Systematic excavation was conducted within the NMDOT-defined APE, which extended 38 m to the east of the right-of-way fence (12,412 sq m, or 53.8 percent of the total site area). This resulted in the documentation of 21 features and four non-features and the collection of over 2,000 artifacts and samples. The field crew consisted of Richard Montoya, Isaiah Coan, Karen Wening, Mary Weahkee, Gavin Bird, and Vern Foster. Stephen C. Lentz and Matthew J. Barbour were co-project directors; Donald E. Tatum served as the geomorphologist. Robert Dello-Russo Ph.D., Deputy Director, OAS, was the principal investigator. The Deming-based firm Dollarhide Construction LLC performed mechanical excavations. In all, 155 person-days were spent on fieldwork.

Archaeological work performed by OAS complied with the plan set forth in the DRP (Greenwald et al. 2009). The area excavated by OAS along US 180 has been constructed, with new rights-of-way purchased and roadway improvements completed. The portion of LA 159879 that presently extends beyond the US 180 right-of-way onto privately owned lands contains in situ cultural remains. Potential future impacts to this remaining site portion will require formal consultation and mitigation treatments.

Local residents have known about the site and have collected chipped and ground stone tools from the area since at least the 1930s (Olin Offutt, personal communication to Stephen Lentz, March 23, 2011). These activities have likely diminished the integrity and the data content of LA 159879.

This document outlines the results of archaeological investigations at LA 159879 and addresses the questions proposed in the DRP. These questions

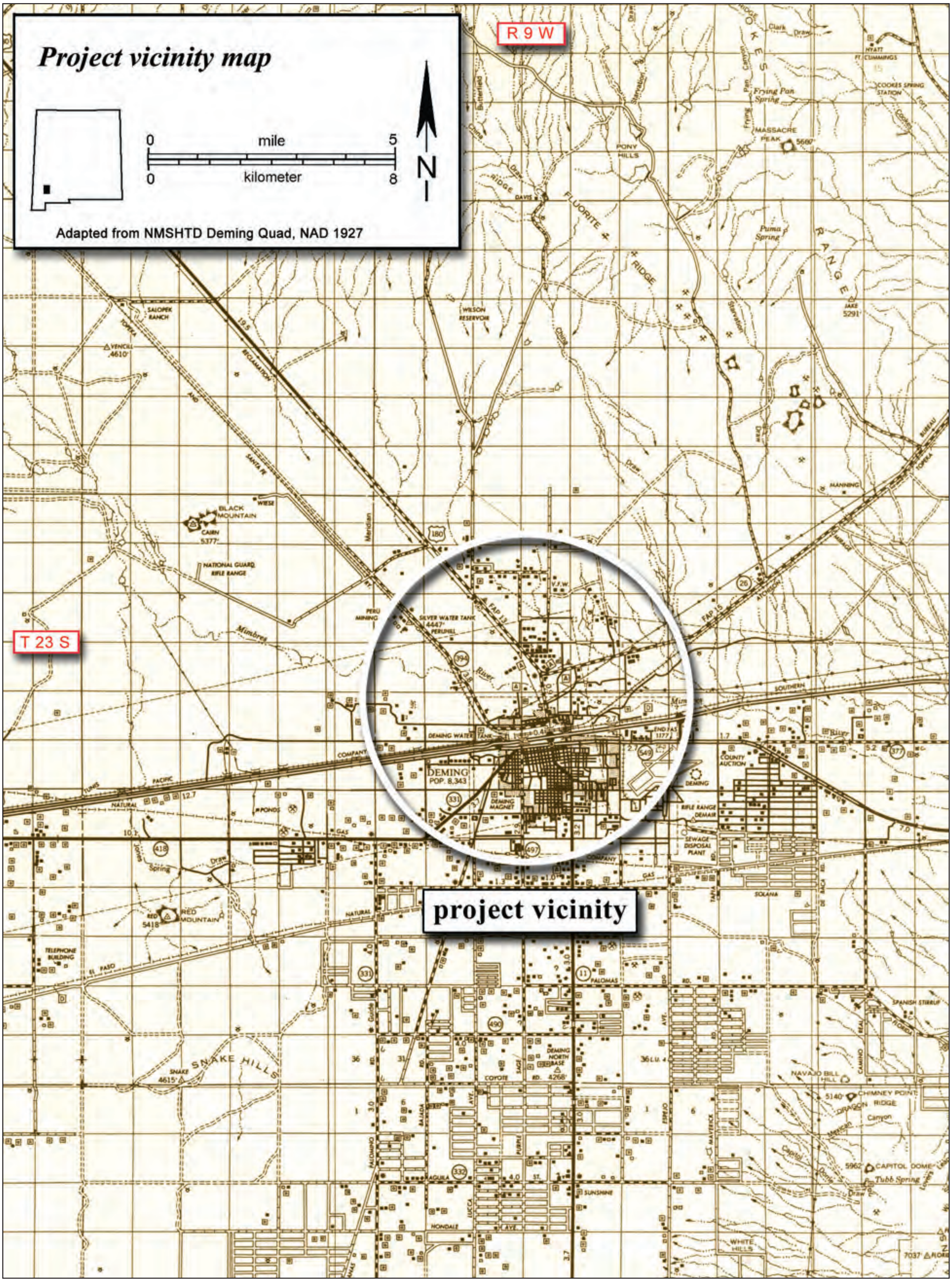


Figure 1.1. LA 159879, project vicinity map.

focus primarily on chronology, site function, and subsistence patterns. Our conclusions suggest that LA 159879 functioned as a Late Archaic/Early Agricultural–period base camp.

SITE SETTING

DONALD E. TATUM

Physiography and Geology

LA 159879 is situated in the central part of the down-faulted Mimbres Basin (also referred to in this report as the Mimbres Bolson), which is defined by the juncture of three distinct tectonic provinces all comprising part of the eastern Mexican Highlands. On the east side, the basin is transitional to the Rio Grande Rift province, while the western and southern parts of the basin are extensional from the Basin and Range province. The northern part of the Mimbres Basin is transitional to the Colorado Plateau. The Mexican Highlands occupy the lower Rio Grande valley of New Mexico, trans-Pecos Texas, and Chihuahua, Mexico, and the San Pedro valley in southeast Arizona. The inter-mountain bajadas and basins of the Rio Grande Rift and Mexican Highlands below 1,424 m (4,672 ft) in elevation comprise a vast part of the Chihuahuan Desert. The basins occupy 60 to 80 percent of the Highlands area and are bordered by block-faulted, north-trending mountain ranges of Cenozoic, Mezozoic, Paleozoic, and Precambrian age (Morrison 1985, 1991). The basins are characterized by broad, internally drained alluvial plains terminating in pluvial lake (playa) basins or bolsons (Hill 1900). With few exceptions the bolsons lack deeply incised valleys and integrative drainages.

During the Miocene and Pliocene periods, Mimbres Basin fill sediments derived from the surrounding hills and ranges aggraded into the north- and northwest-trending, structural sub-basins that form the valley floor sections. The thickest alluvial fill occurs near Deming and is more than 1,316 m (4,318 ft) deep (INTERA, Inc., 2009). In the southern part of the Mimbres Basin, Pliocene and younger basalts overlie valley fill alluvial deposits (Heywood 2002).

During extreme pluvial periods in the late Pleistocene and early Holocene, the Mimbres River drained into Lake Palomas in the Los Muertos Basin in northwest Chihuahua (Love and Seager 1996). This was the largest pluvial lake in the region and was also the terminal drainage basin of the ancestral Rio Grande during Pliocene and early Pleistocene times (Reeves 1969; Hawley and Kottlowski 1969; Hanson et al. 1994).

Occupying about 13,300 sq km, the Mimbres Basin is almost equal in size to the Tularosa Basin. The surface extent of the closed and partially internally drained basin is defined by the topographically determined surface watershed. Unlike the Tularosa Basin, where the watershed originates in mountain slopes bordering the basin along both sides and extending for most of its length, the main watershed for the Mimbres Basin originates at its north end. The Mimbres River trends axially down the center of the northern part of the basin, where it is bordered along the east side by two north-trending ranges, the Black Range and the Mimbres Mountains. Farther to the south, the east side of the basin is bounded by the Good Sight Mountains, the Sierra de Las Uvas, the Sleeping Lady Hills, the Aden Hills, and the West Portillo Mountains, where the watershed crosses the international border and terminates in the Los Muertos Basin. Along the southwestern edge of the Mimbres Basin, the basin is bordered by the east-trending Sierra Boca Grande in Chihuahua, the Carizalillo Hills immediately to the north of the international border, and the Cedar Mountain Range. The western and northwestern edges of the basin are defined by north-trending sub-ranges of the Continental Divide: the Little Burro and Big Burro Mountains, the Pinos Altos Range, and Reeds Peak in the Black Range.

Hydrologically, the topographic prominences defining the basin margins contribute significant amounts of water to the aquifer. Precipitation falling on the mountain slopes drains toward the center of the basin in intermittent streams and travels as groundwater through alluvial sediments underlying the stream channels, eventually filtrating to the water table. Mimbres headwaters originating in the Continental Divide and the Mimbres Mountains contribute the most to the surface watershed area, sustaining a permanent flow in the Mimbres River until it reaches the valley floor north of Deming (New Mexico Water Research Institute 2011; Heywood 2002). During an exploratory survey for a Mississippi River to Pacific Ocean railway route in 1856, Thomas Antisell described the terminus of the Mimbres as a free-flowing surface waterway at its point of dissipation on the valley floor as "*a large collection of fresh standing water in pools or lagoons, surrounded by willow thickets*" (Blake et al. 1856).

LA 159879 occupies the lower margin of a broad alluvial slope descending from the southern and southwestern flanks of Cookes Range and Goat Ridge. The site is on the low-relief crest of a linear, southeast-trending alluvial terrace. The finger terrace forms the southwestern border for one of an extensive network of alluvial distributary channels providing avenues for runoff to the Mimbres drainage from the steep highlands to the north. The location is less than a half mile (0.8 km) north of the incised Mimbres channel, 16 km (9.9 mi) upriver from the terminus of the channel incision marking the point of high-flow dispersal across the bolson of the Florida sub-basin. The site is 12 km (7.5 miles) northeast of the apex of the Deming Fan, a multi-stage sequence of fluvial deposits created at the head of the Seventy-six sub-basin when the incised Mimbres channel was overrun during late Pleistocene-early Holocene periods of extraordinarily high flow (Love and Seager 1996).

The Seventy-six sub-basin is separated from Florida sub-Basin to its east by the Florida and Little Florida Mountains. The sedimentary, igneous, and metamorphic complex comprising the Florida Mountains has evolved into an eastward-tilted, block-faulted assemblage of craggy summits and steep-walled, deeply incised canyons (Clemons 1998). The Little Florida Mountains were derived from uplifted interbeds of middle Tertiary-aged andesitic, dacitic, and rhyolitic ash-flow tuffs and lavas (McLemore and Dunbar 2000). The Seventy-six sub-basin and the Florida sub-basin converge on the southeast side of the Florida Mountains at the Columbus sub-basin, which is bounded to the west by the Tres Hermanas Mountains and to the east by the West Potrillo Mountains (Love and Seager 1996). The Columbus sub-basin integrates into the Los Muertos Basin in Chihuahua, Mexico, defining the maximum southerly extent of the Mimbres Basin (Love and Seager 1996; Reeves 1969; Hanson et al. 1994).

Modern Climate: Precipitation, Temperature, and Growing Season

Environment, landscape, human health, prosperity, and behavior are linked to elements of weather and climate. Aspects of climate such as precipitation quantity and type, temperature, humidity, number of frost-free and freezing days, evaporation, and storm patterns have major impacts on human behavior. Agricultural practices such as livestock grazing, dryland farming, irrigation farming, and other food procurement practices like hunting, fishing, and foraging are controlled by climate. Settlement patterns, the selection of suitable sites for dwellings, gathering places, and transportation routes are critically influenced by weather patterns. Climate is also a major determining factor in the establishment of vegetation communities and ecosystems that thrive within them, affecting the viability of wild plant foods, game animal, and fish populations (Calvin 1934; Scurlock 1998).

Human attempts to exploit and manipulate resources can result in drastic ecological changes with negative consequences for human behavior. For example, the mid- to late nineteenth-century grazing by large herds of cattle and sheep resulted in widespread overgrazing and depletion of native grasses. Deprived of its protective grass coating, the arid landscape was dramatically altered by wind deflation and erosion, which contributed to the formation of coppice dunes and colonization by desert shrub species (Allen et al. 2003; Fredrickson et al. 2006; Monger and Bestelmeyer 2006; Ogburn 2006). Havstad and Beck (1995) conducted vegetation studies on 58,492 hectares (ha) of land in the Jornada Basin. From their reconstruction of land surveyors' notes from 1858, they deduced that "good" grass cover was present on more than 90 percent of the study area. By 1963, less than 25 percent of the area had good grass cover; instead, the land was occupied by honey mesquite, creosote bush, and tarbush, effectively altering the land's ability to support grazing animals. Another unintentional side-effect of overgrazing with unwelcome consequences is arroyo cutting, the result of high-volume runoff from seasonal torrential rains flowing downhill across a denuded landscape, incising and transporting exposed soil and re-depositing it down valley (Monger and Bestelmeyer 2006). Ultimately, this changes the base level of the drainage system, potentially resulting in increased frequency of flooding and more erosion (Thornbury 1954).

The climate of the Mexican Highlands/Rio Grande Rift is as variable and diverse as the landscape with which it articulates. Climate variability in the region reflects both seasonal and daily weather and terrain dynamics. The moisture regime ranges from arid to semi-arid, allowing for rapid heat accumulation in the atmosphere during the day and rapid heat radiation at night, resulting in pronounced diurnal temperature fluctuations—hot or warm summer days, cool summer nights; warm or cool winter days, freezing winter nights. Daytime/nighttime temperature fluctuations of 4.45° C (40° F) are not uncommon during both winter and summer. This climate variability is robust for several reasons: New Mexico spans six degrees of latitude; for every degree of latitude the mean temperature change is between 1.5 and 2.5° F. The territory is far from coastal areas, where oceanic currents tend to drive atmospheric currents, thus moderating humidity and temperature. It is geographically close to regions with cooler, moister climates, which can influence the climate of neighboring regions. Many parts of New Mexico, such as the Mimbres Mountains and the Black Range, are of moderate to high elevation; for every 328 m (1,076 ft) of elevation gain, temperature decreases by 15.8–15° F. Also, dramatic variations in regional landscapes sometimes result in diverse, small-scale climate variations. Two similar landforms that are a few dozen kilometers apart on the same geographic parallel, separated by a geomorphically divergent landform, may have seasonally disparate temperatures and rainfall, as when a mountain range obstructs prevailing weather patterns. The result is a localized variation in storm track patterns, such as the "rain shadow effect," as occurs when the lea, or downwind side, of the mountain range receives less precipitation due to the blockage of the prevailing weather pattern by the topographic prominence (Tuan et al. 1973; Haugland 2010).

Elevation and topographic variables have other influences on temperature and amount of precipitation that can fall on a given area, such as the orographic effect. If a moisture-laden air mass is forced up and over the Black Range by prevailing winds, the moisture will condense at altitude, as precipitation, consistently resulting in more rainfall or snowfall with higher elevation on the windward side of the mountains. In the Mimbres Basin the climate is low-humidity, arid to semi-arid, precipitation is orographically controlled, and temperatures are subject to large diurnal variation. From 1941 to 1970, mean annual precipitation ranges were between 22.86 cm (9 in) in the southern part of the basin to 60 cm (23.6 in) on higher-elevation mountain slope of the Black Range (Hansen et al. 1994; Daniel B. Stephens and Associates 2005). Because higher-elevation landforms have lower temperatures and more precipitation, they also have a lower rate of evaporation; thus, they are extremely important contributors to aquifer recharge (Newton et al. 2009).

The precipitation regime in the Mimbres Basin is bimodal. One-third to one-fourth of the precipitation occurs as lower elevation rainfall and higher elevation snowfall between December and March. Most of the precipitation occurs during the months July through September as seasonal North American monsoon (NAM) thunderstorms, the primary source of warm season rainfall. The NAM is initiated when moist air from the Gulf of California and the eastern Pacific Ocean is deflected into the southwestern United States/northwestern Mexico by low atmospheric pressure resulting from solar heating of the earth's surface. An additional source of moisture-laden air comes from easterly winds blowing across the Gulf of Mexico. Tropical disturbances such as tropical depressions, tropical storms, or hurricanes originating in the eastern Pacific or Gulf of Mexico can also contribute very significant amounts of rainfall to the continental interior southwest. Mid-latitude frontal storms also contribute rainfall or snow to the region throughout the year, but especially in winter, as the storms track southeast across a cooling land surface from the northwest Pacific coast (Newton et al. 2009).

Not only are heating and cooling effects on the land surface major drivers behind seasonal precipitation events. Large-scale temperature variations in the Pacific Ocean also have major effects on the strength of wet-season storms on the continental United States. "El Niño" occurs when water off the coast of South America becomes unusually warm. The result causes winter storms to track farther south across North America, increasing the precipitation budget of the winter storm season in the southwest. In other years, cooler water develops off the South American coast, pushing the winter storm track farther north and decreasing winter storm moisture contribution in the southwestern United States.

Precipitation falling on the mountain slopes drains toward the center of the basin in intermittent streams feeding into the Mimbres River or travels as groundwater through alluvial sediments underlying the stream channels. At the apices of the alluvial fans some runoff precipitation infiltrates to the water table. As the remaining runoff reaches the valley floor, some of it flows into the basin and coalesces in playas and evaporates. Because snow melt achieves greater subsurface saturation than fast-flowing monsoonal precipitation, the water table receives more water from winter storms than from the summer monsoons (INTERA, Inc., 2009).

The mountain ranges and high mesas defining the boundaries of the Mimbres Basin display considerable variation in rainfall amount and frost-free days, not only by region, but from year to year as well. The number of frost-free days available for cultivating food crops, as with precipitation and temperature, is closely tied to elevation, slope, and cyclical weather patterns.

In the vicinity of Reeds Peak in the Black Range, which defines the northern end of the Mimbres Basin, the elevation is about 3,051 m (10,011 ft). The average growing season is about 120 frost-free days. The first killing frost occurs on average about September 30. The mean occurrence of the last killing frost is about May 30. The Black Range receives an average of about 60 cm (23.6 in) of precipitation per year. About 81 km (50.3 mi) southwest of Reeds Peak, the Continental Divide crosses Burro Peak at 2,449 m (8,035 ft) elevation, defining a point along the northwest edge of the Mimbres Basin. During a period of two years of record, a weather station recorded an average of 54.19 cm (21.34 in) per year. The first killing frost occurs on average about October 30. Average occurrence of the last killing frost is about April 5. The mean annual temperature was about 10.3° C (50.5° F).

The lowest altitude portion of the Mimbres Basin is near the boundary with the Los Muertos Basin, south of the international border in the southeast quadrant of the basin. With the arrival of a relatively lengthy growing season in the basin floor of 220 days, the last killing frost occurs about March 20. At Deming, near the center of the basin, the elevation is 1,320 m (4,331 ft). A weather station there recorded temperature and precipitation data over a 118-year period of record (1892–2010). The town received an average of 23.8 cm (9.37 in) of rainfall per annum. The mean annual temperature for this time period was 15.75° C (60.35° F). The lower elevations of the Mimbres Basin are an arid, hot, and windy environment in which total evaporation greatly exceeds total precipitation received (Gabin and Lesperance 1977; Tuan et al. 1973; Western Regional Climate Center 2011).

Without the use of controlled irrigation, the ability to successfully sustain subsistence agriculture is completely dependent on the spatial and seasonal weather dynamics. The variability of topography, of seasonal and daily temperature fluctuations, rainfall amounts, and long-term climate cycles are contributing factors to an arid to semi-arid agricultural environment where growing conditions are marginal, even during a favorable season. The vegetation communities of the region indicate that these conditions have probably been the normal since the mid-Holocene advancement of xeric-adapted plant and animal species.

Paleoenvironment and Dendroclimatology

Numerous paleoclimate-related studies have been undertaken in the Mexican Highland section and surrounding environs. These provide a background from which the paleoclimate history of the area can be inferred. Regionally and temporally specific paleoclimate data have been derived from packrat midden palynology and plant macrofossil studies conducted in the Sacramento, San Andres, Hueco, Florida, and Hatchet Mountain ranges of New Mexico and Texas, and in the Jornada Basin, New Mexico (Betancourt, VanDevender, and Martin 1990; Van Devender and Spaulding 1979; Holmgren et al. 2003). Studies of fossil insect species extracted from packrat middens in the northern Chihuahua desert have provided additional insight into climate during the transition from early to late Holocene (MacKay and Elias 1992). Studies of Holocene alluvial fan deposits in the Organ and Sacramento Mountains (Frechette and Meyer 2009; Gile 1987) and deflation/lag deposit studies at Fort Bliss (Monger 1993) have also contributed to the body of paleoclimate knowledge of the region. Other geochronologic evidence for climate change through time includes sedimentation studies of pluvial and perennial lake basins in southern and central New Mexico and in northern Mexico (Allen et al. 2009; Allen 1994; Castiglia and Fawcett 2006; Gile 2002; Hall 2001; Ortega-Ramirez et al. 2004). Stable carbon isotope and soil geomorphology have been used to identify and date major climate shifts in the northern Chihuahuan Desert (Buck and Monger 1999; Monger 2009).

The most chronologically detailed studies with implications for the recent Holocene in the Mexican Highland area include dendroclimatology data obtained from living old-growth wood samples in El Malpais National Monument, Chiricahua National Monument, the Organ, Mimbres, and Gallinas Mountains, and at Sierra del Nido and Las Tinajas in northern Chihuahua, Mexico (Stahle et al. 1993; Parks et al. 2006; Grissino-Mayer 1996; Graybill 1986; Dean and Robinson 1977; Naylor 1971). Speleochronology studies also contribute correlatable, high resolution climate data from the late Pleistocene through the late Holocene (Brook 1999; Polyak et al. 2001). Finally, Poore and colleagues (2005) have used comparisons of sedimentation rates and relative abundance of the planktic foraminifer *Globigerinoides sacculifer* in cores from the Gulf of Mexico with dendroclimatology records as corroborative proxy indicators for the southwest monsoon (Mann et al. 1999).

Paleoclimate Overview

Some of the more extensively documented climate events with implications for the Mimbres Basin and eastern Mexican Highlands are the major climate shifts of the Late Pleistocene and early to mid-Holocene that had wide-ranging effects across much of North America. Many climate processes that contributed to more recent paleoenvironmental conditions of these regions are rooted in the Wisconsin Glacial Episode, the most recent glacial maximum in North America. Based on studies of Pleistocene lake expansion as indicated by relict shorelines and sedimentary facies changes in Lake Otero and Lake Estancia, the Wisconsinan ended between about 18,000 and 16,300 years ago (Allen 2005; Allen et al. 2009).

Studies of packrat midden pollen and fossil insect assemblages (Coleoptera and Hymenoptera) from various locations in the northern Chihuahuan Desert indicate that from about 42,000 to 12,875 years ago, the climate was more mesic than it is today. During the late Pleistocene, average summer temperatures for the region have been estimated to be about 1–4° C (33.8–39.2° F) lower than present-day temperatures (Brackenridge 1978; Hawley 1993; Mackay and Elias 1992; Mehringer and Haynes 1965; Phillips et al. 1986; Sebastian and Larralde 1989; Wendorf and Hester 1975). Fossil pollen studies conducted in the region indicate that piñon-juniper-oak woodlands were the dominant vegetation on upland slopes; shrubs (including sage), steppe grass, and sparsely scattered non-coniferous trees grew on the lowland landscapes (Betancourt et al. 1990; Mackay and Elias 1992; Hall 2001; Holliday 1987: Van Devender et al. 1984).

The presence of cienega and spring deposits dating to the late Pleistocene indicates that there was more surface water during this time than at present (Hall 2001). Perennial and pluvial lakes occupied closed playa basins in the southern High Plains, the ancestral Rio Grande Valley and Mexican Highlands of southern New Mexico and Arizona. Wetlands and shallow lakes developed in the valley floor of the Tularosa Basin beginning about 49,000 years ago. By about 35,400 years ago the wetland and lake systems hosted dense stands of emergent aquatic vegetation, attracting Pleistocene mammals, as indicated by fossiliferous plant fragments and mammalian skeletal remains and footprints preserved in extensive fine-grained gypsum deposits (Allen et al. 2005, 2009; Allen 1994; Gile 2002; Holliday et al. 2008; Hawley 1976; Lucas et al. 2002, 2007; Morgan and Lucas 2002, 2005).

Geochronology studies of depositional facies in three lakes in the region indicate lakes were repeatedly freshened, beginning about 29,300 years ago for Lake Otero in the Tularosa Basin, at about 28,700 years ago for Lake Estancia (just north of the Tularosa Basin), and about 27,600 years ago for Lake King in the Salt Basin just southeast of the Tularosa Basin (Allen and Anderson 2000; Allen et al. 2005, 2009; Allen 1994; Gile 2002; Hawley 1976). Similarly, a Pleistocene shoreline terrace at pluvial Lake Palomas in northern Chihuahua is dated at about 29,000 years ago (Reeves 1969). This time frame is consistent with playa high stands recorded across the western United States and northern Mexico during the late Wisconsinan (Polyak and Asmerom 2005; Metcalfe et al. 2002; Smith and Street-Perrott 1983). Sedimentation records also indicate periods of drought and minimization of lake pooling. For Lake Estancia, a severe desiccative period occurred between about 18,100 and 16,340 years ago, when the lake shrank to its minimum pool. Lake Otero may have completely dried up during the drought. Consequently, wind deflation and erosion obliterated or obscured the sediment record, and any subsequent mesic-period deposition would probably have been within those eroded areas. Researchers examining sediment cores from Laguna Alta Babicora in northern Chihuahua noted distinctive changes in diatom flora, possibly indicating dry, stable catchment conditions during this time period (Metcalfe et al. 2002). On the Llano Estacado sedimentation rates based on radiocarbon date extrapolation at White Lake indicate lake desiccation by 16,400 years (Hall 2001). The lake sediment record of drought between 18,100–16,340 years ago is loosely corroborated by groundwater isotope studies in northwestern New Mexico, which infer that between 20,000 and 17,000 years ago, a short period of higher temperatures—3° C (37.4° F) higher than the rest of the late Wisconsinan—and decreased precipitation occurred (Phillips et al. 1986). Two more periods of pluvial expansion between about 16,340 and 14,480 years ago are indicated by Lake Estancia's sediment record. This mesic interval temporally correlates with a major influx of fresh water into the North Atlantic ocean derived from melting northern hemisphere ice shelves (Heinrich event H1). The reduced salinity of sea water resulted in changes to oceanic current circulation and atmospheric temperature and weather patterns (Maslin et al. 2001). The H1 event has been geochronologically dated to between 16,500 and 17,500 years ago, indicating a climatic event of global proportion (Ellwood and Gose 2006).

The termination of the cooling period around 17,000 years ago signaled the transition from the mesic Wisconsinan period into a more xeric, post-glacial late Pleistocene–early Holocene. In the eastern Mexican Highlands and Basin and Range areas, fossil insect, plant, and pollen evidence from packrat middens indicates that the full-glacial Wisconsinan interval was followed by successively warmer and drier intervals alternating with multi-decadal periods of greater effective moisture, cooler temperatures, and diminished evaporation (Van Devender and Spaulding 1979; Betancourt et al. 1990; Hawley 1993; Holmgren et al. 2003). Such short-term, cool, wet weather cycles have been linked to Pacific Decadal Oscillation and El Niño-Southern Oscillation climate cycles and related southward shifts of winter storm tracks—processes still recurrent in modern times (Asmerom et al. 2007; Castiglia and Fawcett 2006; Collier and Webb 2002; Rasmussen et al. 2006).

About 14,500 years ago, the first xeric-adapted ant species began appearing on the Mexican Highlands (Mackay and Elias 1992). Sedimentation rates in the drainages leading into the playas began increasing shortly thereafter, indicating more sediment from drying playa basins being re-deposited into the drainage channels and eolian sediments deposited in the playa basins (Hall 2001; Holliday et al. 2008). Piñon pine began disappearing from lower elevation woodland assemblages, retreating to the highlands and leaving oak, juniper, and desert-adapted grasslands as the dominant species in areas that formerly also supported piñon (Van Devender and Spaulding 1979; Van Devender 1990; Allen et al. 2003).

Younger Dryas

In the final millennia of the late Pleistocene, during the Clovis and Folsom periods, the warming, drying climate abruptly returned to near-glacial conditions in the northern hemisphere (Haynes 2008). This dramatic climate shift, known as the Younger Dryas, lasted from about 12,900 to 11,200 years ago. Pollen extracted from sediment cores from high-altitude lake sites in the Rocky Mountains of Colorado show declines in pollen from high altitude-adapted tree species corresponding to alpine glacial advancements at about 12,900—11,700 years ago (Reasoner and Jodry 2000). Shoreline alluvial sequences from Pleistocene Laguna Babicora, northern Mexico, indicate a lake level high stand occurring about the same time period (Ortega-Ramirez et al. 2004). The sediment record from the Lake Estancia basin indicates renewed lake freshening between about 12,900 and 11,.000 years ago (Allen and Anderson 2000; Anderson et al. 2002). The cooling episode has been theorized to have resulted from a glacial meltwater pulse originating from a thawing Antarctic ice sheet that caused sea level to rise around 20 m. Consequently, the influx of fresh water altered the flow of salinity currents in the North Atlantic Deep Water formation, warming the North Atlantic region and triggering the Bolling-Allerod interstadial (about14,600 years ago), which initiated the end of the Wisconsinan glacial stade and contributed to the melting of the northern hemisphere Fennoscandian and Laurentide ice sheets. As a consequence of freshwater forcing in the North Atlantic, the response by the NADW initiated the Younger Dryas cooling event in the northern hemisphere (Weaver et al. 2003).

Folsom Drought

The Younger Dryas was punctuated by a 900-year period of climatological vacillation during the Clovis/Folsom transition. The Folsom drought saw fluctuating water levels in playas and marshes and the beginning of sandsheet deposition in upland areas (Holliday 2000). The cooling episodes were accompanied by a resurgence of higher precipitation levels and the recharging of aquifers. Favorable rainfall conditions led to the re-emergence of wetlands and cienegas, environments that were conducive to riparian plant growth.

Wetland and cienega deposits are dark, organically enhanced, sometimes peaty deposits that have been recorded across North America. They can be associated with the Younger Dryas period, or may be Holocene-related. Younger Dryas-aged deposits of this type are referred to as black mat deposits (Haynes 2008). They are sometimes immediately underlain and overlain by eolian silt or fine sand facies that are indicative of warmer, drier depositional environments. The stratigraphic sequence represents the more xeric climate conditions that prevailed across a broad geographic area after the Wisconsinan glacial terminus, the sudden onset of Younger Dryas cooling, followed by an abrupt shift back to more xeric climate conditions occurring between 11,300–10,900 years ago. This was a time period when pluvial lakes may have reached their lowest levels until the mid-Holocene (Haynes 1991). The black mat deposit, when present in Clovis-period deposits, may signify the apparent termination of Clovis culture and the sudden demise of many Rancholabrean faunal species (Firestone et al. 2007; Haynes 2008; Polyak et al. 2001; Stuiver et al. 1995; Taylor et al. 1997). In the Mexican Highlands area and adjacent environs, some of the extinct paleofauna are represented by the faunal assemblage recovered from Pendejo Cave, in the Sacramento Mountain western foothills, and examined by Harris (2003). The assemblage included *Equus* spp. (horse), *Capromeryx* (midget goat), *Stockoceros* (Stock's pronghorn), *Coragyps occidentalis* (Western vulture), *Hemauchenia* (lamine camelid), *Camelops* (camel), and *Aztlanolagus agilis* (hare) (Harris 2003).

Scharbauer Interval

After the Younger Dryas, the climate in the southern High Plains/northern Chihuahuan Desert continued warming and drying—a period known as the Scharbauer Interval (11,200–10,200 years ago) (Wendorf and Krieger 1959; Sebastian and Larralde 1989). Piñon and juniper woodlands disappeared from lowland areas (Holmgren et al. 2003) and moved upslope into the highlands (Sebastian and Larralde 1989). As a result of increased eolian movement of sediment, soil deflation occurred, creating localized accretions of coarse-grained particles known as lag deposits, which have been dated to this drying period (Monger 1993).

Lubbock Subpluvial

Beginning around 10,900 years ago, the region experienced increasing rainfall and slightly cooler temperatures during the Scharbauer Interval, a period that would become known as the Lubbock Subpluvial. Pollen preserved in packrat middens indicates a brief re-advance of piñon-juniper forest into lowland areas (Betancourt et al. 1990; Sebastian and Larralde 1989). Additional evidence for the Lubbock Subpluvial, was documented by climate researchers working in caves in the Guadalupe Mountains conducting geochemical and geochronological studies gauging oxygen-stable isotope concentrations and speleothem growth recorded a resurgence of speleothem growth between about 11,100 and 10,800 years ago (Asmerom et al. 2007)

Altithermal Period

During the middle Holocene, the southern High Plains, the southern Rio Grande Rift province, and the Mexican Highlands experienced long-term, overall drying and warming conditions during a time known as the Altithermal (Antevs 1948, 1952; Holliday 1989; Meltzer 1991). Eolian reworking of playa basin sediments continued as lake replenishment rates slowed (Allen et al. 2005, 2009; Holliday et al. 2008; Langford 2002). Drought-related accretionary lag deposits and erosional alluvial fans dating to this time period have been recorded on Fort Bliss and in the Organ Mountains (Monger 1993).

At Laguna Babicora, coarse alluvial deposits, arroyo-cutting episodes, and accumulated eolian sediments in valley fill indicate sediment flux, lack of landscape stability and soil development, and flash flooding indicative of increasingly xeric conditions (Ortega-Ramirez et al. 2004). During the Altithermal, more xeric-adapted plant and animal species began arriving on the southern High Plains and northern Chihuahuan Desert in the time period leading up to the establishment of the modern climate regime about 4,000 years ago (Elias 1987; Holmgren et al. 2003). Pollen records infer the final demise of the late Wisconsinan winter rainfall regime during this time period (Betancourt et al. 1990). Desert grass species continued to gain inroads into territory previously dominated by piñon-juniper-oak species, followed by the arrival of Chihuahuan Desert Scrub vegetation into the region (Buck and Monger 1999). Xeric-adapted ant species began replacing mesic adapted species (Mackay and Elias 1992). Perhaps for the first time on the southern High Plains, people began excavating water wells to replace former surface water sources. Altithermal-period wells have been recorded near former playas, springs, and valley floor stream beds at Blackwater Draw, New Mexico and at Mustang Springs, Texas (Meltzer and Collins 1987; Meltzer 1991). Charcoal-rich alluvial fans in the Sacramento Mountains dating between 5,800 and 4,200 years ago indicate episodic forest fires and slope failure during the Altithermal period (Frechette and Meyer 2009).

Evidently, this period was punctuated by more mesic climate intervals. For example, Castiglia and Fawcett (2006) have recorded the mid-Holocene (7,000–7,600 years ago) development of constructional beach ridges for Lagunal al Fresnal and Laguna Santa Maria closed playa basins of the northern Mexico Chihuahuan desert borderlands (located south of the Mimbres Basin). Poore and colleagues (2005) used the relative abundance of the planktic foraminifer *Globigerinoides sacculifer* in sediment cores from the Gulf of Mexico and comparisons to relative abundance of packrat middens as indicators for the summer monsoon in the southwestern United States. *G. sacculifer* increased in abundance in Gulf sediments during an enhanced monsoon. Conversely, packrat middens decrease in abundance during enhanced monsoon because they are unstable and susceptible to damage by insects (Spaulding et al. 1990). Their research indicates enhanced monsoonal activity during the time of pluvial lake enhancement recorded for Lagunal al Fresnal and Laguna Santa Maria subbasins.

Speleoclimatology data from caves in the Guadalupe Mountains also provide correlative proxies of increased effective rainfall during the mid-Holocene. Researchers recorded a resurgence of speleothem growth occurring about 7,270 years ago (Asmerom et al. 2007).

Neoglacial and Post-Neoglacial Periods

For the Mid- to Late Holocene, stalagmite growth and stable oxygen isotope records from speleothems in Guadalupe Mountain caves; dendroclimatology records from the Organ, Gallinas, and Mimbres Mountains, the Sierra del Nido and Las Tinajas in north-central Mexico, El Malpais National Monument on the southwestern Colorado plateau, and Chiracahua National Monument in the western Mexican Highlands; and sediment cores from the Gulf of Mexico provide a somewhat correlative, chronologically specific, subdecadal record of climate. The marine sediment cores provide data from the early Holocene onward, and show an overall drying trend with lower effective precipitation after about 7,000 years ago, with multidecadal and multi-century periods of increased precipitation.

The El Malpais chronology begins about 136 BC. The other dendro records begin in the late sixteenth century (AD 1569–1597; Sierra del Nido and Organ mountains), the early seventeenth century (Las Tinajas, AD 1621), and the mid- to late seventeenth century (AD 1650 and 1670; Mimbres Mountains, Chiracahua National Monument); (Polyak and Asmerom 2001; Betancourt et al. 1990; Grissino-Mayer 1990, 1996b; Stahle et al. 2009; Poore et al., 2005; Naylor 1971; Stokes et al. 1971). Some climate researchers have placed the final establishment of the modern climate regime in the Mexican Highlands area as occurring about 3,000 to 4,000 years ago (Ortega-Ramirez et al. 2004). Beginning about 4,000 years ago another cycle of slightly moister, cooler climate took hold. Researchers have recorded magnetic susceptibility variations occurring around 4,400 years ago in Hall's Cave sediments (Edwards Plateau), linking them to a North American climate event termed the Neoglacial period (Ellwood and Gose 2006). During the Neoglacial, a resurgence of alpine glacial activity occurred in the North

American Cordillera (Pielou 1991; Wood and Smith 2004).

Again, the contemporaneous formation of constructional playa beach ridges around 4,200-4,800 years ago coinciding with playa lake level high stands in the northern Chihuahuan Desert provides corroborative evidence for a mesic interval during the Neoglacial (Castiglia and Fawcett 2006). In a study of stable carbon isotopes from shells of gastropods recovered from Hinds Cave on the southern High Plains, Goodfriend and Ellis (2000) have recorded a period of progressively moister conditions dating to the onset of the Neoglacial. Geomorphology and geochemistry studies conducted in the Tularosa Basin (Fort Bliss) identified stable geomorphic surfaces with stable pedogenic carbon isotopes dating to the Neoglacial, between 4,000 and 2,200 years ago (Buck et al. 1999). At Laguna Babicora the sediment record for this time period indicates a fluctuating climate between periods of soil development and landscape stability with marshes and bogs, and periods marked by erosional events and debris flow deposits (Ortega-Ramirez et al. 2006).

Asmerom and colleagues (2007) recorded low stable oxygen isotope signatures, indicative of Neoglacial pluvial conditions and corresponding to increased speleothem development during moist climate conditions. These pluvial conditions, based on more recent speleothem growth data, were generally similar to the climate during the recent Holocene; that is, lengthy intervals of somewhat more mesic, then less mesic conditions, with intervals of true drought. The middle Holocene pluvial, beginning about 7,000 years ago, continued until about 4,600 years ago. This period was followed by a 1,300-year period of decreased effective annual precipitation. By about 3,300 years ago somewhat more pluvial conditions returned to the Guadalupe Mountains vicinity, lasting for another 200 years. Decreased moisture and more arid conditions prevailed again for about 300 years. Pluviality returned about 2,800 years ago for half a millennium, followed by the onset of aridity beginning about 340 BC. This drier, less mesic interval, according to speleothem data, lasted until about 10 BC (Asmerom et al. 2007). The final decades of this drier interval are revealed in the dendrochronology record from the El Malpais Long Chronology, where its effects seem to persist for several more decades (Grissino-Mayer 1996a). Another pluvial record appears in the speleothem growth data during the first decade AD and persisting until about AD 265. This period is also reflected in the El Malpais chronology, as is the xeric period that follows. The stalactite record shows it continuing until about AD 470. The tree-ring chronology indicates a period of near-perfect drought lasting between about AD 250 and 500 that was punctuated by brief pluvial intervals several years in duration, with most decades being severe. This dry period is also apparent in the sediment core record from the Gulf of Mexico (Poore et al. 2005).

One notable almost continual period of reduced tree-ring growth that is not reflected in the stalactite record, but is apparent in the El Malpais record—either because of small-scale regional climate variations or because the events affecting tree-ring growth did not affect speleothems—encompasses the years between AD 536–543, AD 560–570, and AD 577–585, which show tree growth as markedly reduced at El Malpais. Tree-ring chronologies from three old tree sites in Colorado (Almagre Mountain 1 and 2; Mount Goliath) also indicate a period of greatly reduced growth spanning three to four decades during the same period (Lamarche and Harlan 1968; Graybill 1983). Historic accounts and dendroclimatic evidence from Europe also indicate a major climate event around AD 536 that inhibited vegetative growth. Baillie (1994) has referred to the event as a “dust veil,” which is thought to have been the result of a major volcanic eruption or the collision of a cosmic object with earth (Larson et al. 2008).

The so-called Anasazi Drought may be evident in the stalagmite record as a period of reduced speleothem development occurring from AD 1047–1180. This somewhat xeric interval also shows up in the Long Chronology from El Malpais, although intermittently punctuated by several multi-year pluvial periods. Another lengthy xeric period with pluvial intermissions occurred in the early to mid-fifteenth century, according to El Malpais dendrochronology records, Gulf sediment cores, and stalagmite annular growth data (Poore et al. 2005; Grissino-Mayer 1996a; Polyak et al. 2001). Also evident in the Gulf sediment cores and in at least several dendroclimatology records (the El Malpais tree-ring record, the Sierra del Nido record, the Gallinas Mountains record, and the records from Las Tinajas, Chiracahua National Monument, and the

Organ Mountains) is the AD 1660–1670 drought that contributed to abandonment of the Salinas Pueblos and other cultural upheavals (DeMenocal 2001; Stahle et al. 2009; Parks, Dean, and Betancourt 2006; Poore et al. 2005; Grissino-Mayer et al. 1997; Grissino-Mayer and Swetnam 1981; Naylor 1971; Stokes et al. 1971). Parks, Dean, and Betancourt (2006) have contributed additional dendroclimate data from tree-ring samples collected in Sevilleta National Wildlife Refuge near Socorro, from Chupadera Mesa, and from Mountainair. The evidence from these samples also indicates a xeric interval spanning about a decade beginning around AD 1660. However, this dry period is not quite as apparent in the speleothem data, although a xeric blip occurs in the record about AD 1680. This could be because the middle to late seventeenth-century drought lasted only about 10 years and the sampling interval for the speleothem was 32 years (Polyak et al. 2001).

Major Historic-period xeric climate episodes that are visible in all of the previously cited dendroclimatology records and in the Gulf of Mexico sediment core records include mid-eighteenth-century episodic drought and a mid-twentieth-century interval of significant drought that have also been documented in dendroclimate studies conducted in northern Mexico (Cleaveland et al. 2006; Villanueva et al. 2006). The eighteenth-century drought episodes were implicated in mass livestock die-offs, river desiccation, and cultural abandonment events that were recorded in northern Mexico and what is now Texas by Spanish colonial settlers and religious officials. The 1950–1960 drought had disastrous effects in the trans-Pecos and borderlands regions (Cleaveland et al. 2006; Holden 1928; Villanueva et al. 2006). The tree-ring records from piñon pines in the Mimbres Mountains indicate that in the vicinity of the Mimbres Basin, this late twentieth-century period of drought may have begun much earlier and lasted well into the late 1970s.

Major pluvial periods with implications for human occupation and adaptation in the Mexican Highlands are also documented through dendroclimatology research and may be correlated with the Gulf of Mexico sediment cores, and, to a lesser extent, with the speleothem-stable isotope research. However, some period of lag between the appearance of a pluvial period in annular tree rings and its appearance in the annular rings of stalactites is apparent, possibly because of the time lag between the onset of the pluvial event, the rainfall absorption in the ground, its dissolution of calcium carbonate and the occurrence of mineral deposition and resolution on the speleothems.

Based on interpretations of Gulf sediment cores and abundance of *G. sacculifer* forams, the relative absence of packrat middens, and annular tree ring growth, it appears that major pluvial events of multi-decadal duration occurred during the late second to mid-third century, late sixth to the mid-seventeenth century, early to middle eleventh century, and from 1825 to 1900. This latter pluvial event may have reached its maximum peak around the turn of the nineteenth to twentieth centuries. The monsoonal indicators from the Gulf of Mexico sediment core records suggest that it was the strongest pluvial period since the late fifteenth century (Poore et al. 2005). Scurlock (1998) has compiled documentation of 13 major to moderate floods (10,000 cubic feet per second or more) on the Rio Grande between 1890 and 1911. Tree-ring records from Las Tinajas, El Malpais and Chiracahua National Monuments, the Sierra del Nido, Gallinas, and Mimbres mountains, all indicate a pluvial period beginning around 1890 and continuing through the first decade of the twentieth century (Grissino-Mayer et al. 2004; Grissino-Mayer and Swetnam 1981; Stockton 1981; Stokes et al. 1971).

Resources

Biotic Zones and Vegetation

The USDA Forest Service Ecological Classification and Mapping Task Team (ECOMAP) was formed to provide forest managers with basic classification tools to assist in defining, mapping, and describing parcels of environment with increasingly uniform ecological potentials. "Ecological types are classified and ecological units are mapped based on associations of those biotic and environmental factors that directly affect or indirectly express energy, moisture, and nutrient gradients which regulate the structure and function of ecosystems. These factors include climate, physiography, water, soils, air, hydrology, and potential natural communities" (McNab and Avers 1994). According to this classification system, the Middle Rio Grande Rift Zone sub-basins are classified as the Central Rio Grande Intermontane ecological section of the Basin and Range subregion. The Sacramento Mountains forming the east boundary of the Tularosa Basin fall under the Sacramento-Manzano section of the Basin and Range subregion, while the San Andres, Oscuro, Organ, and Franklin ranges also fall under the Basin and Range subregion.

The North American biomes classification (biotic community) (Brown 1994) is hierarchically ecosystem-based, after Merriam's life-zone concept (1898), though also in accord with the geography-based system of North American biotic provinces, after which the ECOMAP system takes. Biomes, or biotic communities, are described by distinctive vegetation physiognomy occurring within a biotic province. Biotic communities are living organism communities' responses to climate; their limits are determined by climate. Their actual boundaries are defined by elements of the environment that are closely linked to climate, that in part are determined by climate and also influence the climate, e.g., slope exposure, elevation, soil porosity, longitude, solar exposure, and much more. Combinations of these factors contribute to biodiversity, occasionally resulting in multiple biomes within one ecological section, subregion, or biotic province (Brown 1994).

The Chihuahuan Desert as a biome for the unique species that inhabit it is a relatively recent meteorological, geological, and biological phenomenon that began to develop with the establishment of the early modern climate regime during the early Holocene. This time period initiated the adaptation of modern plant and animal species. Species not able to adapt were displaced to higher elevations or other places outside the desert environment, or were extirpated.

The Mimbres Basin is encompassed by the Northern Plains and Sierra Madre Occidental foothills ecological subsections of the Northern Chihuahuan Desert, an arid to semi-arid biotic system that includes the bajadas, basins, and isolated desert mountains of the Mexican Highlands and western Rio Grande Rift provinces. The most prominent and prolific biotic communities include Semi-Desert Grasslands and Chihuahuan Desert Scrub. The latter biotic community occupies elevations from 1,100 to 1,500 m (3,600–5,000 ft) (Nature Conservancy 2010; Brown 1994). The dominant vegetation species characteristic of the Chihuahuan Desert Scrub community in the Mimbres Basin are creosote bush (*Larrea tridenta*), honey mesquite (*Prosopis glandulosa*), four-wing saltbush (*Atriplex canescens)*, sand sagebrush (*Artemisia filifolia*), broom snakeweed (*Gutierrezia sarothrae),* cane cholla *(Opuntia imbricate),* various species of prickly pear cactus, and soaptree yucca *(Yucca elata).* Also common along roadsides and in disturbed or eroded areas are coyote gourd *(Cucurbita palmata)* and Russian thistle *(Salsola sp.).* Species of potential economic importance inhabiting the Chihuahuan Desert Scrub biome include mesquite, Atriplex, yucca, prickly pear, and plants in the genus Chenopodium and Amaranthus (Brown 1994; Bowers and Wignall 1993; USDA–NRCS 2010; Carter 1997; Native American Ethnobotany 1993).

In the northern and central parts of the Mimbres Basin, the Chihuahuan Desert Scrub biotic community encompasses the Mimbres River, and an arroyo riparian biome dissects the Tularosa Basin floor. Desert willow *(Salix sp.)* is one of the dominant species here, along with cottonwood (Populus sp.), littleleaf sumac *(Rhus microphylla),* Apache plume *(Fallugia paradoxa),* and hackberry *(Celtis sp.)* (Dick-Peddie et al. 1993).

The upper reaches of the Chihuahuan Desert Scrub biome are more topographically variable than most of the valley floor and receive more rainfall. They may have a greater variety in vegetation, enabling some plant species to become established in these microhabitat ecotones (Brown 1994; Neilson 1987). These upslope areas can host an increasing abundance and variety of scrub community plants, including leaf and stem succulents, cacti, and large woody shrubs.

At the upper limits of the desert scrub community, the ecotone-inhabiting species grade into semi-desert grasslands. The elevation range of this community can extend as high as 1,900 m (6,232 ft). Desert scrub species occasionally intermingle with the semi-desert grassland species, especially in areas where overgrazing, and consequently, deflation and erosion, have taken a toll on the vitality of grassland species and allowed shrub species such as one-seed juniper (*Juniperus monosperma*) and mesquite (*Prosopis* sp.) to attain co-dominance. In turn, this trend has impacted the viability of grassland-adapted animal species, such as pronghorn, drastically reducing their numbers over much of their former range. Consequently, the range of scrub/shrubland–adapted species such as javelina and mule deer has increased (Briggs et al. 2006;

Fredrickson et al. 2005; Allen et al. 2003; Havstad and Beck 1995; Brown 1994). Dominant semi-desert grasses include bunch grasses and sod grasses such as curly mesquite grass (*Hilaria belangeri*), black grama (*Bouteloua eriopoda*), slender grama (*Bouteloua filiformis*), Chino grama (*Bouteloua breviseta*), numerous species of three-awn (*Artisida* sp.) and others. Black grama and tobosa are the most diagnostic grasses of the semi-desert grassland (Brown 1994; Bowers and Wignall 1993).

Semi-desert grasslands encompass the Mimbres River, which, along with its more hydrologically prolific tributaries, constitute a locally unique arroyo riparian biome. Desert willow is one of the dominant species here, along with cottonwood, littleleaf sumac, Apache plume, and hackberry (Dick-Peddie 1993).

The upper range of the semi-desert grasslands sometimes overlaps with the lower range of elevation of the Great Basin Conifer Woodland biome, forming savanna- and park-like landscapes with shrub and grass understories. The dominant woodland biome between 1,500–2,500 m (4,900–8,050 ft) is piñon-juniper forest. Subdominant shrub species include cliffrose (*Cowania mexicana*), Apache plume, barberry or algerita (*Berberis fremonti* and *B. haematocarpa*), and four-wing saltbush. Species of potential economic importance are piñon (*Pinus edulis*), red raspberry (*Rubus idaeus*), western chokecherry (*Prunus virginiana*), skunkbrush (*Rhus aromatica*), Oregon grape (*Mahonia repens*), white snowberry (*Symphoricarpos albus),* and New Mexico locust (*Robinia neomexicana*) (USDA-NRCS plants database 2010; Native American Ethnobotany 2003).

The higher elevation range for this biome receives more precipitation, particularly as snowfall; hence, these woodland species are more mesically adapted. Freezing temperatures may occur at least 150 days a year in the northern part of the range.

In isolated areas around the periphery of the Mimbres Basin (for example, in the Burro Mountains and the Mimbres and Tres Hermanas Mountains), the dominant Great Basin conifer woodland species, piñon pine and one-seeded juniper, are replaced by Madrean evergreen woodland species; alligator juniper (*Juniperus deppeana*), gray oak, emory oak, and Arizona oak (*Quercus* sp.) become dominant. These species are more xerically adapted than their Great Basin conifer counterparts.

At the upper reaches of the Great Basin conifer and Madrean evergreen biomes, the oak-juniper-piñon forests fasciate with the ponderosa pine (*Pinus ponderosa)*, Gambel oak (*Quercus gambelii*), and New Mexico locust that inhabit the lower tier of the Rocky Mountain Montane Forest. This evergreen-dominated biome occupies the northern part of the Mimbres Basin where elevations in the Black Range and Mimbres Mountains extend south to almost 3,050 m (9,532 ft). On slopes with a southerly aspect, Douglas fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), limber pine (*Pinus flexilis*), and aspen (*Populus tremuloides*) inhabit the upper reaches, where the ponderosa pine does not thrive. In the ponderosa-dominated lower tier of the Rocky Mountain evergreen forest, understory plants of potential economic importance grow, including Gambel oak, various types of currant and gooseberry (*Ribes* sp.), blue and velvet elderberry (*Sambucus* sp.), smooth sumac (*Rhus glabra*), dandelion (*Taraxacum officinalis*), and wild strawberry (*Fragaria ovalis*) (USDA-NRCS plants database 2010; Native American Ethnobotany 2003).

Petran Subalpine Conifer Forests inhabit elevations as low as 2,450 m (8,036 ft) in colder, moister sites such as steep canyons with a northerly aspect; the upper reaches may extend to timberline ca. 3,500–3,800 m (11,480–12,464 ft), depending on the forest latitude. In the Mimbres Basin, this biome is only present in the highest elevations of the Black Range. The dominant tree species are the Engelmann Spruce (*Picea engelmanni*) and either the subalpine fir (*Abies lasiocarpa*), or in the most southerly ranges, the corkbark fir (*Abies lasiocarpa arizonica*). The subalpine forests can receive in excess of 1.0 m (3.28 ft) of precipitation annually. The growing season is typically less than 75 days; late season and early season frosts are common. At lower elevations, aspen sometimes colonize disturbed areas, especially burns, where blue spruce (*Picea pungens*) sometimes co-inhabits with aspen and Engelmann spruce. Other deciduous trees may be present in more sheltered, wetter areas, including Rocky Mountain maple (*Acer glabrum*), Bebb willow and Scouler willow (*Salix* spp.), or bitter cherry (*Prunus emarginata*). Lower elevations within the subalpine conifer biome may support Douglas fir, white fir, and even upslope pioneering individuals of ponderosa pine, making delineation of the lower range of subalpine growth indistinct. Economically useful species of understory shrubs sometimes live in natural openings and marginal areas of the subalpine forest where more sunlight filters through. These species may include Oregon grape, red elderberry, currants, raspberries, snowberries, blueberry, snowberry, and Kinnikinnick (*Arctostaphylos uvaursi*). Flowering herbaceous species are more abundant in aspen stands, while mosses, lichens, fungi, liverworts, and sedges inhabit the evergreen understory (Brown 1994; USDA-NRCS plants database 2010; Native American Ethnobotany 2003).

The Florida Mountains are host to a unique biotic community not found in other mountainous areas of the Mimbres Basin. Interior Chaparral occupies Florida mountain slope and canyon habitats between 1,050–2,000 m (3,445–6,560 ft) in elevation. The dominant species of the Interior Chaparral community is the economically important shrub live oak (*Quercus turbinella*). Birchleaf mountain mahogany, skunkbush sumac (*Rhus trilobata)*) and desert ceanothus are sometimes co-dominant. Scrub species that are prolific and economically important include sotol (*Dasylirion wheeleri*), yucca, catclaw (*Acacia greggii*) and agave (*Agave* sp.). Numerous species of forage-supporting grasses are also present (Brown 1994; USDA-NRCS plants database 2010; Native American Ethnobotany 2003).

Fauna

In the Chihuahuan Desert Scrub and semi-desert grasslands of the Mimbres Basin two commonly visible large native mammalian species are the pronghorn (*Antilocapra americana)* and the coyote (*Canis latrans*). The former especially uses the area in the summertime as a breeding ground. During the winter months, mule deer (*Odocoileus hemionus*) may occasionally foray out of the mountain foothills into the basin grasslands in search of easy forage.

Smaller mammals common in the Mimbres Basin include the desert cottontail rabbit (*Sylvilagus audubonii*) and the blacktailed jackrabbit (*Lepus californicus*). Various species of bats and rodents are also present.

Other common, though more secretive mammalians include the American badger (*Taxidea taxus*), gray fox (*Urocyon cinereoargenteus*), kit fox (*Vulpes macrotis)*, bobcat (*Lynx rufus*), and ringtail (*Bassariscus astutus*). Hog-nosed, spotted, and striped skunks are also very common in the region.

Some common bird species of the area include the common raven*(Corvus Corax)*, American crow (*Corvus brachyrhynchos*), Gambel's quail (*Callipepla gambelii*), mourning dove (*Zenaida macroura*), golden eagle (*Aquila chrysaetos*), zone-tailed hawk, (*Buteo albonotatus*) Swainson's hawk (*Buteo Swainsoni*), lesser night hawk(*Chordeiles acutipennis*), red-tailed hawk(*Buteo jamaicensis*), great horned owl(*Bubo virginianus*), and cliff swallow(*Petrochelidon pyrrhonota*). The Aplomado falcon (*Falco femoralis)* was once common to the trans-border desert grasslands. It is now a federally listed endangered species (New Mexico Avian Conservation Partners 2011).

Common reptile species in the vicinity of the data recovery area include the New Mexico whiptail (*Aspidoscellus* sp.), collared lizard (*Crotaphytus* sp.), side-blotched lizard (*Uta stansburiana*), and eastern fence lizard (*Sceloporus undulates*). Four species of rattlesnakes (*Crotalus* sp.) live in the Mimbres Basin. The reticulate gila monster (*Heloderma suspectum*) is found in the Florida and Little Florida Mountains (Biota Information System of New Mexico 2011).

CULTURE HISTORY
(ADAPTED FROM GREENWALD ET AL. 2009:7–18)

The archaeology, both prehistoric and historic, of the Deming Plain and Mimbres Bolson has received little attention from academics and has largely been generated by recent cultural resource management (CRM) compliance projects. In comparison with other areas of New Mexico, the current project area has few sites on record with the ARMS and BLM databases, possibly due to the amount of privately held land in the area. Archaeological remains are represented by artifact scatters, thermal features, and historic structures.

The city of Deming, New Mexico, has numerous buildings of historic age and historical significance. A railroad town, Deming was originally named New Chicago and was established in 1881. It was relocated west of its present site a few years later, to a location already known as Mimbres Junction or that was called Mimbres Junction for a short time (Julyan 1998:108) and grew to include the former railroad camp of Whitney City (1882–1888 or 1889) (Robinson 1985).

A broad range of cultural resources representing the full spectrum of cultural traditions found in southwestern New Mexico are found within the general area. Therefore, the following overview of the culture history presents a brief discussion of both the prehistory and history of the region, including some discussion focused on specific local events.

Paleoindian Period

Throughout the southwestern United States, the earliest occupation on record began during the Paleoindian period, which is estimated to have occurred sometime after 10,000 BC (Stuart and Gauthier 1984:28–33). Although evidence is mounting for a pre-Paleoindian occupation in several regions of North America (Madsen 1999), a proposed ca. 12,000–37,000 BP occupation of Pendejo Cave near Orogrande in southern New Mexico has yet to be accepted by archaeologists other than those who investigated the site (Chrisman et al. 1996). Likewise, the purported pre-Clovis Sandia complex, named after materials from Sandia Cave near Albuquerque, has never been replicated by similar finds (Stuart and Gauthier 1984) and is now rarely referenced with contemporary North American Pleistocene complexes (Faught and Freeman 1998).

The Paleoindian period in North America spans a time from the end of the Pleistocene glaciations through the beginning of the Holocene or modern era, an interval from which numerous radiocarbon dates have been recovered between 13,500 and 10,000 BP (Fiedel 1999). The consensus view of Pleistocene archaeologists is that the Clovis culture is one of the first indisputable human occupations in the New World, followed by a rapid succession of other traditions and complexes, such as the Folsom and Plano traditions of the American Southwest, although the term "Plano" is rarely used today. Archaeological evidence for the Paleoindian period has been recovered from nearly every region of the Americas, but the origins of this culture are still disputed. A review of radiocarbon dates from Alaska, the purported entry-point to North America of Siberian immigrants, revealed no dates older than Clovis, and some contemporaneity of the three principal Paleoindian complexes (Kunz et al. 2003). The grasslands of the southern plains of New Mexico and Western Texas may have supported Paleoindian peoples as late as 5500 BC (Irwin-Williams 1973), long after the advent of hunter-gatherer economies of the Archaic period had developed elsewhere (Sherwood et al. 2004).

During the Paleoindian period, emphasis was placed on big game hunting, with the exploitation of wild plant foods as a supplemental strategy. A distinctive attribute of the early Paleoindian period is the use of the lanceolate fluted projectile point, which has a geographic range that extends through North America. Later Paleoindian complexes utilized a variety of well-made, unfluted lanceolate points with only regional distribution. This period is characterized by climatic fluctuations, which resulted in localized environmental settings that were cooler and wetter than those of today (particularly during the Folsom era), with much of the lowlands throughout the Southwest probably having been grasslands or savannas (Van Devender and Spaulding 1979). During the late Pleistocene and early Holocene in southern New Mexico, west Texas, and northern Mexico, pluvial lakes attracted big game animals and their human hunters (Breternitz and Doyel 1983). Most of the archaeological evidence for this period comes from hunting-related sites, including preparatory sites, processing sites, and base camps located near pluvial lakes and other water sources.

Archaic Period

Noticeable climatic changes began throughout the Southwest around 7000 BC (Dello-Russo 2012), resulting in drier conditions than those found in the late Paleoindian period. Around this time, human responses to environmental conditions also began to change. Drier conditions led to a decrease in big-game numbers and a change in the distribution of plant species, although it is believed that the current plant communities were essentially in place by about 6,000 years ago. Hunting was increasingly supplemented with plant foods, obtained from a variety of environmental zones from the basin floors to the mountain slopes. This type of subsistence system required the seasonal movement of groups of people that depended upon the availability of specific floral and faunal resources as they became available and as other resources were depleted. Archaic groups in the southern Southwest may have utilized an area that extended from the Rio Grande River Valley and Mesilla Bolson to the Chiricahua Mountains of southeastern Arizona and from the

Mimbres Mountains south to the lower Rio Casas Grandes Valley.

By late in the Archaic period, population growth, coupled with increased cultural complexity, was occurring. Groups developed a greater reliance on domesticated food resources and, subsequently, became more sedentary. In New Mexico, corn (maize), beans and other cultigens first appeared during the late part of the Middle Archaic period, but, in general, domesticated crops played only a minor role in the subsistence system until near the end of the Archaic period. The subsequent transition to a more sedentary existence, with a greater reliance upon agriculture, took several centuries to come about. In some places, such as the perennial streams of southern Arizona and at Keystone Dam near El Paso, semi-sedentary agricultural villages developed concurrent with continued hunter-gatherer use of adjacent upland areas (Carmichael 1984; Gregory 1999). Bruce Huckell (1996) has termed this lifeway the Early Agricultural period (1500 BC–AD 200; Gregory 2001). Much of this period overlaps with the Late Archaic phase (B. Huckell 1984; Mabry 1998).

The Archaic artifact assemblage consists of a wide variety of tool forms, with an increased emphasis on grinding implements that indicates the change in adaptive strategies during this period. Archaic projectile points were hafted as darts rather than spears, and consequently are generally shorter than those of the Paleoindian period, yet larger than later arrow points. Points of this period are generally stemmed or corner-notched, reflecting changes in hafting technology, and exhibit more extensive morphological variability and less precision in quality of manufacture than those of the Paleoindian period (Sebastian and Larralde 1989). Archaic assemblages often contain a higher percentage of formal tools and bifacial-flaking debris than later assemblages.

Various chronological schemes describe the Archaic period. In southwestern New Mexico and southeastern Arizona, considerable effort has resulted in the definition of the Cochise Culture (Sayles and Antevs 1941; Sayles 1983). Four phases have been defined for the Cochise Culture: Sulfur Springs (10,500–9000 BC); Cazador (9000–6000 BC); Chiricahua (6000–1500 BC); and San Pedro (broadly dated to 1500 BC–AD 1, but more specifically to between 900 BC and AD 200, e.g., Hueco phase). In the Tularosa Basin, MacNeish and Beckett (1987) have assigned the cultural remains there to the Chihuahua Tradition of the Chihuahua Desert, beginning with the Gardener Springs Complex (6000–4000 BC) and followed by three phases: Keystone (4000–2500 BC); Fresnal (2500–900 BC) and Hueco (900 BC–AD 200). Many similarities exist between the resources found in southwestern New Mexico and the Tularosa Basin, yet considerable dissimilarities have caused researchers to play close attention to the differences in attempting to define a local sequence.

Similarities, however, led B. Huckell (1984) to subsume local Archaic traditions such as Cochise, Oshara, and Desert cultures under the term Southwestern Archaic, which he divided into Early, Middle and Late phases to avoid problems in temporal and cultural affiliation present in the previous phase schemes. The appearance of early maize and an increased reliance on domesticated plant resources coincides with a significant change in tool kits, resulting in less variety of forms and more focus on plant processing activities. Furthermore, archaeological evidence suggest that groups during this time became increasingly more sedentary, living in shallow, short-term houses (Carmichael 1984; Gregory 1999) and establishing base camps (MacNeish and Beckett 1987:12) along major drainages from which logistical forays could be made into adjacent ecozones to exploit seasonally available resources.

Early Archaic

Characteristic of the Early Archaic (6000-4000 BC) is an increase in variability of projectile point styles that suggest regional spheres of interaction (Carmichael 1984:18), which further implies that groups traversed smaller territories while still employing a highly mobile hunter-gatherer subsistence strategy. Point types include Jay, Bat Cave and Bajada variants. Associated is a tool complex that includes both chipped and ground stone implements that indicate plant processing as an important aspect of subsistence strategies during this time. Milling stones, anvil mortars, mullers, pebble hammers, pestles, scraper planes, and core choppers indicate that plant resources were processed by pounding and grinding. Faunal remains of pronghorn and deer, together with projectile points, suggest that hunting remained an important component of the subsistence strategy. Sites during this time were small, and their locations suggest that the highly mobile site occupants were dependent on seasonally available resources while exploiting a broader range of topographic settings.

Middle Archaic

The Middle Archaic is represented by a wide range of projectile point types—Pelona, Amargosa, Almagra, Shumla, Bat Cave, and Chiricahua points—several of which were recovered during the excavation of LA 159879. In addition to bifacial and unifacial tools, scraper planes, mullers and milling stones, manos and metates made an appearance in the tool assemblage. Faunal resources remained an important part of the resource base, but plant resources appear to have increased in importance, as suggested by the appearance of ground stone tools. Shallow, short-term structures, which were first recognized in the regional archaeological record at the Keystone Dam site toward the end of this phase, suggested a move toward a more settled lifestyle (Whalen 1994).

The Middle Archaic was marked by the introduction of limited agriculture toward the end of the period. Early corn appears to have been widespread in this portion of the Southwest by 1500 BC, with several examples dating as early as approximately 2,000 BC. The initial appearance of Chapalote maize and beans in the archaeological record (2,945 ± 55 BP at Fresnal Shelter, Tagg 1996; and 3,210 ± 60 BP at High Rolls Cave, Lentz 2005) may account for an increase in grinding implements in the latter part of the Middle Archaic, when processing methods were modified in response to these new economic resources. Also, *Cucurbita* occured with greater frequency. The occurrence of early corn and an increased reliance on domesticated plant resources coincided with a significant change in tool kits, resulting in less variety of forms and more focus on plant processing activities.

Late Archaic

Late Archaic (2500–600 BC) diagnostic point types include Chiricahua, Nogales, Augustin, La Cueva, San Pedro, and Fresnal. Manos and metates became much more common than the earlier mullers and milling stones, increasing in frequency with time and in conjunction with the increased adoption of early agriculture. Furthermore, the increasingly more sedentary groups, living in shallow, short-term houses (Carmichael 1984; Gregory 1999) established base camps (MacNeish and Beckett 1987:12) along major drainages from which logistical forays could be made into adjacent ecozones to exploit seasonally available resources.

Early Agricultural Period

Semi-sedentary agricultural villages developed as upland areas continued to be exploited by hunter-gatherers during this period (B. Huckell 1996). In southern and southwestern New Mexico and adjacent areas, the Early Agricultural period compares closely with the Hueco Phase (900 BC–AD 250), overlapping into the late Fresnal phase (2500–900 BC) when groups had a greater reliance on domesticated plants, such as corn, beans, squash, and amaranth. Sites assigned to the Early Agricultural period (incorporating Hueco phase sites) far outnumber those of the previous phases, and some of these sites appear to have had semi-sedentary or sedentary occupations. It is doubtful that these were full-time agriculturalists, although considerably more importance was placed on crop production for consumption. Hunting was still practiced, as indicated by San Pedro, Hatch, Hueco, Cienega, and Fresnal points. More sophisticated corn varieties were beginning to emerge, and the extensive processing of corn is witnessed by changes in manos from one-hand forms to bifacial/rectangular, two-hand forms and changes in metates from slab to basin to trough varieties. Mortar use increased, suggesting a concomitant intensification in the processing of wild economic plant resources, perhaps mesquite pods, beans, succulents, and other foodstuffs that could be prepared and stored for periods of time when fewer food resources were available (e.g., during drought periods). While this all reflects a population that was shifting toward a less mobile settlement system, vast geographical basin features such as the Mimbres Bolson may have remained primarily broad resource procurement zones. The Deming Plain, the area in which the Mimbres River traverses the Mimbres Bolson, may have been a focal point of resource procurement and agricultural production during periods of less-than-effective moisture.

The Wood Canyon Site (LA 99631), located north of LA 159879 in the Burro Mountains (Turnbow 2000a:91–173), had four shallow, circular pit structures, large capacity storage facilities, burials, and numerous thermal and non-thermal pit features. Corn was found in almost every storage pit and thermal feature suggesting relatively intensive agriculture. While the Archaic and Early Agricultural periods in southern New Mexico exhibit a slow evolution from the early big-game hunting tradition to that of early agriculture, Turnbow (2000a:91) argues, based on the Wood Canyon Site, that corn agriculture was a well-established portion of the economy by 800 BC.

Formative Period

Although the advent of the three quintessential Formative traits—corn, pottery, and aggregated settlements—are now known to have existed during the Middle Archaic along the Santa Cruz valley in southern Arizona (Gregory 1999, 2001; Thiel 2002:15), regionally distinctive cultural traditions based on this lifeway did not become visible in the archaeological record of southwestern New Mexico until sometime between 300 BC and AD 700. The Mogollon tradition emerged from an Early Agricultural hunting and gathering base and was defined through the excavation of pit house villages in western New Mexico (Haury 1936) and southeastern Arizona (Sayles 1945). The Formative period began in the Early Pithouse phase, with the use of ceramics, cultigens, and permanent architecture. The difference between hunting/gathering/incipient horticulture and sedentary/Formative occupations is difficult to distinguish. The archaeological record, however, does support a commitment to a settled agricultural life way perhaps as early as AD 200 or 300 (Whalen 1994). MacNeish and Beckett (1987:16) assign the end of the Hueco phase at AD 250 ± 200 years, based on radiocarbon dates and projectile points from reliable contexts, and this compares closely with the end of B. Huckell's (1996) Early Agricultural period. Similarly, the phases recognized within the Mogollon/Mimbres cultural sequence are based on changes in ceramic attributes and trade ware that have been dated fairly reliably. Whalen (1994) places the transition to sedentism in the early centuries AD, but links it to the end of the Hueco phase (B. Huckell's Early Agricultural period). Regardless, the intervening period (perhaps best described as the incipient Mogollon period) may be characterized as a continuation of strategies used by groups who recognized the advantages of early cultigens, who continued to be highly mobile and relied on hunting/gathering tactics. The progressive development of traits that have become identified with the Early Pithouse phase appeared generally by AD 300.

The Formative period of the Mogollon culture in the vicinity of the project area is divided into six phases, including: Early Pithouse, Georgetown, San Francisco, Three Circle, Mimbres, and Animas (Stuart and Gauthier 1984:242–244). Generally included in the Mogollon/Mimbres area (Stuart and Gauthier 1984:175), the Deming Plain and Mimbres Bolson occupy the lower elevation reaches of a cultural area that trails off into northern Chihuahua. Recent studies indicate the Cedar Mountain Range located southwest of Deming supported a Mogollon/Mimbres occupation located over 48.3 km (30 miles) south of the Mimbres River, but the basin floors have not provided much information on Formative-period use. Mogollon/Mimbres occupations have been documented in the Rio Grande valley, as well, and some researchers have argued for a presence extending across the San Andres Mountains into the western edge of the Tularosa Basin (Eidenbach and Wimberly 1980). A brief description of each phase is provided below.

Early Pithouse, Georgetown, and San Francisco Phases

The Early Pithouse phase (AD 250–550) is represented by pit structures situated in relatively high elevation settings and usually associated with Alma Plain ceramics (Stuart and Gauthier 1984:242). The Georgetown phase (AD 550–650) is characterized by sites that were located on lower river benches and were associated with San Francisco Red Ware ceramics (Stuart and Gauthier 1984:242). The San Francisco phase (AD 650–850) appears to have been a continuation of Georgetown phase adaptations, accompanied by a more diverse ceramic assemblage that included Mogollon Red-on-brown, San Lorenzo Red-on-brown, and Three Circle Red-on-white (Stuart and Gauthier 1984:242).

Three Circle, Mimbres, and Animas Phases

The Three Circle phase (AD 850–975) is characterized by more widely dispersed sites with Three Circle Black-on-white, Boldface Black-on-white, and Transitional Black-on-white ceramics (Stuart and Gauthier 1984:243). This phase may have represented a time of expansion in the Mogollon/Mimbres region, with settlement occurring primarily along secondary drainages. The Mimbres phase (AD 975–1150) is characterized by more extensively distributed sites, some of which comprised large villages. The ceramic assemblage included Mimbres Black-on-white and numerous trade wares (Stuart and Gauthier 1984:243). The Animas phase (ca. AD 1175–1375) is characterized by sites that were less extensively distributed, but were larger and were located in agricultural contexts. Casas Grandes polychrome ceramics occurred at these sites, and it has been suggested that the economic system of the area changed during that time, possibly due to population shifts (Stuart and Gauthier 1984:243), or even population migrations. During the Formative period, mobility decreased as sedentism became increasingly more apparent through more permanent architecture and aggregation of population. Subsistence was strongly focused on agriculture, yet archaeological remains found in the areas removed from the primary and secondary drainages indicate that subsistence activities still incorporated wild plant exploitation. This component of the economy is not well understood and requires further evaluation. Archaeologically, the cultural remains found on the Deming Plain and in the Mimbres Bolson share considerable similarities with resource procurement and processing sites assigned to the adjacent Jornada Mogollon region.

Protohistoric/Historic Aboriginal Period

During the period between the abandonment of prehistoric settlements (ca. AD 1375–1400) and the Spanish reconquest (AD 1692), southern New Mexico had become the home of the Apache, an Athapaskan-speaking group closely related to the Navajo of the Four Corners (Worcester 1992:4). Following the abandonment of the area in the late 1300s and early 1400s, little evidence has been found in the archaeological record for the occupation of the Deming Plain, Mimbres Bolson, and surrounding areas for approximately 200 years. When the Spanish arrived in New Mexico in 1540, native populations were located in villages along the Rio Grande and Rio Puerco, with Apache groups roaming over much of southern New Mexico, Arizona, and northern Mexico (Worcester 1992:5). This geographic and cultural division was perpetuated by the Spanish focus on the Rio Grande and Puebloan peoples, and their inability to curtail Apache activities, including raiding. Apaches practiced a mixed hunting/collecting life way, similar in some respects to the seasonal rounds of the Archaic period, including organization by regional bands, each of which occupied large, mostly mountainous territories. Apache settlement in the area is currently believed to have taken place only a few decades before Spanish arrival, probably after AD 1500, although some scholars suggest a much earlier date, based on the intimate familiarity of the Apache with their environment noted by contemporary Spanish observers (Worcester 1992:4). Consequently, the project area was probably never visited by Spaniards—other than perhaps Cabeza de Vaca during his journey in 1535 and Juan Bautista de Anza—who bypassed this area in favor of routes to the north (Coronado 1540–1542) and east (Espejo 1583 and Onate 1598). Spanish records do not indicate that the Mimbres Bolson was ever visited, and the hot, alkaline deserts of southern New Mexico or "Las Salinas," were generally avoided (Welsh 1995:5). Finally, Juan Bautista de Anza passed near the Mimbres River in 1780, while returning from Santa Fe to Sonora after completing his second campaign against the Comanche in northern New Mexico and Colorado.

By the early AD 1700s, various bands of Apaches made extensive use of the southern New Mexico uplands. These semi-nomadic hunters and gatherers withdrew to remote areas as they felt encroachment by the Spanish from the south and west and Comanche from the north and east (Worcester 1992:12). Similarly, sedentary groups, such as the Pima and Papago, vigorously defended their territory from the transitory Apaches. Subsistence in these remote areas of southern New Mexico was based on hunting deer and pronghorn and collecting agave, datil, piñon, and mesquite. All were important to the Apache mainly because of their availability and storage properties (Basehart 1973). Apache adoption of horses, initially stolen from the Spanish, transformed Apache culture, greatly increasing their ability to supplement their subsistence through raiding (Worcester 1992:8), and elevating the status of the Apache to that of a preeminent military power in the Southwest (Worcester 1992:15). The Spanish were ineffective in controlling the Apache, and, during the period of Spanish expulsion (from the Pueblo Revolt in 1680 to the Reconquest in 1692), the Apache expanded their territory at the expense of Puebloan peoples in Arizona and New Mexico (Worcester 1992:9).

EARLY AGRICULTURAL PERIOD SITES

LA 159879 was initially described as a large prehistoric artifact and fire-cracked rock scatter with the potential to inform researchers about settlement patterns and subsistence strategies during the Late Archaic or Early Agricultural period (900 BC–AD 200) (e.g., MacNeish and Beckett 1987, 1994; Harris et al. 2008). Because remains of early cultigens were recovered from LA 159879 during data recovery, a review of three sites located approximately 71 km (44 miles) northwest of LA 159879 are of particular relevance. These are: the Forest Home site (LA 78089), Wood Canyon (LA 99631), and the Beargrass site (LA 121158), all of which have Late Archaic/Early Agricultural–period components and evidence of early cultigens (Turnbow et al. 2000). Prior to 1999, the Late Archaic/Early Agricultural period was basically unknown in the area. Only three sites in the Mimbres region dated to the Late Archaic period (Fitting et al. 1982a, 1982b). At these sites, radiocarbon determinations that fell into the Late Archaic/Early Agricultural period ranged from around 895 BC to approximately AD 200 (Turnbow 2000b:Table 24.1, Figure 24.1). With the exception of two that have 2-sigma calibrated dates extending into the San Pedro phase, all of the sites date to within the Cienega phase 800 BC to AD 200 (as defined by Mabry 1998). Along NM 90, there were two separate Cienega phase components at the Wood Canyon site; one at the Forest Home site, and a major Late Archaic component at the Beargrass site (Reycraft 2000:626).

Wood Canyon

The earliest Cienega-phase component was found at the Wood Canyon site. Six samples of juniper seed, walnut seed, and corn cupules produced 2-sigma ranges from as early as 895 to 505 BC. All but one of the dates overlapped between 810 and 750 BC, and probably are best dated to between 800 and 700 BC (Cienega phase); however, in Bruce Huckell's (1995) chronological sequence, the early component at Wood Canyon would be placed in the San Pedro phase (1200–500 BC). This site contains oval pit structures, numerous bell-shaped storage pits, and Cienega points were common in the features. The early component included a structure, two burials, four extramural bell-shaped pits, maize, a red-tailed hawk burial, and both Cienega and San Pedro projectile point types (Turnbow 2000a:626).

Several hundred years after the abandonment of the Forest Home site, the Wood Canyon site was re-occupied by another Cienega phase population. This component was dated by only three AMS determinations from a mazie cupule, a walnut shell, and a juniper seed (Turnbow 2000b: Table 24.1; Figure 24.1). The dated materials were obtained from a pit structure, deposits above two burials, and a bell shaped storage pit. At a 2-sigma range, the dates span the period between 165 BC and AD 350. Like the Forest Home component, the later Cienega phase occupation at Wood Canyon had shallow, circular pit structures, bell-shaped storage pits, and both San Pedro and Cienega point types (Turnbow 2000b:626).

Forest Home

This site dates around 400 years later than the original occupation at the Wood Canyon site. The Cienega phase settlement was dated by six samples of juniper and walnut seeds, and from maize cupules. These samples were obtained from two structures and two extramural pits clustered within a 25 by 11 m area on the northern side of the highway. At a 2-sigma calibrated range, the dates varied from 400 to 45 BC, but overlap from 365 to 205 BC. Since one of these dates came from Feature 12, a roasting pit superimposed on Structure 1, the component is assumed to have accumulated in several discrete episodes of occupation over the course of several decades. The occupation produced both Cienega and San Pedro projectile points and a stone tray that may be diagnostic of the phase (Turnbow and Reycraft 2000:87–90).

Beargrass

The final Late Archaic/Early Agricultural component in the NM 90 study came from the Beargrass site. Two AMS dates were derived from a possible structure and a large storage facility. The 2-sigma calibrated date ranges vary from AD 20 to 300. Alma series ceramics, which were present in the structure but could have been intrusive, fall within the late transitional period of the Late Archaic/Early Agricultural and the early Pit House period (Reycraft 2000:218).

RESEARCH QUESTIONS

The data recovery plan developed by Greenwald and colleagues (2009:18–28) identified five problem domains focusing on questions related to site age, function, and cultural affiliation.

Problem Domain 1: Cultural/Temporal Affiliations

Problem Domain 1 was designed to address the most basic archaeological questions: when did the cultural depositional events occur and what cultural groups were responsible for the deposits at site LA 159879? Cultural deposition represents formation processes that are directly related to the activities and material remains left by the occupants of the site. Typically, hunter and gatherer sites are characterized by artifact scatters, features, and occasionally by structures. Recovery and identification of temporally diagnostic artifacts, such as projectile points, in combination with dateable samples, such as radiocarbon, thermoluminescence, and achaeomagnetic assays, provide a means of defining cultural and temporal parameters. The presence of temporally sensitive materials is thus critical to site interpretation. Another important adjunct to archaeological interpretations is the placement of the site into a geomorphological context. The relationship between the cultural composition of the site and the geological deposits can be used to define broad time periods when a site may have been occupied.

To address this problem domain, Greenwald and colleagues (2009:20), posed the following questions:

1. Using all available means (diagnostic artifacts, chronological samples, and geomorphological associations), what are the cultural and temporal affiliations of site LA 159879?

2. What temporally and culturally diagnostic artifacts (e.g., ceramic, projectile points, specific ground stone forms) are present, and what do they imply regarding single or multiple site components? As an aceramic site, what Archaic phase is site LA 159879 affiliated with?

3. What temporal range of occupation is suggested by recovered dateable samples (e.g., radiocarbon assays, obsidian hydration), and how do these date intervals fit with other archaeological data sets?

4. If more than one occupational component is represented, what is the temporal affiliation of each occupation? What is the cultural association of each occupation? To what extent can cultural affiliation be defined for distinguishable occupations?

5. Are stratified cultural deposits present, and what are the implications of such deposits regarding their temporal associations?

6. What are the estimated ages of the surface sediments? Is the site situated on, or embedded in, the surface of a younger A-horizon of recent or late Holocene age? Is this soil covered by recent eolian deposits? Is the site located within stratified or buried deposits exposed in some areas, or is the site resting on, or embedded in an eroded older soil strata (Early B-horizon) to late (C-horizon) Holocene age? What are the implications of these associations?

7. To what extent can distinct lithic material assemblages be associated with particular time periods? What morphological attributes, portions of assemblages, technology, and/or materials can be identified as distinct indicators of specific cultural/temporal/affiliations?

8. What was the depositional environment at the time of the site's occupation and how did this environment effect the formation or transformation of the site?

Problem Domain 2: Subsistence and Economy

Greenwald and colleagues (2009:22) observed that aceramic, nonagricultural, and non-herding groups relied on various means to satisfy their daily subsistence requirements. Because LA 159879, as an Archaic site, was thought to represent non-agricultural activities by non-sedentary groups, the focus of the problem domain focused on the subsistence activities of mobile groups of hunters-and gatherers. This interpretation was strengthened by the presence of fire-cracked rock scatters and certain ground stone forms. These are typically viewed as indicators of processing activities associated with wild plant foods. This problem domain requires an evaluation of the spatial structure and organization of efforts applied to meet subsistence needs: procurement, storage, processing, and consumption. Procurement and processing activities often require specific tools or tool kits. Therefore, the artifact assemblages from the site will be examined top address specific types of uses, such as cutting, sawing, grinding, pounding, and polishing along with the materials, morphology, and condition of tools.

To address this problem domain, Greenwald and colleagues (2009:22–23), posed the following questions:

1. What economic resources were exploited by the occupants of the site? Do the exploited resources represent locally available flora and fauna that are indigenous to the Mimbres River floodplain, or were the economic resources procured from elsewhere and brought to the site?

2. What remains represent the collecting and gathering of floral resources? What elements can define behavioral strategies associated with resources procured from elsewhere and brought to the site?

3. What resources were obtained through hunting or trapping? What strategies were used when game animals were procured?

4. Are cultigens represented in the assemblages, and what are the implications of the presence of cultigens? What percentage of the biomass do cultigens represent?

5. What economic resources represent procurement through exchange?

6. What resources were used for food, construction, firewood, tools and clothing?

7. Based on the economic resources recovered, how was resource procurement and use scheduled? At what stage of development are plant taxa represented, and how does stage of development imply seasonality? Similarly, what season of exploitation is represented by the faunal resources?

8. What procurement and processing methods were employed for economic resources? Specifically, what tool forms in the artifact assemblages inform on methods used to procure plants and animals, and what were these methods? What does tool condition suggest about the procurement and processing of resources, or changes in resource procurement strategies?

9. What evidence is there of storage? What types of storage facilities were used?

Problem Domain 3: Land-Use Strategies

Land-use strategies are related to subsistence and economy in many ways. When addressing land-use strategies of mobile groups, it is necessary to define the spatial extent of the area utilized by the group, the variability of landforms exploited, and the diversity of resources encompassed within that area. Within the current project area, and prior to historic disturbance, resources were available in riparian, grassland, and desert scrub zones. The local landform is a broad valley floor that extends throughout the southern extent of the Basin and Range Physiographic province. Desert ranges and uplands also occur adjacent to the area. The analysis and identification of floral and faunal species for site LA 159879 should reflect the various resource zones and associated landforms exploited by the various groups that occupied the site. This, in turn, will augment our understanding of site function, period, and seasonality of use, the spatial range in which task groups would have traveled, and the diversity of resource zones and landforms used.

In order to address the subsistence models presented above, Greenwald and colleagues (2009:25) suggested the following questions:

1. What is the potential spatial extent or range of the area used by the groups associated with site LA 159879?

2. What resource zones and landforms were available to site occupants? How did resource availability affect site selection?

3. Using botanical remains and raw materials, what resource zones and landforms were exploited by project groups?

4. To what extent are site occupations associated with specific seasonal regimes?

5. What implicatons can be drawn from the archaeological record that suggest site location is associated with specific subsistence strategies and the exploitation of specific resource zones and landforms?

Problem Domain 4: Site Function and Activities

During the reconnaissance survey, Harris and colleagues (2008) described LA 159879 as a large prehistoric artifact and fire-cracked rock scatter which, because of sand deposits, did not provide many surface indications that would characterize the range of activities that occurred or could be used to evaluate its general function. From the artifact assemblage, which includes fire-cracked rock, chipped stone, informal lithic tools, a projectile point, and ground stone, it can be inferred that resource processing activities were conducted at the site. Greenwald and colleagues (2009:26) speculated that it is possible that a range of features could occur on this site, which might include thermal, residential or storage features used by mobile foraging groups. Such features may initially be recognized as stains or concentrations of fire-cracked rock or artifacts. Accordingly, each such anomaly would be evaluated as to its form and function. The following questions were formulated to structure the field recovery and analytical methods for the project.

In order to address the subsistence models presented above, Greenwald and colleagues (2009:26) suggested the following questions:

1. What is the range of activities at this site? What functions did these pits serve? What is the source of the fire-cracked rock?

2. What evidence exists to address occupation longevity and site function?

3. What types of resources were processed, and where were these resources procured?

4. Were structures built and, if so, what were the general composition and attributes of structures?

5. Spatially, how were activities organized? If the site was used on a repeated basis, did occupants reuse the same areas or establish new activity areas with each visit?

Problem Domain 5: Geomorphological Associations and Implications

Greenwald and colleagues (2009:27) observed that, due to the type of deeply stratified, well-drained soils (Neher and Buchanan 1980:10, 21) that occur in the project area (primarily Doña Ana sandy loam derived from mixed sources and secondarily Maricopa sandy loam derived from alluvium on alluvial fans of recent origins), cultural deposition may be fairly recent as well. Thus, understanding the geomorphological processes that have contributed to the formation of site LA 159879 is essential to the project. As considered under Problem Domain 1, the site is probably affiliated with Archaic or even historic mobile groups. It is also necessary to determine whether the site contains culturally stratified, superimposed deposits. Once a determination has been made regarding the relative age of the modern soil horizons and buried paleosol horizons at the site and the presence or absence of stratified cultural deposits, the temporal range of deposits can be better understood.

To guide the research orientation of this problem domain, the following avenues of inquiry were suggested by Greenwald and colleagues (2009:27):

1. What are the estimated ages of the eolian sands and alluvial soils? Are cultural deposits positioned on the surface of younger soils (A-horizon) or embedded within the soil horizons (B or upper C-horizons)? Do components extend downward into older soil strata (C-horizon)?

2. Does site LA 159879 have any significant depth or stratification to its cultural deposits? To what extent can superimposed components be defined?

3. What are the implications, for the cultural deposits, of the estimated ages of the soils in the project area? In other words, do the younger cultural deposits intrude into older sediments? Did the formation processes of both the cultural deposits and sediments co-occur, or were cultural deposits buried by recent eolian or alluvial sediments?

4. What natural processes, such as periodic alluviation, bio- or cryoturbation, or erosion, have affected the integrity of cultural deposits?

2 Data Recovery

Prior to excavation, LA 159879 was an area of area of low dunes and blow-outs covered with a variety of dense dry annuals, grass, mesquite, and yucca (Fig. 2.1). US 80, its right-of-way fence, a buried fiber-optic line, fences demarcating private holdings, and ATV and foot trails impacted parts of the site. Chipped stone artifacts, expedient and formal tools, ground stone, and fire-cracked rock were observed during the initial survey and in a subsequent visit to the site (Greenwald et al. 2009:4–6).

As identified by the NMDOT, the APE for the road-widening project extended 38 m to the east of the right-of-way fence as located in 2011 (Fig. 2.2). OAS research at LA 159879 began with total station mapping of artifacts and features both within and outside of the APE. Artifacts inside the APE were collected for laboratory analysis. Those outside of the APE were mapped, but left in place.

Hand and mechanical excavations were limited to the area within the APE. A total of 224 linear

Figure 2.1. LA 159879, pre-excavation.

meters were excavated during backhoe trench investigations. This was followed by the hand excavation of 190 sq m of area to provide a representative sample of cultural materials within the project area (Fig. 2.2). After the hand excavations, a backhoe was used to systematically strip all portions of LA 159879 within the APE and locate features not found during trenching or hand excavation.

In all, 25 possible features were investigated and 21 of these were determined to be cultural. The other four were not features. Features included one definite and two possible residential structures, six postholes, and 12 thermal features.

Field Methods

At the outset, a site grid was established, with a Trimble Geo-XH 2005 Series, using the NAD 83 Universal Transverse Mercator (UTM) projection. Both horizontal and vertical controls were maintained using a Nikon 330-DTM total station. However, for this report, northing and easting data are reported using only the last three digits of the three-dimensional coordinates. The total station was also utilized to locate existing and expanded right-of-way boundaries, existing disturbances (fence lines, fiber optic line, etc.), site datums, hand excavation (1 by 1 and 4 by 4 m units), mechanical excavation units (i.e., trenches), features, surface artifacts, site boundaries, and the relationship of the site to nearby physiographic features. The main site datum (Datum 1) was located at 317N608.2E, elevation 404.85 m (1328.248 ft).

Surface artifacts both outside and within the APE were point provenienced to provide accurate information regarding surficial distribution. Those within the APE were collected for laboratory analysis, with the exception of fire-cracked rock, which was noted and then discarded. Those outside the APE were identified by artifact class in the field (e.g., chipped or ground stone) and left in place. The distribution of surface artifacts (Fig. 2.3) indicates that LA 159879, for the purposes of this project, measures 324.6 m northwest–southeast and 102 m northeast–southwest, and encompasses roughly 23,069 sq m (2.3 ha) of area. It was recognized that these boundaries were somewhat arbitrarily imposed, and that the actual site extends an unknown distance to the north, west, and particularly to the east where it abutted the active floodplain of the Mimbres River.

Four shovel tests were used to provide initial stratigraphic descriptions in conjunction with 11 backhoe trenches. A total of 224 linear meters of backhoe trench (or 201.6 sq m of area) were excavated during archaeological investigations. These included five trenches 26–28 m in length placed throughout the site area. Following the excavation of the first five backhoe trenches, up to 90 percent of the project area was mechanically scraped to expose buried cultural features. The surface scrape, which removed the upper soil profile almost to the Bk/K-horizon contact, was monitored by an archaeologist, to ensure no features or materials were overlooked. Eleven features were discovered during this process. After scraping, six trenches 12–15 m in length were excavated. All trenches were 90 cm in width. The stratigraphy in both the shovel tests and backhoe trenches was described by Donald E. Tatum (see Chapter 3 for detailed descriptions of the site strata) and 10 OSL samples were collected to date the deposits (Appendix 1). Soil taxonomic nomenclature and a Munsell Soil Color chart were used to characterize the sediments. Sediment and cultural deposit descriptions included, but were not limited to, sediment color, texture, moisture content, the nature of inclusions, organic content, and the presence of cultural materials, if any.

Hand-excavation units were placed in areas with both high and low artifact concentrations, inside fire-cracked rock scatters, adjacent to features discovered in backhoe trenches and during mechanical scraping of the site. In all, 190 sq m of area were hand excavated using a combination of 1 by 1, 1 by 2, 2 by 2, and 4 by 4 m excavation areas. Fill was screened using no greater than one-quarter inch (6.35 mm) mesh. In some instances, one-eighth inch (3.175 mm) mesh was used in deposits where micro-flakes were encountered or suspected. All artifacts were collected, provenienced, counted, and recorded by artifact type using a field specimen (FS) log.

The pre-excavation indication of the feature was initially mapped in plan view. Then, approximately one-half of the feature was excavated in order to expose the profile in cross-section. This view was illustrated and photographed, and each stratigraphic unit described using the same methods discussed for site strata encountered in the backhoe

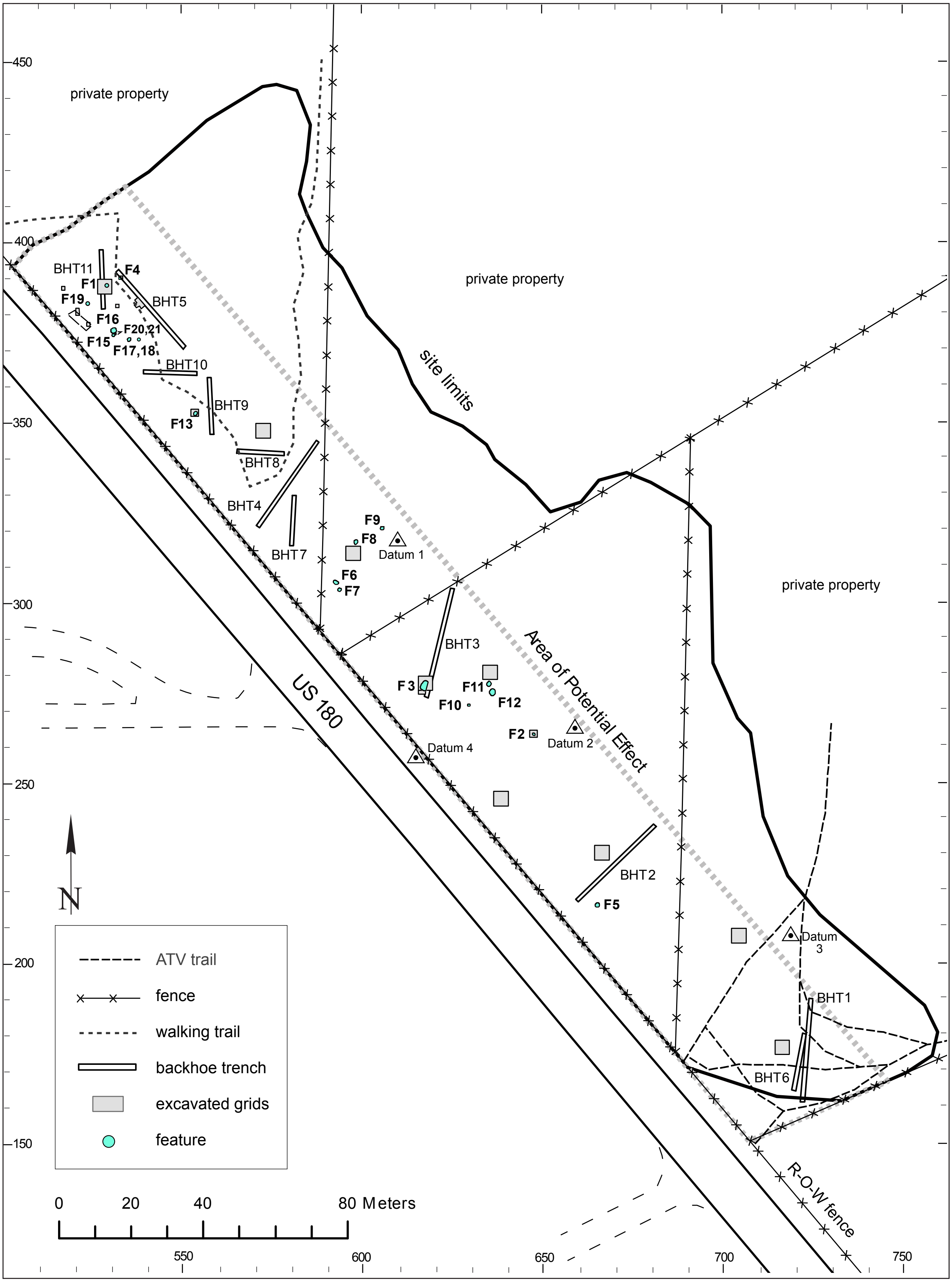


Figure 2.2. LA 159879, plan map.

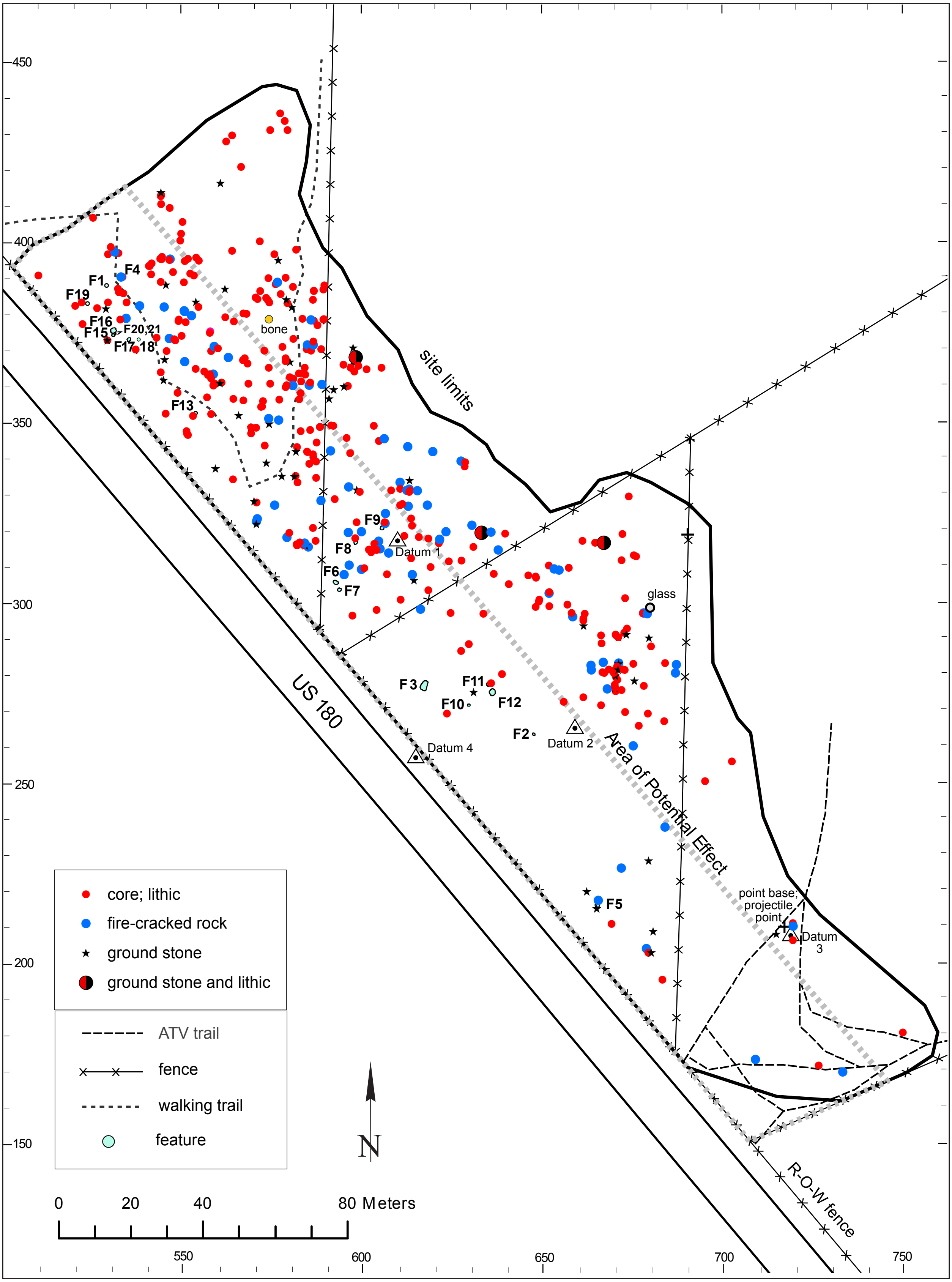


Figure 2.3. LA 159879, surface artifact distribution.

trenches. Fill was screened using 1/8-inch mesh to recover artifacts. Once the feature was excavated in its entirety, a plan-view map was generated in conjunction with a narrative description of size, shape, construction details, fill composition, depositional sequence, assumed function, associated artifacts, recovered samples and the relationship to other features and artifact activity areas. Digitally captured images were generally taken of each feature and profile during the various stages of excavation.

Special attention was given to the collection of archaeobotanical and chronometric samples from features. These included flotation, pollen, phytolith, and radiocarbon samples (both charcoal and bulk sediment). Sample sizes and collection strategies followed those outlined in the data recovery plan (Greenwald et al. 2009:33). All samples were point-provenienced within their respective features, backhoe trenches, or excavation units.

After the hand and feature excavations were completed, a backhoe was employed to systematically strip all portions of LA 159879 within the APE to search for features not found during testing, trenching, or excavation (Fig. 2.4). Backhoe stripping removed fill in 2–5 cm levels using the front bucket. When features were encountered, these were investigated using the feature excavation strategies described above. Systematic scraping of the site was halted when a solid layer of caliche was reached.

After the completion of archaeological investigations, LA 159879 was backfilled using a backhoe/front end loader. The trenches and excavation areas were filled and leveled but were not water compacted. The bottoms of the excavation units and trenches were not lined with landscape cloth or marked in any other fashion to indicate the depth of disturbance because all portions of LA 159879 within the APE were to be destroyed during highway construction.

Shovel Tests

Before the hand excavations were done and the backhoe trenches were excavated, four hand-excavated shovel tests were done in the area just north of the fence bisecting the Silva property and east

Figure 2.4. Overview, OAS fieldwork in progress at LA 159879.

of the Searcy property fence line (Appendix 5, Fig. A5.2). These tests were just large enough to observe and record the stratigraphy—about 50 by 50 cm—and were excavated to or into the Bk- or caliche horizon. Soil identifications in these tests provided the stratigraphic framework for the hand-excavated grid units. Strata descriptions were refined and further described after the backhoe trenches were completed and soils mapped. Chapter 3 provides detailed descriptions of the strata and their archaeological and geological significance.

Shovel Test 1, at 298N/593.1E (elevation 404.6 m, 1327.49 ft), encountered a weak A-horizon (Stratum 1) extending from the surface down about 12 cm. It overlay a Bw-horizon (Stratum 2) that extended to about 42 cm where it turned into a Bk or mixed Bw and caliche soil (Stratum 3) until caliche (Stratum 4) was reached at 50 cm.

Shovel Test 2 at 304N/601.7E (elevation 404.6 m, 1327.44 ft) was nearly identical to Shovel Test 1, except the Bw (Stratum 2) layer was slightly thicker and caliche overlay a 10 cm Bt-horizon. This test was excavated to 60 cm without reaching the caliche substrate.

Shovel Test 3 (292N/589.4E; elevation 404.84 m, 1328.21 ft) was impacted by roadbed fill and sand accumulating along the fence line. The upper recent sand and dune deposits were 60 cm thick and overlay another 50 cm of Bw-horizon containing highly dispersed charcoal and decomposing organic material. Excavation stopped at 1.10 m at the top of the Bk-horizon.

The final shovel test, Shovel Test 4 (311N/611.1E; elevation 404.6 m, 1327.43 ft), had about 28 cm of weak A-horizon sand over 22 cm of Bw soils. The Bk-horizon was about 18 cm thick where it overlay caliche. Excavation continued through 10–12 cm of the K or caliche horizon to a depth of 80 cm.

Backhoe Trenches

There were several purposes for excavating backhoe trenches (BHT) during the data recovery at LA 159879. The trenching provided opportunities to observe and better understand the site stratigraphy and to help guide the excavation strategy. It also led to a clearer understanding of the geomorphic processes involved in the evolution of the landform on which the site developed. In turn, these observations supported inferences about past climate processes, and therefore, potential insight into the adaptations to climate change by the site inhabitants. The trenching also helped in determining the extent of and character of the subsurface archaeological components—where to look and what to look for. Finally, mechanical excavation assisted in the process of discovering subsurface cultural features that otherwise might not have been discovered.

In all, 11 backhoe trenches were excavated (Table 2.1). Initially, five 26 to 28 m long trenches (BHT 1 through BHT 5) were excavated at regular intervals from the south end of the project area to the north end. Six additional trenches were excavated after the site was bladed. All backhoe trenches were 90 cm wide. Grid coordinates for these trenches are provided in Table 2.1. Detailed stratigraphic profiles were drawn for all but BHT 1 and 6.

BHT 1 was a north-trending trench excavated in the southeast project area (Fig. 2.5). The maximum depth of this trench was 1.5 m. Strata 1, 2, 3, 4, and 5 were encountered in BHT 1; it was the only trench in which Stratum 5 was recorded. The profile of the west wall of the trench was photographed (Fig. 2.6). Four optically stimulated luminescence (OSL) sample sets and one bulk sediment radiocarbon sample were collected. OSL samples were taken from the top and bottom of Stratum 5, a buried A-horizon. The bulk sediment sample was taken from Stratum 5. OSL samples were also taken from the base of Stratum 2 (the Bw-horizon) and from near the base of Stratum 3 (the Bk-horizon). The radiocarbon soil sample was not processed.

BHT 2 was a northeast-trending trench excavated in the south-central project area. The maximum depth of this trench was 1.25 m. Strata 1, 2, 3, and 4 were encountered in BHT 2. The profile of the southeast wall of the trench was mapped (Fig. 2.7) and photographed (Fig. 2.8). OSL sample sets were collected from the bottom of the Bw-horizon and from the bottom of the Bk-horizon.

BHT 3 was a north-trending trench excavated in the central project area. The maximum depth of this trench was 1.0 m. Strata 1, 2, 3, and 4 were encountered in BHT 3. The profile of the west wall of the trench was mapped (Fig. 2.7) and photographed (Fig. 2.9). Feature 3 was a pit that was discovered in the west wall. OSL samples were taken from the base of the Bw-horizon and from the Bk-horizon, both adjacent to the north end of Feature 3, in hopes

Table 2.1. LA 159879, backhoe trench summary table.

Backhoe Trench	Orientation	South or West Grid Coordinate		North or East Grid Coordinate		Linear Meters
		Northing	Easting	Northing	Easting	
1	north–south	161.85	721.06	190.55	723.31	28
2	east–west	217.17	659.80	237.84	681.37	27
3	north–south	247.30	616.75	304.40	623.99	28
4	northeast–southwest	320.98	571.49	344.70	587.64	26
5	northwest–southeast	371.42	550.40	391.94	531.15	26
6	north–south	164.99	719.86	180.75	722.70	14
7	north–south	316.11	579.40	330.03	580.14	12
8	east–west	341.97	564.82	341.14	577.82	13
9	north–south	347.06	558.26	362.69	557.62	15
10	east–west	363.89	538.80	363.40	553.58	15
11	north–south	381.87	527.16	398.14	526.56	15
Total						**219**

Figure 2.5. BHT 1, view east showing Stratum 5.

Figure 2.6. BHT 1, detail of soil horizons, west wall.

of being able to date the time of deposition of the strata into which Feature 3 intruded.

BHT 4 was a northeast-trending trench excavated in the north-central project area. The maximum depth of this trench was 1.0 m. Strata 1, 2, 3, and 4 were encountered in BHT 4. The profile of the southeast wall of the trench was mapped (Fig. 2.10) and photographed (Fig. 2.11). No samples were collected from the shallow, heavily eroded and bioturbated soil profile.

BHT 5 was a northwest-trending trench excavated in the northwest project area (Fig. 2.12). The maximum depth of this trench was 1.1 m. Strata 1, 2, 3, and 4 were encountered in BHT 5. The profile of the southwest wall of the trench was mapped (Fig. 2.10) and photographed. Feature 4 was a diffuse stain or thermal feature that was discovered in the southwest wall. No samples were collected from the shallow, heavily eroded and bioturbated soil profile.

After completion of the surface scrape, six more backhoe trenches were excavated to expose the deep subsurface profile across the site. BHT 6 was a north-trending trench excavated in the southeast project area. It was 14 m long and 1.4 m deep. Strata 4 and 7 were encountered in BHT 6. The soil profile of BHT 6 was unstable because it was excavated close to BHT 1. No profile map was found.

BHT 7 was a north-trending trench excavated in the north-central project area. It was 12 m long and 1.8 m deep. Strata 7 and 7.1 were encountered in BHT 7. The profile of the west wall of the trench was mapped (Fig. 2.13) and photographed (Fig. 2.14). A single OSL sample was collected from Stratum 7 near the bottom of the trench to determine the age of the red sand deposit.

BHT 8 was an east-trending trench excavated in the northwest project area. It was 13 m long and 1.4 m deep. Strata 4, 7, and 7.1 were encountered in BHT 8. The profile of the south wall of the trench was mapped (Fig. 2.13) and photographed (*see* Fig. 3.3).

BHT 9 was a north-trending trench excavated in the northwest project area. It was 15 m long and 1.4 m deep. Strata 4, 7, 7.1, and 8 were encountered in BHT 9. The profile of the east wall of the trench was mapped (Fig. 2.15) and photographed (Fig. 2.16).

BHT 10 was an east-trending trench excavated

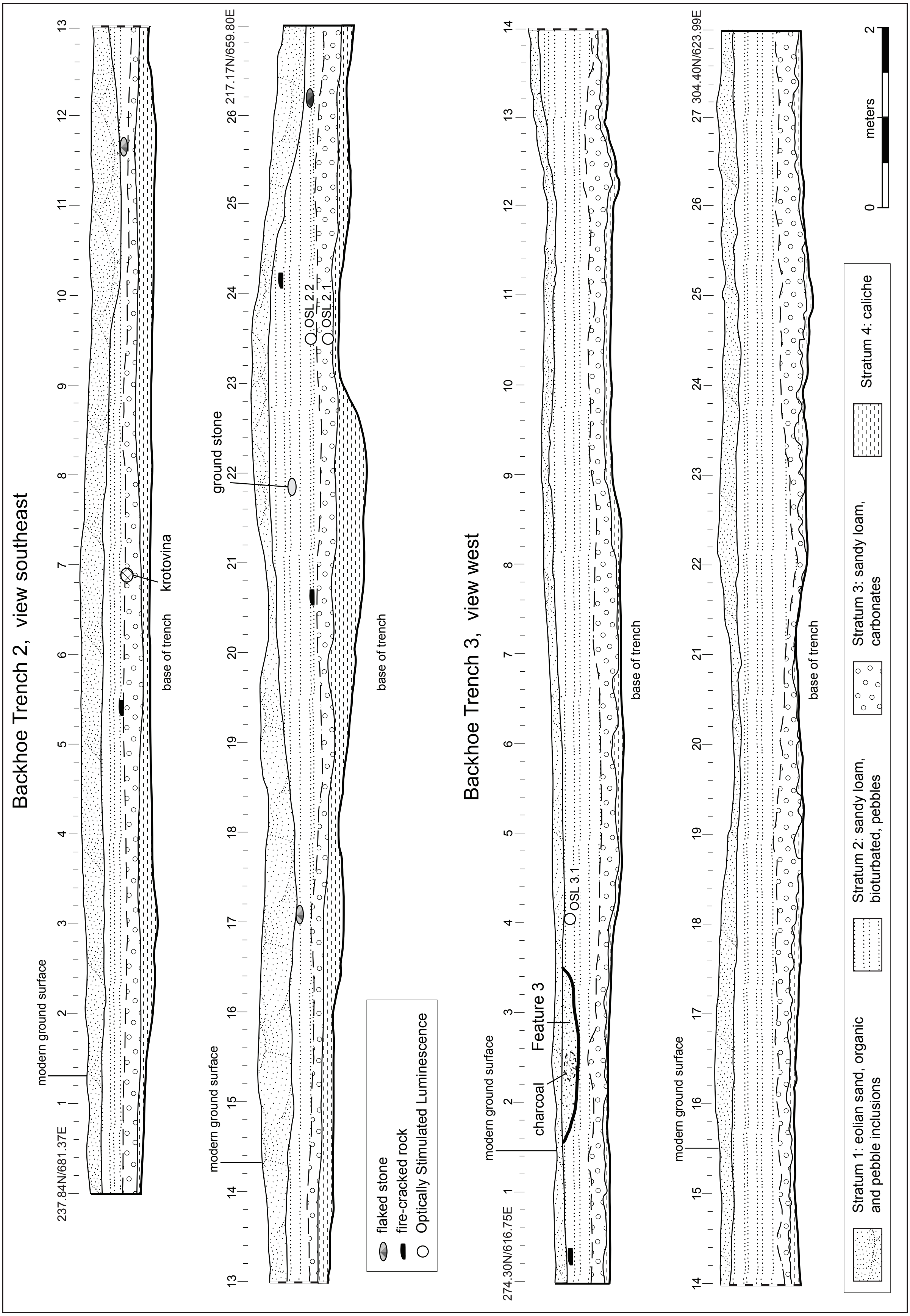


Figure 2.7. BHTs 2 and 3, stratigraphic profiles.

Figure 2.8. BHT 2, detail of soil horizons, south wall.

Figure 2.9. BHT 3, detail of soil horizons, west wall.

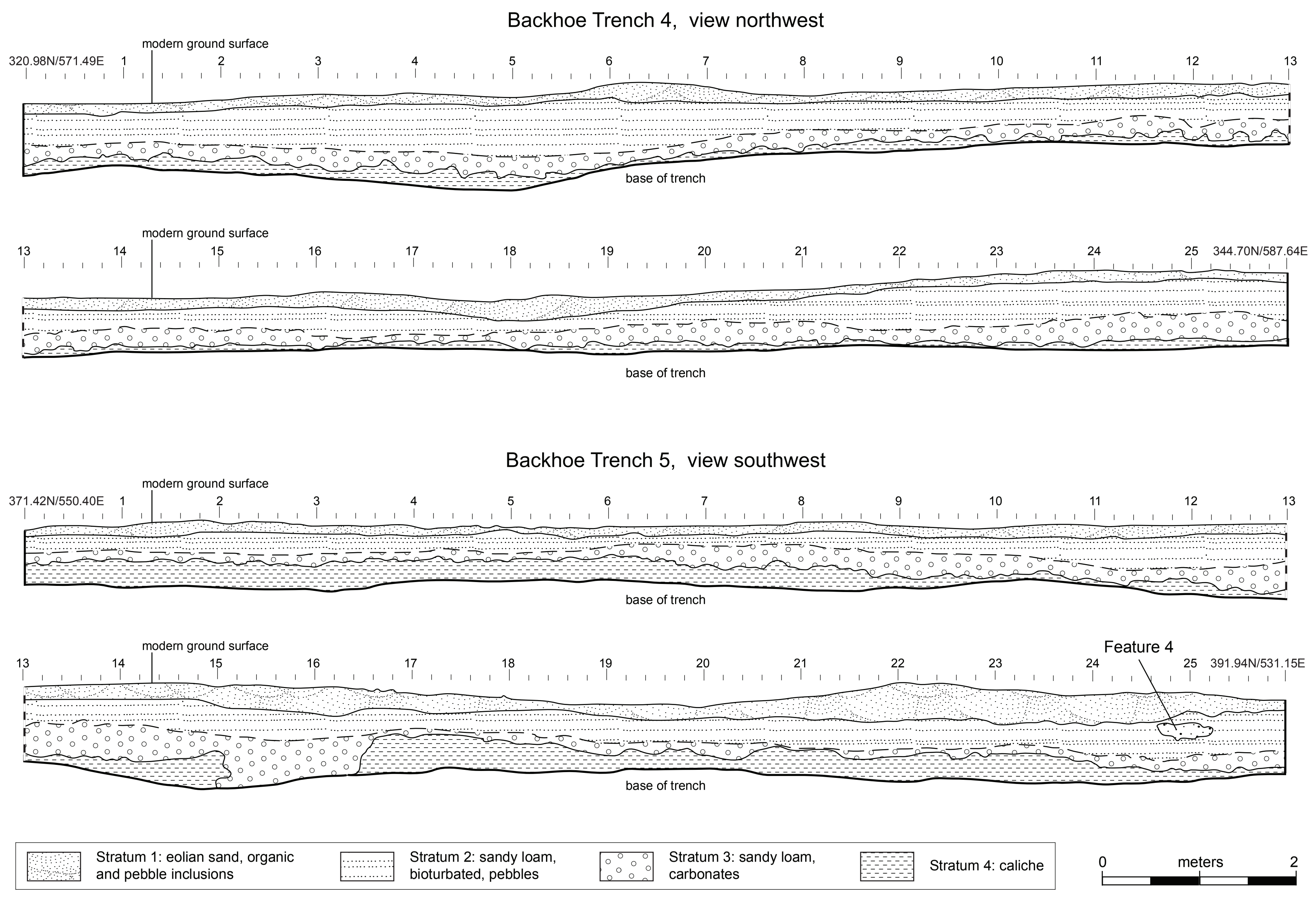


Figure 2.10. BHTs 4 and 5, stratigraphic profiles.

Figure 2.11. BHT 4, detail of soil horizons, south wall.

Figure 2.12. BHT 5, view southeast.

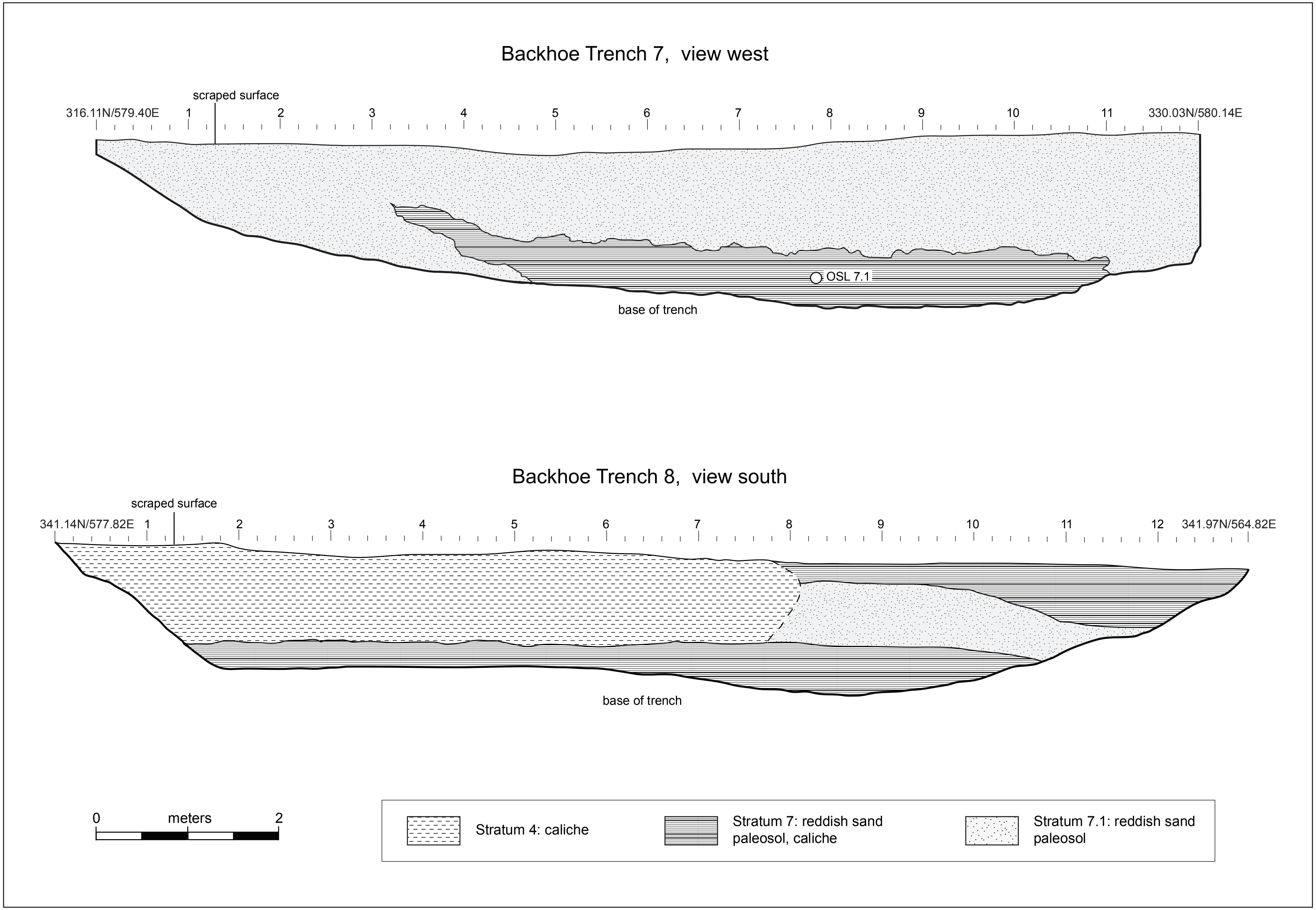


Figure 2.13. BHTs 7 and 8, stratigraphic profiles.

Figure 2.14. BHT 7, detail of soil horizons, west wall.

in the northwest project area. It was 15 m long and 1.4 m deep. Strata 4, 7, 7.1, and 8 were encountered in BHT 10. The profile of the south wall of the trench was mapped (Fig. 2.15) and photographed (Fig. 2.17). Stratum 8 was at the base of the trench and does not show up in the profile.

BHT 11 was a north-trending trench excavated in the northwest project area. It was 15 m long and 1.1 m deep. Strata 4, 7, 7.1, and 8 were encountered in BHT 11. The profile of the west wall of the trench was mapped (Fig. 2.15) and photographed (Fig. 2.18).

Backhoe trenching and surface blading at LA 159879 revealed aspects of site stratigraphy, soils, and geomorphology. The data recovered from the study of the stratigraphy aided our inferences about past climate (see Chapter 3). The mechanical excavations also proved to be useful in determining the horizontal and vertical extent of cultural deposits and in locating archaeological features.

Hand-Excavated Units

In all, 190 sq m of area were hand excavated by stratum using a combination of 1 by 1, 1 by 2, 2 by 2, and 4 by 4 m excavation areas (Fig. 2.2). Artifacts were collected by 1 by 1 m grid units and stratigraphic layer. A grid excavation form was completed for each 1 by 1 grid unit and each stratum in that grid unit. Profiles were drawn and the units photographed.

The 4 by 4 m hand-excavated units (Table 2.2) were placed at regular intervals across the site and all but one were excavated to sterile—the top of the caliche layer (Figs. 2.19, 2.20). Smaller units were either placed around a known feature or were used to investigate stains or other phenomena that were determined to be noncultural. Grid units excavated after the site was mechanically scraped had only Stratum 3 removed and two other units had only the recent sand sheet (Stratum 1) removed. Fire-cracked rock was counted by some excavators,

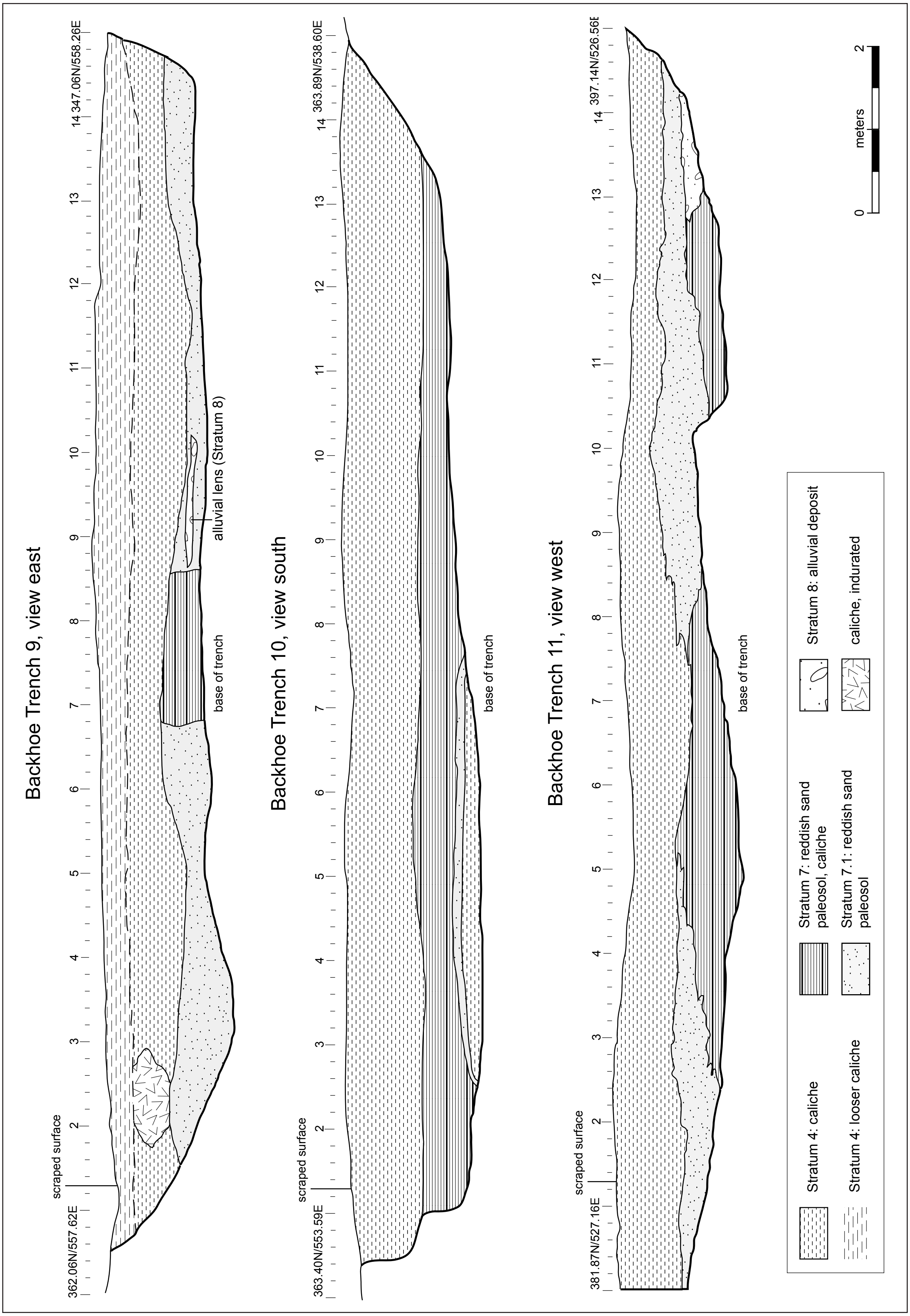


Figure 2.15. BHTs 9, 10, and 11, stratigraphic profiles.

Figure 2.16. BHT 9, detail of soil horizons, east wall.

Figure 2.17. BHT 10, detail of soil horizons, south wall.

Figure 2.18. BHT 11, detail soil horizons, west wall.

noted as present by some, and not mentioned by the others.

Stratigraphy was similar in all of the hand-excavated units. Thickness of strata varied, especially for the cultural layer (Stratum 2) and was most extensive at the south end of the site area. One unit (244N/636E) had an A-horizon (Stratum 2.1) that was not observed elsewhere at the site (see Chapter 3).

Not all of the hand-excavated grid units produced artifacts (Table 2.2) and larger chipped stone counts were not always associated with features (e.g., 215N/702E). Ground stone was more likely to be found near features, as was bone. All of the ground stone and bone was analyzed but the chipped stone was sampled. Table 2.2 gives both the rough field counts and the number of artifacts analyzed.

Feature Descriptions

In all, 21 features (and four subfeatures—postholes in one of the structures) were identified at LA 159879. Of the 21, nine were determined to be prehistoric, two were historic, and the other six were not dated. The four remaining features were determined to be noncultural. Below is a brief description of each feature. Table 2.3 gives the grid coordinates, size, start and end depth, shape, fill description, and artifact counts for each of the features and noncultural phenomena. For this discussion, all of the thermal features are considered fire pits and will be compared and contrasted at the end of the feature descriptions. Radiocarbon dates are the most accurate and most precise dates determined by evaluating the Beta Analytic dates using Calib and OxCal (Chapter 8; Appendix 2).

Feature 1 (Noncultural)

Feature 1 was a small concentration of caliche nodules on the present-day ground surface in the

Table 2.2. LA 159879, hand excavation unit summary table.

SW Grid Coordinates		**Unit Dimensions (m)**	**Unit Area (m^2)**	**Screening Size (in)**	**Start Depth**	**End Depth**	**Strata**	**Fire-cracked Rock**	**Contents**			**Comments**
Northing	**Easting**				**Meters Above Sea Level**				**Lithic***	**Bone****	**Ground Stone****	
175	713	4 X 4	16	1/4	1326.90	1326.73	1,2,3	11	26/0	0	1	–
215	702	4 X 4	16	1/4	1327.45	1326.66	1,2,3	?	152/0	7	12	–
216.62	665.92	1 X 1	1	1/8	–	–	–	–	–	–	–	Feature 5 excavation
229	664	4 X 4	16	1/4	1327.70	1327.25	1,2,3	11	73/69	0	2	–
244	636	4 X 4	16	1/4	1328.09	1327.27	1,2,3	12	136/0	0	9	–
263	646	2 X 2	4	1/8	–	–	–	–	–	–	–	Feature 2 excavation
271.56	628.48	1 X 1	1	1/8	–	–	–	–	9/8	–	–	Feature 10 excavation
274.69	634.64	2 X 2	4	1/8	–	–	–	–	–	–	–	Feature 12 excavation
275	616	4 X 4	16	1/8	1328.05	1327.52	1,2,3	5+++	378/138	12	24	Feature 3 area; backhoe trench through unit
276.96	634.64	2 X 2	4	1/8	–	–	–	–	–	–	–	Feature 11 excavation
279	633	4 X 4	16	1/4	1328.11	1327.89	1,2,3	?	0/1	0	0	–
303.54	592.66	2 X 2	4	1/8	–	–	–	–	–	–	–	Feature 7 excavation
305.33	591.27	2 X 2	4	1/8	–	–	–	–	5/4	–	–	Feature 6 excavation
312	595	4 X 4	16	1/4	1328.07	1327.55	1,2,3	19+	77/55	0	6	–
316.84	597.41	1 X 1	1	1/8	–	–	–	–	1/1	–	–	Feature 8 excavation
322.3	604.51	2 X 2	4	1/8	–	–	–	–	0/1	–	–	Feature 9 excavation
346	570	4 X 4	16	1/4	1328.12	1326.98	1	6	34/0	0	3	–
352	552	2 X 2	4	1/8	–	–	–	–	6/6	–	–	Feature 13 excavation
372.84	534.46	2 X 2	4	1/8	–	–	–	–	–	–	–	Feature 17 excavation
374.52	530.44	1 X 2	2	1/8	–	–	–	–	9/9	–	–	Feature 15, 16, 20, 21 excavation
377	524	1 X 1	1	1/4	1328.32	1328.10	1,2	?	0	0	0	–
380	520	1 X 1	1	1/4	1328.30	1328.25	1	?	0	0	0	modern posthole in grid
382.86	532.25	1 X 1	1	1/4	1328.31	1327.64	3	?	2/1	0	0	–
382.56	537.25	1 X 1	1	1/4	1328.24	1327.66	3	–	8/6	–	1	Feature 14/not a feature
383.06	524.1	1 X 1	1	1/8	1328.22	1327.90	–	–	5/1	–	–	Feature 19/not a feature
383.53	537.03	1 X 1	1	1/4	1328.28	1327.82	3	?	2/2	0	0	–
384.31	536.43	1 X 1	1	1/4	1328.29	1327.62	3	?	0	0	0	–
386	526	4 X 4	16	1/4	1328.44	1327.43	1,2,3?	?	312/267	3	9	Feature 1 excavation/not a feature
387	516	1 X 1	1	1/4	1328.43	1328.38	1	?	0	0	0	–
390	532	1 X 1	1	1/8	–	–	–	–	16/16	–	–	Feature 4 excavation
Total* **			**190**						**841/770**	**22**	**67**	

*Field counts/number analyzed for lithics.

** analyzed counts for bone and ground stone.

***includes surface collection

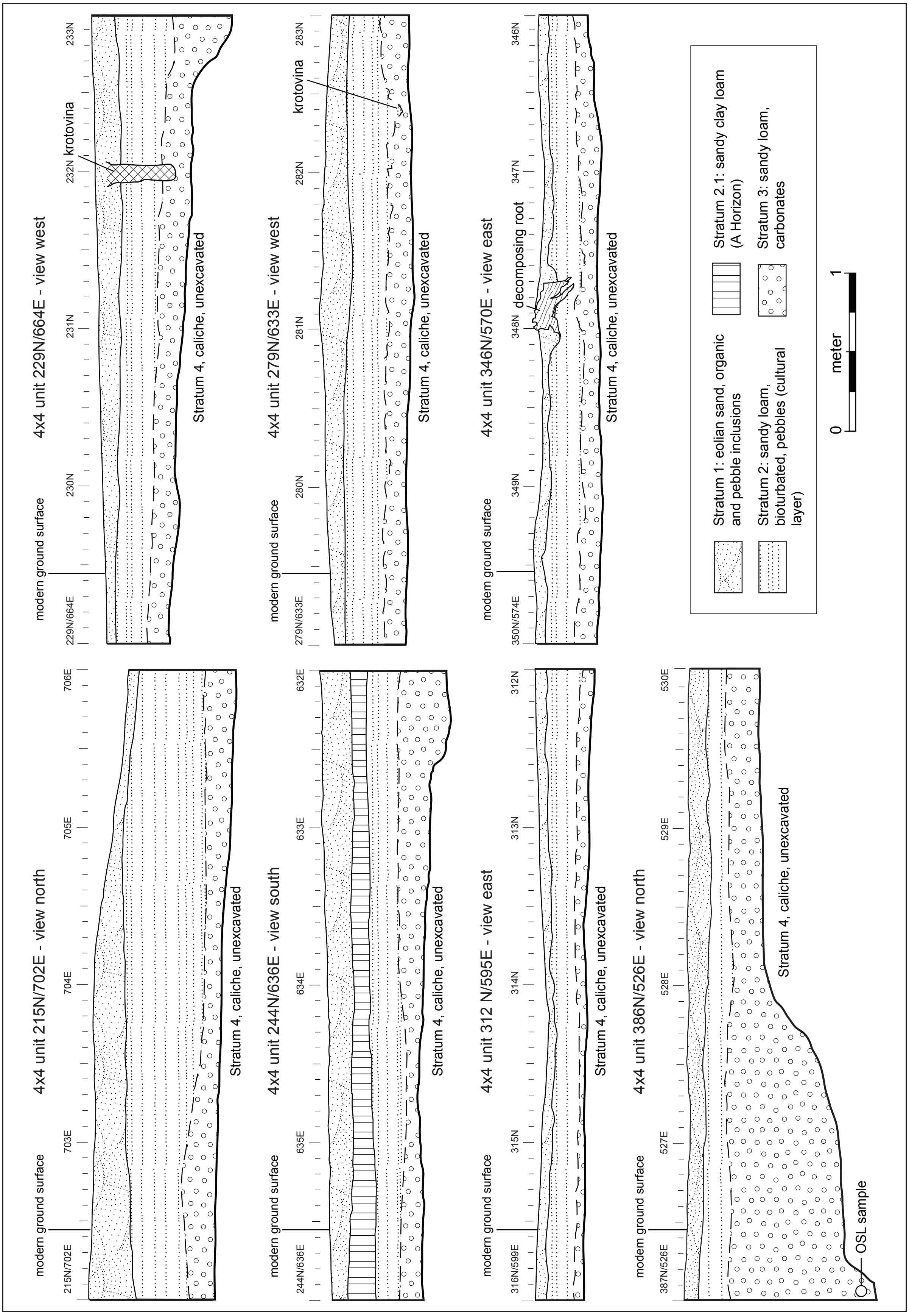


Figure 2.19. 4 by 4 m excavation units, stratigraphic profiles.

Figure 2.20. Grid 229N/664E, after excavation, view west.

northwestern portion of the site (Fig. 2.21). A 1 by 1 m grid unit that was expanded into a 4 by 4 m hand-excavated unit (386N/526E) determined that the caliche on the surface was due to subsurface rodent activity.

Feature 2 (Fire Pit)

Feature 2 was a small thermal pit located in the central portion of the site. It was discovered by means of mechanical scraping that removed the upper 5 cm of the feature. A small amount of root disturbance was also noted. The feature was circular, 80 cm in diameter, and 5 cm deep (Fig. 2.22) and had a fire-reddened base (Fig. 2.23). Feature fill was carbon-stained sand. A flotation sample from this feature contained burned amaranth, goosefoot, and dropseed along with mesquite wood. Charcoal and wood collected as a dendro sample were submitted for radiocarbon dating; four date ranges came back, with the most accurate and most precise dating between AD 1470 and 1640 (Beta-307889). It is not clear how this sample relates to the feature, which appears to have been an expedient, single-use fire pit. No artifacts were collected from the 2 by 2 m excavation around this feature.

Feature 3 (Possible Structure)

Feature 3 was a large shallow pit discovered by mechanical trenching that, unfortunately, removed the eastern portion of the eastern side of the feature. Feature 3 was oval in plan view with a shallow bowl-shaped profile. It was at least 1.94 m in diameter and 14 cm deep (Figs. 2.24, 2.25, 2.26). The base of the feature was somewhat flat with caliche in places and had evidence of oxidization. Feature fill was a grayish brown (10YR 5.2) semi-consolidated, fine-grained, silty sandy loam with sparse inclusions of charcoal, sparse pea-sized gravels, and occasional fire-cracked rock. Sixteen 1 by 1 m grids were ultimately excavated around this feature. An activity area with charcoal staining, complete and fragmented ground stone objects, an unutilized core, core flakes, and fire-cracked rock was found adjacent to the southwest corner of the feature.

Table 2.3. LA 159879, feature summary table.

No.	Feature	Location		Size (cm)			Start Depth	End Depth	Shape		Fill	Contents						Comments
		Northing	Easting	Length	Width	Depth	Meters Above Sea Level		Plan	Profile		Lithic	Bone	Ground Stone	Pollen	^{14}C	Flota-tion	
1	Caliche conc.	387.92	529.37	–	–	–	1328.57	–	–	–	–	–	–	–	–	–	–	Noncultural.
2	Fire pit	265.85	647.09	80	80	5	1327.57	1327.52	Oval	Basin	Carbon-stained fine sand. Entire fill collected as a flot sample.	–	–	–	–	1	1	Informal fire pit.
3	Struc-ture or pit	276.80	616.40	194	152	14	1327.68	1327.54	Oval	Basin	Semi-consolidated, fine-grained, silty sandy loam w/ carbon staining and <1% pea-sized gravel and FCR.	42	36	7	3	9	5	Large shallow pit, possible burned structure. Counts include adjacent activity area.
4	Fire pit or stain	390.50	532.26	54	28	6	1328.14	1328.08	Oblong	Basin	Loose sandy loam w/ carbon-stained soil inclusions and charcoal flecking.	15	–	–	1	1	1	Small informal fire pit or rodent burrow fill.
5	Struc-ture	216.68	664.79	105	95	20	1327.52	1327.32	Circular	Basin	Lightly carbon stained fine-medium sand w/ charcoal flecks and sparse FCR. Base of feature oxidized.	2	–	–	–	2	4	Possible small structure excavated into caliche.
6	Fire pit	305.23	591.57	120	66	17	1327.81	1327.64	Oval	Basin	Semi-consolidated, fine-grained sand w/ charcoal flecking and an oxidized base.	4	7	1	1	–	1	Informal fire pit.
7	Fire pit	304.00	593.30	70	60	15	1328.65	1328.50	Circular	Basin	Sand w/ < 1% gravel and charcoal. Large portion of soil collected as a flot sample.	–	–	1	1	–	1	Informal fire pit.
8	Fire pit	317.00	597.70	109	80	9	1327.70	1327.61	Oval	Basin	Very dark grayish brown, fine-coarse sandy loam w/ 2 pieces of FCR.	2	–	3	–	–	2	Informal fire pit. Much bioturbation.
9	Fire pit	321.00	605.00	65	60	15	1327.95	1327.80	Oval	Basin	YR 5/3, brown, sandy matrix w/ FCR, some gravels, 1% charcoal flecking and 1% caliche pebbles.	3	2	7	1	1	2	Small informal fire pit.
10	Fire pit	271.56	628.48	50	45	31	1327.90	1327.59	Circular	Basin	Reddish brown, semi-consolidated sand w/ FCR.	16	–	3	5	–	1	Small rock-filled fire pit.
11	Fire pit	276.96	634.10	120	95	18	1327.60	1327.42	Oval	Basin	Stratum 3 mixed with 1-5% charcoal. Surrounding soil oxidized.	–	3	1	–	1	1	Informal fire pit.

Table 2.3 (continued)

No.	Feature	Location		Size (cm)			Start Depth	End Depth	Shape		Fill	Contents						Comments
		Northing	Easting	Length	Width	Depth	Meters Above Sea Level		Plan	Profile		Lithic	Bone	Ground Stone	Pollen	^{14}C	Flota-tion	
12	Fire pit	274.69	634.64	170	150	5	1327.40	1327.35	Oval	Basin	Loose Stratum 3 lightly carbon-stained. Caliche base slightly oxidized.	–	1	–	–	–	1	Informal fire pit.
13	Fire pit	353.00	553.00	95	70	5	1328.10	1328.05	Oval	Basin	dark grayish brown fine to coarse sandy loam with a small amount of FCR.	6		1	1		1	Informal fire pit.
14	Not a feature	382.56	537.67	–	–	–	1328.30	–	–	–	–	12	–	–	–	–	–	Noncultura.l
15	Fire pit	374.52	530.44	50	50	20	1328.04	1327.84	Circular	Basin	Dark reddish brown, very compact sand w/ burned caliche and large amounts of charcoal. Excavated into caliche, oxidized.	11	31	–	2	1	2	Fire pit. Protohistoric date.
16	Struc -ture	376.17	530.88	136	124	32	1328.16	1327.88	Circular	Basin	Loose, fine-grained sandy loam w/ 1% pea-sized gravel, very sparse charcoal.	6	–	–	1	1	2	Structure with 4 post holes.
16.1	Posthole	375.41	350.23	5	5	17	–	–	Circular	Cylind-rical	Silty, sandy loam.	–	–	–	–	–	1	Structural support
16.2	Posthole	374.69	530.64	5	5	16	–	–	Circular	Cylind-rical	Silty, sandy loam.	–	–	–	–	–	1	Structural support
16.3	Posthole	374.89	531.33	5	5	15	–	–	Circular	Cylind-rical	Silty, sandy loam.	–	–	–	–	–	1	Structural support
16.4	Posthole	375.87	530.70	5	5	17	–	–	Circular	Cylind-rical	Silty, sandy loam.	–	–	–	–	–	1	Structural support
17	Pit?	373.34	534.81	148	144	60	1328.06	1327.46	Circular	Basin	Loose, unconsolidated sandy loam.	–	–	2	1	–	2	Possible feature or burrow
18	Not a feature	373.66	536.28	–	–	–	1327.97	–	–	–	–	–	–	–	–	–	–	Noncultural; badger burrow?
19	Not a feature	383.06	524.10	–	–	–	1328.14	–	–	–	–	1	–	–	–	–	–	Noncultural; burrow.
20	Posthole	374.40	530.90	20	15	15	1328.08	1327.92	Circular	Cylind-rical	Loose, very fine grained, silty sandy loam w/ very small amount of FCR.	–	–	–	–	–	1	Posthole associated w/ Feature 21 and Feature 16.
21	Posthole	374.06	531.00	16	16	17	1328.07	1327.91	Circular	Cylind-rical	Loose, very fine-grained silty, sandy loam.	–	–	–	–	–	1	Posthole associated w/ Feature 20 and Feature 16.

analyzed counts for lithics, bone, and ground stone
FCR = fire-cracked rock

Figure 2.21. Feature 1 (noncultural), prior to excavation, view east.

Feature associated artifacts include: chipped stone, bone, and ground stone. In addition, a variety of samples was taken, including flotation, pollen, and ^{14}C.

Chipped stone artifacts from the feature fill, two of the grid units overlying the feature, three grid units to the north of the feature, and two grid units east of the feature, as well as three point-plotted chipped stone artifacts from the activity area were analyzed (Tables 2.4, 2.5). Most of the artifacts from the grid units and feature are unulitized angular debris or flakes. Several cores, two scrapers, and a partial San Pedro projectile point were also found. Chert was the dominant material type (78.0 percent). Few of the materials were regarded as coarse-grained (2.3 percent), with the majority considered medium-grained (63.9 percent) and the rest fine-grained (33.9 percent); most were considered strong (72.9 percent) but not-durable (86.4 percent), and a few were considered brittle and durable (13.6 percent). Relatively few exhibited the luster associated with heat treatment (13.6 percent).

Ground stone was recovered from the activity area, the fill of the feature, and from 12 grid units above and around the feature (Table 2.6). Artifacts from the activity area included a complete pestle/crusher, an abrader, fragments of a second abrader, and an indeterminate fragment. Those from the structure fill were all fragmentary. The grid units also contained several whole tools, including a complete mano and a shaped or painted stone from the grid just north of the activity area.

A good portion of the site's bone was recovered from this feature (38 of the 103 specimens). All but two were from the feature fill. The two include a piece of egg shell that is too thin for turkey and a piece of a jackrabbit mandible from Stratum 3 in the grid just east of the activity area. Most of the assemblage consists of small pieces of bone identified only as small mammal (n = 23), equal numbers of cottontail and jackrabbit bones (n = 7), and the egg shell. Of the 38 specimens from the feature, eight were recovered from flotation samples. Of the 10 feature specimens that were burned, six were from

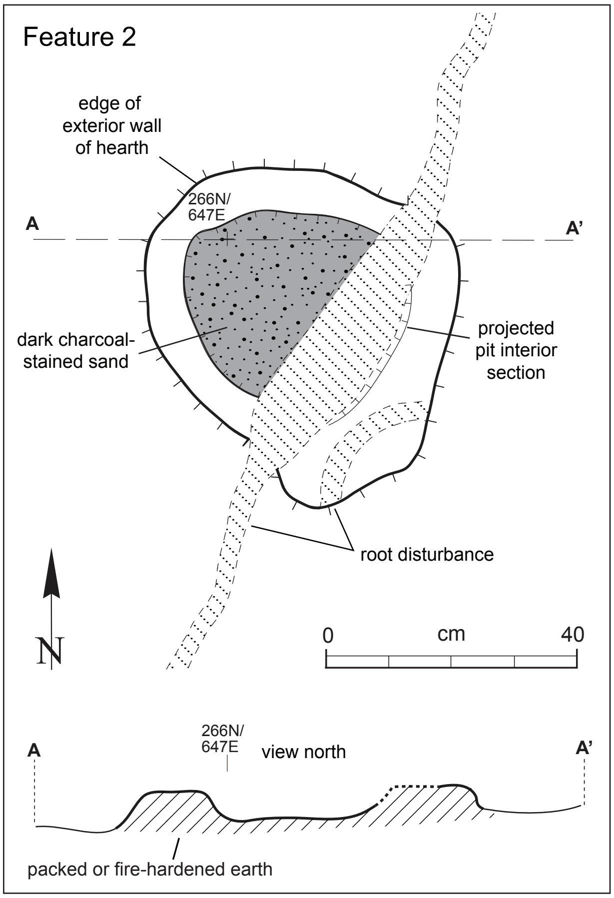


Figure 2.22. Feature 2 (fire pit), plan and profile (view north).

Figure 2.23. Feature 2 (fire pit), after excavation, view west.

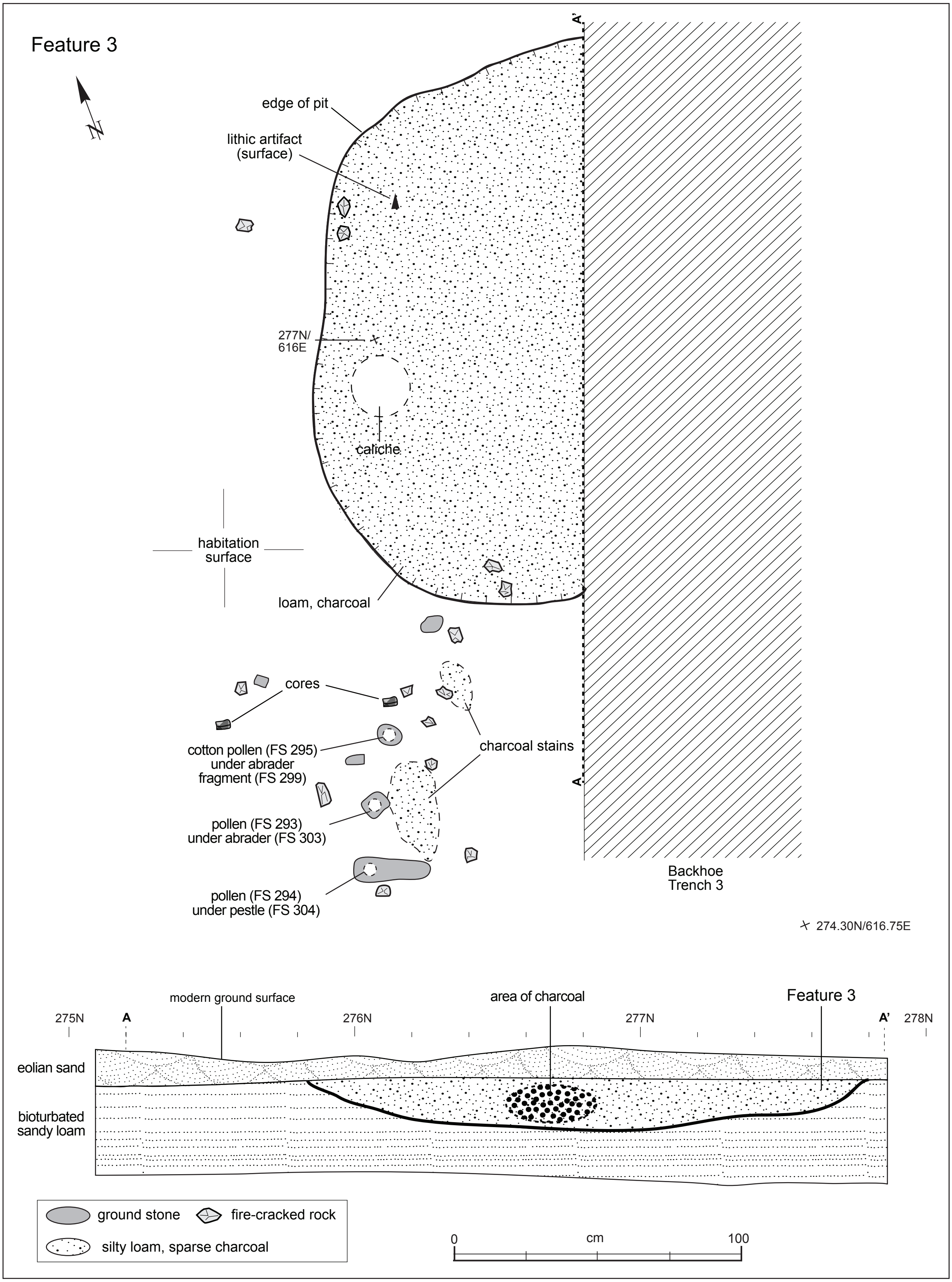


Figure 2.24. Feature 3 (possible structure), plan and profile.

Figure 2.25. Feature 3 (possible structure), partially excavated, view east.

Figure 2.26. Feature 3 (possible structure), profile, view southwest.

Table 2.4. LA 159879, Feature 3 and associated hand-excavated grid units, chipped stone artifact types.

		Unutilized Angular Debris		Unutilized Flake		Unutilized Core		End Scraper		Side Scraper		San Pedro Point		Total	
North	**East**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**
Grid Units															
275.08	615.40	–	–	1	100.0	–	–	–	–	–	–	–	–	**1**	**100.0**
275.65	615.64	–	–	1	100.0	–	–	–	–	–	–	–	–	**1**	**100.0**
275.80	615.00	–	–	–	–	1	100.0	–	–	–	–	–	–	**1**	**100.0**
276	616	–	–	6	100.0	–	–	–	–	–	–	–	–	**6**	**100.0**
276	617	–	–	15	93.8	–	–	1	6.3	–	–	–	–	**16**	**100.0**
277	616	1	12.5	7	77.8	–	–	–	–	1	–	1	11.1	**9**	**100.0**
277	617	3	12.5	19	79.2	2	8.3	–	–	–	–	–	–	**24**	**100.0**
279	615	1	3.6	24	85.7	3	10.7	–	–	–	–	–	–	**28**	**100.0**
279	616	–	–	31	96.9	1	3.1	–	–	–	–	–	–	**32**	**100.0**
279	617	2	9.1	14	63.6	5	22.7	–	–	1	4.5	–	–	**22**	**100.0**
Feature 3															
Feature Fill		1	2.8	34	94.4	1	2.8	–	–	–	–	–	–	**36**	**100.0**
277.48	616.24	1	100.0	–	–	–	–	–	–	–	–	–	–	**1**	**100.0**
Total		**9**	**5.1**	**152**	**85.9**	**13**	**7.3**	**1**	**0.6**	**1**	**0.6**	**1.0**	**0.6**	**177**	**100.0**

Table 2.5. LA 159879, Feature 3 and associated hand-excavated grid units, chipped stone material types.

		Chert		Basalt		Rhyolite		Metaquartzite		Total	
North	**East**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**
Grid Units											
275.08	615.40	1	100.0	–	–	–	–	–	–	**1**	**100.0**
275.65	615.64	–	–	1	100.0	–	–	–	–	**1**	**100.0**
275.80	615.00	1	100.0	–	–	–	–	–	–	**1**	**100.0**
276	616	4	66.7	–	–	1	16.7	1	16.7	**6**	**100.0**
	617	12	75.0	1	6.3	1	6.3	2	12.5	**16**	**100.0**
277	616	8	88.9	–	–	1	11.1	–	–	**9**	**100.0**
	617	17	70.8	3	12.5	3	12.5	1	4.2	**24**	**100.0**
279	615	23	82.1	1	3.6	4	14.3	–	–	**28**	**100.0**
	616	26	81.3	–	–	5	15.6	1	3.1	**32**	**100.0**
	617	15	68.2	–	–	7	31.8	–	–	**22**	**100.0**
Feature 3											
Feature Fill		30	83.3	–	–	–	–	6	16.7	**36**	**100.0**
277.48	616.24	1	100.0	–	–	–	–	–	–	**1**	**100.0**
Total		**138**	**78.0**	**6**	**3.4**	**22**	**12.4**	**11**	**6.2**	**177**	**100.0**

Table 2.6. LA 159879, Feature 3 and associated hand-excavated grid units, ground stone.

North	East	Function	Material	Portion	Heat-Fractured
Activity Area					
275.08	615.40	Pestles & crushers	Quartzitic sandstone	Whole	No
275.32	615.48	Abraders, smooth	Andesite	Whole	No
275.48	615.45	Indeterminate	Limestone	Internal fragment	No
275.92	615.88	Abraders, smooth	Andesite	Edge fragment	Yes
Feature 3					
Fill		Indeterminate	Vesicular basalt	Internal fragment	Yes
		Abraders, coarse	Basalt	Flake split off lengthwise	No
		Shaped or painted stone	Quartzitic sandstone	End fragment	No
Grid Units					
275	617	Manos	Vesicular basalt	Internal fragment	Yes
		Miscellaneous	Tuff	End fragment	No
276	615	Manos	Quartzitic sandstone	Whole	No
			Rhyolite	Medial fragment	Yes
		Mortars	Tuff	Internal fragment	No
		Shaped or painted stone	Tuff	Whole	No
	616	Manos	Quartzite	Internal fragment	Yes
	617	Manos	Vesicular basalt	Internal fragment	Yes
277	615	Indeterminate	Vesicular basalt	Internal fragment	Yes
		Abraders, smooth	Andesite	Broken & reused	No
		Polishing stones	Andesite	End fragment	No
	617	Indeterminate	Vesicular basalt	Internal fragment	Yes
278	615	Polishing stones	Andesite	Whole	No
	616	Manos	Vesicular basalt	Edge fragment	Yes
		Abraders, smooth	Andesite	Whole	No
	617	Manos	Vesicular basalt	Internal fragment	Yes
		Abraders, smooth	Andesite	Edge fragment	Yes
279	615	Manos	Basalt	Edge fragment	Yes
		Abraders, smooth	Rhyolite	Edge fragment	No
			Andesite	Edge fragment	Yes
		Metates	Quartzitic sandstone	Edge fragment	No
	616	Indeterminate	Quartzitic sandstone	Internal fragment	Yes
		Manos	Basalt	Edge fragment	Yes
	617	Ornamental	Andesite	Whole	No

small mammals, one was cottontail, and two were jackrabbit. Almost all of the bones are small fragments, with the exception of a complete cottontail phalange that is burned and nearly half a jackrabbit humerus.

Five flotation samples were taken from within Feature 3. Burned cheno-ams, dropseed, mesquite, and an unknown taxon were identified. Wood charcoal was all mesquite or saltbush (Chapter 7). Pollen samples from beneath the pestle/crusher, from under a fragment of a cobble abrader, and under a complete abrader in the activity area, and a phytolith/starch sample from the cobble abrader fragment in the activity area were analyzed. The pollen samples mainly reflect vegetation growing in the general area, on the floodplain, and in the mountains. Enough mesquite was present in the sample from under the pestle/crusher to suggest it was processed with this tool near the structure. Also found was a single grain of cotton pollen on the sample from around the cobble abrader fragment. The phytolith/starch sample from the same cobble abrader fragment produced dendroform phytoliths indicating use for processing grass seeds (Appendix 1). Pooled most accurate radiocarbon dates fall between 864 and 778 BC and the pooled most precise dates between 833 and 796 BC (Beta-307890, 397891, 390892 (Chapter 8, Table 8.4).

Based on the fire-reddened floor and about 10 pieces of fire-cracked rock in and around the feature (mainly in the activity area), the initial assessment of this feature was that it was a roasting pit. However, the fill was not darkly stained and the amount of rock was small for a roasting pit. The overall configuration with charcoal stains that could be the remains of an expedient fire in the activity area adjacent to the feature is more suggestive of a small brush structure than a large fire pit. This type of structure is usually burned and often lacks interior features (Akins 2014:720–724). Similar structures dating to the Late Archaic have been reported by Jones and colleagues (2010:10150–1016, 1464–1469).

Feature 4 (Fire Pit?)

Feature 4 was a stain in the northern portion of the site found through mechanical trenching that removed the northeast half of the feature. It was a thin lens of carbon-stained soil just beneath the surface and had evidence of insect and rodent disturbance. The remaining portion of Feature 4 suggests it was oblong in plan view and shallow basin-shaped in profile (Figs. 2.27, 2.28). It was at least 54 cm in diameter and 6 cm deep. Its base showed no evidence of oxidization, suggesting a low-level burn over a short duration, or that it was a pocket of stained soil and not an actual feature. The fill of the feature was a charcoal-stained loose, sandy loam with pea-sized gravels, and about five pieces of fire-cracked rock

A total of 15 chipped stone artifacts were collected from the excavation of Feature 4. Two are angular debris and the rest are unutilized flakes (14 core and 1 biface flake). Only two flakes are whole but just over half had a lustrous texture suggesting heat-treatment. Most are chert (n = 11) with the rest evenly divided between basalt and rhyolite.

The flotation sample from this feature contained no burned plant material. Pollen identified in the sample from Feature 4 reflects local and regional plants with none from cultigens.

Feature 5 (Structure)

Feature 5 was first observed as a large stain in the southern part of the site that was revealed by mechanical scraping (Fig. 2.29). Scraping may have removed the upper portion of the feature and rodent disturbance was prevalent throughout. Feature 5 was circular in plan view and a steep-sided basin in profile (Figs. 2.30, 2.31). It measured 1.05 by 0.95 m in diameter and was 20 cm deep. Excavated into the caliche layer (Stratum 4), the base had some reddening (oxidation) of the sediments and graying (reduction) of the caliche. The fill of the feature was lightly carbon-stained (10YR 4/3) fine-medium sand with inclusions of charcoal and sparse fire-cracked rock (Fig. 2.32).

Only the feature and enough fill to define the perimeter were excavated resulting in the recovery of few artifacts. The two pieces of chipped stone were recovered in a flotation sample. Both are unutilized core flake fragments made of chert and basalt

Two flotation samples—one 6.45 liters in size—were analyzed. Cheno-ams and goosefoot were the only burned plant material found. Wood types included mesquite, saltbush, and cf. piñon. No pollen samples were taken. Radiocarbon samples date this feature are some of the earliest for this site with pooled most accurate dates of 1009–841 BC and most precise dates of 980–899 BC (Beta-390893 and Beta-390894).

The initial interpretation of this feature was that

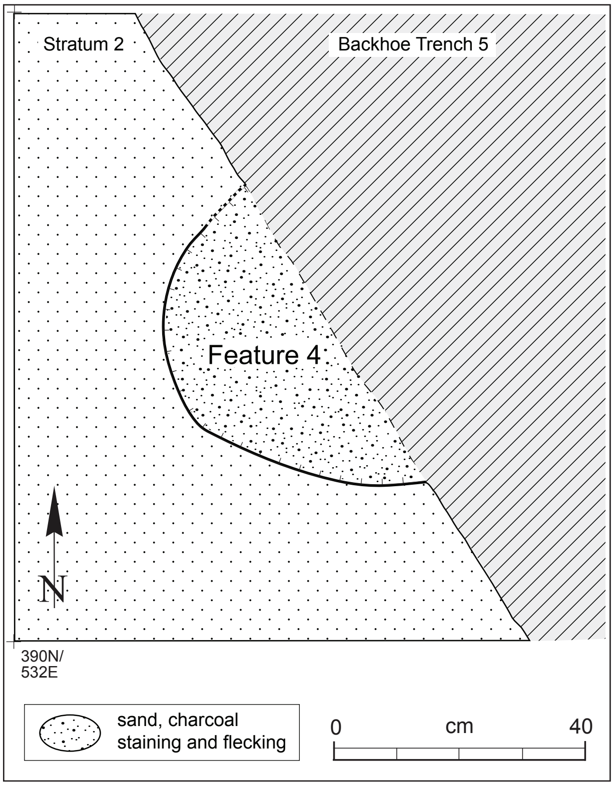


Figure 2.27. Feature 4 (fire pit?), plan.

Figure 2.28. Feature 4 (fire pit?), after excavation, view southwest.

Figure 2.29. Feature 5, stain, prior to excavation, view north.

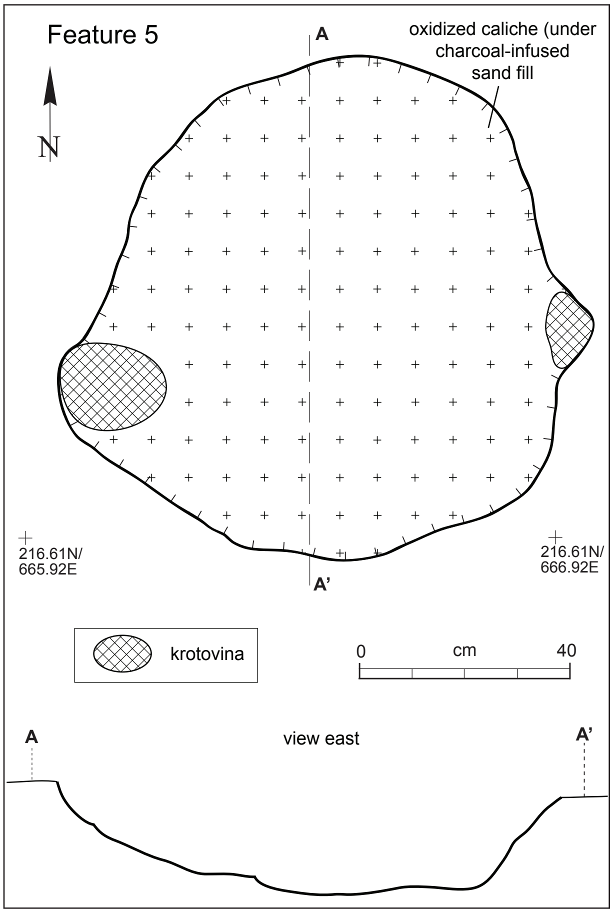


Figure 2.30. Feature 5 (structure), plan and profile (view east).

Figure 2.31. Feature 5 (structure), after excavation, view west.

Figure 2.32. Feature 5 (structure, partially excavated, showing fill, view north.

it was a large thermal pit. However, given the size, shape, and fill, Feature 5 may represent the remains of a small structure. It lacks evidence of extramural activities, but these would have been removed by mechanical scraping. The nearest hand-excavated units were just over 10 m north of the feature and none of the lithic artifacts from that unit were analyzed.

Feature 6 (Fire Pit)

Feature 6 was a stain located in the central portion of the site near Feature 7, a similar stain. Both were found by mechanical scraping, which may have removed the upper portion of Feature 6. The pit was oval in plan view and basin-shaped in profile, measuring 1.20 m long, 66 cm wide, and at least 17 cm deep (Figs. 2.33, 2.34). It was excavated into fairly soft matrix and did not have well defined walls. The base of the feature was lightly oxidized and the fill was semi-consolidated, fine-grained sand with inclusions of charcoal (Fig. 2.35). Based on its dimensions and the presence of oxidized sediments, Feature 6 appears to have been an informal fire pit.

The 2 by 2 m excavation to expose this feature and feature excavation resulted in the recovery of small numbers of artifacts, all from feature fill. The lithic artifacts made of chert (n = 3) or basalt; all four were core flakes, two were complete. One has potlids, which are indicative of heat treatment or discard into the active fire. A fire-fractured basalt cobble mano fragment was found in the feature fill.

Seven pieces of bone were recovered from the feature, one from a flotation sample. Three were identifiable only as small mammal–one burned, two cottontail, a jackrabbit, and a turtle capace shell fragment. The flotation sample from this feature had only a seed coat and possible mesquite and mesquite wood. Pollen observed in a sample from Feature 6 represents the regional and local vegetation. The radiocarbon sample indicates that the most accurate date is 980–830 BC and the most precise is 929–843 BC (Beta-307896).

Feature 7 (Fire Pit)

Feature 7 was a small informal fire pit located in the central portion of the site and found by mechanical scraping that removed the upper portion of the feature. The pit was circular in plan view and basin-shaped in profile, measuring 60–70 cm in diameter and at least 15 cm deep (Figs. 2.36, 2.37). Like Feature 6, it was stained soil in a similar Stratum

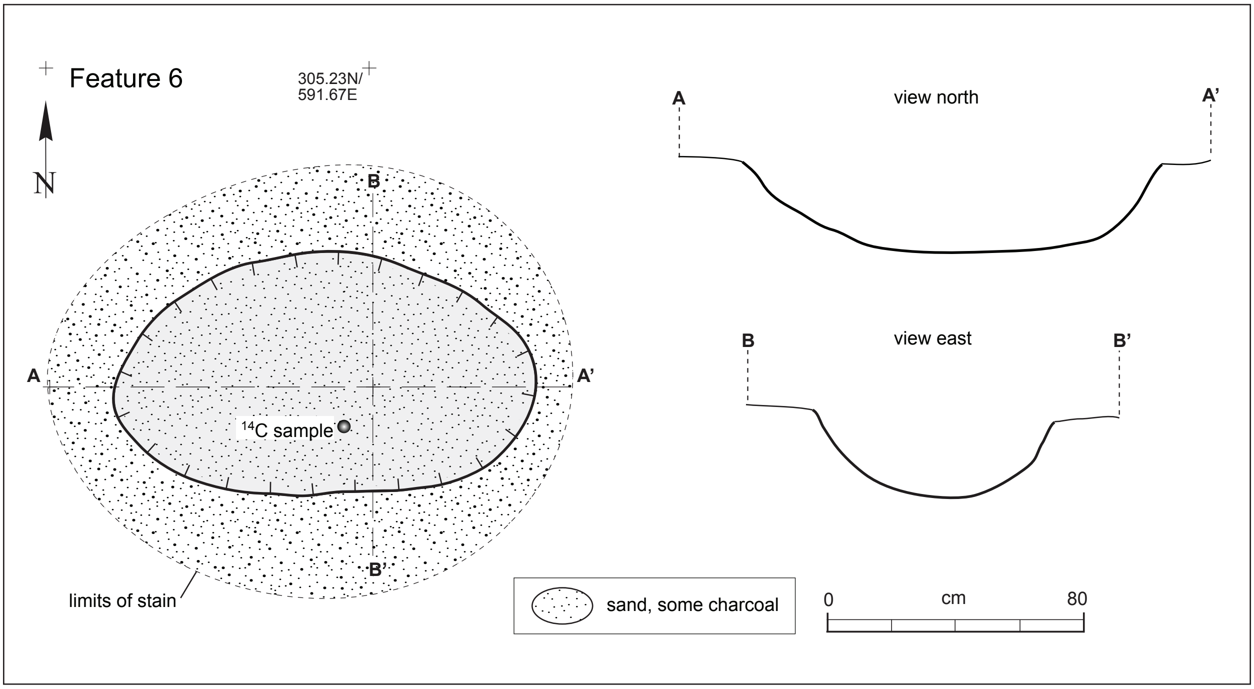


Figure 2.33. Feature 6 (fire pit), plan and profiles (views north and east).

Figure 2.34. Feature 6 (fire pit), after excavation, view south.

Figure 2.35. Feature 6 (fire pit), partially excavated, showing fill, view south.

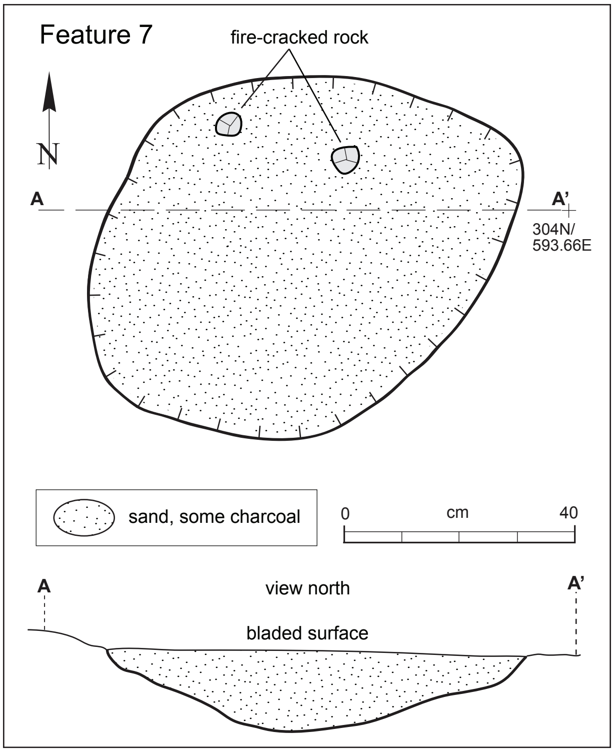


Figure 2.36. Feature 7 (fire pit), plan and profile (view north).

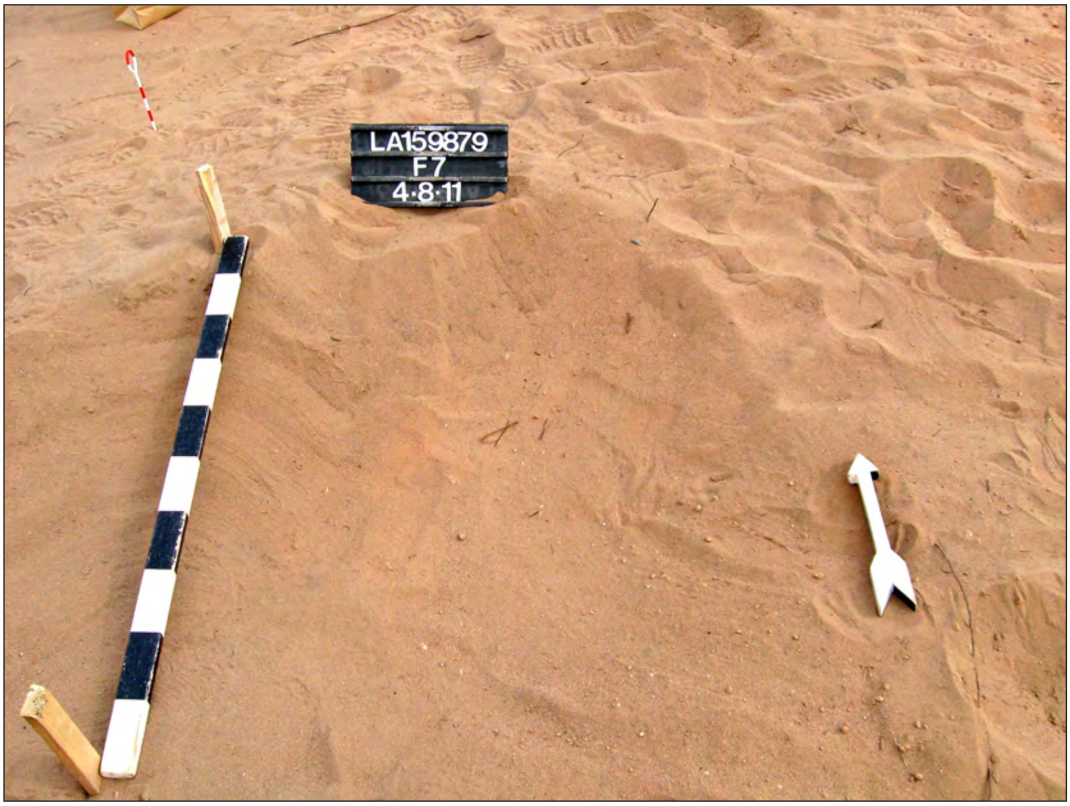


Figure 2.37. Feature 7 (fire pit), after excavation, view north.

2 matrix and had no well-defined or burned walls. Feature fill was a 10YR 5/3 brown, loose sand with inclusions of gravel, charcoal, and two pieces of fire-cracked rock.

No chipped stone artifacts were found in this feature. A single ground stone artifact consisting of a vesicular basalt cobble abrader fragment was the only stone found. The flotation sample produced the only bone, a small fragment of unburned small mammal bone. Otherwise, the flotation sample contained burned goosefoot. Pollen identified in a sample from this feature mainly records the local and regional vegetation but also contained a small quantity of corn pollen. Phytolith and starch grain analysis of the ground stone fragment found corn glumes suggesting a more primitive variety of corn (Chad Yost, personal communication to Stephen Lentz, May 2013) and dendric fragments indicating grass seeds were processed with this stone. The most accurate and most precise radiocarbon date for this feature is 791–538 BC (accurate to only 72 percent) (Beta-319042).

Feature 8 (Fire Pit)

Feature 8 was a large fire pit located in the central portion of the site near Feature 9, another informal fire pit, and just north of Features 6 and 7, also informal fire pits. Like the others, it was found by mechanical scraping, which exposed an area of carbon-stained soil and a few fire-cracked rocks (Fig. 2.38). A large amount of rodent activity was noted. The feature was oval in plan view and basin-shaped in profile, measuring 1.09 by 0.80 m and at least 9 cm deep (Figs. 2.39, 2.40). Again, the feature walls were formed by relatively loose Stratum 2 soil and were not well defined, however, the base was excavated into the caliche layer (Stratum 4) and fire-reddened. The fill was a dark grayish brown, fine coarse-grained sandy loam with about 20 pieces of fire-cracked rock (Fig. 2.41).

Few artifacts were recovered from the feature fill but the feature was just north of one of the 4 by 4 m hand-excavation areas. An estimated 77 chipped stone artifacts and 6 ground stone were recovered from the hand excavation. Tables 2.7 and 2.8 summarize the chipped stone from both the feature and the area where 56 chipped stone artifacts were analyzed. Most are core flakes with two biface flakes, two unidirectional cores, a bidirectional core, and a piece of angular debris. One of the unidirectional cores—made of rhyolite—had a utilized edge and the bidirectional core was used as a hammerstone. A variety of materials was found, including one of he three pieces of obsidian analyzed from the site. Nearly half had dorsal cortex that was noted as waterworn when it was recorded. Dorsal potlids were noted for one, and 11 have luster, suggesting heat treatment. Less than half were complete (46.4 percent). If these artifacts are representative of activities that could be associated with the fire-pit area, primary core reduction is suggested by the large number of flakes with cortex and by the hammerstone. The single biface flake could indicate tool manufacture also took place.

All of the ground stone found in and near the feature were fragments (Table 2.9) so they provide little information on food-processing activities associated with this feature. Most were probably gathered and heated. Neither of the two flotation samples contained cultural plant remains or burned wood. No pollen sample was collected due to the amount of bioturbation, but a piece of the ground stone collected from this feature was submitted for phytolith and starch-grain analysis. The phytoliths reflected the surrounding vegetation, with two dendriforms that provide only weak evidence of grass-seed processing.

Feature 9 (Fire Pit)

Feature 9 was a small carbon stain located in the central portion of the site near Feature 8 (Fig. 2.42). It was exposed by mechanical scraping that likely damaged the upper portion of the feature. Excavation of the dark fill indicates that the feature was scooped out of semi-consolidated Stratum 2 fill so that the walls and base were not distinct. It was oval in plan and basin-shaped in profile (Figs. 2.43, 2.44), and it measured 60–65 cm in diameter and was at least 15 cm deep. The fill was a 10YR 5/3 brown, sandy loam with small inclusions of gravel and fire-cracked rock. There was no evidence of oxidization.

Only three pieces of chipped stone were recovered and one of those was a flake from a piece of a basalt ground stone. The others were core flakes of metaquartzite and basalt. All three had large amounts of dorsal cortex (100 percent for both basalt lithics and 40 percent for the metaquartzite artifact). The core flakes are complete and the other is a medial fragment. Ground stone was more abundant (Table 2.10) and included a complete non-

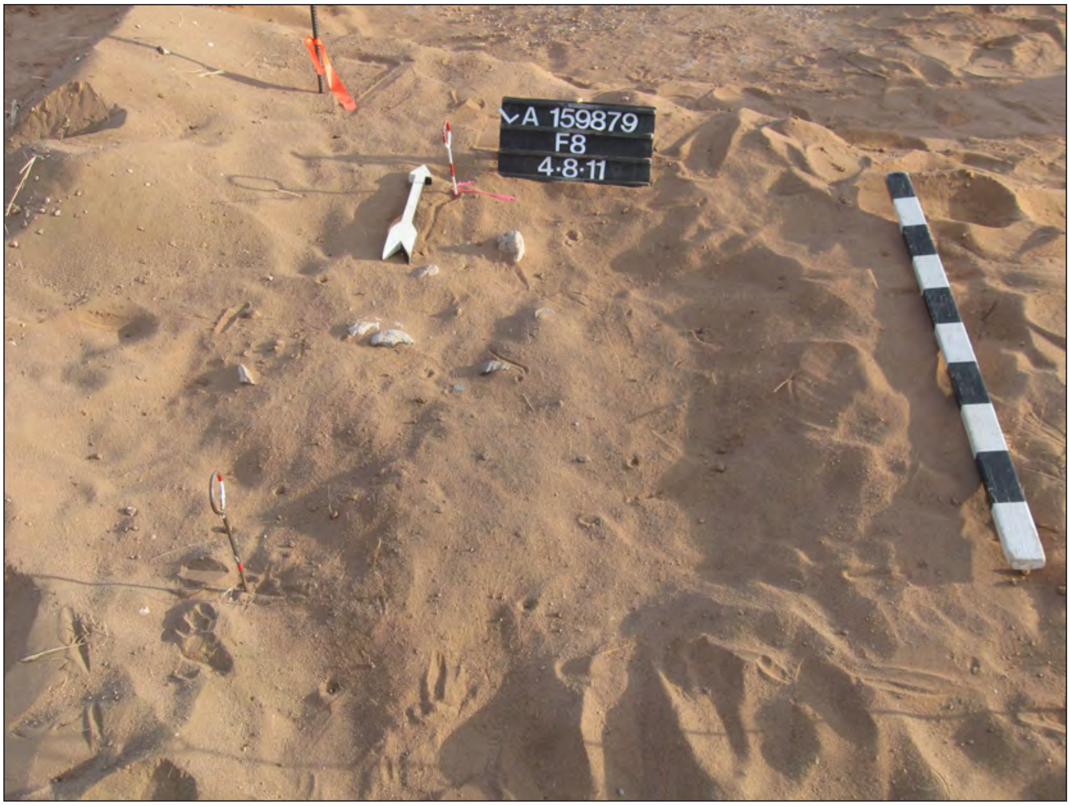


Figure 2.38. Feature 8 (fire pit), before excavation, view north.

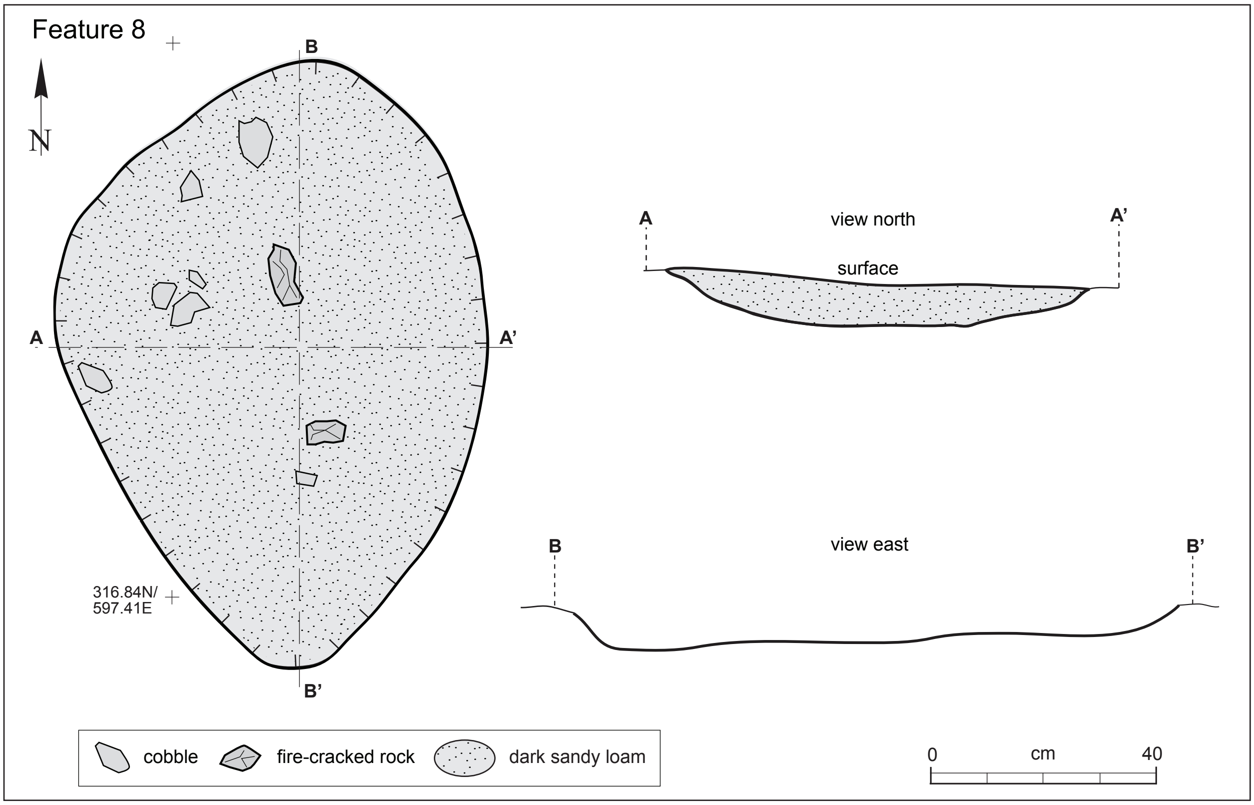


Figure 2.39. Feature 8 (fire pit), plan and profiles (views north and east).

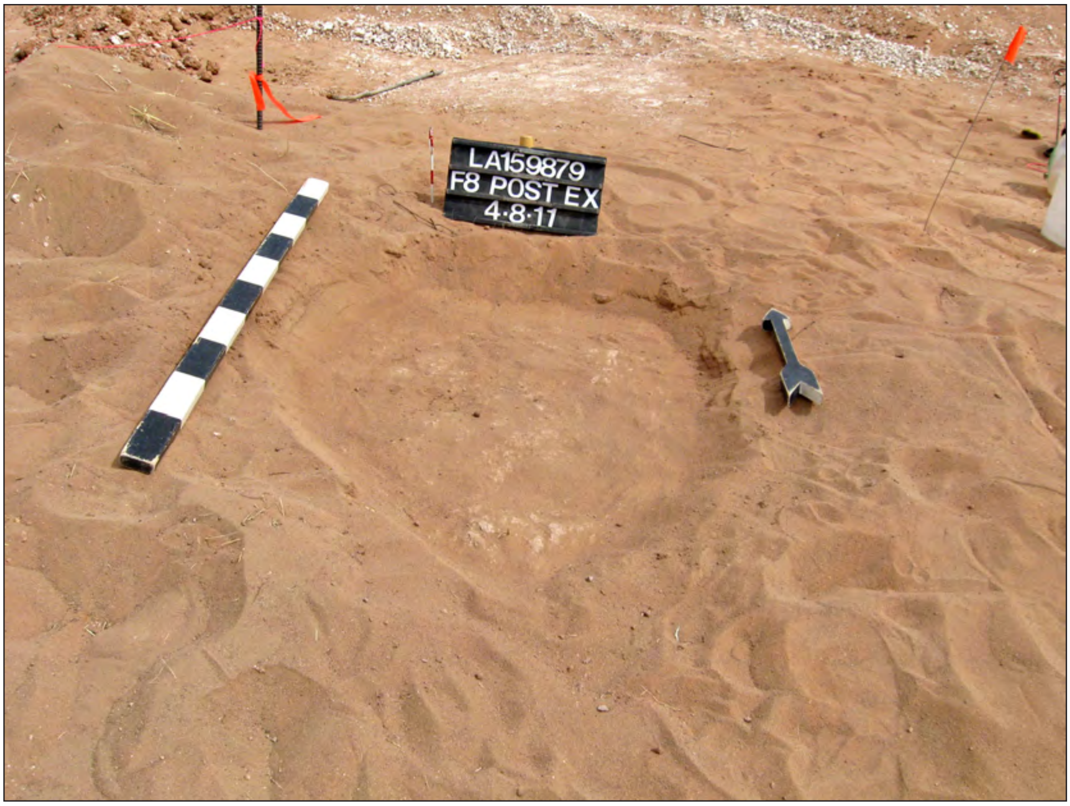


Figure 2.40. Feature 8 (fire pit), after excavation, view north.

Figure 2.41. Feature 8 (fire pit), partially excavated, showing fill, view northeast.

Table 2.7. LA 159879, Feature 8 and associated hand-excavated grid units, chipped stone artifact types.

		Angular Debris		Core Flake		Biface Flake		Unidirectional Core		Bidirectional Core		Total	
North	**East**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**
Grid Units													
312	595	–	–	5	83.3	1	16.7	–	–	–	–	**6**	**100.0**
	596	–	–	1	100.0	–	–	–	–	–	–	**1**	**100.0**
	597	–	–	3	100.0	–	–	–	–	–	–	**3**	**100.0**
	598	–	–	4	66.7	–	–	2	33.3	–	–	**6**	**100.0**
313	595	–	–	5	100.0	–	–	–	–	–	–	**5**	**100.0**
	596	–	–	6	85.7	–	–	–	–	1	14.3	**7**	**100.0**
	597	–	–	3	100.0	–	–	–	–	–	–	**3**	**100.0**
	598	–	–	3	100.0	–	–	–	–	–	–	**3**	**100.0**
314	595	–	–	4	80.0	1	20.0	–	–	–	–	**5**	**100.0**
	596	–	–	3	100.0	–	–	–	–	–	–	**3**	**100.0**
	597	–	–	1	100.0	–	–	–	–	–	–	**1**	**100.0**
	598	–	–	2	100.0	–	–	–	–	–	–	**2**	**100.0**
315	595	–	–	2	100.0	–	–	–	–	–	–	**2**	**100.0**
	598	1	14.3	6	85.7	–	–	–	–	–	–	**7**	**100.0**
Feature 8													
316.84	596.4	–	–	2	100.0	–	–	–	–	–	–	**2**	**100.0**
Total		**1**	**1.8**	**50**	**89.3**	**2**	**3.6**	**2**	**3.57**	**1**	**1.8**	**56**	**100.0**

Table 2.8. LA 159879, Feature 8 and associated hand-excavated grid units, chipped stone material types.

		Chert		Obsidian		Basalt		Rhyolite		Metaquartzite		Quartz		Total	
North	**East**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**	**Count**	**Row %**
Grid Units															
312	595	5	83.3	–	–	–	–	1	16.7	–	–	–	–	**6**	**100.0**
	596	1	100.0	–	–	–	–	–	–	–	–	–	–	**1**	**100.0**
	597	3	100.0	–	–	–	–	–	–	–	–	–	–	**3**	**100.0**
	598	2	33.3	–	–	–	–	3	50.0	–	–	1	16.7	**6**	**100.0**
313	595	4	80.0	1	20.0	–	–	–	–	–	–	–	–	**5**	**100.0**
	596	3	42.9	–	–	1	14.3	2	28.6	1	14.3	–	–	**7**	**100.0**
	597	2	66.7	–	–	–	–	–	–	1	33.3	–	–	**3**	**100.0**
	598	1	33.3	–	–	–	–	1	33.3	1	33.3	–	–	**3**	**100.0**
314	595	3	60.0	–	–	–	–	1	20.0	1	20.0	–	–	**5**	**100.0**
	596	–	–	–	–	–	–	1	33.3	2	66.7	–	–	**3**	**100.0**
	597	–	–	–	–	–	–	1	100.0	–	–	–	–	**1**	**100.0**
	598	–	–	–	–	–	–	2	100.0	–	–	–	–	**2**	**100.0**
315	595	2	100.0	–	–	–	–	–	–	–	–	–	–	**2**	**100.0**
	598	3	42.9	–	–	–	–	4	57.1	–	–	–	–	**7**	**100.0**
Feature 8															
316.84	596.41	1	50.0	–	–	–	–	–	–	1	50.0	–	–	2	100.0
Total		**30**	**53.6**	**1**	**1.8**	**1**	**1.8**	**16**	**28.6**	**7**	**12.5**	**1**	**1.8**	**56**	**100.0**

Table 2.9. LA 159879, Feature 8 and associated hand-excavated grid units, ground stone.

North	East	Artifact Type	Material Type	Portion	Heat Fractured
Grid Units					
312	597	Abraders, smooth	Quartzitic sandstone	Edge fragment	No
313	596	Abraders, smooth	Quartzite	End fragment	No
	598	Metates	Grey rhyolite	Edge fragment	No
314	598	Metates	Quartzitic sandstone	Edge fragment	No
315	597	Abraders, coarse	Vesicular basalt	Internal fragment	No
	598	Metates	Quartzitic sandstone	Internal fragment	No
Feature 8					
316.61	596.61	Indeterminate	Nonvesicular basalt	Internal fragment	No
		Abraders, smooth	Andesite	Medial fragment	Yes
		Metates	Nonvesicular basalt	Internal fragment	Yes

Figure 2.42. Feature 9 (fire pit), stain, before excavation, view north.

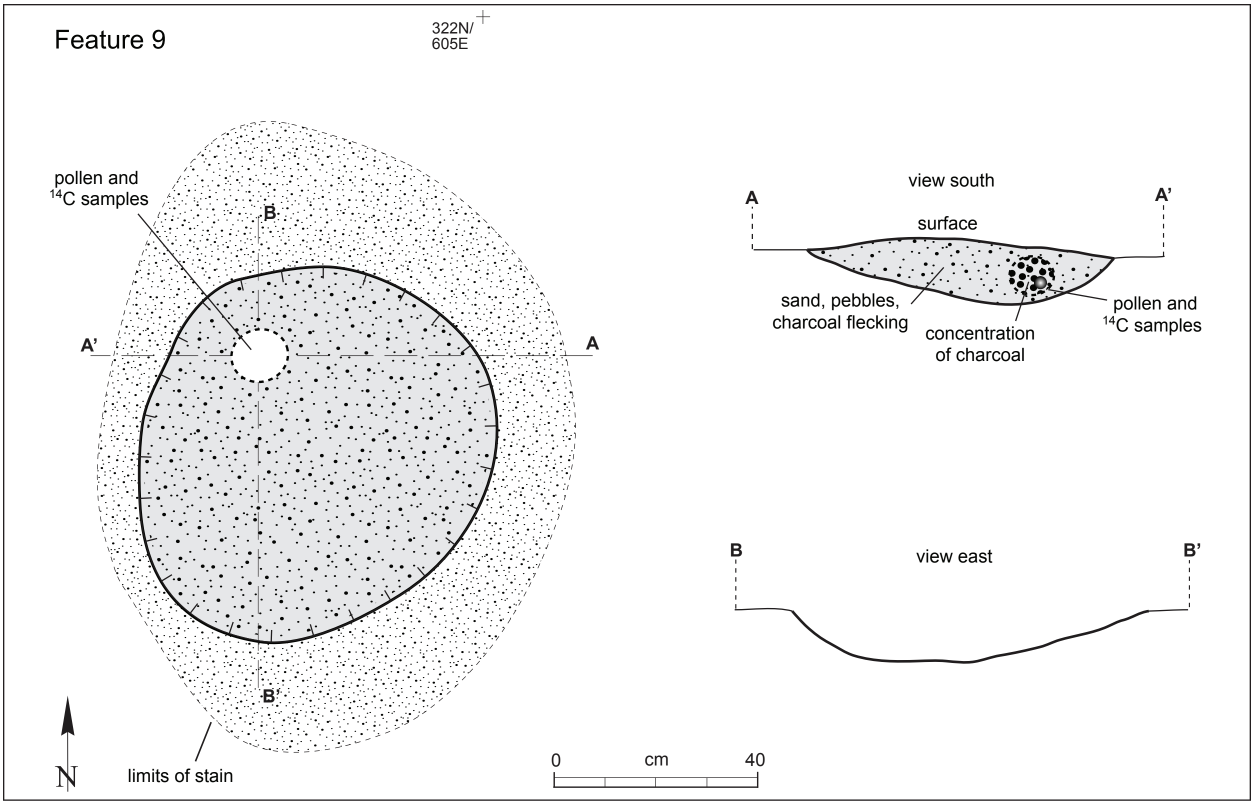


Figure 2.43. Feature 9 (fire pit), plan and profiles (views south and east).

Figure 2.44. Feature 9 (fire pit), after excavation, view southwest.

Table 2.10. LA 159879, Feature 9, ground stone.

Artifact Type	Material Type	Portion	Heat Fractured
Indeterminate	Brown sandstone	Internal fragment	Yes
Manos	Nonvesicular basalt	Edge fragment	Yes
Abraders, smooth	Andesite	Edge fragment	No
Metates	Nonvesicular basalt	Whole	No
		Internal fragment	Yes
	Red sandstone	Internal fragment	No
Raw material	Tuff, white	Whole	No

vascular basalt metate as well as several fire-cracked fragments of ground stone objects. The metate and a smooth andesite abrader with red pigment were found in the vicinity of the feature after the wind had scoured the area in the course of excavation and exposed the ground stone and fire-cracked rocks. Two small pieces of bone were found in one of the flotation samples. These are both from small mammals and burned. Burned plant material was sparse in the two flotation samples, which also contained burned cheno-ams and mesquite, saltbush, and an unknown wood. The pollen sample from feature fill had mainly cheno-am pollen, which was interpreted as reflecting saltbush in the local vegetation. However, given the presence of burned cheno-ams in the flotation sample, it could be from processing cheno-ams or both could reflect local saltbush used as fuel. This feature had the oldest radiocarbon date for the site—most accurate 1050–895 BC and most precise 1000–925 BC (Beta-307895). Based on the lack of oxidization, the feature may have been briefly used as a fire pit. The presence of a complete metate and ground stone in the vicinity suggests at least limited food processing, possibly of cheno-am seeds in the general area.

Feature 10 (Rock-lined Fire Pit)

Feature 10 was located in the central portion of the site near Features 3, 11, and 12. It was found by means of mechanical scraping that may have removed the upper portion of the feature. Again, the pit was scooped out of soft Stratum 2 matrix so that the actual pit walls were not distinct and the pit walls were not burned. At least 25 cobbles and fragments of rock were placed in the shallow pit. The underlying pit appears to have been circular in shape, measuring 45–50 cm in diameter and at least 31 cm deep (Figs. 2.45–2.47). The fill between and beneath the cobbles was essentially site Stratum 2 fill, a 5YR 4/4 reddish brown, semi-consolidated sand with a small amount of gravel and little charcoal.

Artifacts collected from the feature excavation were sparse but fairly diverse. Chipped stone (Table 2.11) was mainly core flakes but a core and angular debris were also found. Only one had cortex and one had evidence of heat treatment. No utilization was observed. Three of the cobbles and fragments of rock in the pit were ground stone. These include a fire-fractured fragment of an andesite abrader, a complete andesite cobble abrader, and a quartzite one-hand cobble mano or pestle fragment with adhering red pigment.

Burned plant material in the single flotation sample included a monocot stem and a part from an unknown taxon. Pollen samples were collected from the fill of the feature (n = 3) and two pieces of ground stone were submitted for phytolith/starch analysis. Identified pollen grains document the presence of nearby cheno-ams and wind-transported mesquite, box elder, and fir. The quartzite mano fragment had no starch grains but corn and sedge phytoliths were present and these plants were probably ground with this tool. The andesite abrader fragment had phytoliths that could be, but are not, diagnostic of corn and a dendriform phytolith that would indicate seed processing if the count were not so low (Appendix 3).

The interpretation of Feature 10 as a fire pit was based on the presence of fire-cracked rock and ground stone in the feature. Any charcoal-laden fill associated with this feature must have blown away leaving only the cobbles and a small number of chipped stone artifacts. Phytoliths document the processing of corn at the site, but this cannot be

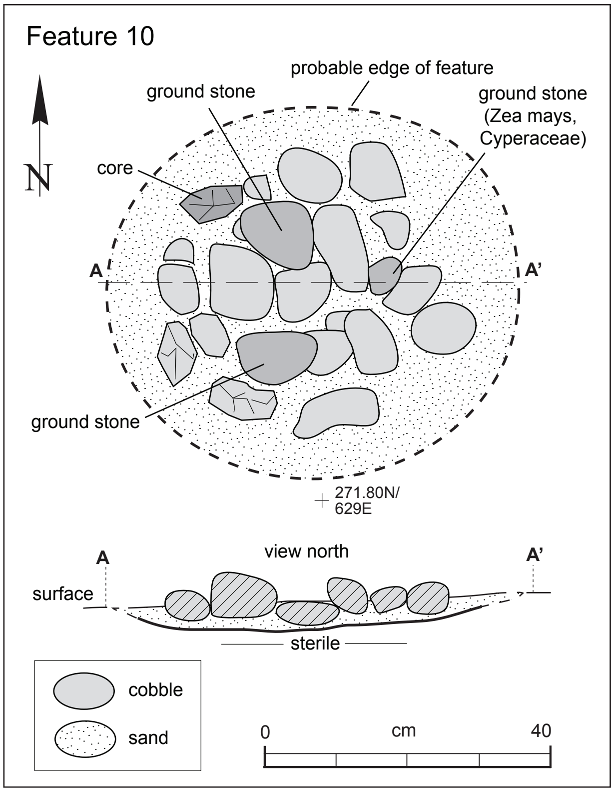


Figure 2.45. Feature 10 (fire pit), plan and profile (view north).

Figure 2.46. Feature 10 (fire pit), with rock exposed, view north.

dated since the feature had insufficient charcoal for a radiocarbon date; further, the ground stone was a reused item so a radiocarbon date would not directly date the corn phytoliths.

Feature 11 (Fire Pit)

Feature 11 was a large thermal pit located in the central portion of the site near Features 10 and 12 and adjacent to one of the 4 by 4 m hand-excavated units. The feature was found by means of mechanical scraping. It was oval in plan view and basin-shaped in profile (Figs. 2.48, 2.49), measuring 1.20 by 0.95 m in diameter and was at least 18 cm deep. Excavated through the soft Stratum 2 fill into Stratum 3 with caliche nodules, the caliche at the base of the feature was oxidized. Feature fill was mainly Stratum 2 with some Stratum 3 mixed in and flecks and pieces of charcoal.

The only artifact collected from the 2 by 2 m excavation for this feature and the 4 by 4 m hand-excavation area, was a quartzitic sandstone cobble one-hand mano. The flotation sample from this feature produced a small fragment of a burned jackrabbit radius and an unburned small mammal

Figure 2.47. Feature 10 (fire pit), with rock removed, view north.

Table 2.11. LA 159879, Feature 10, chipped stone artifacts.

Artifact Type	Material	Portion	% Dorsal Cortex	Cortex Type	Heat Treatment	Count
Angular debris	Chert	Whole	0	None	None	1
			10	Waterworn	None	1
Core flake	Chert	Medial	0	None	Lustrous	1
		Distal	0	None	None	1
	Basalt	Whole	0	Waterworn	None	1
		Medial	0	None	None	1
	Metaquartzite	Whole	0	None	None	1
Unidirectional core	Chert	Whole	20	Waterworn	None	1

long-bone fragment. The sample also contained burned cheno-am and goosefoot as well as burned mesquite and saltbush. The most accurate range of radiocarbon dates is 930–812 BC and the most precise is 901–836 BC (Beta-307897).

This feature was sufficiently burned to positively indicate it was used as a fire pit. The absence of artifacts in the general area and in the 16 grid units excavated may suggest that blading removed any associated material rather than implying an absence of activities in this portion of the site.

Feature 12 (Fire Pit)

Feature 12 was a large, shallow fire pit located just south of Feature 11 in the central portion of the site. It, too, was a stain (Fig. 2.50) discovered during the removal of overburden through mechanical scraping. The remaining pit was oval in plan view with a very shallow basin profile measuring 1.50 to 1.70 m in diameter and at least 5 cm deep (Figs. 2.51, 2.52). Like Feature 11, it was excavated through Stratum 2 and the base into Stratum 3 where the caliche was reddened from oxidation. A large rodent

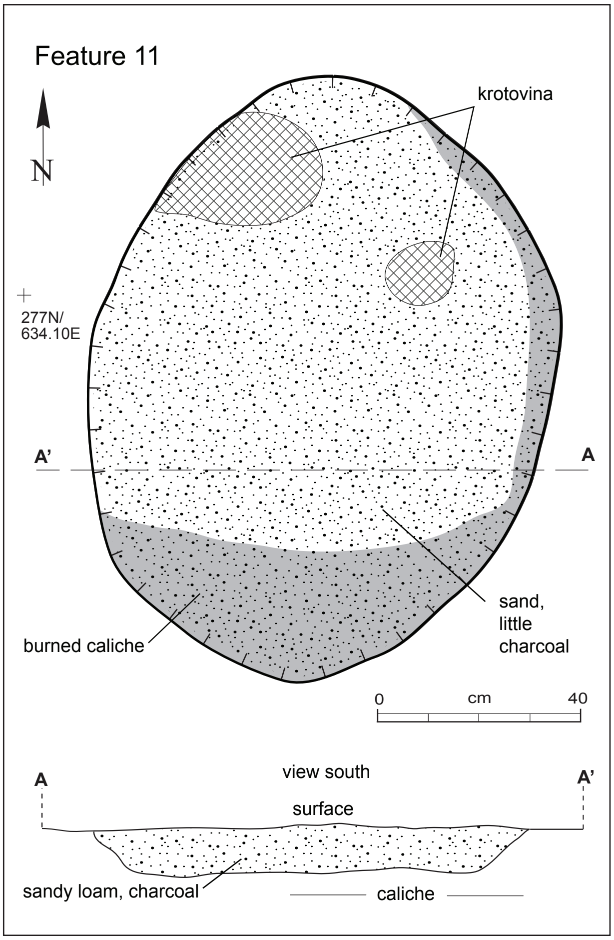


Figure 2.48. Feature 11 (fire pit), plan and profile (view south).

Figure 2.49. Feature 11 (fire pit), after excavation, view southwest.

Figure 2.50. Feature 12 (fire pit), stain, before excavation, view east.

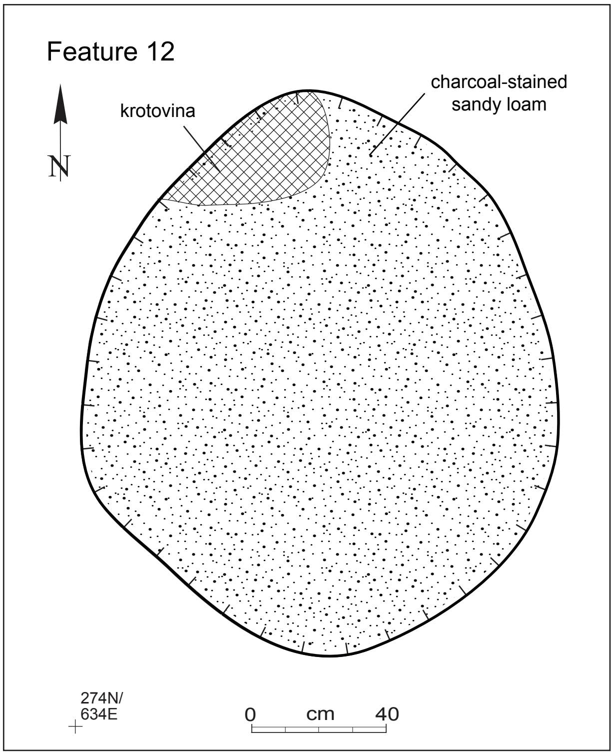


Figure 2.51. Feature 12 (fire pit), plan.

hole impacted the northern portion of the pit bottom. The feature fill was similar to Stratum 2 and was lightly charcoal stained.

No chipped or ground stone artifacts were encountered in or around the feature, but a large portion of the feature fill was collected as a flotation sample. One bone, a fragment of an unburned jackrabbit humerus, was recovered from that sample. Otherwise, the only burned plant material is from an unknown taxon.

Feature 13 (Fire Pit)

Feature 13 was a good-sized stain with sparse fire-cracked rock (Fig. 2.53) discovered in the northern portion of the site by means of mechanical scraping that removed the upper portion of the feature. Excavated through soft Stratum 2 fill, the feature walls were indistinct. It was ovoid in plan with a basin-shaped profile, measuring 70 to 95 cm in diameter and at least 5 cm deep (Figs. 2.54, 2.55, 2.56). The fill was dark gray fine to coarse sandy loam with a small amount of fire-cracked rock that graded into mottled Stratum 3 sandy loam with caliche nodules.

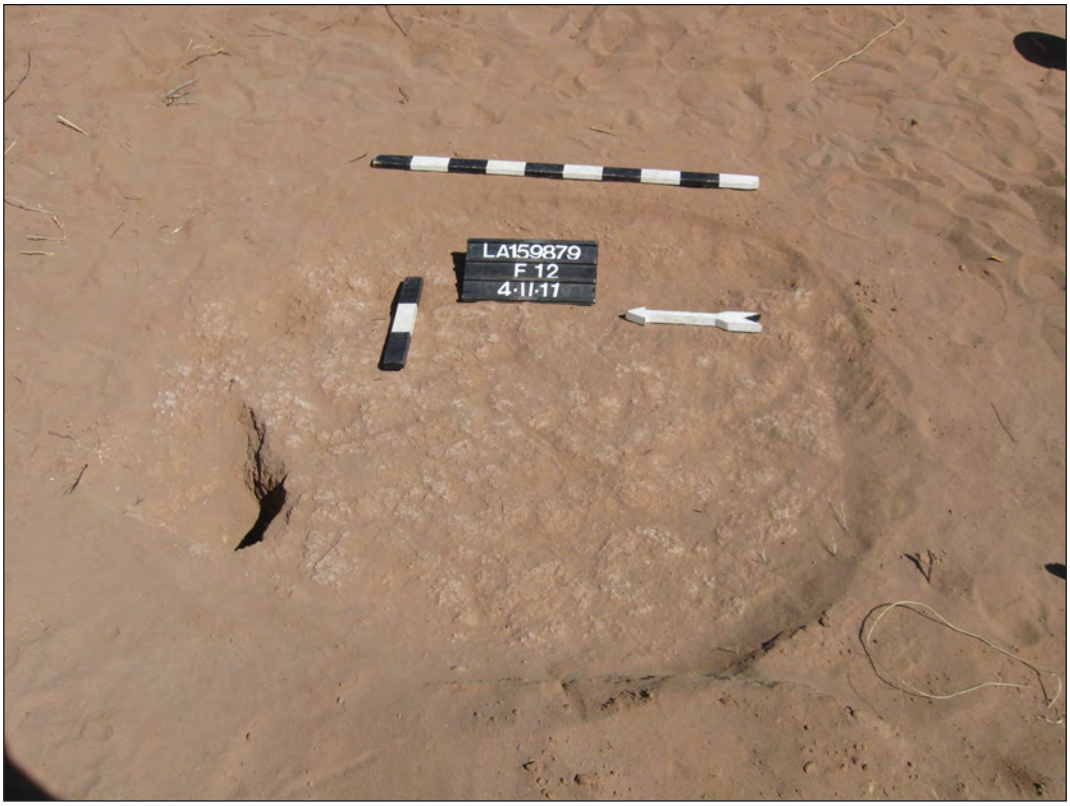


Figure 2.52. Feature 12 (fire pit), after excavation, view east.

Figure 2.53. Feature 13 (fire pit), stain, before excavation, view north.

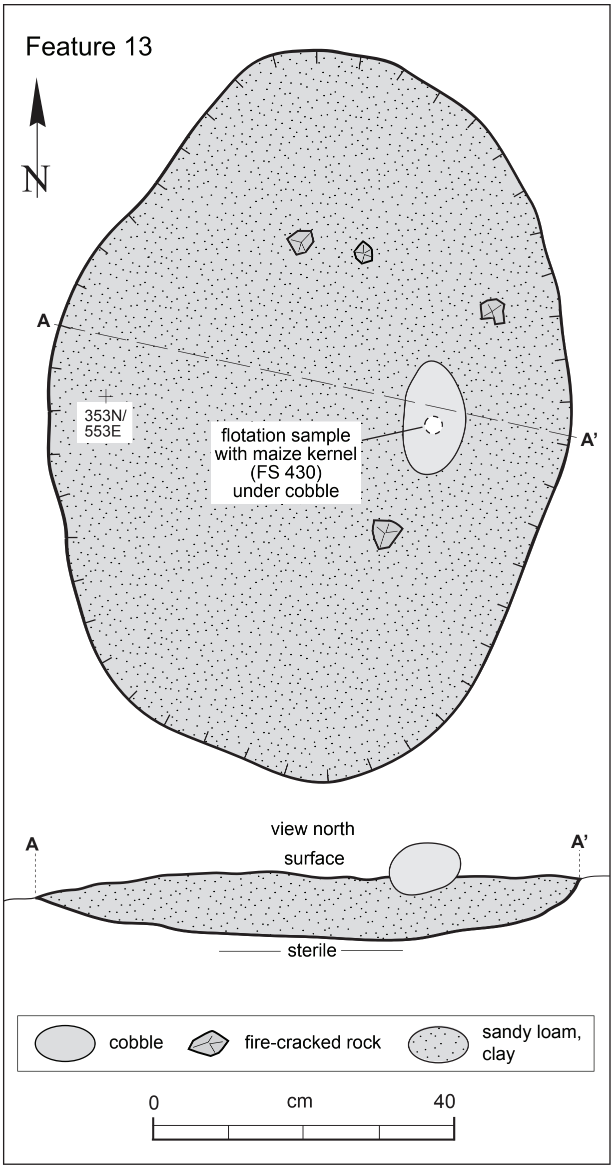


Figure 2.54. Feature 13 (fire pit), plan and profile (view north).

The six pieces of chipped stone attributed to this feature were all recovered from back dirt from the scrape. Two are angular debris and the rest are core flakes. Materials are chert (n = 4), rhyolite, and metaquartzite. Two of the flakes are fragments and two are lustrous, suggesting heat alteration. A heat-fractured piece of an andesite cobble metate is the only ground stone recovered. Cultural plant material recovered in the flotation sample was an unknown taxon and mesquite bean fragments. The unknown plant parts could be fragments of corn kernels and were submitted for radiocarbon analysis. No wood is reported. Pollen samples from the fill had mainly cheno-am pollen and a small amount of pollen from a plant in the sunflower family along with pollen reflecting the local vegetation. Corn pollen was observed in both samples. No starch grains and few phytoliths were observed in the phytolith/starch sample. Most were probably derived from the surrounding vegetation except for one large dendritic that could be, but cannot, be positively confirmed as corn. A radiocarbon sample indicates the feature dates between 758–429 cal BC (most accurate and most precise dates; Beta-319043).

Feature 14 (not a feature)

Feature 14 was a small stain in the wall of BHT 5, located in the central portion of the site. Excavation of 40 cm of Stratum 3 fill found that the stain did not extend beyond the trench wall and that it was noncultural. Fill excavated while investigating the "feature" produced a few artifacts. Chipped stone items were all core flakes made of chert, n = 2), basalt (n = 1), or rhyolite (n = 3). It was complete and had evidence of heat treatment. None had cortex and only one of the chert flakes was lustrous, suggesting heat treatment. None were utilized. A fire-fractured andesite cobble abrader was also recovered.

Features 15, 16, 20, and 21
(Structure, Fire Pit, and Postholes)

These four features include a small structure, a fire pit, and postholes located in the northern portion of the site. The structure (Feature 16) and fire pit (Feature 15) were exposed by mechanical scraping (Figs. 2.57, 2.58). Unfortunately, the scrape was deep enough to have removed any evidence of an activity area associated with these features and only a 1 by 2 m grid unit was excavated in the area. The features are described individually, then the artifacts and dates discussed.

Feature 15 (Fire Pit)

Feature 15 was the smaller of the two pits found during mechanical scraping. It was excavated into the caliche layer (Stratum 4) but could have originated in fill removed by the backhoe. It was round in plan view measuring 50 cm in diameter and was at least 20 cm deep with a basin-shaped profile. The base was oxidized (Figs. 2.59, 2.60). Fill was a

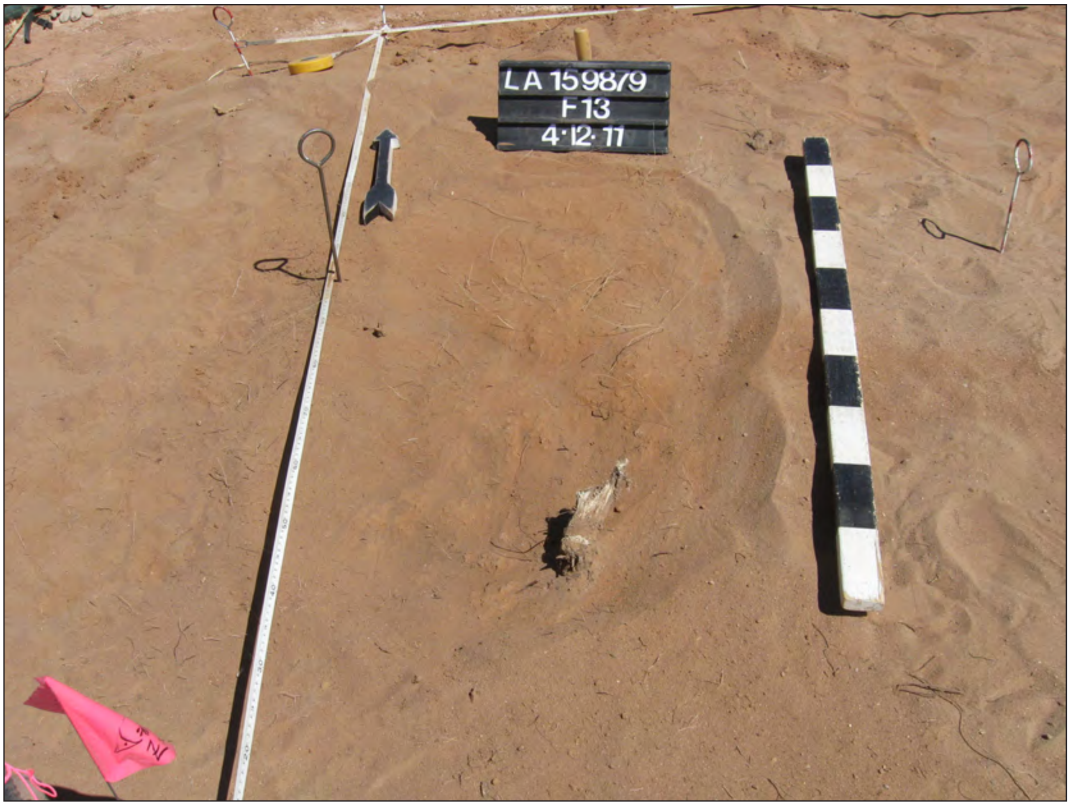


Figure 2.55. Feature 13 (fire pit), after excavation, view north.

Figure 2.56. Feature 13 (fire pit), partially excavated, showing fill.

Figure 2.57. Features 15 (fire pit) and 16 (structure), revealed by mechanical scraping, view north.

2.5YR 3/4 dark reddish brown, compact sand with charcoal in some parts of the fill—especially along the east edge (Fig. 2.61). The charcoal in the fill, the oxidized base, and position fronting the structure suggest it was a fire pit used in conjunction with the structure.

Feature 16 (Structure)

Feature 16 was a small circular pit structure with a basin-shaped profile, measuring 1.24–1.36 m in diameter and at least 32 cm deep (Figs. 2.62, 2.63). Excavated into the caliche layer (Stratum 4), fill was a loose, fine-grained sandy loam with occasional pea-sized gravel and sparse charcoal flecks (Fig. 2.64). Slight oxidation was noted along the eastern edge of the feature.

Four small postholes that probably supported a roof (Features 16.1, 16.2, 16.3, and 16.4) were found around the perimeter, just inside the structure (Fig. 2.62). The postholes were roughly the same size, 5 cm in diameter and 16 cm deep.

Feature 20 (Posthole)

Feature 20 was a small pit that was not immediately apparent after mechanical scraping but was located after the structure and fire-pit excavations were completed. Features 20 and 21 were located between but offset to the east of the structure and the fire pit (Fig. 2.58). Feature 20 measured 15–20 cm in diameter and was 15 cm deep (Figs. 2.65, 2.66). Pit fill was loose, fine-grained silty sand with a small amount of fire-cracked rock. Feature 20 appears to have been a posthole supporting a windbreak or other feature associated with the structure.

Feature 21 (Posthole)

Feature 21 was a second small pit located about 25 cm south of Feature 20 (Fig. 2.65). It was 16 cm in diameter and 17 cm deep with a more cone-shaped profile than Feature 20 (Figs. 2.66). Pit fill was loose fine-grained silty sand. The feature was probably associated with Feature 20 and appears to have been a posthole and part of a windbreak or other feature associated with the structure.

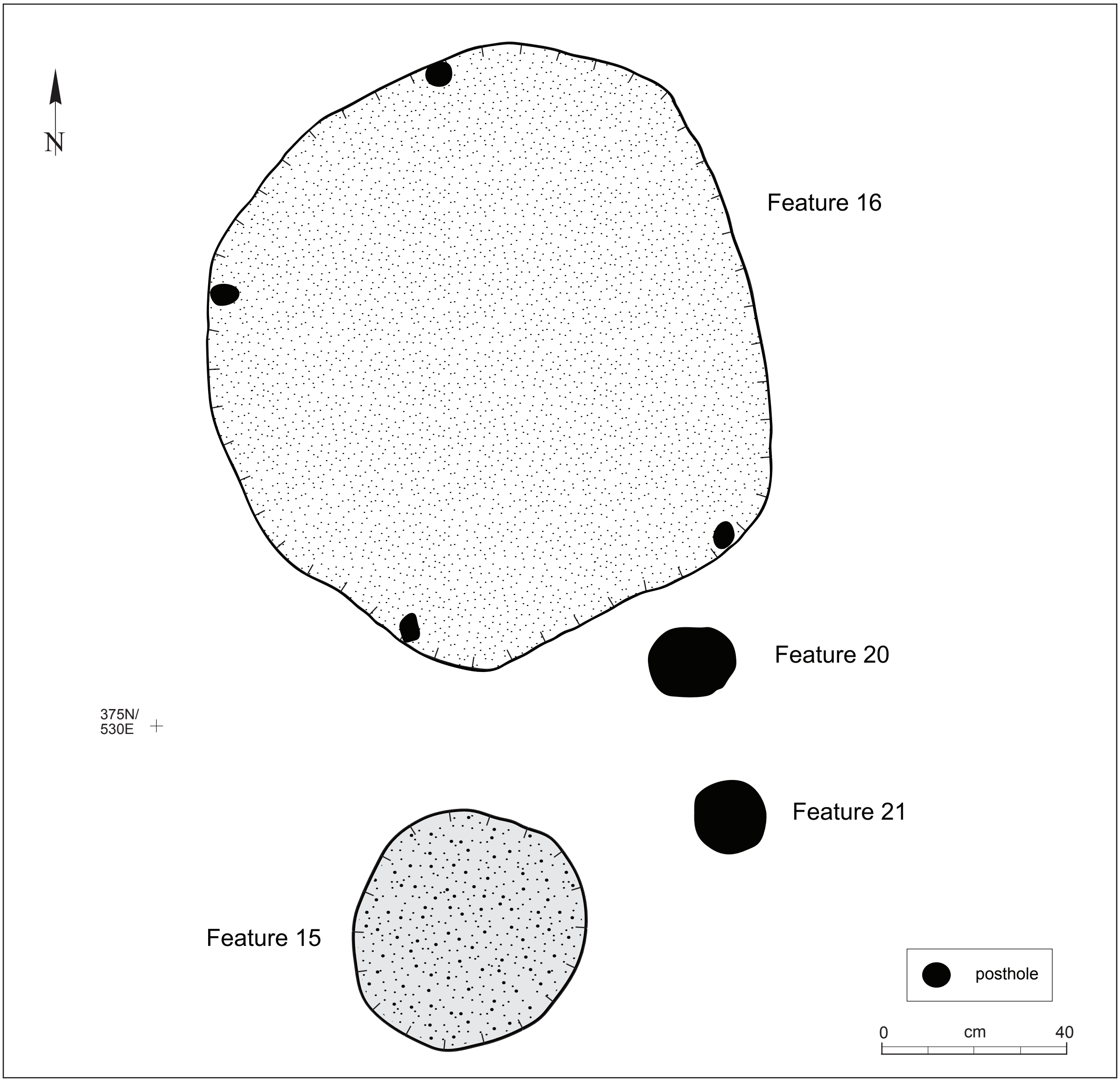


Figure 2.58. Features 15 (fire pit), 16 (structure), 20 (posthole), and 21 (posthole), plan.

Features 15, 16, 20, and 21: Artifacts and Dating

No chipped artifacts were recovered from around Features 15, 16, 20, and 21, probably because of the depth of the mechanical scraping that located the features. The few found are from the two larger features (Table 2.12) and are mainly chert core flakes. None have cortex and a few have lustrous textures suggesting heat treatment. No ground stone was found in the vicinity of these features.

The fire pit (Feature 15) produced a good portion of the fauna recovered from the site (31 of the 103 specimens). Nearly half (48.4 percent) were recovered from flotation samples and most are burned (74.2 percent), indicating they were discarded into the burning pit. The majority of the bones are small fragments identifiable only as small mammal (83.9 percent), with a single burned cottontail metapodial fragment and four jackrabbit specimens—three tooth fragments and a rib fragment, all burned.

Numerous flotation samples were taken from this complex (Chapter 7) including two from the

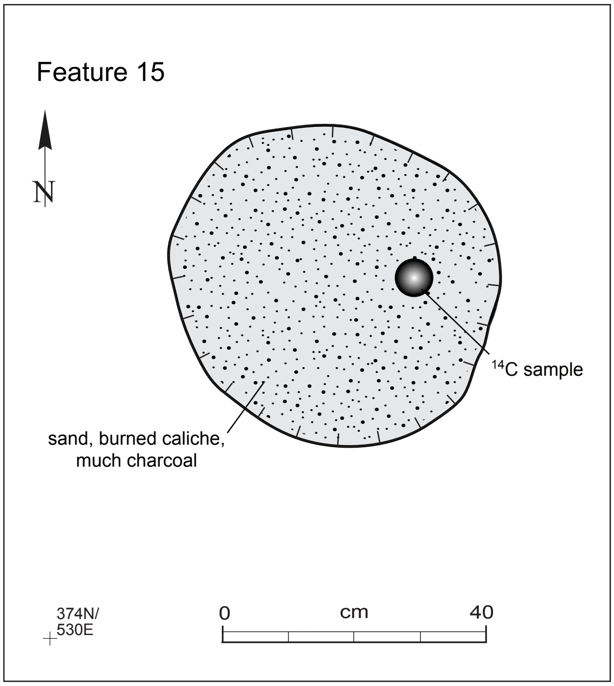


Figure 2.59. Feature 15 (fire pit), plan.

fire pit, two from general fill in the structure, four from postholes in the structure, and one each from the Features 20 and 21 postholes. The two exterior posthole samples and one of those from the structure contained no burned plant material. The other samples contained goosefoot (3 samples) and an unidentifiable seed. Mesquite and saltbush wood were recovered from the fire pit.

Two pollen samples from Feature 15 produced a different pollen record than others features from this site (Appendix 3). Along with the usual cheno-am pollen, grass and sunflower pollen were particularly abundant and globemallow was present. A sample from the structure was predominately cheno-ams. Samples from both features appear to reflect local vegetation rather than the regional pollen rain.

Radiocarbon dates from the structure and the fire pit present a dilemma. The structure has most accurate dates of 1027–891 BC and most precise dates of 996–915 BC (Beta-307899), but the date for the fire

Figure 2.60. Feature 15 (fire pit), after excavation, view north.

Figure 2.61. Feature 15 (fire pit), partially excavated, showing fill, view north.

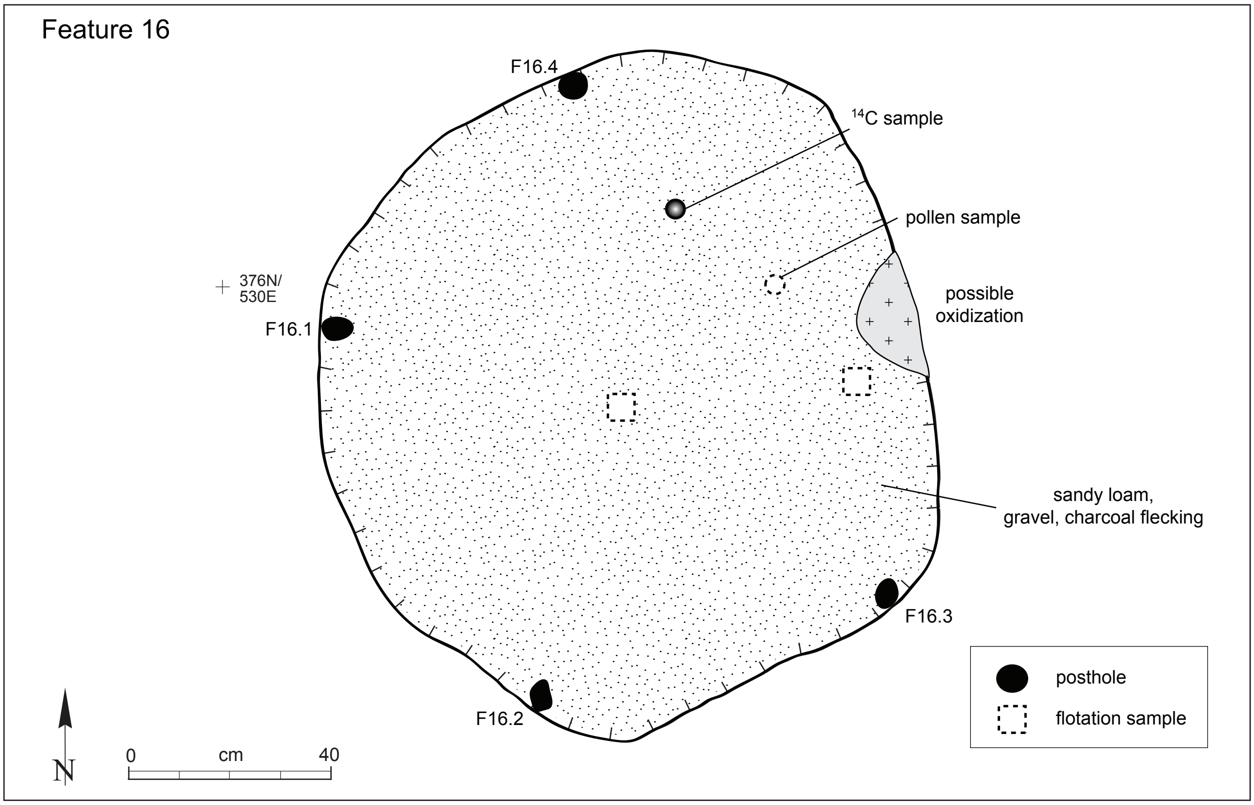


Figure 2.62. Feature 16 (structure), plan.

Figure 2.63. Feature 16 (structure), after excavation, view north.

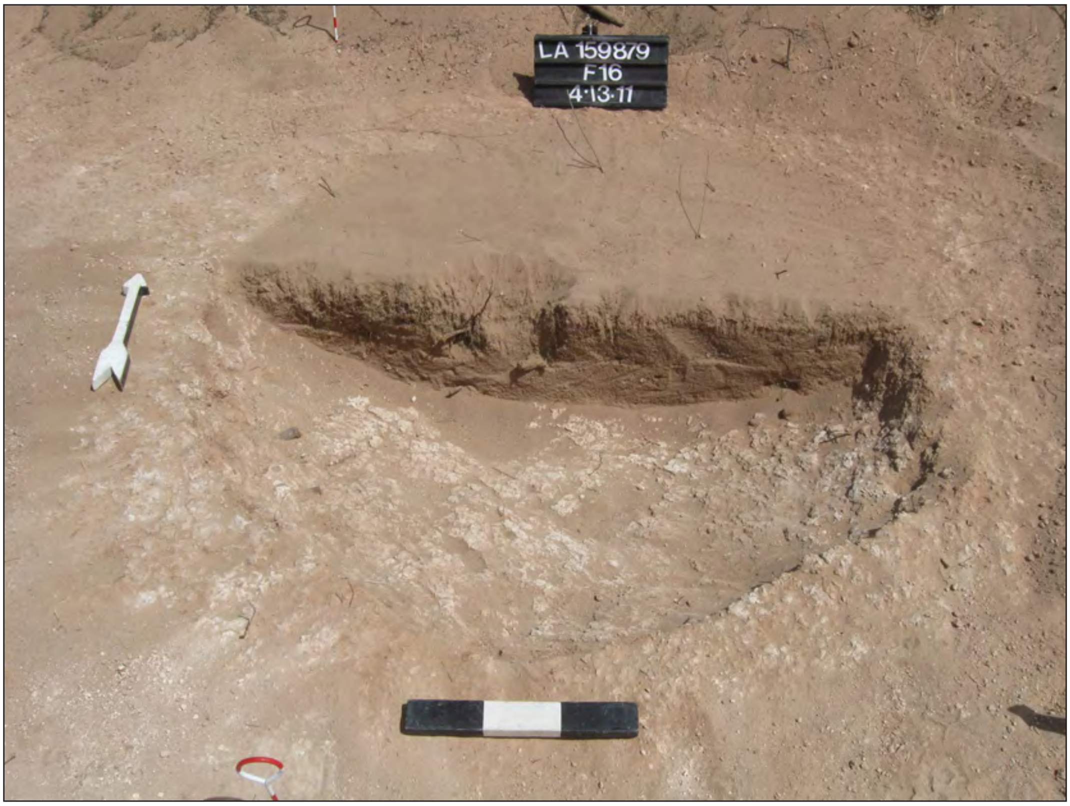


Figure 2.64. Feature 16 (structure), partially excavated, showing fill, view north.

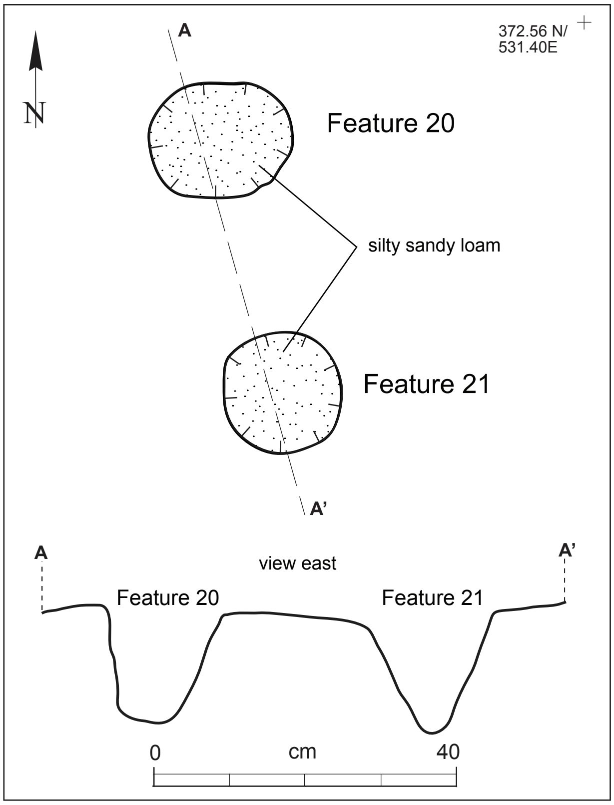


Figure 2.65. Features 20 and 21 (postholes), plan and profile (view east).

pit is much later. The fire-pit sample was listed on the Beta Analytic form as "wood" and the most accurate date is AD 1520–1670 and the most precise is AD 1636–1666 (Beta-307898; Chapter 8). All but one of the other project samples are "charred material." The other "wood" sample from Feature 2 is also late.

Features 15 and 16: Discussion

While the positioning (Fig. 2.67) and construction of Features 15 and 16 suggest they were built and used together, dating suggests otherwise. Chipped stone assemblages from the two features are similar in both artifact type and materials (Table 2.12). Identified fauna is all rabbit, which is consistent with both Late Archaic and Protohistoric subsistence, as is the burned goosefoot found in both features. Both have a more local pollen rain than other features at the site. This leaves at least three options. First, the two features could be totally unrelated and any similarity in construction and positioning were merely a coincidence. Second, these features were built and used together and date to the Late Archaic. Finally, they were built and used together but date to the

Figure 2.66. Features 20 and 21 (postholes), after excavation, view east.

Table 2.12. LA 159879, Features 15 and 16, chipped stone artifacts.

Artifact Type	Material Type	Portion	% Dorsal Cortex	Heat Alteration	Count
Feature 15 - Fire Pit					
Angular debris	Rhyolite	Whole	0	None	1
Core flake	Chert	Whole	0	None	3
				Lustrous	1
		Medial	0	None	1
Feature 16 - Structure					
Core flake	Chert	Whole	0	None	1
		Distal	0	Lustrous	1
		Lateral	0	None	1

Figure 2.67. Features 15 (fire pit, below [south]) and 16 (structure, above [north]), after excavation, view north.

Protohistoric period. Unfortunately, there is no way of resolving the question, especially given a general lack of excavation data on structures from both time periods.

Feature 17 (Pit?)

Also exposed by mechanical scraping, Feature 17 was a large patch of slightly darker and looser soil in the northern portion of the site. It was circular in plan view and basin-shaped in profile, measuring 1.44 by 1.48 m in diameter and about 25 cm deep, with a very irregular base caused by a rodent burrow extending to at least 60 cm deep (Figs. 2.68, 2.69). A rodent burrow on the east side connected Feature 17 to Feature 18 and it was impacted by small mesquite roots. The feature fill was an unconsolidated sandy loam similar to Stratum 2 with small pieces of caliche throughout (Fig. 2.70). The irregular base and sides and absence of charcoal suggest that this was either a badly disturbed feature or that it, too, was not a cultural feature but part of the Feature 18 burrow complex.

The only artifacts associated with this feature were two cobble fragments, one definitely fire fractured. One was a quartzite abrader fragment and the other a quartzitic sandstone mano fragment. A large flotation sample from this feature contained burned goosefoot, a monocot stem, and a stem from an unknown taxon. No burned wood was collected and no radiocarbon dates were obtained. The pollen sample contained mostly cheno-am pollen along with walnut and purslane pollen. It also included a *Trichuris* or whipworm parasite egg. These parasites infest humans, dogs, pigs, and mice (Appendix 3) and support an interpretation of a burrow, or at best, a highly disturbed feature.

Feature 18 (Noncultural)

Feature 18 was a smaller area of darker looser soil located near Feature 17 in the northern portion of the site. Upon investigation, Feature 18 appears to be the burrow of a large animal, perhaps a badger. No artifacts or samples were collected from this feature.

Feature 19 (Noncultural)

Feature 19 was a small patch of soil in the caliche layer revealed by mechanical scraping. It was located in the northern portion of the site and investigation concluded it was most likely a rodent burrow. A single chipped stone artifact was collected from investigating this feature. It was a piece of angular debris made from a quartz cobble. No samples were taken.

Discussion

Fire Pits

Fire pits were used for a number of purposes ranging from warmth to cooking a variety of plant and animal foods to burning waste. Rarely is the function clear-cut. The 10 likely thermal features (not counting Feature 14, which is fairly unlikely to have been a feature, or the two that are more likely to be structures) are variable in size, fill, and rock content. Maximum diameters ranged from 0.50 to 1.70 m and depths from 5 to 31 cm. Only one had significant amounts of rock in the fill while half had no rock at all and the same number had no charcoal or charcoal flecks only. More are radiocarbon dated to the Late Archaic/Early Agricultural period (n = 8) than any other period. One each dated to the Protohistoric and the Protohistoric/Early Historic periods. Wood was mainly mesquite, found in five of the features, and saltbush, which was found in four. Potential food items found in flotation samples include cheno-ams in five and dropseed in one. Corn phytoliths were found in two. Small pieces of bone, usually burned, were found in six of the fire pits. None of the Deming fire pits have evidence of much effort put into their construction, other than the few where the bases were excavated into the caliche layer. Given the loose soil matrix above the caliche, there was probably not much they could do to stabilize the pit walls. The general absence of quantities of rock in the fill is probably more a reflection of the feature function than an absence of cobbles in the vicinity. These fire pits were most likely used relatively few times in what was more a camp-like setting than a prolonged occupation of this area.

To examine how these were used, the LA 159879 fire pits are considered in light of a southern New Mexico and El Paso area thermal-feature database compiled for the Spaceport America research project (Akins 2014:701–720). With the addition of the Deming features, this database now has descriptive information on 207 thermal features. The data was

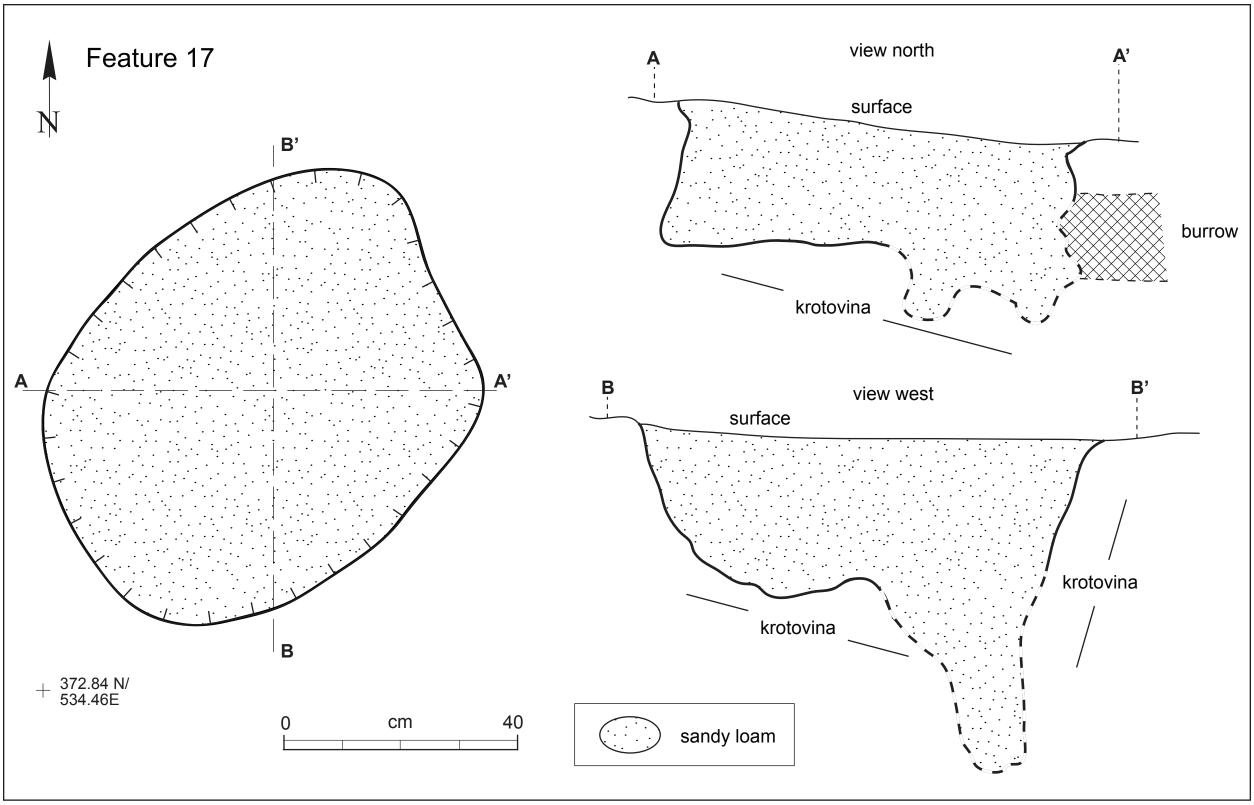


Figure 2.68. Feature 17 (pit?), plan and profiles (views north and west).

Figure 2.69. Feature 17 (pit?), after excavation, view north.

Figure 2.70. Feature 17 (pit?), partially excavated, showing fill.

originally collected on features that had at least one dimension that was 70 cm or greater, so is not precisely comparable since three of those from Deming are smaller with diameters of 50 to 65 cm.

Late Archaic features in the database (n = 67)—not including those from LA 159879—are mainly in the southeastern (n = 21) and southwestern (n = 30) areas of the state with fewer from the Tularosa Basin (n = 9), and Fort Bliss/El Paso (n = 7) areas. These tend to be small—56.7 percent were less than 1.0 m in diameter—and shallow—80.6 percent were less than 30 cm deep. Unlike those from LA 159879 most were rock-filled (82.1 percent and another 3.0 percent did not have the rock content documented). Mesquite wood was found in more features (n = 11) than saltbush (n = 8). Evidence of food plants reported for 31 of the features is also diverse, although none had yucca, cacti, or composite remains. Cheno-ams were by far the most common, found in six features. Others had grass (n = 2), corn (n = 3) or corn phytoliths (n = 3), or walnuts (n = 2), or juniper seed.

The Late Archaic/Early Agricultural–period features from Deming differ in that rock was either absent or found in trace amounts. They are similar in that all but one are small and all are shallow, and mesquite and saltbush are common as fuel wood. All but one had cheno-ams in the fill and one had corn phytoliths.

Fewer thermal features in the database are from the Late Archaic–Early Formative transition (n = 6). One each was recorded for the Spaceport, southeast New Mexico, Fort Bliss/El Paso, and the Tularosa Basin with two from southwest New Mexico. Features attributed to this period are mainly small (66.7 percent), shallow (66.7 percent), and rockless (50.0 with 16.7 percent unknown). Fill was charcoal stained or unknown. Mesquite fuel was found in two and saltbush in three. None had potential plant foods. The Deming feature dating to this period was also small and shallow with a trace of fire-cracked rock. Saltbush was the only fuel wood found and no food remains were recovered.

Features attributed to the Protohistoric period are also rare (n = 7), one from the Spaceport, three from southeastern New Mexico, two from Fort Bliss/El Paso, and one from southwestern New Mexico. Unlike the earlier periods, most are large (71.4 percent) with one more that was shallow than deep. Only one was not rock-filled and all had charcoal or ash fill. Mesquite fuel was found in at least four and one is unknown, and saltbush in two with two where it is unknown. None had cheno-ams but grass was found in one, yucca in one, agave in two, prickly pear in one, and mesquite beans in one. The Deming feature that could date to this period was small, but then the database did not record features under 70 cm in diameter so it does not contain comparable features. Wood use was similar but the Deming feature had cheno-ams.

Only two of the thermal features in the database are from the Historic period, one at the Spaceport and one at Fort Bliss/El Paso. Both are large-sized and charcoal- or ash-filled, one shallow, one deep; the deep one has rock in the fill. Both had mesquite fuel wood and one also had saltbush. Potential food items include grass in one, cheno-ams in one, prickly pear cactus in one, and aster in one. The Deming feature was not like the others recorded in the database. It was small and shallow with no rock. It did have ash or charcoal fill, mesquite fuel, and cheno-ams.

Assuming that the LA 159879 features were mainly used for cooking, the size and rock content suggest the foods prepared were high in sugars and fast-release starches and lean meats. Foods like acorns, small mammals, and birds all take relatively little time to cook (up to 2 hours), while yucca can take 15–30 hours and cactus buds 12–18 hours (Wandsnider 1997:Fig. 6). The Deming pits are not the types associated with mass processing of storable resources for storage such as agave and yucca stems that require prolonged heating using methods like pit roasting. The presence of small numbers of fire-cracked rocks in the features and scattered throughout the site area may be an indication that fuel wood was sparse in the site area. In fuel-poor settings, such as deserts and grasslands, the use of rocks to trap and hold heat would aid in cooking (e.g., Thoms 2008:445), and would help to explain the scatter and reuse of so many of the ground stone tools as heating elements.

Small Structures

Shallow dish-shaped structures lacking prepared floors and walls have been reported throughout the southern part of the state and are generally interpreted as ephemeral brush huts or wickiups built by mobile groups. These have been documented from at least the Middle Archaic where they were small and shallow, averaging less than 2.0 m in diameter and 15 to 20 cm in depth, rarely had subfloor features, and occasionally produced daub (Miller and Kenmotsu 2004:224, 239). A brief review of many of the same reports as used for the Spaceport America project roasting-feature database and additional reports resulted in a sample of 40 features referred to as brush shelters, huts, or even small pit structures (Table 2.4) (Akins 2014:720–724). These features have diameters ranging from about 1.4 to 5.6 m, with a mean of 2.8 m, and depths ranging from 0.04 to 1.0 m, with a mean of 0.26 m. Fill generally was charcoal-stained with only one reported as recent sand and three that claim only charcoal flecks. Nearly half (43.6 percent) report no features. Many were not dated (n = 14) and of those that were, most date to the Late Mesilla phase (46.2 percent of the dated structures). The others include a single structure from the Middle Archaic, two each from the Late Archaic/Early Formative and Early Mesilla, three early Doña Ana, and four Doña Ana. In this small sample, those dating to the Doña Ana phase are the largest and deepest followed by those from the Late Mesilla phase, while the Late Archaic/Formative and Early Mesilla tend to be the smallest.

In these structure descriptions, wood is not consistently reported but mesquite is the most common species (n = 7), followed by saltbush (n = 4) and creosote (n = 3). Unlike the large roasting features, the most common possible food item reported is burned bone (rabbit or small mammal, n = 10) followed by corn (n = 5), grass (n = 4, plus 3 dropseed), purslane (n = 4), hedgehog cactus (n = 3), prickly pear cactus (n = 2), and yucca (n = 2). The corn from dated structures includes one dated at AD 900 to 1160 (Turnbow and Kuroto 2008:83–94) and one between AD 910 and 1180 (Turnbow and Kuroto 2008:105). These contrast with more substantial structures built by groups that practiced early agriculture that tended to be larger, averaging 3.4 m in diameter, and deeper, averaging 28 cm. Nearly all had corn (Table 2.13).

The Deming structure and possible structures are small, but all were truncated by mechanical scraping and erosion so that the actual size of the structures could have been slightly larger. Otherwise, it is not unusual for these early structures to be small and to lack internal features. The three other Archaic or Archaic/Early Formative structures tend to be larger but shallow. One had a hearth and another had a small pit. Most structures dating to this early era were probably short-term shelters that were occupied for only a few days or weeks so that little effort was put into their construction or maintenance.

Table 2.13. *Sample of regional brush structures, the LA 159879 (Deming) structures, and the Big Burro Mountain structures.*

Area	**Site**	**Feature or Structure**	**Dimensions (m)**	**Depth (m)**	**Fill**	**Features**	**Dates**	**Subsistence/ Wood**	**Reference**
Deming	LA 159879	3	1.9 x 1.5	0.14	charcoal-stained soil	none	830–790 BC	cottontail, jackrabbit, cheno-ams, dropseed, cotton, mesquite, wood mesquite and saltbush	this report
		5	1.1 x .95	0.2	charcoal-stained soil	none	1010–900 BC	cheno-ams, goosefoot, wood mesquite, saltbush and cf. piñon	this report
		16	1.4 x 1.2	0.32	lightly stained	4 postholes	1010–900 BC	goosefoot	this report
Spaceport	LA 111435	8	1.5 x 1.6	0.1	charcoal-stained soil	none	AD 807–976	saltbush, yucca, purslane, hedgehog cactus, grass stems, burned small mammal bone	Moore and Akins 2013: 169–171
Cambray Dunes	LA 135343	1	2.1 x 2.2	.10-.25	charcoal-stained soil	none	BC 60–AD 90 (mesquite)	burned rabbit bone	Jones et al. 2010: 1015–1016
	LA 9563	4	1.9 x .9	.02-.09	charcoal-stained soil	small pit	site: Late Archaic early formative	disturbed; no samples analyzed	Jones et al. 2010: 1464–1469
		8	3.6 x 2.5+	0.04	charcoal-stained sand	none	–	disturbed ; 3 small mammal; 2 burned	–
Big Burrow Mountains	LA 99631	1	2.66 x 2.72	0.24	charcoal-stained soil	13 exterior postholes, 4 postholes, 2 pits, 2 hearths	Early Agricultural 165 BC–AD 120	oak, juniper, corn, goosefoot, jackrabbit, deer	Turnbow 2000a:130–136
		2	1.6 x 1.5	0.24	charcoal-stained soil	hearth	Protohistoric AD 1525–1690	juniper, corn, small mammal	Turnbow 2000a:136–1138
		3	4.45 x 3.4	0.19	charcoal-stained soil	hearth and pit	Early Agricultural 820–540 BC	corn, cheno-ams, ground cherry, small mammal, deer	Turnbow 2000a:138–140
		4	3.0 x 3.0	0.2	cultural fill; dark brown sandy loam	none?	unknown	jackrabbit, deer	Turnbow 2000a:142–143
	LA 78089	1	3.1 x 3.2	0.2	charcoal flecked	19 postholes, 2 hearths, 4 storage pits	Early Agricultural 390–155 BC	corn, cheno-ams, acorn, juniper, grass, goosefoot, deer small mammal	Turnbow and Reycraft 2000:64–67

Table 2.13 (continued)

Area	Site	Feature or Structure	Dimensions (m)	Depth (m)	Fill	Features	Dates	Subsistence/ Wood	Reference
		2	3.8 x 4.1	0.15	cultural fill; loam	11 postholes, hearth, 4 storage pits, 2 pits	Early Agricultural 395–180 BC	oak, juniper, corn, jackrabbit, artiodactyl	Turnbow and Reycraft 2000:67–70
		3	3.64 x 4.0	.04+	cultural fill; loam	2 postholes, hearth	Early Agricultural AD 245–430	corn, cheno-ams, juniper, grass, acorn, jackrabbit, pronghorn	Turnbow and Reycraft 2000:70–73
	LA 121158	1	5.2	0.68	charcoal-stained soil	hearth, posthole, pit	Early Agricutlural AD 265–540	corn, cheno-ams, juniper, acorn, rodents, rabbits, deer	Reycraft 2000:194–199
		2	4.2 x 3.8	0.6	charcoal-stained soil	2 hearths, 3 postholes	Pit house period AD 675–940		Reycraft 2000:199–202
		5	2.3	0.25	cultural	none?	Early Agricultural AD 20–240	juniper, cottontail, jackrabbit, deer	Reycraft 2000:206–208
Fort Bliss	LA 97944	7A	3.0 x 2.5	0.37	charcoal-stained soil	none	AD 700–1000	–	Condon et al. 2007:149–150
		4A	4.75 x 3.75	0.54	charcoal-stained soil	none	AD 750–1000	prickly pear seed	Condon et. al 2007: 156–157
		8A	2.7 x 2.2	0.25	charcoal-stained soil	none	AD 700–1000	–	Condon et. al 2007: 158–159
		10A	2.7 x 2.2	0.1	charcoal-stained soil	2 postholes, 3 hearths	AD 770–900	–	Condon et. al 2007: 162–163
		32A	5.7 x 5.6	0.4	charcoal-stained soil	6 postholes, hearth	AD 600–850	roof fall	Condon et. al 2007: 167–169
	LA 97943	6	4.0 x 4.5	0.78	mottled, lightly stained	4 hearths	AD 750–1000	not burned; sunflower, Mormon tea, yucca seed	Condon et. al 2007: 188–196
		24	4.0 x 4.5	1	charcoal-stained soil	1 hearth?	AD 1000–1200	prickly pear and yucca seeds	Condon et. al 2007: 198–202
	LA 126397	1-2	2.2 x 3.0	0.3	mottled, stained soil	none	–	tarbush, mesquite, ocotillo	Church and Sale 2003:82, 121
		3-1	3.0	0.15	mottled, stained soil	1 post	AD 570 ± 100	burned grass stems and wood; yucca residue	Church and Sale 2003:82–84, 118
		4	2.0	0.15	mottled, stained soil	ashy stain	–	burned grass stems	Church and Sale 2003:84
		6	3.0	0.3	mottled, stained soil	area of dark staining	–	saltbush, creosote, mesquite	Church and Sale 2003:84, 91, 118
	LA 126698	1-4	3.5	0.1	mottled, stained soil	ashy deposit	AD 650 ±100	burned grass stems, burned bone, ocotillo, creosote, residue: prickly pear, chenopod, yucca, rabbit, deer	Church and Sale 2003:93, 119, 123

Table 2.13 (continued)

Area	Site	Feature or Structure	Dimensions (m)	Depth (m)	Fill	Features	Dates	Subsistence/ Wood	Reference
		12	3.0	0.1?	mottled, stained soil	unknown	–	–	Church and Sale 2003:101
		13	3	0.3	mottled, stained soil	none	–	–	Church and Sale 2003:102
		23	2.8	0.1	charcoal-stained soil	none	–	tarbush, dropseed	Church and Sale 2003:105, 122
US 54 Tularosa Basin	LA 6829	5	5 x 2.8	0.4	ashy midden	5 post holes, 5 pits	AD 1030–1280	burned rabbit, rodent, artiodactyl; flotation unknown	Railey et al. 2002:99–224
		6	3.3 x 2.54		charcoal-stained soil	none	AD 900–1260	burned small mammal; flotation unknown	Railey et al. 2002:99–224
		7	2.55 x 1.95	0.33	ashy midden	none	–	flotation unknown	Railey et al. 2002:99–224
		8	2.75 x 2.5	0.06	charcoal-stained soil	none	–	flotation unknown	Railey et al. 2002:99–224
		9	1.9–1.65	0.1	charcoal-stained soil	hearth, posthole	–	corn cob; flotation unknown	Railey et al. 2002:99–224
		10	2.3 x 1.42	0.26	charcoal-stained soil	hearth	–	burned rabbit; corn cob & kernel; flotation unknown	Railey et al. 2002:99–224
		13	2.26 x 2.5	0.29	ashy midden	none	AD 1200–1400	burned rabbit; flotation unknown	Railey et al. 2002:99–224
		14	2.5 x 2.4	0.12	ashy midden	none	–	burned rabbit; corn cobs; flotation unknown	Railey et al. 2002:99–224
		16	2.55 x 2.0	0.37	ashy midden	none	–	burned rabbit; flotation unknown	Railey et al. 2002:99–224
		17	3.0 x 1.6	0.36	charcoal-stained soil	none	AD 1160–1300	burned rabbit; flotation unknown	Railey et al. 2002:99–224
	LA 115262	1	2.1 x 1.9	0.17	charcoal-stained soil	hearth	AD 230–550	mesquite wood	Railey et al. 2002: 225–249
		2	inferred 2.75 x 2.06	unknown	recent sand	hearth?, 3 postholes, 4 pits	ceramics post AD 1060	–	Railey et al. 2002: 225–249
	LA 128699	1	2.8+ x 2.9	0.31	ash stained	2 hearths	AD 610–880	–	Railey et al. 2002:363–405
		2	3.22 x 2.64	0.37	ash stained	1 hearth, 2 other	AD 620–880	–	Railey et al. 2002:363–405

Table 2.13 (continued)

Area	Site	Feature or Structure	Dimensions (m)	Depth (m)	Fill	Features	Dates	Subsistence/ Wood	Reference
		3	2.9 x 2.15	0.22	dark sandy loam with gravel	hearth	2140–1920 BC and 1910–1 BC	–	Railey et al. 2002:363–405
Santa Teresa	LA 86774	1	3.2 x 2.95	0.3	charcoal-stained soil	rock-filled heating pit	AD 615–790	sunflower seeds, purslane, dropseed/mesquite wood	Moore 1996:148–156
Alamogordo	LA 119530	1	4.0 x 3.0	0.4	sandy loam with charcoal flecks	none; external posthole	unknown	mustard, pigweed, purslane, grouncherry, 4 wing saltbush, hedgehog cactus, globemallow, monocot stems/pinion, desert willow, mesquite, saltbush	Turnbow and Kuroto 2008: 78, 81
		2	3.2 x 2.4	0.23	post-abandonment with ash and charcoal flecks	hearth	unknown	–	Turnbow and Kuroto 2008: 78, 82
		3	4.2 x 3.5	0.24	ashy silt	hearth, small pit	early Dona Ana; AD 990–1160	mustard, purslane, yucca, corn, mesquite/creosote, mesquite, saltbush, juniper	Turnbow and Kuroto 2008: 78, 83–94
		8	3.04 x 2.68	0.26	trash-filled	hearth	early Dona Ana	saltbush	Turnbow and Kuroto 2008:78, 108
		6	1.8 x 2.15	0.25	loam with charcoal	hearth; 2 postholes	early Dona Ana; AD 910–920 and 960–1180	corn, dropseed, purslane, globe mallow, hedgehog/charred brush	Turnbow and Kuroto 2008: 78, 105

cf. = resembles taxon

3 Soils and Stratigraphy

Donald E. Tatum

This section presents a geomorphological evaluation of site soils and stratigraphy, backhoe trench excavations, archaeological features, and collected artifacts and samples. The stratigraphy in both the shovel tests and backhoe trenches was profiled and described by Donald E. Tatum, and 10 optically stimulated luminescence (OSL) samples were collected to date the deposits (Table 3.1; Appendix 1). Soil samples from the same area as the OSL samples were sent to the Milwaukee Soil Laboratory for analysis (Appendix 4).

INTRODUCTION AND METHODS

LA 159879 is located on the low-relief crest of a linear, southeast-trending lobate alluvial terrace. The finger terrace forms the southwestern border for one of an extensive network of alluvial distributary channels descending to the Mimbres River drainage from the Cookes Peak massif to the north of the site. The channel network provides avenues for runoff from the upland areas to the Mimbres Basin about 30 km (18.6 mi) to the east. The site is north of the Mimbres River and northeast of the Deming Fan, a fluvial fan created when the Mimbres drainage was overrun during late Pleistocene-early Holocene periods of extraordinarily high flow (Love and Seager 1996). The nature of sedimentary deposits exposed in backhoe trenches and hand-excavation blocks at LA 159879 can be inferred from the geomorphic characteristics of landforms associated with the site.

The Thein method of determining soil texture by feel was used in the field descriptions of soils and strata encountered during the data recovery project (Thein 1979). This method uses damp soil

Table 3.1. LA 159879, summary of OSL dates.

FS	Stratum	Location	Depth (m below ground surface)	UNL Sample	Age (ka)*	Years
309	1	BHT 1	0.19	3407	0.15 ± 0.01	150 ± 10
309*					0.10 ± 0.01	100 ± 10
308	2	BHT 1	0.35	3406	2.10 ± 0.12	2,100 ± 120
313	2	BHT 2	0.66	3410	1.81 ± 0.12	1,810 ± 120
314	2	BHT 3	0.16	3411	2.51 ± 0.13	2,510 ± 130
310	3	BHT 1	0.90	3408	3.90 ± 0.21	3,900 ± 210
312	3	BHT 2	0.88	3409	5.01 ± 0.33	5,010 ± 330
312*					2.53 ± 0.15	2,530 ± 150
315	3	BHT 3	0.53	3412	11.8 ± 0.70	11,800 ± 700
503	3	388N 526E	1.12	3413	10.4 ± 0.60	10,400 ± 600
307	5	BHT 1	0.60	3405	2.14 ± 0.13	2,140 ± 130
504	7	BHT 7	1.45	3414	35.2 ± 2.7	35,200 ± 2700

* Minimum age model; mean age unless noted.

cohesiveness and grittiness or smoothness characteristics of the soil matrix to characterize the texture.

SITE STRATA

Stratum numbers were assigned in the order in which they were identified at the site. Thus, field strata designations do not necessarily correspond with the stratigraphic superposition. Also, field stratum numbers do not necessarily imply temporal or depositional variables in sediment (facies changes). The assignment of individual stratum numbers was intended to delineate changes in soil matrix characteristics reflecting differing formation processes as they relate to intact archaeological deposits (Reed et al. 2000).

Stratum 1

Stratigraphy, Geomorphology, and Soil Morphology

The surface sediment consisted of recent and historically redeposited sheet and dune-forming blow sand. For excavation purposes, the deposit was designated Stratum 1, a loose, unconsolidated sediment sheet underlain by the sandy Bw-horizon soils from which it originated. Stratum 1 extended as deep as 8 cm below surface with historic coppice dunes extending as high as 75 cm above the surrounding surface. Where dunes occurred, Stratum 1 was sometimes stabilized by shrub vegetation, allowing for the development of a thin, discontinuous weak A-horizon (Aw-horizon).

The Stratum 1 matrix consisted of poorly sorted, very fine- to coarse-grained sand with a widely variable degree of weathering and sphericity. Organic clastic materials, which derived from decomposing vegetable matter, rodent and rabbit feces, and insect parts, were common in this horizon. Pebble and granule inclusions were also common, though still comprising but a very small fraction of the total volume of the deposit.

Geochronology and Archaeological Significance

The OSL data indicate that the Stratum 1 eolian surface deposit began forming at least 100 ± 10 years ago (0.10 ± 0.01 ka) (Table 3.1). Historic windblown sand is widespread throughout the northern Chihuahuan Desert. Its deposition has been documented as occurring between about 100 and 150 years ago, following the onset of intensive cattle ranching. Its occurrence is attributed to overgrazing and/or the onset of an increasingly xeric climate that resulted in defoliation (Buck et al. 1999:738–739). Because of ongoing intensive eolian deflation, erosion, and bioturbation, sand dunes often accumulate on top of cultural materials, while blowouts expose cultural artifacts and features on the modern ground surface. These cultural materials—especially chipped stone artifacts and small fragments of fire-cracked rock—then become incorporated into the sediment of Stratum 1. The mixing of cultural materials of differing ages and occupations readily occurs under these circumstances (Buck et al. 2002).

Stratum 2

Stratigraphy, Geomorphology, and Soil Morphology

With the exception of two localized variations, Stratum 1 was immediately underlain by Stratum 2 across most of the excavation area. This stratum formed the parent material for a weakly developed B-horizon (Bw) extending from 15 to 30 cm below ground surface. The Bw matrix consisted of massively bedded, poorly sorted very fine to coarse sand inclusive of spherical to subangular weathered grains. Pebbly and granular inclusions were plentiful, though comprising but a very small fraction of the overall matrix. Texturally, the Bw-horizon was a sandy loam. This soil had weak, fine to medium sized peds with subangular blocky to platy structure. The Stratum 2 boundary was diffuse and indicated by a slightly lighter coloration coincident with the appearance of fine carbonate filaments and granules that became more progressively defined with greater depth.

Krotavina and insect burrow disturbances were frequently encountered in the Bw, as was bioturbation caused by the roots of desert scrub vegetation such as mesquite, saltbush, Mormon tea, yucca, and various grasses. Excavations in the northern part of the project right-of-way revealed a Bw-horizon that was heavily eroded and weathered by bioturbation and eolian processes. This compromised the structural integrity of the soil resulting in a loose, heavily mixed character to the matrix. Pebble and granule inclusions were frequent, though still comprising a very small fraction of the total volume of the deposit.

Geochronology and Archaeological Significance

The Bw-horizon was the main stratum of archaeological significance at LA 159879. It frequently contained cultural artifacts including chipped stone artifacts, fire-cracked rock, ground stone, and small fire-cracked pieces of ground stone. Most, if not all, cultural features encountered during the data recovery excavations originated in the Bw-horizon, although the original surfaces of most features were probably altered by erosion and bioturbation and some were removed by mechanical scraping. The same processes of weathering that compromised the soil development characteristics in the upper Bw-horizon (especially in the northern part of the project area) also affected cultural features originating in this horizon, resulting in some poorly preserved feature. OSL data indicate that the deposition of parent material for the Bw- and Bk-horizons (Stratum 3) began prior to 11.8 ± 0.7 ka (11,800 ± 700 years) and continued until at least 2.51 ± 0.13 ka (2,510 ± 130 years). OSL dates for Stratum 2 range from 2,510 to 1,810 years ago (Table 3.1).

Stratum 2.1

Stratigraphy, Geomorphology, and Soil Morphology

In the vicinity of hand-excavation block 244N/636E, Stratum 1 was immediately and unconformably underlain by a strongly expressed buried A-horizon that extended from about 10 to 20 cm below ground surface (Fig. 3.1). Stratum 2.1 was only visible in the south and west walls of that excavation unit. The buried A-horizon matrix consisted of a single layer of very dark grayish-brown, fine to medium sized, moderately well-sorted sand inclusive of highly rounded to subangular weathered grains. Pebble and granular carbonate inclusions grading in size from 3– 6 mm were frequent but comprised a very small fraction of the total matrix. The buried soil had medium-strong, fine- to medium-sized, subangular blocky peds. Fine- to medium-coarse roots and root pores were abundant, and clay films were common filling root pores and as slips on ped faces. This soil was strongly bioturbated from roots, insects, and rodents. Relict soil casts from overlying deposits were visible in larger root channels and insect burrows.

Figure 3.1. Hand-excavated unit 244N/636E, soil profile showing Stratum 2.1, east wall.

Texturally, Stratum 2.1 was a sandy clay loam, exhibiting much greater particle cohesiveness and finer-grained particles than the overlying Stratum 1 or the underlying Stratum 3. These properties provide additional evidence that 2.1 was a remnant of a well-developed soil horizon protected from the impacts of deflation and the winnowing of fine-grained material from the deposit. The Stratum 2.1 boundary was clear, smooth, and distinctive in its contrast with the underlying Bk-horizon.

Geochronology and Archaeological Significance

Along with the underlying Stratum 2, the Stratum 2.1 A-horizon was the source of many of the cultural materials recovered in this block. Artifacts attributed to Stratum 2.1 include chipped stone, ground stone, and fire-cracked rock. The limited extent of this soil horizon under the thick dune deposit indicates that it represents a relict A-horizon protected from deflation and erosion by the sand dune. It may have been broader in extent prior to the widespread overgrazing and erosion of the late nineteenth and early twentieth centuries that affected the soil formation processes and sediment deposition in parts of the Chihuahuan Desert (Fredrickson et al. 2006; Allen et al. 2003).

Stratum 3

Stratigraphy, Geomorphology, and Soil Morphology

Stratum 3 was the Bk-horizon. It had a cohesiveness and grain-size characteristics of a sandy loam. The Stratum 3 boundary with the underlying calcic (caliche or K-horizon) was irregular or wavy and present across the entire project area. In the northern portion of the site where the soil profile was less intact and more heavily eroded, the boundary was the most irregular. Stratum 3 was typified by early-stage carbonate inclusions—filaments, granules, and discontinuous or partial carbonate slips on sand grain surfaces and ped faces. These characteristics became more strongly expressed with depth and proximity to the underlying caliche. Nodular inclusions of caliche and carbonate-coated alluvial pebbles were abundant toward the bottom of the Bk, comprising a significant fraction of the total soil matrix.

The fine-grained fraction of the Bk-horizon consisted of poorly sorted very fine to coarse sand. Grain sphericity covered the entire spectrum from well-rounded to angular, with no apparent internal bedding structure. The Bk soil was encountered between 25 and 45 cm below the surface. Bioturbation, mainly large burrows and from fine and more coarsely sized roots and root pores, was common. Caliche-filled root casts were abundant along the irregular contact with the calcic substrate (Stratum 4).OSL dates for Stratum 3 range from 2,530 to 11,800 years ago (Table 3.1).

Archaeological Significance

Cultural artifacts decreased abruptly in the Bk-horizon across the area of excavation. When found, artifacts in the Bk were attributed to soil-disturbing processes such as bioturbation. However, cultural features originating in the Bw-horizon and continuing into the Bk were relatively common. Less common were intrusive cultural features where the fill was also Stratum 3 soil. Even when intruding into the Bk-horizon, feature fill was similar to the Bw-horizon. Features with Bk development, such as fine-scaled carbonate inclusions, slips, and coatings on grains, can be chronologically older than features that do not have early-stage carbonate development in their matrices and could possibly date concurrently with the formation of the Bk-horizon. At LA 129300, near the southern High Plains/northern Chihuahuan Desert ecotone in Eddy County, New Mexico, faintly defined thermal features intruding into the Bk-horizon with matrix characteristics of the Bk-horizon yielded early Archaic-period dates. These dates contrasted with other Bk-intrusive thermal features at the same site that did not exhibit early-stage carbonate development. These features dated to Late Archaic or early Formative periods (Wiseman 2015).

Stratum 4

Stratigraphy, Geomorphology, and Soil Morphology

The calcic horizon was designated as Stratum 4. The Stratum 4 boundary was highly irregular and clear or abrupt and extended laterally across the entire project right-of-way. At the heavily eroded north end of the project area, it extended downward from about 30 cm below the surface. It was encountered at greater depths in the less eroded central and southern portions of the project area. The caliche had characteristics indicative of middle-stage carbonate development such as a horizontally continuous carbonate horizon, plentiful carbonate nodules, and internodular filling.

In some areas, particularly in the northern part of the project area, the upper boundary was extremely irregular, revealing deep voids in the K-horizon that were in-filled with sandy material derived from overlying Bk soils. The voids may represent pipes, or solution cavities caused by the dissolution of calcium carbonate that filled with overlying sediments. Such activity might indicate strong pluvial periods when greater effective moisture percolated deeper into the soils than the more recent atmospheric moisture regime allows (Monger et al. 2009; Reeves 1970; Knapp 1979).

Stratum 5

Stratigraphy, Geomorphology, and Soil Morphology

At the southeast end of the project area, in the profile of BHT 1, a second buried A-horizon (Stratum 5) was exposed. Limited in horizontal extent, it extended from about 15 to 60 cm below the surface and ranged in thickness from 25 to 50 cm. The buried A-horizon was overlain by the Bw-horizon (Stratum 2) and was immediately underlain by the Bk-horizon (Stratum 3) along most of the trench exposure. However, at the south end of the trench, Stratum 5 was close to the modern ground surface. In this area the overlying Bw-horizon was truncated and the buried A-horizon was overlain by Stratum 1. As the modern ground surface rose gradually in elevation toward the north, the Bw-horizon gradually increased in thickness on top of the buried A-horizon. In the trench profile the buried A-horizon dipped slightly to the north, eventually breaking into diffuse, trailing pockets near the north end of the trench.

The buried A-horizon matrix consisted of a single, massive deposit of brown silt with a small fraction of very fine to fine-grained, well-sorted sand with subrounded to subangularly weathered grains. Granular and pebbly inclusions grading in size from sub-centimeter to 3 cm in diameter made up a very small fraction of the total matrix. The buried soil had medium-strong, fine- to medium-sized, platy, and subangular blocky peds. Fine- to medium-sized roots and root pores were abundant, and clay films were common as fillings in root pores and as mottled slips on ped faces. Bioturbation from root growth and insect burrowing was subtle but pervasive. Relict soil casts from overlying deposits were visible in larger root channels and insect burrows. Several large krotavina were visible in the trench profile. A few small fragments of fire-cracked rock and flaked stone appeared in this stratum where it was exposed in the trench walls.

Texturally, Stratum 5 was a silty clay loam with a much greater particle cohesiveness and finer-grained particles than any other non-calcic soil horizon encountered in the project area. Fine grain-size characteristics and an enhanced organic content indicate that Stratum 5 may have been an overbank deposit produced when floodwaters from the nearby Mimbres River ponded in an isolated, low-lying area and were left stranded as the waters receded back into the main channel (Appendix 4).The only other soil sample with an elevated silt and organic content is also from BHT 1 and has a similar OSL date (2,100 ± 120 years ago).

Geochronology

Stratum 5 overlaid the Bk-horizon with an abrupt and wavy to irregular boundary, factors that reflect the erosional forces at work at the top of the Bk parent material. Such erosional forces were the result of soil desiccation, subsequent eolian and/or flood turbation, and erosion during flooding episodes from the nearby Mimbres River. An OSL date of 2.14 ±-0.13 ka (2,140 years ago) was obtained from the base of the Stratum 5 buried A-horizon, indicating the earliest possible time period for deposition of Stratum 5 (Table 3.1). Proxy data from paleoclimate and geomorphology studies undertaken in the Hueco Basin some 125 km (77.7 miles) east of the project area suggest a period of increasing erosion and proliferation of C_3 grasses beginning about 22 ka (2,200 years ago), a time period corresponding to the erosion at the top of the Bk, as indicated by the irregularities in the boundary (Buck et al. 1999:741)

An OSL date of 2.1 ± 120 ka (2,100 years ago) from the top of the buried A-horizon dates the period of abrupt cessation of Stratum 5 deposition and resumption of eolian sand accumulation. The closely spaced dates from the upper and lower margins of the buried A-horizon suggest the occurrence of a single depositional event or a rapid succession of such events, lending support to the Mimbres River flood deposit theory of origin for this stratum.

Paleoclimate data provide support for the Stratum 5 flood deposit hypothesis. Speleothem growth ring patterns from Carlsbad Caverns and Hidden Cave in the Guadalupe Mountains indicate a mesic period of increasing effective rainfall occurred during the time of deposition of the buried A-horizon parent material (Polyak et al. 2001). Similarly, tree-ring growth patterns from a very old Douglas fir at El Malpais National Monument indicate a mesic period coincident with Stratum 5 deposition (Grissino-Mayer 1996a). Other proxy records for a slightly cooler, moister climate around 2000–2200 BP include a study of macrobotanical remains recovered from packrat middens in the southern Sacramento Mountains, which indicates a slight increase in more mesically adapted species such as oak and piñon pine (Van Devender et al. 1984:353).

Stratum 6

Stratigraphy, Geomorphology, and Soil Morphology

In the vicinity of hand-excavation unit 346N/570E, at about 1.10 m below ground surface (Fig. 3.2), a petrocalcic horizon of indurated caliche (calcrete) was exposed. A petrocalcic horizon develops when the calcic horizon becomes plugged or exposed on the surface, producing conditions where carbonate-laden water is unable to move downward through the soil profile. These conditions result in more rapid precipitation of the carbonate solute, forming a solid laminar crust—the petrocalcic horizon (Monger et al. 2009).

Stratum 7

Stratigraphy, Geomorphology, and Soil Morphology

Backhoe trenches excavated in the northern half of the project area after mechanical removal of surface deposits provided an opportunity to examine the older stratigraphy beneath the K-horizon. The boundary of the K-horizon was extremely irregular with horizontally discontinuous, vertically indiscreet laminar interbeds welded into the surface of a buried paleosol, Stratum 7 (Fig. 3.3). Laminar calcic horizons are characteristic of early late-stage carbonate development and may indicate formerly exposed, weathered surfaces (Monger et al. 2009).

The buried paleosol consisted of very fine- to fine-grained sand and silt. The sand grains were sub-rounded to round. A very small fraction of the matrix consisted of irregularly shaped to subrounded granules 1 mm in diameter. The paleosol had a different parent material than the overlying soils. Texturally, this soil was a hard, strongly structured loam with fine to coarse, blocky and subangular ped development. Small root pores less than 1 cm in diameter were abundant. Carbonate and manganese slips commonly occurred in the root pores and as coatings on granules. When treated with hydrochloric acid, the matrix did not react, indicating a non-calcic horizon. The massively bedded paleosol was a slight reddish color, had a well-developed soil structure, and there was a loss of carbonates except for the illuvial carbonates in pore spaces characteristic of cambic horizons (Waters 1992).

The paleosol was assigned a field designation of 2Bwb, for a second, buried, Bw-horizon. The welded zone at the top of this paleosol was designated Stratum 7.1; the reddish cambic horizon was designated Stratum 7. The fine-grain size uniformity and lack of bedding in the 2Bwb-horizon suggests an eolian origin for the parent sediment (Maker et al. 1970).

Geochronology

A single OSL date obtained from Stratum 7 at 1.45m below the base of the K-horizon indicates that deposition of this material began prior to 35.2 ± 2.7 ka (35,200 ± 2,700 years ago). Deposition was likely complete prior to 11.8 ± 0.7 ka (11,800 ± 700 years ago), as indicated by an OSL sample taken deep in the Bk-horizon above the K-horizon (Table 3.1).

Stratum 8

Stratigraphy, Geomorphology, and Geochronology

Three of the deep backhoe trenches also had shallow, horizontally discontinuous lenticular deposits of unconsolidated, unsorted sand with angular and sub-rounded pebbly inclusions. Deposition of coarse alluvium requires an environmental shift from one of dynamic transport energy, such as an alluvial channel where sediments are carried by water flowing downhill, to one of static transport energy, such as the inside bend of a stream or alluvial channel or an alluvial fan where sediments are dispersed laterally. Coarse alluvium derived from the upper reaches of the alluvial fan on which LA 159879 is located would have been transported from one of the narrow alluvial channels providing drainage from the flanks of

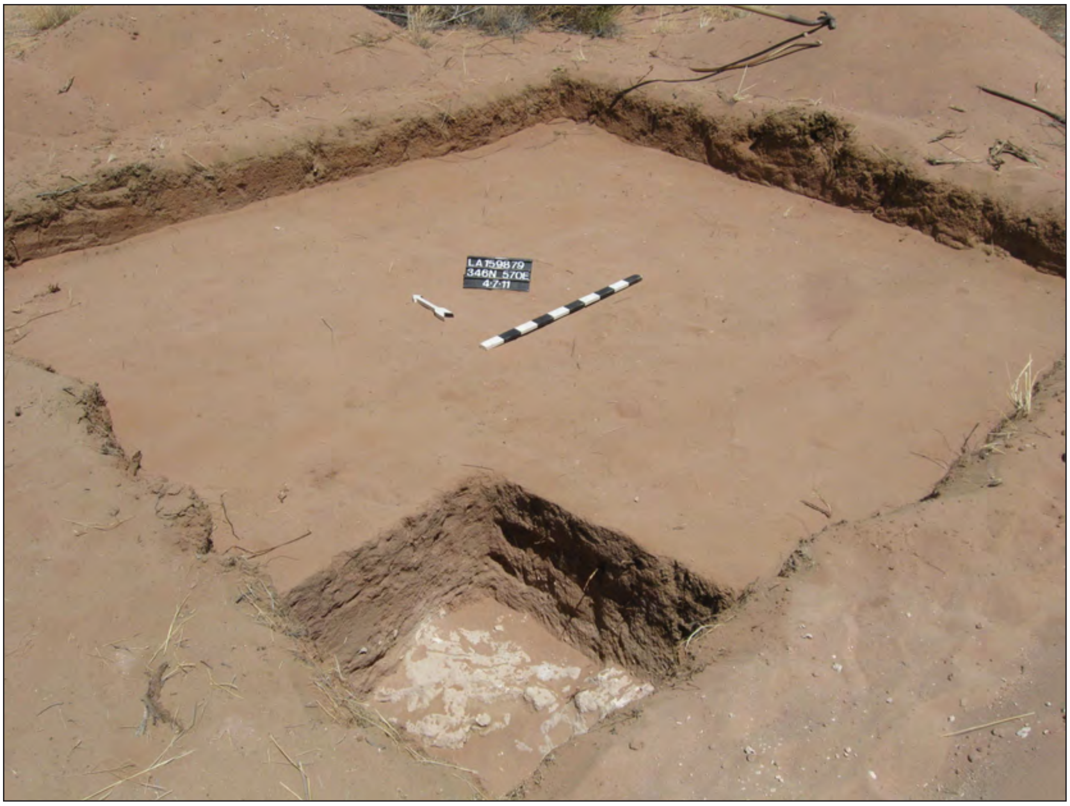


Figure 3.2. Calcrete exposed in hand-excavated unit 346N/570E, view northeast.

Figure 3.3. BHT 8, showing Stratum 7, south wall.

Cookes Range. Upon reaching the lower elevation of the Mimbres valley, current velocity and carrying capacity of the drainage channel would diminish, resulting in deposition of a sediment load consisting of coarse alluvial materials confined channels and sheets.

The Stratum 8 coarse alluvial materials occurred within Stratum 7, indicating deposition prior to 35,200 ± 2,700 years ago. As these types of deposits are transported through high-energy depositional environments in fluvial or alluvial settings, they indicate erosion of exposed surfaces during periods of greater effective moisture.

Proxy data supporting the existence of environmental conditions responsible for the weathering, erosion, and rapid re-deposition indicated by Stratum 7 and Stratum 8 are found in the oxygen isotope signatures of sediments in the Gulf of Mexico. These indicate that the Stratum 7 material was deposited during an interstade in the Wisconsin glacial period—a lengthy period of warming accompanied by sea-level rise equivalent to about 12.5 m, beginning about 36,500 years ago and continuing for a millennium. The warming period triggered glacial melting, contributing to a rise in sea level, and could have also led to drought conditions and changes in the vegetation regime, contributing to weathering, erosion, and re-deposition of large volumes of sediment (Hill 2006).

Additional proxy data comes from a sediment core study of the Alta Babicora basin in northern Mexico's Chihuahuan Desert, which indicates a period of high rainfall variability culminating in a period of decreased effective moisture and decreasing lake levels about 38,000 years ago. This xeric period was followed by a gradual return to pluvial conditions about 29,000 years ago (Metcalfe et al. 2002:91–101). Environmental conditions such as these could also have contributed to drought, vegetation changes, weathering, erosion, and re-deposition.

Soil Classification

Soils at LA159879 consist entirely of Doña Ana sandy loam. The Doña Ana sandy loam is found in level to slightly sloping fan remnants and alluvial fans. Its parent material is alluvium derived from igneous and sedimentary rock. It is a well-drained, non-saline or slightly saline soil with a maximum calcium carbonate content of up to 40 percent (USDA-NRCS 2011). This soil is a thermic, light-colored soil of warm desert regions and of Haplargid association. Haplargid soils form in valley fill sediments at the lower margins of piedmont slopes, in the plains between desert mountain ranges, and in valley floors. The Haplargids support various types of grasses and desert shrubs such as mesquite, yucca, Mormon tea, sand sagebrush, broom snakeweed, and wolfberry (Maker et al. 1978).

Site Formation Processes

OSL chronologies indicate that the upper eolian sediment comprising Strata 1, 2, and 3 began accumulating during a shift from late Wisconsin mesic conditions into the early Holocene prior to 11.8 ±.7 ky (11,800 ± 700 years ago) (the earliest OSL date obtained from the basal Bk parent material, which overlies the K-horizon) and continued until about 2,000 years ago. This deposit is the parent material for the Aw, Bw, and Bk soil horizons in which the archaeological site was formed, and was the parent material for the eolian surface horizon into which cultural materials erode. OSL data indicate that the eolian surface deposit began forming at least 100 years ago (Appendix 1).

The presence of older artifacts on the surface of younger deposits, such as the historic dune sand, indicates that deflation and lag is an ongoing geomorphic process in the vicinity of the site. Because of intensive deflation, bioturbation, and erosion, artifacts occur on the surface and within the sediment of Stratum 1—the historic surficial eolian deposits. Where stabilized by shrub vegetation, Stratum 1 sometimes has weak A/B-horizon development.

Radiocarbon and OSL data also allows us to infer that the site developed on the parent material for the upper Bk (Stratum 3) and the middle to upper Bw-horizon (Stratum 2). OSL dates indicate that post-occupational sand accumulation continued until at least 2,510 years ago. Cultural features originating in the Bw-horizon intrude into older soil horizons. For example, some features originating in the Bw-horizon intrude into the Bk- and K-horizons. Charcoal obtained from Feature 3, for instance, was radiocarbon dated to 2,690–2,640 BP (840–800 BC). Assuming a constant rate of deposition and extrapolating between OSL dates obtained from sediment deposits bracketing Feature 3 suggests that the Stratum 3 parent material began to be buried by Stratum 2 parent eolian deposits after 9.5 ka (9,500 years ago).

Proxy evidence for renewed eolian deposition comes from the Hueco Basin, where isotopic signatures from pedogenic carbonates suggest that, prior to about 9,000 years ago, a stable geomorphic surface supported the growth of C_4 grasslands. The grasslands were abruptly replaced between about 7,000 and 9,000 years ago by C_3 desert scrub, an indication of the onset of a more xeric climate. Along the same lines, geomorphic evidence suggests that the drying climate was accompanied by the onset of erosion.

The upper horizon of archaeological deposits on the site appears to be severely eroded—an observation confirmed by the presence of artifacts in the historically deposited, surficial eolian sand derived from the deflation of underlying intact soils during the late nineteenth and early twentieth centuries. Other evidence for erosion and deflation of cultural features includes the shallow, truncated thermal pits that were not visible until seen in contrast with deeper, lighter-colored calcic soils, such as the Bk-horizon, and the highly diffuse, unconsolidated characteristics of the upper horizons of archaeological pit features that actually were visible in contrast to the somewhat darker-colored Bw-(Stratum 2) horizon. None of the cultural deposits at LA 159879 appeared to be significantly stratified. The vast majority of radiocarbon-dated features were created over a 600-year period between 2970 and 2360 BP (1050–429 BC). However, it is possible that the erosion of the tops of features obscured or obliterated evidence stratification.

The range of depths and elevations for deposits of similar ages further suggest that a significant amount of dune-forming erosion and mixing took place. This is particularly evident in the top of the Bw-horizon—the soil of principal archaeological importance. Regardless of the impact of erosive forces, predominantly bioturbation and wind deflation, a persistent age range for radiocarbon-dated carbonized material recovered from the lower portions of cultural features indicates that at least these parts of the features remained relatively intact and the contexts from which pollen and phytolith samples were collected secure.

4 Chipped Stone Analysis

James L. Moore

INTRODUCTION

The Deming chipped stone assemblage was sampled in three rounds. The first sample included all artifacts recovered from features at the site. The second sample consisted of artifacts from four areas on the site. Each of these areas consisted of the zone around one or more features, and included an east–west band between northing lines across the section of LA 159879 that was investigated, as shown in Table 4.1. In order to further increase sample size, all specimens that had not previously been examined in the area north of the 300N grid line were then added to the sample. A sample of 770 artifacts was examined, representing 53.7 percent of the entire assemblage (n = 1,434). Artifacts were examined at two analytic levels. Artifacts in Sample Areas 1, 1.1, 2, and 2.1 were subjected to an expedited analysis (as discussed below), while those from the features and the sample obtained from north of the 300N grid line were examined by full analysis. Because of confusion caused by the addition of the last analytic phase (the area north of the 300N grid line), 234 artifacts from earlier analytic phases were re-examined, and the data from the full analysis of these specimens was used in place of the original expedited analysis. Thus, about 570 of the 770 artifacts were examined using the full analysis, and only the remaining approximately 200 were subjected to expedited analysis.

While analysis was conducted by sampling, chipped stone artifacts are discussed by cluster in this chapter. The cluster designations are loosely based on those used in the ground stone analysis, but are divided slightly differently. Table 4.2 lists the features included in each cluster and any dates that were obtained, and Figure 4.1 shows the locations of each cluster. Cluster areas were arbitrarily separated along northing lines, and each cluster had a group of thermal features in its center. Only chipped stone artifacts occurring in the extreme south end of the site were entirely excluded from sampling.

In the following discussion, analytic attributes and methods are described first, followed by a detailed analysis of the sample assemblage. The analysis includes a site-level synthesis of data, as well as a comparison of the contents of the clusters in order to determine whether any important similarities or variations are visible between different parts of the site.

Table 4.1. LA 159879, chipped stone sample areas.

Sample Area	Northings	Features
All features	n/a	All feature contents
1	339–390N	4, 13, 14, 15, 16, 19
1.1	300–335N	6, 8, 9
2	270–300N	3, 10
2.1	203–240N	2
3	300–400N	n/a

ANALYTIC METHODS

All artifacts were examined under a binocular microscope at 10X–80X power magnification, with higher magnification used to examine wear patterns and platform characteristics. Utilized and modified edge angles were measured with a goniometer, and artifacts were weighed on a digital scale.

Four general classes of chipped stone artifacts are recognized in this analysis: flakes, angular debris, cores, and tools. Flakes are debitage that ex-

Table 4.2. LA 159879, cluster definitions used in the chipped stone analysis, also listing associated features, feature types, and dates.

Cluster	Northings	Features	Content	Most Accurate Dates (Chapter 8)
1	275–299	3	structure, activity area, 4 X 4	864–788 BC
2	200–232	5	structure(?), 4 x 4	1009–841 BC
3	300–330	6,8, 9	fire pits, 4 X 4	1050–830 BC
4	356–389	14, 15, 16, 19	structure (16), fire pit (15), noncultural	16 = 1027–891 BC; 15 = AD 1520–1670
5	335–355	13	fire pit, 4x4	758–429 BC
6	–	10	fire pit	–
7	390+	4	fire pit or stain	–

hibit one or more of three characteristics: definable dorsal and ventral surfaces, bulb of percussion, and striking platform. Pieces of angular debris are debitage that lack these characteristics. Cores are nodules from which debitage were struck and that exhibit three or more negative flake scars originating from one or more platforms. Tools are debitage or cores whose edges were damaged during use or modified to create specific shapes or edge angles to function in certain tasks.

Analytic Attributes

The attributes recorded for all artifacts during the full analysis included material type and quality, artifact morphology and function, amount of surface covered by cortex, cortex type, portion, evidence of thermal alteration, and dimensions (length, width, and thickness). In addition, all artifacts were weighed, and wear patterns and utilized/modified edge angles were examined and recorded for all informal and formal tools. Platform type, evidence of platform lipping, dorsal scar orientation, platform angle, type of bulb of percussion, curvature, waisting, and distal termination were recorded for flakes only.

As discussed earlier, two levels of analysis were used to examine the various samples drawn from this assemblage. All of the above attributes were recorded for the sample recovered from features and the sample of artifacts collected from the area north of the 300N grid line. This was the full analysis sample. The artifacts from Sample Areas 1, 1.1, 2, and 2.2 that did not overlap with those examined in the sample of feature artifacts and artifacts from the area north of the 300N grid line were subjected to an expedited analysis, which recorded most of these attributes except for platform lipping, dorsal scar orientation, platform angle, waisting, bulb of percussion, and ventral curvature.

Material Type: Materials were coded by gross category unless specific sources or distinct varieties were recognized. Codes were arranged so that major material groups fell into specific sequences of numbers, progressing from general material groups to specific varieties that could be linked to sources. Cherts, rhyolites, and metaquartzites were separated into a number of distinct varieties based on color combinations because varying colors in these materials could be important indicators of source.

Material Texture and Quality: This attribute provides information on the basic flaking characteristics of materials. Texture subjectively measured grain size *within* rather than *across* material types and was scaled from fine to coarse for most materials, with fine textures exhibiting the smallest grains and coarse the largest. Obsidian was classified as glassy by default, and this category was applied to no other material. Quality recorded the presence of flaws that could affect reduction including crystalline inclusions, fossils, visible cracks, and voids. Inclusions that would not have affected reduction, such as specks of different colored material or dendrites, were not considered flaws. Material texture and quality were recorded together.

Artifact Morphology: This is one of two attributes that provide information on artifact form and use. Artifact morphology categorizes artifacts by their general form, such as core flake or early stage biface.

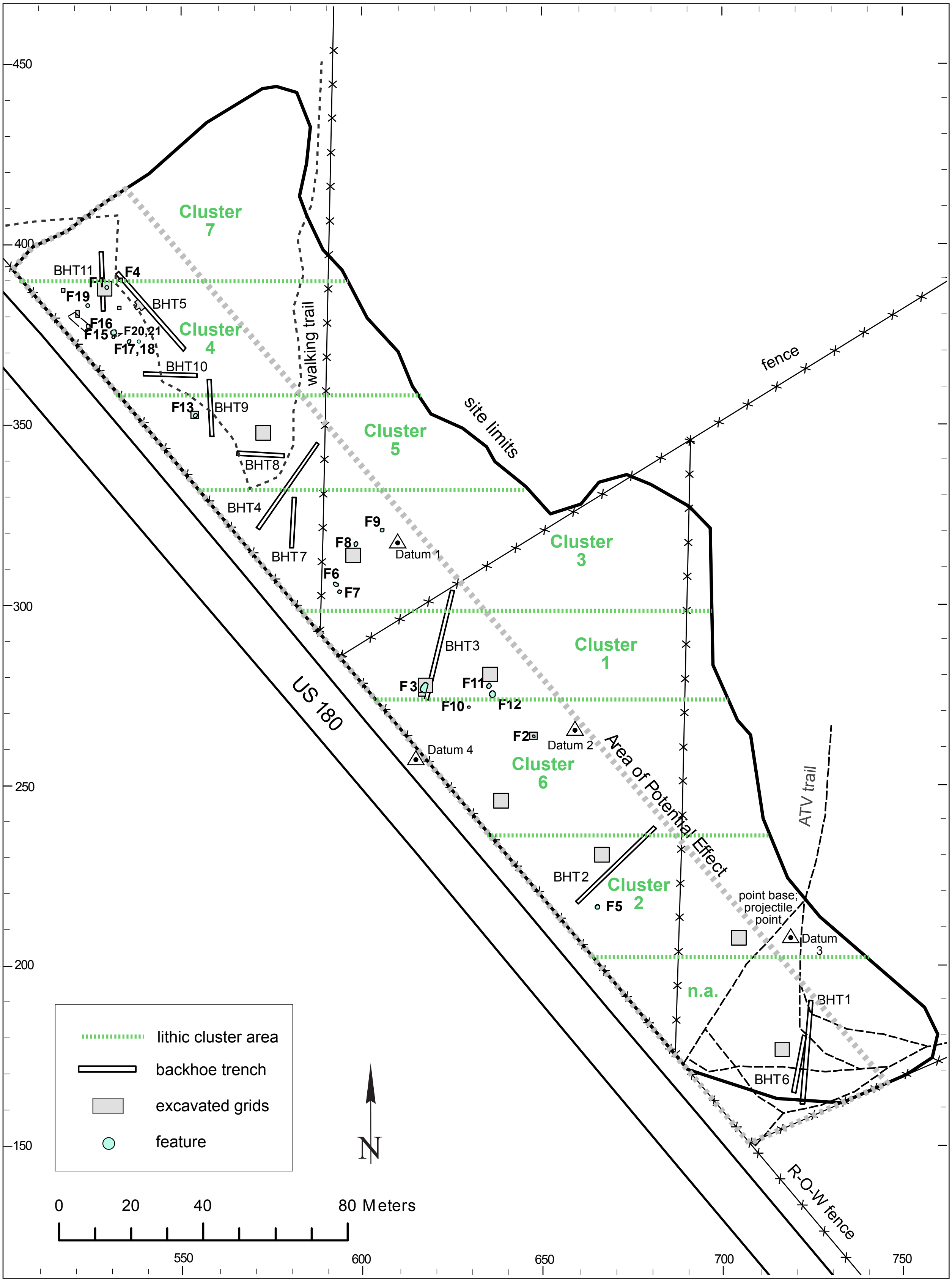


Figure 4.1. Plan of LA 159879, showing locations of cluster areas used for chipped stone analysis.

Artifact Function: This is the second attribute that provides information on artifact form and use, and categorizes specimens by their inferred use (or lack of use) such as end scraper or non-utilized flake.

Cortex: This is the chemically or mechanically weathered outer rind on nodules, and tends to be brittle and chalky and does not flake with the ease or predictability of unweathered material. The amount of cortical coverage is estimated and recorded in 10 percent increments for each artifact—for flakes the percentage of dorsal surface covered by cortex is estimated, while for all other artifact classes the percentage of total surface area covered by cortex is estimated, since other artifact classes lack definable dorsal surfaces.

Cortex Type: The type of cortex can be a clue to its origin. Waterworn cortex indicates that a nodule was transported by water and that its source was probably a gravel deposit. Non-waterworn cortex suggests that a material was obtained from a natural outcrop. Cortex type was identified for artifacts on which it occurred; when identification was not possible, cortex type was coded as indeterminate.

Portion: For flakes and formal tools, the portion represented by each specimen was recorded. Angular debris and cores were considered whole by default, because it is usually impossible to determine whether artifacts In these categories were broken or complete.

Platform Type: This recorded the shape of, and any modifications to, the striking platform on whole flakes and proximal fragments

Platform Lipping: The presence or absence of a lip at the ventral edge of a flake platform was recorded, and coded as either present or absent.

Platform Angle: The angle formed by the intersection of the dorsal surface of a flake and its striking platform was recorded as either greater than 45 degrees or less than 45 degrees.

Bulb of Percussion: These only occur on flakes and were recorded as either pronounced or diffuse.

Flake Curvature: The presence or absence of distinct curvature on the ventral surface of flakes was recorded using this attribute.

Waisted: Soft hammer percussion and pressure flaking can cause the formation of a waist between the platform and main body of a flake, and these are often present on biface flakes. This attribute recorded the presence or absence of waisting on flakes.

Thermal Alteration: When present, the type and location of evidence for thermal alteration were recorded to determine whether an artifact was purposely or incidentally heated.

Wear Pattern: In cases where debitage or cores were used as informal tools, this attribute recorded the pattern of attrition. A second group of codes was used to record formal tool edges. Wear pattern was recorded separately for every altered edge on a tool.

Edge Angle: The angles of all utilized or intentionally modified edges on informal and formal tools were recorded. Edge angle was also recorded separately for every altered edge on a tool.

Length, Width, and Thickness: These attributes were measured in millimeters for all artifacts. On angular debris and cores, length was the largest measurement, width was the longest dimension perpendicular to the length, and thickness was perpendicular to the width and was the smallest measurement. On flakes and formal tools, length was the distance between proximal and distal ends, width was the distance between edges paralleling the length, and thickness was the distance between dorsal and ventral surfaces.

Weight: Weight was recorded to the nearest tenth of a gram.

Discussion

The analytic methods used during this study combine both typological and attribute approaches. In typological approaches, “individual artifacts are classified into types that have some kind of technological or functional meaning” (Andrefsky 2001:6). A benefit of this type of analysis is that behavior can be immediately inferred from the identification of a single artifact (Andrefsky 2001:6). For instance, the presence of a notching flake indicates that a notched tool was made at a site, even if no notched tools are found. However, this method can be criticized because there is often a lack of verification between artifact type and functional or technological interpretation (Andrefsky 2001:7). Attribute analysis examines the distribution of one or more characteristics through an entire population, usually of debitage. Among other things, various attributes can be used to assess the prevalence of specific reduction methods in a debitage population. However, problems can also occur when using this analytic strategy "for a variety of reasons related to the small size of attributes and the number of observations" (Andrefsky 2001:12). Typological and attribute analyses vary in scale; typological analysis is applied to individual artifacts while attribute analysis is applied to entire assemblages. Andrefsky (2001:12) notes that there is no "right" approach to debitage analysis, the approach used can vary according to the types of information desired.

The methods employed in this study assign typological interpretations to individual artifacts, while at the same time gathering attribute data that could be used to test and augment typological data. For instance, a rigorous set of characteristics was used to define flakes struck from bifaces versus those struck from cores. Flakes that did not fulfill the set of characteristics used to define biface flakes were, by default, considered core flakes. However, the definition used to identify biface flakes models ideal examples, and all flakes struck from bifaces (especially those struck in the early stages of manufacture) do not fit that ideal. By combining attribute analysis with a typological approach we are able to determine which flakes were definitely struck from bifaces (typological approach) as well as those that were probably struck from bifaces but do not quite fit the model (attribute analysis). The two approaches complement one another and help provide a deeper understanding of reduction technology and tool use.

The main questions this analytic scheme was designed to explore include what types of materials were selected, what reduction techniques were used, and what types of stone tools were used. These topics can provide information about ties to other regions, mobility patterns, and site function. Material selection studies do not always reveal *how* materials were obtained, but they can provide information on *where* materials came from. Cortex type can be used to determine whether materials were obtained at outcrops or came from secondary gravel deposits. Studies of reduction technology can help show how different peoples solved the problem of producing the chipped stone tools they needed from resources at hand. Various approaches could have been used, depending upon the level of residential mobility, types of stone available, and the range of other materials that could be used as tools. Examination of the tools recovered from a site can help define the range of activities that occurred there, and in many cases this will also aid in defining site function. Chipped stone tools can sometimes be used to provide temporal data, but are usually less time sensitive than other artifact classes like pottery. For this reason, the chipped stone assemblages are only used to provide temporal data at a very coarse-grained level.

Two attributes are used to record typological categories in this analytic scheme—artifact morphology and artifact function. Morphology describes the basic appearance of an artifact, especially debitage. Function describes its presumed use based on shape and evidence of use. Information on the typological placement of debitage and cores is coded into artifact morphology, while tools are only generalized by this attribute into uniface, biface, and cobble tool categories. Conversely, the typological placement of formal tools is coded into the artifact function category and is based on shape and flaking patterns, while most debitage and cores are generalized into utilized and unutilized categories. The exceptions are pieces of debitage that were marginally modified, either by use or design, into definable tool types. This category mostly includes tools such as scrapers and spokeshaves that were made on debitage with a minimum of modification, and in most cases the source of that modification (use versus purposeful shaping) is questionable. By using both artifact morphology and function, each artifact can be assigned to a specific type. The debitage category contains flakes and angular debris. While all angular debris are assigned a single code, multiple types of flakes can occur in an assemblage, and each type can have a different origin. One of the aspirations of this analysis is to distinguish between major varieties of flakes, including core flakes, biface flakes, resharpening flakes, notching flakes, bipolar flakes, blades, channel flakes, and potlids. With the exception of core and biface flakes, and possibly resharpening flakes, these categories are usually rare or absent from most assemblages. Thus, distinguishing between core and biface flakes is a critical analytic need.

Flakes were divided into removals from cores and bifaces using a polythetic set of attributes (discussed in detail later). While not all flakes removed from bifaces can be distinguished in this way, those that are can be considered definite evidence of biface reduction. Instead of rigid definitions, the polythetic set provides a flexible means of categorizing flakes and helps account for some of the variability seen in experiments. Other flake types were identified by unique characteristics. Notching flakes are produced when the hafting elements of bifaces are notched and generally exhibit a recessed, U-shaped platform and deep, semi-circular scallop at the juncture of the striking platform and dorsal surface. Bipolar flakes are produced when nodules are smashed, and sometimes exhibit evidence of having been struck at one end and crushed against an anvil at the other. Channel flakes are removed when Paleoindian dart or spear points are fluted and do not occur in later sites except as curated artifacts. Blades are defined as long, narrow removals from specially prepared cores, and are rare after the Clovis period. The traditional definition of blades in the Southwest follows that developed by Bordes (1961), which classifies as a blade any flake that is twice as long as it is wide. However, as Collins (1999) points out, the context of that definition is often overlooked by archaeologists in the New World:

> He was defining the term for use in classifying Lower and Middle Paleolithic stone tools, where blades by any definition are relatively infrequent.…In contrast, during the Upper Paleolithic, blades—often called "true blades"—are far more common and they meet more stringent definitions, even in Bordes own writings…where emphasis is placed on the techniques of production, not just the proportions of the piece (Collins 1999:7).

This is important to note, because many flakes removed from large Archaic bifaces fit the proportional criteria that are often used to define blades, but result from an entirely different reduction technique. Large biface flakes often appear to be prismatic in form and are slightly curved as can be common for blades. However, blades are struck from specially prepared cores, have platform angles approaching 90 degrees, and exhibit evidence of platform preparation on the dorsal surface below its juncture with the platform (Collins 1999). Large biface flakes are struck from bifacially flaked tools or biface-cores have platform angles approaching 45 degrees, and exhibit evidence of platform preparation across the platform as well as along the edge where the platform and dorsal surface meet. Even though there is a superficial resemblance between some of the byproducts of blade and biface reduction they represent two distinct techniques, each with its own set of attributes.

Resharpening flakes are removed from formal tool edges that become dull from use, and usually fit the polythetic set for biface flakes. They are often impossible to separate from other biface flakes, but can sometimes be distinguished by the presence of an extraordinary amount of damage on the platform and on the section of dorsal surface adjacent to the platform. Potlids are debitage that were blown off the surface of a chipped stone artifact during thermal alteration, and are not indicative of purposeful flaking.

Cores are nodules of raw material modified by the removal of debitage during reduction. Some cores were reduced in a standardized fashion, while flakes were removed from others in a more haphazard manner. Core shape and size are often clues to the relative availability of materials. Materials represented by small, carefully reduced cores may have been uncommon or highly desired. Materials represented by large cores, often with haphazard or unplanned flake removals, tend to be common and not highly prized. Core analysis in the Southwest tends to be rather simplistic since evidence of specialized reduction techniques is rare after the Paleoindian period. Since blade technology does not occur after the Clovis period, prismatic (blade) cores associated with this technique rarely occur. Blade technology was replaced by the manufacture of biface-cores during the Archaic period. Biface-cores (or large generalized bifaces) were multifunctional in that they could be used as tools, as sources for informal debitage tools, or modified into other forms. While the manufacture of biface-cores wasted a lot of material, the tools themselves were an efficient adjunct to a hunting and gathering lifestyle. However, because of their multifunctional character they tend to be categorized as formal tools rather than as cores.

Both cores and formal tools represent nuclei from which flakes were removed, but differ in the rationale behind those removals. Flakes were struck from cores for use as informal tools or to be modified into formal tools. Flakes were also removed during formal tool manufacture to create desired shapes or edge angles. Cores are classified with debitage as by-products of the reduction process. Formal tools are considered separately because they are evidence of other unrelated tasks. Since all chipped stone artifacts result from similar reductive processes, this division is in many ways artificial, because formal tools can be used to both aid in the examination of reduction processes and to provide information on the range of tasks performed. This is especially true for unfinished formal tools that were discarded during production because of breakage or problems encountered during reduction.

Material Selection

Examination of the materials reduced at a site and their physical attributes can provide information on several aspects of human behavior. Materials obtained from definable exotic sources can suggest movement range or exchange ties. The texture and flaking qualities of materials can be a clue to the purpose for which they were selected. Identification of materials from local sources—both primary and secondary—provides information on how the local landscape was used. The amount of cortical coverage on debitage can suggest the form in which materials arrived at a site.

Five of the attributes recorded during analysis are specifically aimed at providing information on material selection. Examining the type of cortex that occurs on materials provides information on where those materials were obtained. Non-waterworn cortex indicates procurement at an outcrop, while waterworn cortex indicates that a nodule was collected from a secondary gravel deposit. Since materials collected from gravel beds were often naturally transported a great distance from where they outcrop, this is an important distinction. The amount of cortical coverage on debitage, especially flakes, provides clues concerning the level to which cores were reduced before being brought to a site. Large amounts of debitage exhibiting extensive cortical coverage suggest that nodules were both obtained and reduced at the same location, while the opposite may indicate that cores were transported in an already reduced condition.

The remaining attributes provide information on flaking characteristics, which can be critically important to the material selection process. The first of these is material type itself. Rocks vary considerably in their flaking characteristics; some flake with comparative ease and predictably, while others are more difficult to flake and do not always break in the desired way. Materials that flake easily tend to be brittle and elastic, while those that are harder to flake tend to lack elasticity and are less brittle. These characteristics are tied to what Cotterell and Kaminga (1990:129–130) refer to as *toughness*. Tough materials are durable and able to withstand impacts from pounding or chopping without splintering and coming apart. While materials from different sources vary in toughness, in general Cotterell and Kaminga's (1990:129) comparison indicates that obsidian, quartz, and chert are less tough than andesitic basalt, tuff, and rhyodacitic volcanic rock. Toughness is not equated with hardness, because hard materials also tend to be brittle and fracture easily (Cotterell and Kaminga 1990:129). Thus, non-durable materials are mostly hard and brittle. Fine-grained, non-durable materials produce sharp cutting edges (Cotterell and Kaminga 1990:127) and are less tough than those that are softer and less brittle. While the former are well-suited to the production of cutting and scraping tools, the latter are best for pounding and grinding tools. Non-durable materials are less suitable for pounding or chopping because the same characteristics that allow them to produce sharp edges cause them to splinter and crack when force is applied to their edges.

Cotterell and Kaminga's (1990) system of classification is similar to one presented by Callahan (1990:16) and modified somewhat by Whittaker (1994:66), which ranks materials by degree of toughness and the effective limits of tools used for reduction. While Callahan's (1990:16) rankings are a subjective rather than a quantitative test of toughness, they are based on many years of flint knapping experience and are probably accurate. In this scheme, obsidians and heat-treated fine-grained cherts and chalcedonies are classified as brittle and can be efficiently thinned using soft hammer percussion and pressure flaking. The finest-grained basalts and rhyolites, unheated fine-grained cherts, and other chertic materials are categorized as strong, and can be efficiently thinned using both soft hammerstone and soft hammer percussion as well as pressure flaking. Strong cherts can be transformed into brittle materials by thermal alteration. The coarser cherts, quartzites, quartz crystal, agate, jasper, siltstone, siliceous limestone, coarser-grained quartzites and rhyolites, and most basalts are classified as tough and are best thinned using soft hammer reduction.

Luedtke (1992:80) notes that material strength (also referred to as toughness or tenacity) "is a measure of how much force must be applied to produce a fracture." Thus, strength also equates to the degree of resistance to knapping demonstrated by a material. Strong materials that require the use of hard blows to remove flakes cannot be hit as accurately as materials that require less force to initiate a fracture. Some reduction techniques, like pressure flaking, are not applicable to very strong materials (Luedtke 1992:80). In discussing Callahan's (1990) material scale, Luedtke notes:

> Strength peaks in the middle of the range rather than at either end. The most workable materials, at the low end of his scale, are relatively weak. They should be worked with softer billets or flakers, and they require special procedures to keep platforms from collapsing. Materials at the high end of Callahan's scale, the least workable, are also somewhat less strong and prone to hinge and step fractures. Presumably, fractures start easily in materials at this end of the scale but do not propagate all the way through the stone, as desired (1992:80–81).

Materials categorized as brittle in Callahan's scale are the best for chipped stone reduction. Strong materials can be efficiently worked but require more force to remove flakes. Tough materials at the upper end of the scale generally cannot be efficiently worked because flakes struck from them often terminate in hinges or steps that make further flaking difficult to accomplish.

By combining classification systems, we can categorize materials defined as brittle and strong by Callahan (1990:16) as non-durable, and those defined as tough as durable materials. Non-durable materials are best suited to reduction because they can be efficiently flaked using a variety of methods. Durable materials are less well-suited to reduction because the techniques that can be used to efficiently work them are more limited and they cannot be flaked as efficiently. Thus, by examining the toughness of materials we may be able to determine some of the use-based parameters that factored into their selection. Three attributes are tied to an examination of durability: material type, material texture and quality and presence or absence of thermal alteration.

Material Type

The distribution of material categories is shown in Table 4.3. We refer to material categories rather than material types because multiple varieties occur in several cases; these have been combined into the categories shown in Table 4.3. All but a single projectile point could be assigned to specific clusters. Chert (which includes chalcedony and silicified wood) is the most common material category in all clusters, as well as for the assemblage as a whole, in each case making up 51 percent or more of the total. Rhyolite is the second most common category overall in the five largest cluster assemblages, with basalt in this position in Clusters 6 and 7. Metaquartzite is the third most abundant category in all seven clusters, though in Cluster 5 it is tied with rhyolite for second/third most common. Basalt is the only other material category that can be considered relatively common, and is the fourth most abundant category in the five largest clusters, and second in Clusters 6 and 7. The four remaining material categories in Table 4.3 are comparatively rare, making up less than 2 percent apiece of each assemblage except for Cluster 5, where the somewhat larger percentage of igneous materials is due to small sample size.

By considering only the four most common material categories and eliminating the smallest cluster assemblage (Cluster 6), the makeup of the six remaining cluster assemblages can be compared. Chi-square analysis suggests that these assemblages are significantly different (chi-square = 46.0, df = 12, significance = .000, Cramer's V = .143). Clusters 1 and 4 differ from the other four clusters by containing much higher percentages of cherts. When only these two clusters are compared, chi-square analysis suggests that they belong to the same population (chi-square = 6.1, df = 3, significance = .107; Phi = .109). Comparing the four remaining assemblages (Clusters 2, 3, 5, and 7), chi-square analysis suggests that they are also similar to one another at the 95 percent confidence level (chi-square = 10.4, df = 9, significance = .321, Cramer's V = .121). Since the cluster divisions were arbitrarily defined the meaning of these similarities is uncertain, and

Table 4.3. LA 159879, material category by cluster.

Material Category		No Cluster	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Totals
Unknown	Count	–		–	–	1	–	–	–	**1**
	Col. %	–		–	–	0.3%	–	–	–	**0.1%**
Chert	Count	1	142	42	54	232	16	5	16	**508**
	Col. %	100.0%	77.2%	52.5%	51.4%	69.5%	51.6%	62.5%	59.3%	**66.0%**
Obsidian	Count	–		1	2		–	–	–	**3**
	Col. %	–		1.3%	1.9%		–	–	–	**0.4%**
Basalt	Count	–	6	2	12	19	4	2	5	**50**
	Col. %	–	3.3%	2.5%	11.4%	5.7%	12.9%	25.0%	18.5%	**6.5%**
Rhyolite	Count	–	24	19	20	39	5	–	4	**111**
	Col. %	–	13.0%	23.8%	19.0%	11.7%	16.1%	–	14.8%	**14.4%**
Metaquartzite	Count	–	12	15	15	40	5	1	2	**90**
	Col. %	–	6.5%	18.8%	14.3%	12.0%	16.1%	12.5%	7.4%	**11.7%**
Limestone	Count	–		1	–		–	–	–	**1**
	Col. %	–		1.3%	–		–	–	–	**0.1%**
Quartz	Count	–		–	1	1	–	–	–	**2**
	Col. %	–		–	1.0%	0.3%	–	–	–	**0.3%**
Igneous	Count	–		–	1	2	1	–	–	**4**
	Col. %	–		–	1.0%	0.6%	3.2%	–	–	**0.5%**
Totals	**Count**	**1**	**184**	**80**	**105**	**334**	**31**	**8**	**27**	**770**
	Col. %	**0.1%**	**23.9%**	**10.4%**	**13.6%**	**43.4%**	**4.0%**	**1.0%**	**3.5%**	**100.0%**

if they are not confirmed by analysis of other attributes they may not be meaningful at all. However, if these similarities are confirmed, they provide insights into site structure.

Colors and color combinations were used to differentiate the cherts, metaquartzites, and rhyolites during analysis because it was hoped that these characteristics would be useful in suggesting material sources. The variety of colors and color combinations for these materials are shown in Table 4.4. Forty-four types or color combinations were recorded for chert, two for chalcedony, three for rhyolite, and six for metaquartzite. Using colors to define chert sources can be dangerous, because cherts often vary in color in a single formation, and multiple formations may produce cherts of similar colors. Thus, the only types of chert that can be comfortably sourced using visual characteristics are those that are well-defined in the literature, or that have fairly unique characteristics of color or inclusions. Thus, the only type of chert in Table 4.4 that can be assigned to a specific source is San Andres chert, which outcrops in the San Andres limestone formation. This formation is widespread, and outcrops in west-central as well as south-central New Mexico.

Several types of chert outcrop in the Florida Mountains, including Rancheria chert from the Rancheria formation, and a medium to dark gray chert from the Upham Member of the Montoya formation (Brown 1983:26). The Cookes Range contains dark gray, white, and brown chert in the Aleman formation (Jicha 1954:12). In the Lake Valley mining district, there are massive deposits of red, green, yellow, and milky chert (Jicha 1954:69). Aleman dolomite in the Organ and San Andres mountains contains black chert, as does the Canutillo formation, the Lake Valley formation, and the Las Cruces formation (Seager 1981:23–24, 27). At Bishops Cap, chert in the Lake Valley formation has been observed to weather to reddish-brown or orange (Seager 1981:27). In the Cedar Mountains to the southwest of the project area, Fitting and Stone (1969) identified a quarry producing a low-quality purple chert, and a second quarry producing a yellow or red jasper that could range in the same core to a similarly colored fine-grained quartzite. Since chert sources are common in the region and often contain similarly colored materials, assigning specimens to specific sources based solely on color is impossible to do with any degree of confidence. The best course to follow is to simply note that the

Table 4.4. LA 159879, chert, rhyolite, and metaquartzite varieties by color.

Material Type	Count	Material Type	Count
Clastic chert	1	White and brown chert	3
San Andres chert	12	Gray and black chert	3
Gray chert	41	Tan and gray chert	16
Brown chert	53	Gray and brown chert	12
Tan chert	12	Purple and gray marbled chert	5
Black chert	3	Red and white chert	3
Cream chert	30	Brown and tan chert	3
White chert	23	Black and tan chert	7
Red chert	8	Gray and white chert	3
White and black chert	2	Dark gray chert	32
Tan and cream chert	11	Reddish-gray chert	3
Yellow chert	2	Coarse gray chert	11
Green chert	5	Mottled brown, red, and gray chert	3
Purple chert	2	Yellow, gray, and pink chert	2
Pink and gray chert	3	Mottled red, pink and yellow chert	12
Red-brown chert	39	Mottled black, white, and red chert	3
Pink and tan chert	6	Chalcedony	5
Yellow-brown chert	4	While chalcedony	30
Yellow-gray chert	9	Gray rhyolite	27
Yellow-white chert	3	Red aphanitic rhyolite	5
Yellow-red chert	28	Gray aphanitic rhyolite	72
Cream and brown chert	12	Purple metaquartzite	14
Pink and white chert	3	Gray metaquartzite	32
White and tan chert	9	Brown metaquartzite	9
Yellow and tan chert	2	Red-brown metaquartzite	3
Red and gray chert	20	Yellow-brown metaquartzite	3
Pink chert	2	Brown and gray metaquartzite	29
Brown and black chert	5		

mountains surrounding the project area contain a variety of cherts, as well as other types of materials, many of which are probably available in gravel deposits along streams draining those ranges as well as within outcrops.

The types of sources from which materials used at LA 159879 were obtained can be determined by examining cortex type. As discussed earlier, cortex is the weathered outer rind on nodules. Two types of weathering can generally be distinguished—chemical and mechanical. Chemical weathering is caused by exposure to the elements, and can cause the rind to be discolored and sometimes etched, but does not remove sharp edges or smooth the outer surface. Mechanical weathering is caused by water transport, and results in the rounding of sharp corners and the smoothing of the nodule surface. There is often a zone containing multiple cones of compression just below the cortical rind, reflecting the banging of rocks together as they were forcefully moved downstream. These types of weathering can usually be distinguished from one another, with chemical weathering without evidence for mechanical transport providing evidence for procurement at the source, and mechanical weathering indicating that a nodule was obtained from gravel deposits an indeterminate distance from where it outcropped.

Table 4.5 presents cortical data for the LA 159879 chipped stone assemblage. Only waterworn cortex was identified in this assemblage, suggesting that all materials used at this site were obtained from secondary gravel deposits rather than at their sources. Chert had a much smaller percentage of cortical specimens than the other material categories, and this suggests one of two possibilities. Either chert nodules were transported to the site in an already reduced condition, or they were reduced to a greater

Table 4.5. LA 159879, material type by cortex type.

Material Type	Waterworn Cortex	Percentage of Total	Mean Artifact Weight (g)
Unknown	0	0.0%	3.3
Chert	114	22.4%	7.7
Obsidian	1	33.3%	1.6
Basalt	25	50.0%	9.9
Rhyolite	63	56.8%	8.1
Metaquartzite	24	26.7%	8.1
Limestone	0	100.0%	1.5
Quartz	1	50.0%	12.9
Igneous	3	75.0%	22.7
Totals	**231**	**30.0%**	**5.3**

extent than were those of other material categories. Table 4.5 also presents the mean weight of artifacts for each material category, with chert artifacts having the fourth smallest mean weight overall, but the smallest mean for the four most common materials reduced at the site. In general, however, Table 4.5 shows that mean artifact weight increases with the percentage of cortical artifacts. This suggests that the comparatively small percentage of cortical chert artifacts indicates that cores of this material were reduced to a greater extent than were those of other material categories.

Material Type and Texture

Table 4.6 presents texture and quality data for each material category. Since obsidian is the only material to which the glassy classification is applied and is rare in all assemblages, the glassy and fine-grained categories can be combined, representing the materials best suited to formal tool production. Overall, medium-grained materials were the most heavily selected for, with 48.2 percent of the assemblage falling into this category. Fine-grained materials (with the addition of glassy) are nearly as common, and account for another 45.7 percent. Coarse-grained materials make up only 6.1 percent of the assemblage. Flawed materials were used, especially if they were fine-grained cherts, but they seem to have been selected against, since only 16.2 percent of the artifacts in the overall assemblage exhibit obvious flaws.

Considering only the debitage assemblage, there was a definite tendency to select unflawed fine-grained materials for tool manufacture. Of

Table 4.6. LA 159879, material texture and quality by material category.

Material Category		Glassy	Glassy and flawed	Fine-grained	Fine-grained and flawed	Medium-grained	Medium-grained and flawed	Coarse-grained	Coarse-grained and flawed	Totals
Unknown	Count	–	–	–	–	1	–	–	–	**1**
	Row %	–	–	–	–	100.0%	–	–	–	**0.1%**
Chert	Count	–	–	249	96	155	7	1	–	**508**
	Row %	–	–	49.0%	18.9%	30.5%	1.4%	0.2%	–	**66.0%**
Obsidian	Count	1	2	–	–	–	–	–	–	**3**
	Row %	33.3%	66.7%	–	–	–	–	–	–	**0.4%**
Basalt	Count	–	–	–	–	37	3	8	2	**50**
	Row %	–	–	–	–	74.0%	6.0%	16.0%	4.0%	**6.5%**
Rhyolite	Count	–	–	2	1	84	2	21	1	**111**
	Row %	–	–	1.8%	0.9%	75.7%	1.8%	18.9%	0.9%	**14.4%**
Metaquartzite	Count	–	–	1	–	71	7	8	3	**90**
	Row %	–	–	1.1%	–	78.9%	7.8%	8.9%	3.3%	**11.7%**
Limestone	Count	–	–	–	–	1	–	–	–	**1**
	Row %	–	–	–	–	100.0%	–	–	–	**0.1%**
Quartz	Count	–	–	–	–	2	–	–	–	**2**
	Row %	–	–	–	–	100.0%	–	–	–	**0.3%**
Igneous	Count	–	–	–	–	1	–	2	1	**4**
	Row %	–	–	–	–	25.0%	–	50.0%	25.0%	**0.5%**
Totals	**Count**	**1**	**2**	**252**	**97**	**352**	**19**	**40**	**7**	**770**
	Row %	**0.1%**	**0.3%**	**32.7%**	**12.6%**	**45.7%**	**2.5%**	**5.2%**	**0.9%**	**100.0%**

the 23 definite biface flakes identified in this assemblage, only two (8.7 percent, all fine-grained) exhibit flaws, and only six (26.1 percent) are medium-grained materials. No coarse-grained biface flakes were identified. In contrast, 33.6 percent of the 631 core flakes are fine-grained, 11.4 percent are fine-grained and flawed, 47.4 percent are medium-grained, 2.1 percent are medium-grained and flawed, 4.8 percent are coarse-grained, and 0.5 percent are coarse-grained and flawed. The much higher percentage of medium-grained materials and flawed materials in the core flake assemblage tend to support the idea that unflawed fine-grained debitage were selected for tool manufacture. This is also confirmed by the few formal tools recovered from the site, 71.4 percent of which (5 of 7) are made from fine-grained materials and 28.6 percent from medium-grained materials, none of which exhibit any obvious flaws.

In order to eliminate empty cells and permit the comparison of material quality characteristics between clusters, the flawed and unflawed categories were combined, and glassy and fine-grained materials were also combined. A chi-square analysis of this attribute suggests that these assemblages represent different populations at the 95 percent confidence level (chi-square = 45.8, df = 12, significance = .000, Cramer's V = .173). Various combinations of clusters were then tested, and the result of this analysis strongly suggests that all assemblages other than Cluster 4 belong to the same population for this attribute (chi-square = 9.8, df = 10, significance = .458, Cramer's V = .107).

Table 4.7 presents toughness data for each cluster. In general, there is a higher percentage of brittle materials than might be expected, given the comparatively small percentage of biface flakes recovered. Together, brittle and strong materials make up over three-quarters of the assemblage, suggesting that most materials were selected because they would provide sharp edges for cutting or scraping. However, tough materials also make up a significant percentage of the assemblage, indicating that materials amenable to pounding use were also very important in the selection process. Thus, a fairly wide range of different types of chipped stone-using activities might be expected. When all artifact clusters are compared for material toughness, they represent different populations (chi-square = 92.2, df = 12, significance = .000, Cramer's V = .245). Examining Table 4.7, we find that Clusters 1 and 6 contain much lower percentages of brittle materials than the others, suggesting that they might form one population and the remaining clusters a second. However, when this was tested, Clusters 1 and 6 may belong to the same population (chi-square = 3.5, df = 2, significance = .170, Phi = .136), but the five remaining clusters represent different populations (chi-square = 20.8, df = 8, significance = .008, Cramer's V = .134). Testing different combinations of Clusters 2–5 and 7 indicates that they actually represent two separate populations. Clusters 4 and 7 form one (chi-square = 2.0, df = 2, significance = .368, Cramer's V = .074), and Clusters 2, 3, and 5 form the second (chi-square = 1.6, df = 4, significance = .809, Cramer's V = .061).

Table 4.7. LA 159879, toughness by cluster.

Cluster		Brittle	Strong	Tough	Totals
No Cluster	Count		1		**1**
	Row %		100.0%		**0.1%**
Cluster 1	Count	27	132	25	**184**
	Row %	14.7%	71.7%	13.6%	**23.9%**
Cluster 2	Count	22	35	23	**80**
	Row %	27.5%	43.8%	28.8%	**10.4%**
Cluster 3	Count	27	40	38	**105**
	Row %	25.7%	38.1%	36.2%	**13.6%**
Cluster 4	Count	142	120	72	**334**
	Row %	42.5%	35.9%	21.6%	**43.4%**
Cluster 5	Count	7	12	12	**31**
	Row %	22.6%	38.7%	38.7%	**4.0%**
Cluster 6	Count	1	4	3	**8**
	Row %	12.5%	50.0%	37.5%	**1.0%**
Cluster 7	Count	10	8	9	**27**
	Row %	37.0%	29.6%	33.3%	**3.5%**
Totals	**Count**	**236**	**352**	**182**	**770**
	Row %	**30.6%**	**45.7%**	**23.6%**	**100.0%**

Summary of Material Selection Parameters

To summarize this examination of material selection for LA 159879, we found that the overall assemblage is dominated by various cherts, which make up nearly two-thirds of the total. The chert category includes a range of varieties based on color and color combinations, as well as chalcedony and silicified wood. While these materials may have formed through different processes, they are very similar in appearance and tend to break in similar ways, so it is likely that they were all considered to be the same basic material prehistorically. Examination of the distribution of the four most common material types suggested that the seven clusters defined at this site form two separate populations, with a single projectile point that could not be provenienced and Cluster 6 being eliminated from consideration. These populations consist of Cluster 4 and Clusters 1, 2, 3, 5, and 7.

Cortical data indicate that all of the materials used at this site were probably obtained from secondary gravel deposits along streams. This includes the obsidian, which does not outcrop locally and was therefore probably carried a fairly long distance to this location. Because the gravel beds from which these materials were obtained cannot be determined with any certainty, we can only assume that they were mostly local rather than a great distance from the site.

Examination of material texture and quality provided some interesting information. Medium-grained materials were the most common, followed rather closely by fine-grained, with coarse-grained materials making up only a small percentage of the assemblage. While the cherts were dominated by fine-grained materials (67.9 percent), medium-grained materials dominated every other material category except for undifferentiated igneous, which is represented by very few specimens.

REDUCTION STRATEGY

Two basic reduction strategies have been defined for the post-Clovis occupation of the Southwest: curated and expedient. Curated reduction entails the manufacture of tools in anticipation of use, while expedient reduction involves the production of tools as needed. A curated strategy is usually associated with the manufacture of large bifaces that can be used to fulfill a variety of needs. Kelly (1988:731) defines three types of bifaces: those used as cores as well as tools, long use-life tools that can be resharpened, and bifaces made to replace parts of existing composite tools. The last category can also be referred to as specialized bifaces, which are tools made for one or a very limited set of purposes. Bifaces with multiple functions and those with long use-lives are mostly associated with mobile lifestyles where efficiency is critical. However, these associations are not exclusive; mobile peoples also make specialized bifaces while sedentary peoples manufacture general-purpose bifaces. The difference is more a matter of degree—there is less focus on specialized bifaces by mobile peoples and less focus on general-purpose bifaces by sedentary peoples. Thus, the number of bifaces, or amount of evidence for biface manufacture in an assemblage, is not necessarily indicative of reduction strategy and lifestyle; rather, it is the types of bifaces that were made and used and the types of debris discarded during their manufacture that provide clues to these aspects of prehistoric life.

The first two categories of bifaces defined by Kelly (1988) are necessarily large. Bifaces that function as cores, general purpose tools, and blanks for the replacement of broken or lost tools have to be large to be useful. Similarly, bifaces made with long use-lives in mind have to be large to allow them to be resharpened. In contrast, specialized bifaces need to be no larger than the size required for the task at hand. Projectile points provide a good comparison between these categories. In a curated tool kit broken projectile points could be replaced using blanks that also served as cores and general purpose tools. Large projectile points could be used as knives since they possess a fairly long edge and are usually set into detachable foreshafts. When broken, these points could often be reworked into a new form, so they also served as tools with long use-lives.

Small projectile points are evidence of a different focus. They were not as useful as cutting tools because their edges are short and awkward and inefficient to use, even when set into foreshafts, though this awkwardness did not always preclude their use as cutting tools. The thinness of these tools and the point of weakness formed by notching often caused them to break during use and, because of their small size and the location of most breaks, they usually could not be resharpened. Small projectile points were generally limited to a single function, and quite often could only be used once before being broken and discarded. Other small bifaces, like drills, also tended to be used for a single purpose. Thus, we differentiate between the manufacture of large and small bifaces in this analysis, because they may be indicative of different lifestyle foci.

Curated and Expedient Debitage Assemblages Modeled

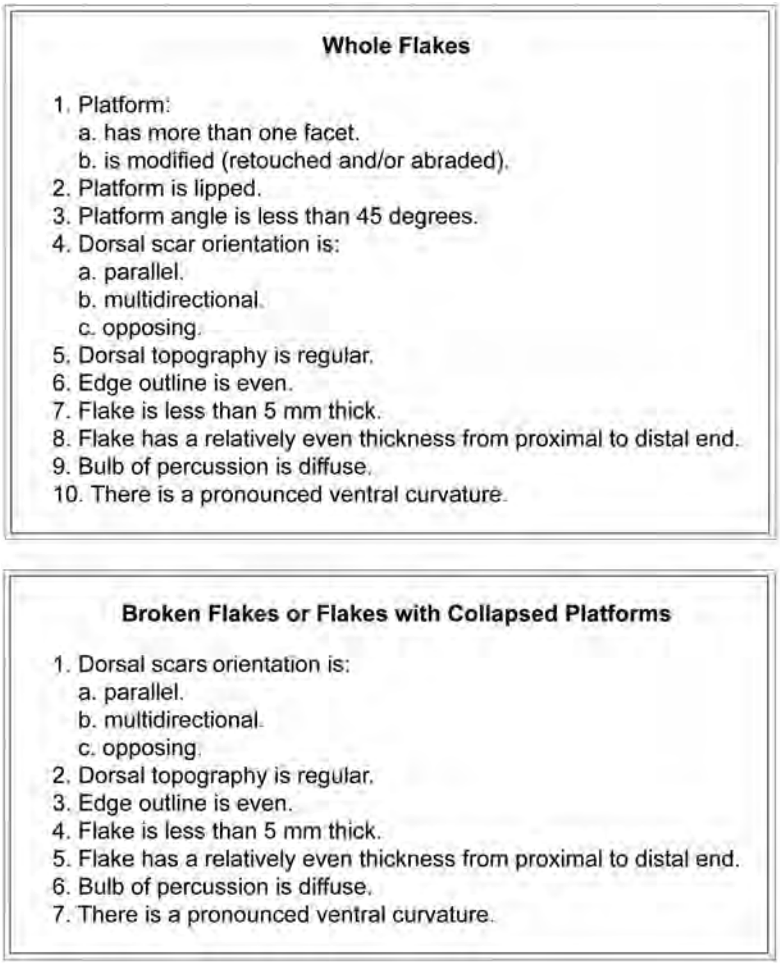
Several attributes can be used to assess assemblages and determine whether they reflect a curated or expedient reduction strategy or a combination of both. Unfortunately, no single indicator can provide this information, so a range of attributes must be used. Assemblages that reflect a purely expedient strategy should contain lower percentages of non-cortical debitage than those in which a curated strategy was employed. Cortex is usually brittle and chalky and does not flake with the ease or predictability of unweathered material. This can cause problems during tool manufacture, so cortex was usually removed early in the process. Large biface manufacture is wasteful, and many flakes must be removed before the proper size and shape are achieved. These flakes are carefully struck, and are generally smaller and thinner than most flakes removed from cores. Thus, as large bifaces are manufactured, many interior flakes lacking cortical surfaces are removed and the proportion of non-cortical debitage increases. The removal of cortex is not as high a priority in expedient reduction, so the chance that a piece of debitage will possess a cortical surface is higher.

The presence of flakes struck from bifaces is usually good evidence that tools were made at a site, though the absolute number or types of bifaces that were made can rarely be defined. A polythetic set of attributes is used to distinguish biface flakes from core flakes in this analysis (Fig. 4.2). Flakes fulfilling at least 70 percent of the attributes in the polythetic set are classified as biface flakes, while those that do not are defined as core flakes by default. This method permits recognition of definite biface flakes, though it often does not identify biface flakes struck early in the tool manufacturing process. Other methods were used to try to distinguish some of those specimens, as discussed later. Biface flake length can be indicative of the size of the tool being made, and lengths of 15 to 20 mm or more suggest that large bifaces were manufactured. However, when only small biface flakes occur, the reverse is not necessarily true. While the presence of small biface flakes may indicate that small, specialized bifaces were made, the possibility that they are debris produced by retouching large biface edges must also be considered. Large percentages of biface flakes in an assemblage suggest that tool production was an important activity. When those flakes are long, large bifaces were probably made or used, and this suggests a curated reduction strategy. Though a lack of these characteristics is not definite proof of an expedient strategy, it does suggest that reduction was not focused on tool making.

While platform modification is used by the polythetic set to help assign flakes to core or biface categories, it can also be used as an independent indicator of reduction strategy. This is because the polythetic set only identifies ideal examples of biface flakes. Many flakes produced during initial tool shaping and thinning are difficult to distinguish from core flakes. However, even at this stage of manufacture platforms were usually modified to facilitate removal. While core platforms were also modified on occasion, this was not as common because the same degree of control over flake size and shape were unnecessary unless cores were being systematically reduced. Since this rarely occurred in the Southwest, a large percentage of modified platforms in an assemblage tends to indicate tool manufacture, while the opposite implies core reduction. When there is a high percentage of modified platforms but few definite biface flakes, an early stage of tool manufacture may be indicated.

Since tool manufacture is usually more controlled than core reduction, fewer pieces of recoverable angular debris are produced. This suggests that a high ratio of flakes to angular debris indicates tool manufacture, while a low ratio implies core reduction. Unfortunately, this is a bit simplistic because the production of angular debris also depends on the type of material being worked, the reduction technique used, and the amount of force applied. Brittle materials shatter more easily than elastic materials, and hard hammer percussion tends to produce more recoverable pieces of angular debris than soft hammer percussion or pressure flaking. The use of excessive force can also cause materials to shatter. In general, though, as reduction proceeds the ratio of flakes to angular debris should increase, and late stage core reduction as well as tool manufacture should produce high ratios of flakes to angular debris.

Flake breakage patterns are also indicative of reduction strategy. Experimental data suggest there are differences in fracture patterns between flakes struck from cores and tools (Moore 2003). Though reduction techniques are more controlled during



Whole Flakes

1. Platform:
   a. has more than one facet.
   b. is modified (retouched and/or abraded).
2. Platform is lipped.
3. Platform angle is less than 45 degrees.
4. Dorsal scar orientation is:
   a. parallel.
   b. multidirectional.
   c. opposing.
5. Dorsal topography is regular.
6. Edge outline is even.
7. Flake is less than 5 mm thick.
8. Flake has a relatively even thickness from proximal to distal end.
9. Bulb of percussion is diffuse.
10. There is a pronounced ventral curvature.

Broken Flakes or Flakes with Collapsed Platforms

1. Dorsal scars orientation is:
   a. parallel.
   b. multidirectional.
   c. opposing.
2. Dorsal topography is regular.
3. Edge outline is even.
4. Flake is less than 5 mm thick.
5. Flake has a relatively even thickness from proximal to distal end.
6. Bulb of percussion is diffuse.
7. There is a pronounced ventral curvature.

Figure 4.2. Polythetic set for defining biface flakes.

tool manufacture, flake breakage increases because debitage get thinner as reduction proceeds. Thus, there should be more broken flakes in an assemblage in which tools were made, as compared to one that simply reflects core reduction. However, trampling, erosional movement, and other post-reduction impacts can also cause breakage and must be taken into account.

Much flake breakage during reduction is caused by secondary compression, in which outward bending causes flakes to snap (Sollberger 1986). Characteristics of the broken ends of flake fragments can be used to determine if breakage was caused by this sort of bending (Fig. 4.3). When a step or hinge fracture occurs at the proximal end of distal or medial fragments, they are classified as manufacturing breaks. Characteristics diagnostic of manufacturing breaks on proximal fragments include "pieces à languette" (Sollberger 1986:102), negative hinge scars, positive hinges curving up into small negative step fractures on the ventral surface, and step fractures on dorsal rather than ventral surfaces. Breakage by processes other than secondary compression causes snap fractures. This pattern is common on flakes broken by trampling or erosion, but also occurs during reduction. Core reduction tends to create a high percentage of snap fractures, while biface reduction creates a high percentage of manufacturing breaks. Since snap fractures can also indicate post-reduction damage, this may be the weakest of the attributes used to examine reduction strategy.

The presence of platform lipping is indicative of reduction technology, and is marginally related

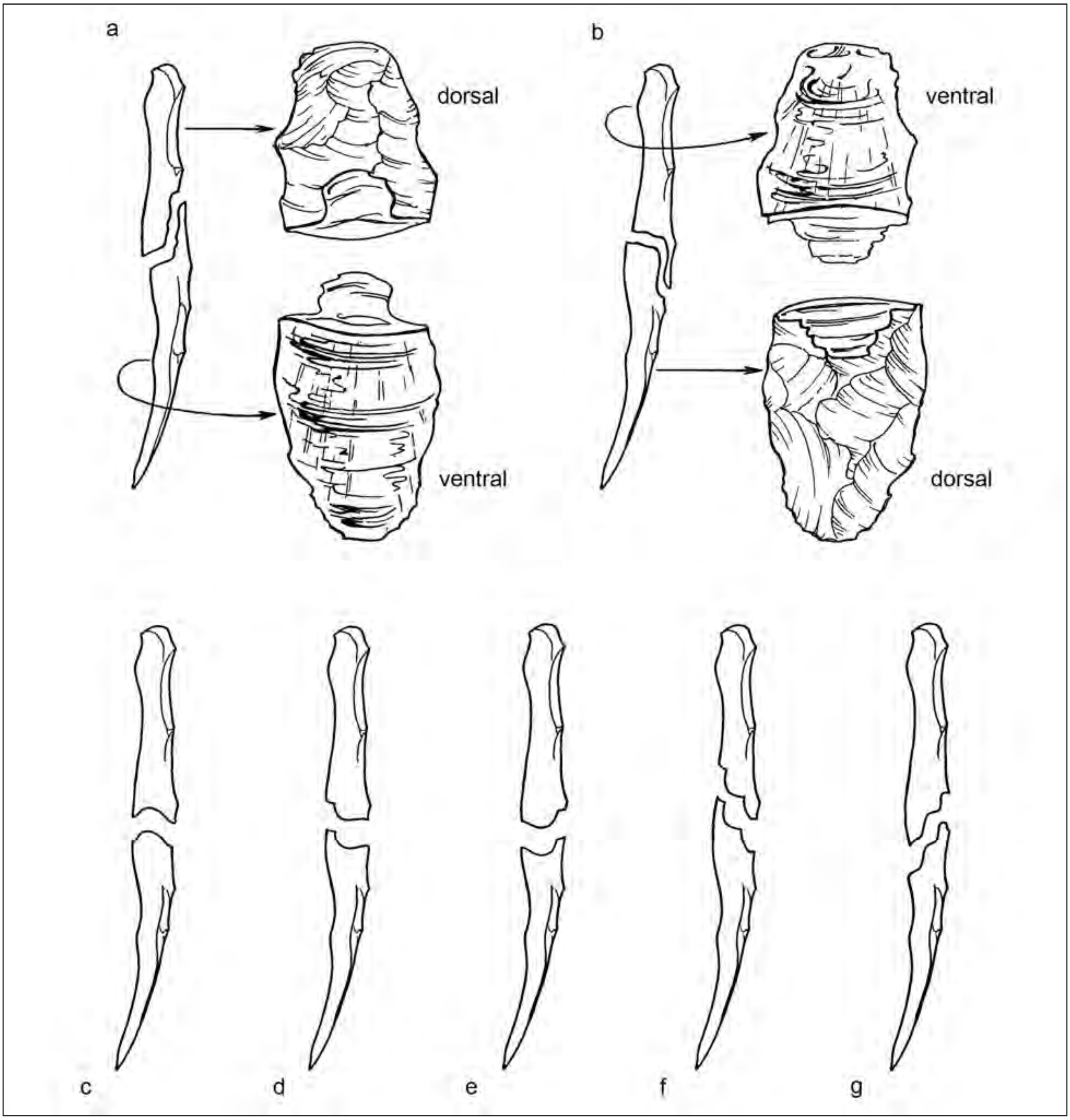


Figure 4.3 [a–g]. Manufacturing breakage on flakes: a–b. pieces à languette, adapted from Sollberger (1986:102); c. negative proximal hinge, positive distal hinge; d. positive proximal hinge with small step off ventral surface, negative distal hinge; e. positive proximal hinge, negative distal hinge; f. proximal step, distal step off dorsal surface; g. reverse proximal step, distal step off ventral surface. Note that proximal fragments of "e" and "f" resemble natural core terminations and would usually be defined as such.

to strategy. Platform lipping usually occurs during pressure flaking or soft hammer percussion, though it sometimes also occurs on flakes removed by hard hammers (Crabtree 1972). The former techniques were usually used to make tools, so a high percentage of lipped platforms suggest a focus on tool manufacture rather than core reduction. While soft hammer percussion can also be used in core reduction, some materials are very hard and more efficiently reduced using hard hammers.

The pattern of scars left by earlier removals on the dorsal surface of a flake can also help define reduction strategy. Since biface reduction removes flakes from opposite edges, some scars originate beyond the distal end of a flake and run toward its proximal end. These are opposing scars, and indicate reduction from opposite edges. Opposing dorsal scars are indicative of biface manufacture, but can also occur when cores were reduced bidirectionally (Laumbach 1980:858). Thus, this attribute is not directly indicative of tool production, but can help in defining the reduction strategy used.

The ratio of flakes to cores on a site is another potential indicator of reduction strategy. As the amount of tool manufacture increases, so does the ratio between flakes and cores. The opposite should be true of assemblages in which expedient core reduction dominates; in that case the ratio between flakes and cores should be relatively low. A potential problem, of course, is that cores were often carried to another location if still useable, while debris from their reduction was left behind. This can inflate the ratio and suggest that tool manufacture rather than core reduction occurred. The systematic reduction of cores can also produce high flake to core ratios. A third ratio that might have some utility in determining reduction strategy is the ratio of core flakes to biface flakes. A high core flake to biface flake ratio indicates the prevalence of core reduction and, consequently, a higher stress on expedient reduction. A low ratio suggests that the manufacture of large bifaces was an important reduction strategy.

The final attribute that can be useful in examining reduction strategy is purposeful thermal alteration. The flaking characteristics of cherts can be improved by the proper application of heat, making them easier to flake and allowing longer flakes to be removed more accurately. Only cherts (including chalcedony and silicified wood) are amenable to this type of alteration. A high percentage of thermally altered cherts may indicate a stress on formal tool manufacture, which often goes hand-in-hand with a curated reduction strategy.

While few of these attributes are accurate independent indicators of reduction strategy, when combined they should allow us to fairly accurately determine how materials were reduced at a site. A curated debitage assemblage should contain high percentages of non-cortical debitage, biface flakes, modified platforms, manufacturing breaks, lipped platforms, and flakes with opposing dorsal scars, and should have high flake to angular debris, flake to core, and biface flake to core flake ratios. Purely expedient debitage assemblages should contain lower percentages of non-cortical debitage and low percentages of biface flakes, modified platforms, manufacturing breaks, lipped platforms, and flakes with opposing dorsal scars. They should also have low flake to angular debris, biface flake to core flake, and flake to core ratios. Unfortunately, "pure" assemblages are rare, and most assemblages can be expected to combine tool manufacture and core reduction.

Re-examining Flake Classifications

The first step in accurately determining the type of reduction strategy that dominated in a site or cluster assemblage is to ensure that flakes were properly classified during analysis. A problem with the polythetic set used to distinguish between biface and core flakes is that it often cannot distinguish flakes removed early in the manufacturing process before biface surfaces became regularized by continued flaking. This problem can be corrected by using several of the attributes related to the polythetic set to provide weights for reclassification of some core flakes. These specimens probably represent flakes removed early in the manufacturing process. Eight variables are used in reclassification including bulb of percussion type, evidence of platform modification, platform angle, platform lipping, ventral curvature, opposing dorsal scars, waisting, and flake thickness. Only specimens that retain their platforms can be reexamined because platform data are critical to accurate type placement.

A similar reclassification was completed for a much larger assemblage recovered during investigations at Spaceport America, which included data from 14 sites dating between the Paleoindian and early Historic periods (Moore 2014:348–349). Each of the above characteristics was examined and compared for that assemblage; each was ranked according to its importance as a reduction strategy indicator, and weights were applied. The rankings and associated weights were based on the comparison of 2,354 core flakes and 304 biface flakes that were either complete or were lateral or proximal fragments that retained their platforms. Since that analysis was looking for misclassified biface flakes, rankings were based on the percentage of biface flakes that exhibited a particular attribute.

In the Spaceport America study (Moore 2014:349), diffuse bulbs of percussion occurred on 90.5 percent of biface flakes and 36.8 percent of core flakes, suggesting that attribute was a fairly strong indicator of flake type, and it was assigned a weight of 7. Platforms were lipped on 71.6 percent of biface flakes and only 18.0 percent of core flakes. This was considered to be another strong indicator of flake type, and was assigned a weight of 6. Waisting occurred on 56.5 percent of biface flakes and only 2.6 percent of core flakes, making this attribute another strong indicator of flake type, so it was assigned a weight of 5. Platform angles of 45 degrees or less occurred on 72.2 percent of biface flakes and on 35.7 percent of core flakes. This variable was categorized as a fair indicator of flake type, and assigned a weight of 4. Platforms were modified on 60.2 percent of biface flakes and 9.9 percent of core flakes, making this characteristic a moderately strong indicator of flake type that was assigned a weight of 3. Ventral curvature occurred on 48.3 percent of biface flakes and 20.1 percent of core flakes, making it a fair indicator of flake type that was assigned a weight of 2. The presence of opposing dorsal scars was another fair indicator of flake type that occurred on 27.3 percent of biface flakes and 4.5 percent of core flakes, and it was assigned a weight of 1. While 94.4 percent of the biface flakes were 5 mm thick or less, this was not as strong an indicator of flake type as it might seem, since 70.5 percent of the core flakes also fell into this thickness range. This attribute was considered a very weak indicator of flake type and it was dropped from further consideration.

Since the population of biface flakes from LA 159879 is very small, a similar analysis could provide very different and potentially misleading results. Thus, the weights used in the Spaceport America study were also applied to the flake assemblage from LA 159879. These weights were applied to all of the whole flakes, proximal fragments, and lateral fragments recovered from LA 159879 that retain their platforms. A total of 451 specimens fit these parameters of which 428 were categorized as core flakes during analysis and 23 as biface flakes. Since the three top weighting categories in the Spaceport America study (diffuse bulb, platform lipping, and waisted platform) appeared to be the most distinguishing characteristics, their combined weight of 18 is used as a cut-off point, and core flakes in the current assemblage with a score of 18 or higher are reclassified as biface flakes. This resulted in the reclassification of 16 core flakes into biface flakes occurring in five clusters including Cluster 3 (n = 1, 1.5 percent of core flakes), Cluster 4 (n = 13, 4.9 percent of core flakes), Cluster 5 (n = 1, 5.9 percent of core flakes), and Cluster 7 (n = 1, 7.1 percent of core flakes). The reclassifications are used in the rest of this discussion.

Examining the Reduction Strategy Indicators

Each of the reduction strategy indicators listed earlier can be used to look for trends that might be important. This level of analysis focuses on the whole site assemblage as well as the cluster assemblages in order to assess the overall reduction strategy used at this site as well as to determine whether there are important similarities or differences between clusters that might reflect temporal or other differences.

Dorsal Cortex

While cortex type was used to examine material procurement patterns, cortex can also be used to examine reduction strategy. Several approaches can be used to examine cortical ratios, each providing a slightly different piece of the puzzle. In this discussion we only consider debitage, which is divided into two categories: flakes and angular debris. Table 4.8 presents information on the occurrence of cortex on debitage as well as non-cortical to cortical debitage ratios for the site and each cluster. Overall, LA 159879 has a moderately low ratio, and none of the ratios for the clusters are particularly high. Except for Clusters 4 and 6, the various parts of LA 159879 have non-cortical to cortical debitage ratios consistent with an expedient reduction strategy. The comparatively high ratio for Cluster 6 can be ignored because it undoubtedly reflects error related to small sample size. This leaves the Cluster 4 ratio as anomalous, suggesting either that there was more tool manufacture in that part of the site than elsewhere, or that core reduction was more intense. The non-cortical to cortical debitage ratio is especially low for Cluster 3, suggesting that more initial reduction of nodules may have occurred in that part of the site than elsewhere, with the possible exception of Cluster 5, which also has a very low ratio.

The intensity of reduction can be gauged by

Table 4.8. LA 159879, cortical data and non-cortical-to-cortical ratios for debitage.

Area	Cortical Debitage	Non-cortical Debitage	Non-cortical-to-Cortical Debitage Ratio
Whole Site	163	552	3.39:1
Cluster 1	43	125	3.91:1
Cluster 2	16	56	3.50:1
Cluster 3	43	57	1.33:1
Cluster 4	43	271	6.30:1
Cluster 5	10	18	1.80:1
Cluster 6	1	6	6.00:1
Cluster 7	7	19	2.71:1

the extent of cortical coverage on the dorsal surfaces of flakes. Chipped stone analyses often divide flakes into groups determined by percentages of dorsal cortex. Traditionally, these classes are termed primary, secondary, and tertiary flakes. Primary flakes are those with 50 percent or more of their dorsal surfaces covered with cortex, secondary flakes are those with less than 50 percent dorsal cortex, and tertiary flakes exhibit no dorsal cortex. Primary flakes are often considered indicative of initial core reduction when the cortical surface was removed, secondary flakes were removed as the core was further reduced, and tertiary flakes are often considered debris from tool manufacture. Unfortunately, these classifications are based on simplistic and erroneous assumptions. For instance, a lack of dorsal cortex is not necessarily indicative of tool manufacture, since flakes removed from a core that has been significantly decorticated will often lack dorsal cortex. Similarly, this scheme assumes that cores are decorticated before flakes are removed for use or for shaping into formal tools, and this is also incorrect. However, stripped of their traditional meanings, these classes remain a useful way to examine flake assemblages. In this analysis, primary flakes are those with 50 percent or more of their dorsal surfaces covered by cortex, secondary flakes are those with 1–49 percent dorsal cortex, and tertiary flakes are those with no dorsal cortex. Varying percentages for these classes can be used to examine the condition of nodules or cores when they arrived at a site and provide information on reduction strategies.

Information on cortical coverage classifications is shown in Table 4.9 for all clusters as well as the site as a whole. Tertiary flakes make up nearly three-quarters of the complete assemblage. While there is considerable variation between clusters, over half of each of those assemblages also consists of tertiary flakes. Examining the distribution of percentages for each cluster assemblage, it appears that tertiary reduction dominated in all areas except for Clusters 3 and 5, with tertiary flakes making up over 76 percent, secondary flakes make up about 18 percent or less, and primary flakes account for less than 8 percent of the flake assemblages. This is especially true for Cluster 4, which has the smallest percentage of primary flakes of all assemblages that contain 18 or more specimens. While Clusters 6 and 7 have no primary flakes, and Cluster 6 also has no secondary flakes, these absences may simply reflect small sample size rather than any difference in the type of reduction done in those areas. In contrast, Clusters 3 and 5 exhibit comparatively large percentages of primary and secondary flakes and smaller percentages of tertiary flakes. This suggests that there was more emphasis on initial core reduction in those parts of the site than elsewhere.

In order to examine the potential relationships between cluster assemblages statistically, the Clusters 6 and 7 assemblages are dropped from consideration because of their small sizes and to eliminate empty cells. While there are similarities in the distribution of cortical coverage classifications for Clusters 1, 2, and 4, analysis suggests that

Table 4.9. LA 159879, cortical coverage classification for flakes by cluster and for the whole assemblage.

Location		Primary	Secondary	Tertiary
Cluster 1	Count	12	27	120
	Row %	7.5%	17.0%	75.5%
Cluster 2	Count	4	9	55
	Row %	5.9%	13.2%	80.9%
Cluster 3	Count	14	26	56
	Row %	14.6%	27.1%	58.3%
Cluster 4	Count	10	23	253
	Row %	3.5%	8.0%	88.5%
Cluster 5	Count	3	4	15
	Row %	13.6%	18.2%	68.2%
Cluster 6	Count			5
	Row %			100.0%
Cluster 7	Count		4	18
	Row %		18.2%	81.8%
Whole assemblage	**Count**	**43**	**93**	**522**
	Row %	**7.5%**	**18.1%**	**74.4%**

they probably belong to different populations (chi-square = 12.84, df = 4, significance = .012, Cramer's V = .112). Further comparison shows a significant relationship between Clusters 1 and 2 (chi-square = .79, df = 2, significance = .674, Phi = .059) and between Clusters 2 and 4 (chi-square = 2.79, df = 2, significance = .248, Phi =.089), but none between Clusters 1 and 4 (chi-square = 12.72, df = 2, significance = .002, Phi = .169). The greatest amount of primary reduction and least amount of tertiary reduction occur in Cluster 1, with the second most primary reduction and second least amount of tertiary reduction occurring in Cluster 2. However, while the percentages for these clusters in Table 4.9 are slightly different, there is really no significant difference in the distributions of their cortical classifications. The smallest amount of primary reduction and the greatest amount of tertiary reduction occurred in Cluster 4, which is not significantly different from Cluster 2 but is from Cluster 1. Ranking these three clusters by levels of primary and tertiary reduction, Cluster 1 exhibits the greatest amount of the former and the least of the latter, Cluster 4 is at the opposite extreme, and Cluster 2 is in the middle.

In strong contrast, there is a good likelihood that Clusters 3 and 5 belong to the same population for this attribute (chi-square = 0.86, df = 2, significance = .651, Phi = .085). These were the loci where the greatest amount of primary reduction and the least of tertiary reduction occurred at LA 159879. These clusters can be added to the reduction gradient so that, in terms of degree of primary versus tertiary reduction (decreasing and increasing amounts, respectively), Clusters 3 and 5 would rank first, followed in order by Clusters 1, 2, and 4.

The way in which the clusters group suggests that reduction was patterned across the site. Cluster 4 contains the densest group of features, and this area appears to have been a focus of late stage reduction, either the reduction of mostly decorticated cores or tool manufacture. Clusters 3 and 5 are directly south of Cluster 4, and were where there appears to have been a focus on primary core reduction. Clusters 1 and 2 are areas where secondary reduction seems to have dominated, though a combination of primary through tertiary reduction is reflected. Clusters 6 and 7 also appear to be areas that were dominated by secondary and/or tertiary reduction, but no definite conclusions can be made for them because of small assemblage size and the more limited distributions of reduction stages.

Flake Type as an Indicator of Reduction Strategy

Flakes were typologically categorized during analysis, with type designation based on a series of analytic observations using the polythetic set discussed earlier to distinguish between biface and core flakes. This was not a perfect system since many flakes removed during the early stages of tool manufacture might not fit the polythetic set and would therefore have been erroneously classified as core flakes. This was partly corrected for by a reclassification, which hopefully identified most examples of biface flakes that were not correctly classified by strict adherence to the polythetic set.

Four categories of flakes were identified. Core flakes and biface flakes were discussed earlier and represent removals from cores and tools, respectively. Potlids are pieces of debitage that were literally blown off the surface of chert artifacts by the improper application of heat. While technically categorized as flakes because they possess definable ventral and dorsal surfaces, potlids have no striking platform because they were removed by an entirely different process, and are eliminated from the flake analysis. Ground stone flakes were struck from ground stone tools, usually after those tools were no longer suitable for their original use. While ground stone flakes might represent removals from tools that were repurposed as cores, they can also be generated during the reshaping of ground stone tools into new tool forms. Unfortunately, there is no way to distinguish between these origins. Thus, we assume that ground stone flakes represent removals from repurposed tools, and will combine this flake category with the core flakes.

Table 4.10 shows the distribution of flake types for the assemblage as a whole and for each cluster. In some ways, these distributions support the conclusions made concerning cortical coverage classifications. The greatest amount of tool manufacture does appear to have occurred in Cluster 4. Much less evidence for tool manufacture occurs in the remaining cluster assemblages, with none evidenced for Clusters 2 and 6. However, in each case, including Cluster 4, core flakes are by far the dominant type. This indicates that striking flakes from cores was the dominant reduction activity in all parts of the site,

Table 4.10. LA 159879, flake types by cluster.

Location		Core Flakes	Biface Flakes
Cluster 1	Count	156	3
	Row %	98.1%	1.9%
Cluster 2	Count	68	–
	Row %	100.0%	–
Cluster 3	Count	93	3
	Row %	96.9%	3.1%
Cluster 4	Count	254	31
	Row %	89.1%	10.9%
Cluster 5	Count	21	1
	Row %	95.5%	4.5%
Cluster 6	Count	5	–
	Row %	100.0%	–
Cluster 7	Count	21	1
	Row %	95.5%	4.5%
Whole assemblage	**Count**	**618**	**39**
	Row %	**94.5%**	**5.5%**

and that biface reduction was much more limited in occurrence, though it may also have occurred to varying extents in nearly all parts of the site.

Flake Platforms

What are referred to as flake platforms in this discussion represent the small section of the original platform present on the edge of an objective piece (e.g., core) that remained attached to flakes after the flakes were removed. Another term for "platform" is "platform remnant." Platforms on objective pieces can be modified to facilitate removal, but the type of modification used will generally vary between cores and formal tools. Core platforms tend to be modified by the removal of overhangs that would collapse when struck and produce pieces of debitage that were much shorter than intended. Unless a core was prepared to strike blades, evidence for this type of modification usually occurs as scars on the dorsal surface of flakes adjacent to the back platform edge, which tends to be indistinguishable from scars left by intentional flake removals. In contrast, formal tool platforms are modified by abrasion that grinds the platform edge and/or removes small flakes from the intended platform, increasing the angle of the platform edge. This process strengthens the platform, allowing the removal of longer and more consistent flakes. Thus, platforms identified as having been modified to facilitate reduction represent removals from formal tools rather than cores.

Platform data are presented for each cluster as well as the entire assemblage in Table 4.11. Nearly a third of the platforms in the overall assemblage are missing, and over 4 percent are collapsed or crushed. In these cases there is no real platform information available because of breakage or damage. Of the types of platforms that do remain on flakes, the most common is single-facet; they are proportionately most common in Clusters 1 and 2. Cortical platforms are the next most common type, and occur most often in Clusters 3 and 6. Multifacet platforms are the third most common type and represent flakes struck from platforms that had previous removals along them. This type occurs most often in Clusters 3, 5, and 7, and is least common in Cluster 4. Multifacet and abraded platforms are the fourth most common type, and represent removals from objective pieces that were ground to facilitate flaking. This type is by far most common in Clusters 4 and 6, but occurs in significant numbers in most of the other clusters as well. However, the comparatively high percentage of this type for Cluster 6 is probably due to sample error. Single-facet and abraded platforms are the least common type, and are most abundant in Clusters 4 and 5, with none found in Clusters 6 and 7. This distribution seems logical, with multifacet platforms commonly occurring in assemblages in which core reduction prevailed and being much less abundant in an area where late stage reduction and possibly tool manufacture occurred. At least a few modified platforms occur in each cluster, with by far the most found in Cluster 4, which is potentially where tool manufacture was most common. Cortical platforms are most abundant in areas where primary reduction was common, and single-facet platforms follow no discernible pattern.

Platform modification by abrasion is common during tool manufacture, but can also sometimes be used during core reduction. Whittaker (1994:102–104) discusses the use of an abrader to modify core platforms by rounding and dulling the platform edge or removing overhangs, though trimming edges using percussion is usually the best way to do this. Thus, *most* flakes with unmodified platforms reflect core reduction, while *most* flakes with modified platforms reflect formal tool manufacture. There are exceptions to both of these norms, and platform type cannot be used by itself to specify when during the reduction process a particular flake was struck.

Table 4.11. LA 159879, flake platform types by cluster.

Location		Cortical	Single Facet	Single Facet and Abraded	Multi-facet	Multi-facet and Abraded	Collapsed	Crushed	Absent	Totals
Cluster 1	Count	29	45	2	20	7	7	3	45	**159**
	Row %	18.4%	28.5%	1.3%	12.7%	4.4%	4.4%	1.9%	28.5%	**24.2%**
Cluster 2	Count	8	18	2	11	4	1	2	22	**68**
	Row %	11.8%	26.5%	2.9%	16.2%	5.9%	1.5%	2.9%	32.4%	**10.4%**
Cluster 3	Count	20	15	2	20	7	3	–	27	**96**
	Row %	21.3%	16.0%	2.1%	21.3%	7.4%	3.2%	–	28.7%	**14.6%**
Cluster 4	Count	26	49	15	28	57	5	7	93	**285**
	Row %	9.3%	17.5%	5.4%	10.0%	20.4%	1.8%	2.5%	33.2%	**43.4%**
Cluster 5	Count	4	5	3	4	–	1	–	5	**22**
	Row %	18.2%	22.7%	13.6%	18.2%	–	4.5%	–	22.7%	**3.3%**
Cluster 6	Count	1	–	–	–	1	–	–	3	**5**
	Row %	20.0%	–	–	–	20.0%	–	–	60.0%	**0.8%**
Cluster 7	Count	4	4	–	4	2	–	–	8	**22**
	Row %	18.2%	18.2%	–	18.2%	9.1%	–	–	36.4%	**3.3%**
Whole assemblage	**Count**	**92**	**136**	**24**	**87**	**78**	**17**	**12**	**203**	**657**
	Row %	**14.2%**	**21.0%**	**3.7%**	**13.4%**	**12.0%**	**2.6%**	**1.8%**	**31.3%**	**100.0%**

However, platform modification can be used as a proxy for the level of biface manufacture. Table 4.12 shows the distribution of modified platforms, unmodified platforms, and cases where platforms are missing or damaged (obscured). Again, excepting Cluster 6 because of the small size of the associated assemblage, Cluster 4 contains by far the largest percentage of modified platforms, and therefore is the best candidate for a locus where tool manufacture was an important activity. Interestingly, Clusters 3 and 5 have the next highest percentages, and have thus far in the analysis appeared to be loci dominated by early stage core reduction rather than tool manufacture.

Flake Breakage Patterns

Flake breakage patterns can be used to examine two issues: how intact and undamaged assemblages are and how prevalent is the evidence for core versus biface reduction. There are three ways in which flakes can break: during removal, during use, and after discard. Various factors cause flakes to fracture during removal. They can break when the force applied to remove them exceeds the tensile strength of the material, resulting in non-diagnostic snap fractures. Breaks can also occur when flaws are encountered during flake propagation. While this type of break can sometimes be correctly categorized, generally they are simply defined as non-diagnostic snap fractures. Flakes can also snap because of secondary compression, in which outward bending during removal causes them to buckle (Sollberger 1986). Cotterell and Kaminga (1987:700) indicate that this type of breakage can occur after a successful flake removal. Citing experiments conducted by Crabtree (1968:475) where high-speed photography captured a blade buckling in this manner *after* it

Table 4.12. LA 159879, platform classification by cluster and for the entire site.

Location		Obscured	Unmodified	Modified
Cluster 1	Count	56	94	9
	Row %	35.2%	59.1%	5.7%
Cluster 2	Count	25	37	6
	Row %	36.8%	54.4%	8.8%
Cluster 3	Count	32	55	9
	Row %	33.3%	57.3%	9.4%
Cluster 4	Count	110	103	72
	Row %	38.6%	36.1%	25.3%
Cluster 5	Count	6	13	3
	Row %	27.3%	59.1%	13.6%
Cluster 6	Count	3	1	1
	Row %	60.0%	20.0%	20.0%
Cluster 7	Count	8	12	2
	Row %	36.4%	54.5%	9.1%
Whole assemblage	**Count**	**240**	**315**	**102**
	Row %	**36.5%**	**47.9%**	**15.5%**

was fully detached from a core, Cotterell and Kaminga (1987:700) suggest that this can only happen when a flake is very thin in relation to its length. Both of these processes may be responsible for flake breakage during removal. The compressive forces applied when striking a flake are probably not immediately released after a flake comes off the objective piece, but instead continue to affect the flake for a very short time after removal. Elasticity allows flakes to rebound from the compressive force unless that force exceeds the elastic limits of the material, in which case a flake will buckle. The key to this type of break is that the flake must be very thin in relation to its length, as is common during tool manufacture and blade-core reduction, and is less common during core reduction.

Table 4.13 shows the distribution of flake portions for each cluster and the whole assemblage. Half of the flakes recovered from LA 159879 are whole, which is a fairly large percentage. Only Cluster 7 contains less than 40 percent whole flakes, which could indicate that something went on there that did not occur elsewhere on the site, though this is a small assemblage and could have been affected by sampling error. Clusters 1 and 5 contain the largest percentages of whole flakes, which is consistent with a focus on core reduction rather than biface manufacture. Surprisingly, Cluster 3 has one of the smallest percentages of whole flakes, similar to that of Cluster 4 where more tool manufacture appears to have occurred. However, there doesn't otherwise appear to be any great correlation between potential reduction stage and percentage of whole flakes.

Characteristics of the broken ends of flake fragments can be used to determine whether breaks were caused by manufacture-related bending, as discussed earlier. While bending fractures can often be correctly identified because of characteristics of the break, snap fractures are much more difficult to distinguish. This is because snap fractures can also be caused by forces unassociated with flake removal. Flakes can snap while being used as informal tools, when they are stepped on, and when unequal pressures are applied by natural processes. These breaks are all classified as snap fractures. Thus, snap fractures are considered non-diagnostic because they can be caused by several different and unrelated processes.

Surprisingly, manufacturing breaks were identified on few flakes. Only 10 fragments exhibit manufacturing breaks on their proximal or distal ends, a third of which (n = 3) apiece are from Clusters 1 and 4. Two flakes that were broken in manufacture came from Cluster 7, while Clusters 2 and 3 each contain single examples. No flakes with manufacturing breaks were found in Clusters 5 or 6. This suggests that little of the flake breakage at this site can be attributing to bending, but that the largest number that exhibit this characteristic came from Clusters 1 and 4. Once again, this is consistent with data presented earlier suggesting that the most evidence for late stage reduction is in Cluster 4, and

Table 4.13. LA 159879, flake portions by cluster and for the whole assemblage.

Location		Whole	Proximal	Medial	Distal	Lateral	Totals
Cluster 1	Count	89	7	16	22	25	**159**
	Row %	56.0%	4.4%	10.1%	13.8%	15.7%	**24.2%**
Cluster 2	Count	33	5	8	11	11	**68**
	Row %	48.5%	7.4%	11.8%	16.2%	16.2%	**10.3%**
Cluster 3	Count	46	11	5	16	18	**96**
	Row %	47.9%	11.5%	5.2%	16.7%	18.8%	**14.6%**
Cluster 4	Count	140	25	47	43	28	**285**
	Row %	49.5%	8.8%	16.6%	15.2%	9.9%	**43.3%**
Cluster 5	Count	13	3	1	3	2	**22**
	Row %	59.1%	13.6%	4.5%	13.6%	9.1%	**3.3%**
Cluster 6	Count	2	–	2	1	–	**5**
	Row %	40.0%	–	40.0%	20.0%	–	**0.8%**
Cluster 7	Count	6	3	3	3	7	**22**
	Row %	27.3%	13.6%	13.6%	13.6%	31.8%	**3.3%**
Whole assemblage	**Count**	**330**	**54**	**82**	**99**	**91**	**658**
	Row %	**50.3%**	**8.2%**	**12.5%**	**15.1%**	**13.9%**	**100.0%**

that some may have occurred in Cluster 1 as well. However, the very small amount of breakage that can be attributed to the manufacturing process suggests that core reduction was the primary activity in all parts of the site.

Platform Lipping and Bulb of Percussion

Platform lipping refers to the presence of a slight overhang at the intersection of the platform and ventral surface of a flake. Lipped platforms generally indicate soft hammer reduction or pressure flaking, though they sometimes occur with hard hammer percussion (Crabtree 1972). Thus, lipping is more indicative of tool manufacture than core reduction. Lipping can be used as an indicator of reduction technique, but it is not absolute and is most accurate when combined with other attributes. As Andrefsky (1998:115) notes: "Even though soft-hammer and hard-hammer flaking techniques produce detached pieces that overlap in their range of bulb morphology and amount of lipping, these characteristics may be effective discriminators in most cases." Thus, platform lipping should mostly occur on flakes that also have diffuse bulbs of percussion indicative of soft hammer reduction or pressure flaking.

Platform lipping data are available for 315 flakes. Of the flakes that exhibit pronounced bulbs of percussion, 6.9 percent also have lipped platforms. In contrast, 20.9 percent of the specimens with diffuse bulbs of percussion have lipped platforms. These percentages are consistent with the idea that most flakes with lipped platforms were removed by soft hammer percussion or pressure. However, since lipping does not always occur with these flaking methods, this factor is not an accurate independent predictor of reduction technique. With the exception of Cluster 6, which has a very small sample, Cluster 7 has the highest percentage of lipped platforms at 42.9 percent. This might be explained by sample error, since only 14 flakes from Cluster 7 have this information recorded for them. Cluster 4 contains the next highest percentage of lipped platforms (29.5 percent), consistent with earlier conclusions that this part of the site was focused on late stage reduction. Cluster 1 also has a fairly significant percentage of lipped platforms (10.9 percent), the percentage for Cluster 2 (8.6 percent) was somewhat smaller, and Clusters 3 and 5 have the smallest percentages (6.3 percent each). With Cluster 6 eliminated to remove empty cells, chi-square analysis indicates that the six remaining clusters do not belong to the same population (chi-square = 28.1, df = 5, significance = .000, Cramer's V = .300). In examining various combinations of clusters to see if any might belong to the same population, chi-square analysis suggests that Clusters 4 and 7 may be related (chi-square = 1.1, df = 1, significance = .302, Phi = -.086). Clusters 1, 2, 3, and 5 strongly form a second population (chi-square = 0.9, df = 3, significance = .815, Cramer's V = .074).

As might be expected, Cluster 4 exhibits the highest percentage of diffuse platforms that are probably indicative of soft hammer percussion (59.8 percent). The next highest percentage is in Cluster 2 (57.1 percent), with the third highest in Cluster 3 (55.2 percent). Cluster 6, with its very small sample size, is the last cluster with diffuse bulbs on 50 percent or more of its flakes (50.0 percent). Much smaller percentages occur in Clusters 1 (34.5 percent), 7 (42.9 percent), and 5 (25.0 percent). At the 95 percent confidence level, these clusters represent more than one population (chi-square = 15.7, df = 5, significance = .008, Cramer's V = .226). For this attribute, Clusters 2, 3, and 4 strongly form a single population (chi-square = 0.4, df = 2, significance = .826, Cramer's V = .042), while Clusters 1, 5, and 7 appear to form a second (chi-square = 1.1, df = 2, significance = .585, Cramer's V = .110). Cluster 6 was eliminated because of its very small sample size.

These data suggest that at least some soft hammer reduction occurred in all cluster areas, but that the largest amount was in Cluster 4. Though Clusters 2 and 3 have comparatively high percentages of diffuse bulbs, the percentages of lipped platforms in those areas are low, suggesting that not much soft hammer percussion occurred there. Interestingly, Cluster 7 had the highest percentage of lipped platforms and a comparatively small percentage of diffuse bulbs. These data seem contradictory, and suggest that sample error may be responsible. Soft hammer reduction may also have been of importance in Cluster 1, based solely on the percentage of lipped platforms.

Opposing Dorsal Scars

When flakes removed from the surface of a biface extend past the midpoint of the tool, they leave tell-tale evidence behind. That evidence consists of opposing dorsal scars, which are negative scars at the distal end of the dorsal surface of a flake that was struck later from the opposing tool edge. However, opposing dorsal scars also occur when cores are reduced bidirectionally (Laumbach 1980:858), and probably during multidirectional core reduction as well. Thus, like the other attributes discussed in this section, opposing dorsal scars cannot be used by themselves to define reduction strategy; they are only meaningful when combined with other characteristics.

For this assemblage, opposing dorsal scars may not be a good indicator of reduction strategy because very few occur, and percentages are skewed by differences in assemblage sizes. Of 22 specimens with opposing dorsal scars, eight occur in Cluster 4, and five each occur in Clusters 3 and 7, and there are four in Cluster 1. While the largest number of flakes exhibiting opposing dorsal scars would be consistent with the presumed focus on late stage reduction in Cluster 4, that area also contained by far the largest number of flakes, suggesting that the comparatively high number of flakes with opposing dorsal scars simply reflects sample size. Indeed, while only 4.3 percent of the flakes in Cluster 4 for which this attribute was recorded exhibit opposing dorsal scars, percentages for the other clusters in which similar specimens occur are 4.9 percent for Cluster 1, 5.3 percent for Cluster 3, and 23.8 percent for Cluster 7. Indeed, the comparatively high percentage of opposing dorsal scars in Cluster 7 could be indicative of a larger amount of tool manufacture than has otherwise been indicated, but it might also be attributed to sample error because of the small number of cases.

Debitage Ratios

Three ratios can be used to examine relationships between various classes of debitage and cores: flakes to angular debris, flakes to cores, and core flakes to biface flakes. The flake to core ratio is probably the weakest of the three because cores can disappear from assemblages in several ways. When exhausted, cores can be smashed using the bipolar technique, turning them into multiple pieces of debitage without leaving an actual core behind. Cores can also be carried elsewhere or transformed into a tool like a hammerstone or chopper when no longer suitable for the production of debitage, again with the potential of being moved elsewhere. Depending on whether or not any of these factors was in play, there might be considerable variation in this ratio between assemblages with attributes that otherwise suggest similar reduction strategies were used.

When cores are struck, the detached pieces do not always come off as recognizable flakes (Andrefsky 1998:82). These shattered pieces are classified as angular debris, and are distinguished from flakes by the lack of a striking platform and definable dorsal and ventral surfaces. Flake removal is also often accompanied by a shower of small pieces of shatter that are usually not recoverable by standard excavation techniques. This is especially true of hard hammer percussion, because the blow used to remove a flake can cause the formation of numerous partial Hertzian crack cones; one crack will dominate and propagate to form the flake, while the others will result in the removal of small flakes that often terminate in a step or hinge (Cotterell and Kaminga 1987:687). These small flakes or pieces of shatter are most common in core reduction, which is usually done by hard hammer percussion. Soft hammer percussion results in comparatively few secondary detachments of this type (Cotterell and Kaminga 1987:690).

Core reduction and tool manufacture both produce non-diagnostic shatter. The main difference is in size—core reduction produces more angular debris that are recoverable by standard archaeological techniques than does tool manufacture. Thus, logic suggests that the ratio of flakes to angular debris should increase with the amount of tool manufacture at a site. Other studies suggest that this is indeed the case (Moore 1999, 2001, 2003). Thus, high flakes to angular debris ratios indicate tool manufacture, while low ratios indicate core reduction.

Table 4.14 shows these ratios for each cluster and the whole assemblage. Flake to angular debris ratios are high for Clusters 1–4 and the overall assemblage, and moderately high for Cluster 7. Only Clusters 5 and 6 have comparatively small ratios. However, since Clusters 5 and 6 are the smallest assemblages and the Cluster 7 assemblage is not much larger, sample error could be having an effect in these cases. In comparison with other analyses including the study of sites in the Santa Fe to Pojoaque Corridor and at Spaceport America (Moore 2014, n.d.), ratios of under 4.0:1 can be considered low and over 7.0:1 can be considered high. In this light, only the ratios for Clusters 5 and 6 are low,

Table 4.14. LA 159879, debitage ratios.

	Flake to Angular Debris	Flakes to Cores	Core Flakes to Biface Flakes	Core Flakes to Biface Flakes[1]
Cluster 1	17.7:1	10.5:1	52.0:1	13.3:1
Cluster 2	17.0:1	8.5:1	n/a	10.3:1
Cluster 3	24.0:1	24.0:1	31.0:1	7.5:1
Cluster 4	10.2:1	19.1:1	8.2:1	2.5:1
Cluster 5	3.7:1	7.3:1	21.0:1	6.3:1
Cluster 6	2.5:1	5.0:1	n/a	4.0:1
Cluster 7	5.5:1	22.0:1	21.0:1	6.3:1
Whole assemblage	**11.5:1**	**14.0:1**	**15.8:1**	**4.6:1**

[1] All flakes with modified platforms reclassified as biface flakes.

and these are the assemblages that may be most affected by sample error. Thus, flake to angular debris ratios are high enough for most clusters and the assemblage as a whole to suggest one of three possibilities. The first is that the late stages of reduction dominated across the site. The second is that core reduction was accomplished carefully to minimize the amount of shattering. The third possibility is that most angular debris was not recovered during excavation, either because it was not recognized as such or because it was too small for the recovery techniques used.

As the amount of tool manufacture increases, so does the ratio between flakes and cores. This is because tool manufacture is a reductive process in which numerous flakes are struck to create a tool. Multiple flakes are removed from a piece of debitage that was originally struck from a core during this process, inflating the number of flakes in an assemblage. However, the size of the tool being made must be kept in mind when considering this ratio. The manufacture of any chipped stone tool results in the production of large numbers of flakes, but those removed during the manufacture of large tools are more easily recovered than are those produced while small tools. Thus, hunter-gatherers making the large bifaces that are indicative of a curated strategy tend to produce large numbers of flakes per core. More sedentary peoples focused on expedient reduction to produce flakes at need for use as tools or blanks, but the number of recoverable flakes per core is far fewer than in a curated strategy. Formal tools produced in an expedient strategy tend to be small in comparison with Archaic bifaces. Though small biface manufacture probably produces as many flakes as result from large biface production, the flakes resulting from this process are mostly too small to be recovered using standard excavation techniques. Under these circumstances, the ratio of flakes to cores is artificially reduced. Thus, a high ratio of flakes to cores is usually indicative of a curated reduction strategy, and a low ratio of an expedient strategy. While the flake to core ratios in Table 4.14 can be considered low in most cases, the ratios for Clusters 3, 4, and 7 are more moderate. For the most part, this suggests limited tool manufacture for most clusters as well as for the site overall.

A high ratio of core flakes to biface flakes suggests a focus on expedient reduction, while a low ratio suggests a focus on curated reduction. This ratio is shown in the last two columns of Table 4.14. The third column includes counts resulting from the flake reclassification presented earlier, while the last column classifies all flakes with modified platforms as biface flakes. There are fairly high core flake to biface flake ratios across most of the site, with comparatively low ratios only occurring in Cluster 4. However, when all flakes with modified platforms are reclassified as biface flakes because of the possibility that they were removed during that reduction stage, low ratios are derived for most clusters and the site as a whole, with low-to-moderate ratios for Clusters 1 and 2. While the core flake to biface flake ratios derived using the more conservative measures suggest that only Cluster 4 may have been a locus where tool manufacture was important, the use of the less rigorous definition suggests that biface reduction may have been important all across the site.

Thermal Alteration of Cherts

Cherts can be altered by the application of heat to make them easier to work. Thermal alteration causes changes at several levels. This process can change the visual quality of chert, and thereby alter color, translucency, and luster (Luedtke 1992:94). Color changes usually result from the oxidation of iron compounds to hematite. Some cherts become darker when heat-treated, others have a reduced translucency. Luster changes in nearly all cherts when they are heat-treated, increasing their gloss (Luedtke 1992:95). However, the most important change is in flaking quality. Thermal alteration reduces the tensile strength of cherts (Luedtke 1992:96), making them easier to fracture and therefore to flake.

Incorrect thermal alteration can damage chert by causing it to craze or explode, the latter producing pot-lid fractures. While these errors do not always ruin a piece, they often create enough problems that to render it unusable. Errors such as crazing and pot-lidding often happen when a piece of chert is unintentionally heat-treated, especially when discarded into an active fire. Thus, this analysis distinguishes between intentional thermal treatment and errors that might be more a reflection of discard behavior than intent. Intentional thermal alteration is exhibited by chert artifacts that are lustrous, display luster variation, or are flawed by mistakes made during thermal alteration but still flaked. Inadvertent thermal alteration is exhibited by chert artifacts that were damaged by heating and were not further flaked. Distinguishing between intentional and inadvertent thermal alteration is critical because, while the former may be an indication of the importance of tool manufacture, the latter is not.

Table 4.15 shows the results of this analysis. Overall, nearly half the cherts were intentionally thermally altered to enhance their flaking characteristics. Intentional thermal alteration was especially prevalent in Clusters 4 and 7. The least amount is evident in Clusters 1 and 6, though in the latter case, error related to small sample size could be responsible for this. Clusters 2, 3, and 5 also have high percentages of intentionally heat-treated cherts. Intentional thermal alteration was not restricted to debitage, since 52.0 percent of the cores (13 of 25) also show evidence of heat treatment. Eliminating Cluster 6 because of small sample size, the remaining clusters appear to belong to different populations (chi-square = 63.2, df = 5, significance = .000, Cramer's V = .357). However, chi-square analysis strongly suggests that Clusters 2, 4, and 7 belong to the same population (chi-square = 1.7, df = 2, significance = .430, Cramer's V = .077). Similarly, Clusters 3 and 5 represent a second population (chi-square = .001, df = 1, significance = .973, Phi = -.004). Cluster 1 represents a statistical outlier that is not significantly similar to any of the other clusters. Despite the fact that the clusters fall into three groups, the percentages of thermally altered cherts in Table 4.15 suggest that tool manufacture may have been important in most parts of the site, with the possible exception of Cluster 1.

Table 4.15. LA 159879, type of thermal alteration of cherts for each cluster and the whole site assemblage.

Location		**None**	**Intentional**	**Non-intentional**
No Cluster	Count	1	–	–
	Row %	100.0%	–	–
Cluster 1	Count	115	27	–
	Row %	81.0%	19.0%	–
Cluster 2	Count	21	21	–
	Row %	50.0%	50.0%	–
Cluster 3	Count	29	23	2
	Row %	53.7%	42.6%	3.7%
Cluster 4	Count	90	139	3
	Row %	38.8%	59.9%	1.3%
Cluster 5	Count	9	7	–
	Row %	56.3%	43.8%	–
Cluster 6	Count	4	1	–
	Row %	80.0%	20.0%	–
Cluster 7	Count	6	9	1
	Row %	37.5%	56.3%	6.3%
Whole assemblage	**Count**	275	227	6
	Row %	54.1%	44.7%	1.2%

Comparison of Reduction Strategy Indicators

This discussion has repeatedly stressed the notion that none of the indicators discussed here can, by themselves, accurately identify the reduction strategy used at a site or in a component. Only by using these indicators in combination and comparing the results of those assessments can we determine what reduction strategy(ies) probably dominated and how prevalent it was. By using a variety of indicators, it may be possible to account for some of the biases introduced by prehistoric activities as well as by archaeological recovery methods. Many indicators overlap, but are used in somewhat different ways and should be considered interrelated.

The data presented in this section are shown in Tables 4.8 through 4.15. Table 4.16 presents an assessment of reduction strategy based on these tables and the accompanying discussions. Only Cluster 4 is dominated by indicators suggesting a curated reduction strategy. Expedient reduction indicators dominate across the rest of the site, but results for the site as a whole are distinctly mixed. At least one indicator suggests a curated strategy in each cluster, except for Cluster 6, which had the smallest assemblage. Similarly, evidence for a mixed reduction strategy occurs in each assemblage, again with the exception of Cluster 6.These results suggest that, as discussed for several of the individual indicators, at least some tool manufacture probably occurred in all parts of the site (except perhaps for Cluster 6), but evidence of this activity is most common in Cluster 4. Expedient core/flake reduction was common in all parts of the site, though there is proportionally less evidence for this activity in Cluster 4. Biface reduction was a common activity at LA 159879, but it was not a focus of reduction. Rather, the expedient reduction of cores to create flakes for use or further modification was the main reduction activity in most parts of the site, and was probably nearly as important in Cluster 4 as was tool manufacture.

This analysis suggests that no part of LA 159879 served as a workshop focused on tool manufacture. Rather, both core-flake reduction and tool manufacture appear to have occurred in all parts of the site to varying degrees. This sort of a mixed reduction strategy is consistent with occupations that reduced locally available materials for immediate use, as well as making a few bifacial tools. An interesting aspect of this analysis is the large percentages of intentionally thermally altered cherts and modified platforms compared to the rather small percentages of definite biface flakes that were identified. This suggests that early stage tool manufacture may have been common at this site, with bifaces being roughed out for transport elsewhere. However, since much of the breakage associated with tool manufacture tends to occur during the early stages, and the assemblage lacks evidence of fragmentary early stage tools, this possibility must remain tentative.

Table 4.16. LA 159879, summary of reduction state indicators.

Attribute	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**	**Cluster 6**	**Cluster 7**	**Whole Assemblage**
Non-cortical to Cortical Debitage Ratio	expedient	expedient	expedient	curated	expedient	error	expedient	**expedient**
Cortical Coverage Classifications	mixed	mixed	expedient	curated	expedient	error	error	**mixed**
Flake Types	expedient	expedient	expedient	expedient	expedient	expedient	expedient	**expedient**
Flake Platforms	expedient	expedient	mixed	curated	mixed	error	expedient	**mixed**
Flake Breakage	expedient	expedient	expedient	expedient	expedient	expedient	expedient	**expedient**
Platform Lipping	curated	expedient	expedient	curated	expedient	expedient	error	**curated**
Bulb of Percussion	expedient	curated	curated	curated	expedient	error	expedient	**mixed**
Flake to Angular Debris Ratio	curated	curated	curated	curated	expedient	expedient	mixed	**curated**
Flake to Core Ratio	expedient	expedient	mixed	mixed	expedient	expedient	mixed	**mixed**
Core to Biface Flakes	expedient	expedient	expedient	curated	expedient	expedient	expedient	**expedient**
Intentional Thermal Alteration	expedient	curated	curated	curated	curated	error	curated	**curated**
Curated Strategy Indicators	**2**	**3**	**3**	**8**	**1**	**0**	**1**	**3**
Expedient Strategy Indicators	**8**	**7**	**6**	**2**	**9**	**6**	**6**	**4**
Mixed Strategy indicators	**1**	**1**	**2**	**1**	**1**	**0**	**2**	**4**

Tool Use

Chipped stone tools were not common at LA 159879, with only 27 being identified during analysis, constituting a mere 3.4 percent of the assemblage. As Table 4.17 shows, tools were only found in four clusters, and were most abundant in Cluster 4. Tools make up only 2.6 percent of the Cluster 1 assemblage, 5.0 percent of the Cluster 2 assemblage, 3.8 percent of the Cluster 3 assemblage, and 4.4 percent of the Cluster 4 assemblage. Thus, the much larger number of tools in Cluster 4 is a reflection of the size of that assemblage in comparison with the others rather than being indicative of a focus on tool-using activities. The small tool assemblage is evenly split between informal and formal tools. As discussed earlier, informal tools are debitage or cores that were visibly damaged by use, but that were not intentionally shaped. In contrast, formal tools are debitage that were intentionally shaped.

There are reasons to suspect that the few tools recovered from LA 159879 represent only some of those that were originally deposited there. Many tools that were once visible on the surface may have been removed by collectors. Indeed, at least one person who owns a portion of LA 159879 has collected tools from the site. The paucity of informal tools can be explained in a different way. Experiments have shown that the informal use of debitage as tools does not always result in recognizable wear patterns. In experiments by Vaughan (1985:22–23), no scarring was observed in 16 percent of cases in which a transverse (scraping) motion was used and in 18 percent in which a longitudinal motion (cutting) was used, ranging from 39 percent of edges used on soft materials to 6 percent of edges used on hard materials. Experiments conducted by Schutt (1980) had similar results. Thus, not all edges used as informal tools show evidence of that use, and this tendency is much greater among edges used to process soft materials. An additional problem for the identification of informal tools is that, though scarring from use often occurred, the amount of scarring was insufficient for it to be distinguished from natural edge attrition caused by soil movement or bagging. Thus, many informal tools are not recorded as such because they were simply not recognized. This means that the number of informal tools in an assemblage does not reflect the intensity of that sort of use, it merely provide an indication that an unknown number of such tools were used.

The absence of chipped stone tools from three clusters is no surprise, since those are the smallest assemblages, containing 31 or fewer artifacts apiece (Table 4.2). This small array of tools can be used to elicit two types of data. Certain types of tools, like projectile points, can have temporal implications. The presence of some tool types suggests that certain tasks were accomplished and can thus be used to define a range of activities for the clusters in which they occur. Both types of data are discussed, and their implications for cluster date and function are explored.

Projectile Points as Temporal Indicators

Though not as temporally sensitive as pottery or radiocarbon dates, projectile points can be used to define basic occupational periods based on their size and style. For instance, small projectile points suitable for tipping arrows rather than darts do not occur before the introduction of the bow, ca. AD 400–600. The presence of arrow points on aceramic sites indicates occupation after AD 400–600, though we cannot always narrow the date further. Certain projectile point styles have well-defined temporal

Table 4.17. LA 159879, tool type by cluster.

Location	Utilized Debitage	Utilized Core	Graver	Scraper-Graver	Chopper-Hammer-stone	Core-Hammer-stone	End Scraper	Side Scraper	San Pedro Point	Pelona Point	Totals
Cluster 1	–	–	–	–	–	–	1	1	1	–	**3**
Cluster 2	2	1	–	–	1	–	–	–	–	–	**4**
Cluster 3	1	1	–	–	–	1	–	–	1	–	**4**
Cluster 4	7	1	1	1	–	1	–	–	2	2	**15**
Totals	**10**	**3**	**1**	**1**	**1**	**2**	**1**	**1**	**4**	**2**	**26**

spans and can be used to date sites or components in the absence of absolute dates or ceramics, especially those from Paleoindian and Archaic occupations.

Unfortunately, projectile points have always been prone to salvaging and curation, so dates based on these tools are not always reliable. For instance, the presence of an Archaic point on a ceramic-period site could indicate an earlier component or it could simply have been salvaged for reuse. In such an instance other data corroborating an earlier occupation would be necessary to confirm it. The projectile points recovered from LA 159879 are presented by cluster, and those that cannot be assigned to a specific cluster are discussed in the context of the site as a whole. How they fit with any dates from potentially associated features is then discussed.

Cluster 1

One fragmentary projectile point was recovered from this part of the site (Fig. 4.4[a]). This gray chert San Pedro point is missing both its point and base. While both breaks are snap fractures, their locations suggest that they could have occurred as a consequence of impact. No evidence of thermal alteration was noted on this specimen.

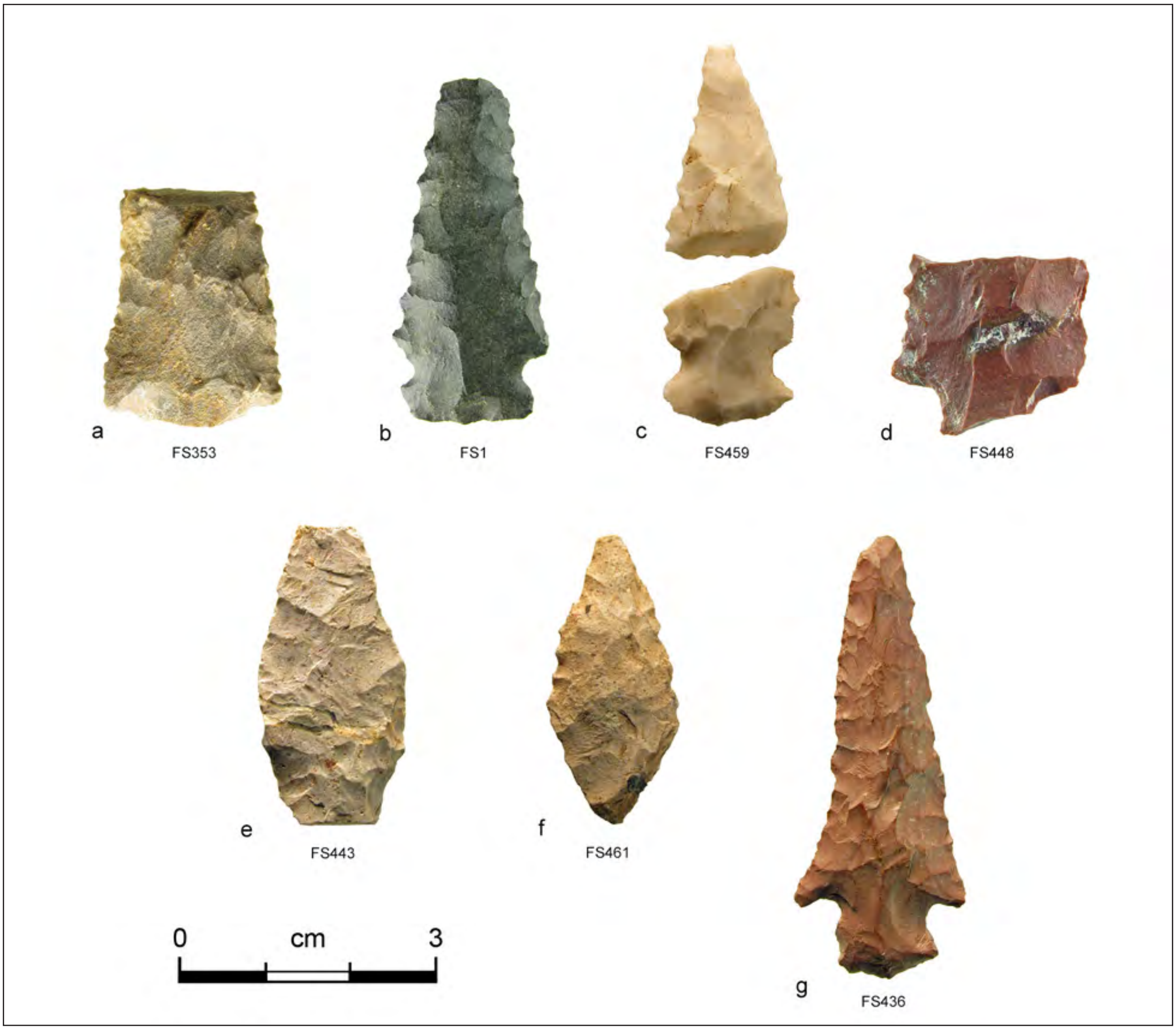


Figure 4.4 [a–g]. Projectile points recovered from LA 159879 during data recovery excavations: a. San Pedro point from Cluster 1 (FS 353); b. San Pedro point from Cluster 3 (FS 1); c–d. San Pedro points from Cluster 4 (FS 459, FS 448); e–f. Pelona points from Cluster 4 (FS 443, FS 461); g. unprovenienced San Pedro point (FS 436).

Cluster 3

A single gray chert San Pedro point was found in this part of the site (Fig. 4.4[b]). This specimen exhibits an impact fracture at its tip, and does not appear to have been thermally altered. It was probably removed from its haft and discarded at this site.

Cluster 4

This part of the site yielded four projectile points, including two San Pedro points and two Pelona points (Fig. 4.4[c–f]). One San Pedro point is made from white chert and was found as two fragments, with the tip missing (Fig. 4.4[c]). The breakage on this specimen appears to be attributable to post-depositional impact, and it exhibits no signs of thermal alteration. The second San Pedro point is made from pink chert and exhibits a haft snap at its proximal end and a possible impact fracture at its distal end (Fig. 4.4[d]). This specimen was probably broken during use and returned to the site in a meat package. One Pelona point is made from a gray aphanitic rhyolite and is missing both its tip and a portion of its base (Fig. 4.4[e]). These breaks are probably not attributable to impact. The second Pelona point is complete, and is made from white chert that does not appear to have been thermally altered (Fig. 4.4[f]).

No Provenience

One projectile point cannot be assigned to any specific part of the site (Fig. 4.4[g]). This is a complete red-brown chert San Pedro point that was not thermally altered but does appear to have been resharpened. In addition to this specimen, three other specimens can be attributed to the site as a whole and were collected by a landowner in the 1980s. One specimen appears to be a Jay point (Fig. 4.5[a]), though it could also be classified as a Bajada point because of its concave base. In either case, this specimen dates to the Early Archaic period. Two specimens appear to be Late Archaic–period Hueco or San Pedro points (Fig. 4.5[b,c]), though this remains uncertain in one case because the specimen is missing its barbs and one tang. A fourth specimen is a middle-stage biface (Fig. 4.5[d]), which cannot be dated but provides some evidence that large bifacial tools were indeed made at this site.

Dating

Most of the projectile points date to the Late Archaic period. Roth and Huckell (1992:356) suggest

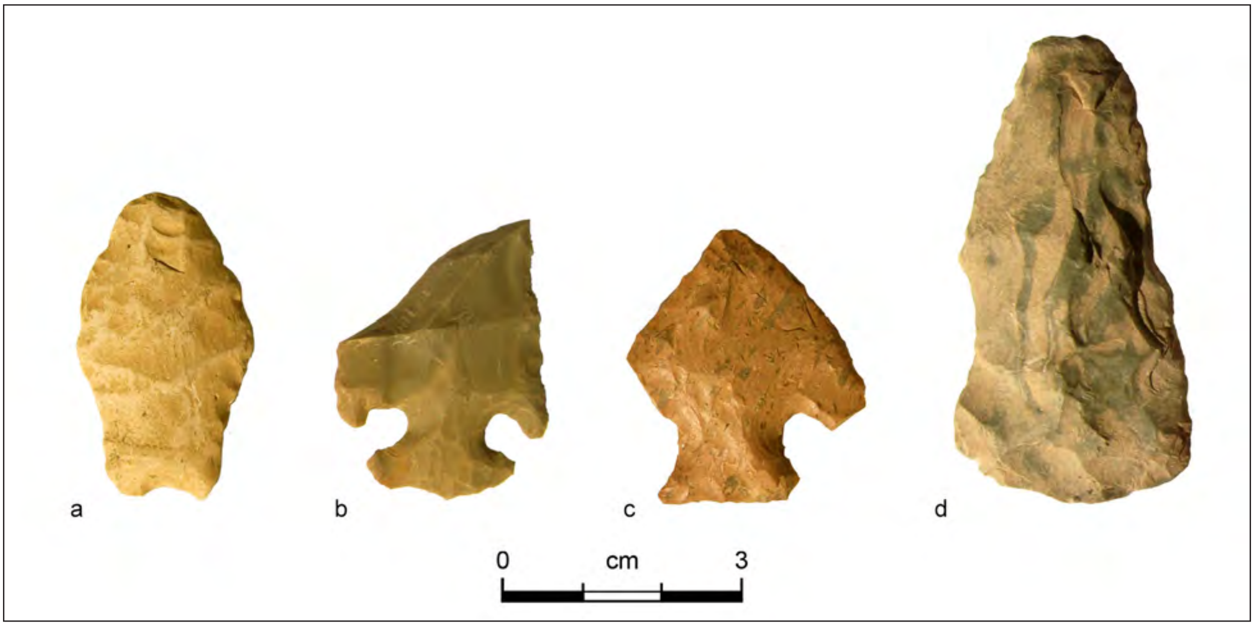


Figure 4.5 [a–d]. Projectile points collected from LA 159879 by a land owner: a. Jay/Bajada point; b. Hueco/San Pedro point; c. Hueco/San Pedro point; d. large middle stage biface.

that the San Pedro type, of which there are five from LA 159879, date between 3000 and 1800 BP (roughly 1000 BC–AD 200). Justice (2002:191) suggests a date range of 3500 to 1000 BC for the Pelona type, two of which were identified in this assemblage. Hueco points (n = 2) are similar in shape and date to the San Pedro point, and are also assigned to the Late Archaic (Turner et al. 2011:116). Justice (2002:195) subsumes the Hueco point under the San Pedro type, and assigns it the same date range. The single Jay or Bajada point is the only specimen that does not date to the Late Archaic. This specimen can be assigned to the Early Archaic between ca. 5500 and 3200 BC. Except for Historic-period dates for Features 2 and 15, all of the other dated features at LA 159879 are from Late Archaic occupations, and the projectile point dates tend to confirm this period of use, with the sole exception of the Jay/Bajada point.

Unfortunately, because of the rather long time spans assigned to each of these point types, they cannot be used to narrow the occupational date(s). Since the Jay/Bajada point cannot be associated with any of the analytic clusters or even the part of the site that was excavated during this project, we remain uncertain whether it indicates the presence of an earlier component, or represents an item that was collected from an earlier site and reused in this location during either one of the later occupations.

Multiple occupations are indicated for the Late Archaic period. If the dates assigned to these point types are correct, the Pelona points represent one or more occupations during the early part of the Late Archaic before around 1000 BC, while the San Pedro/Hueco points are evidence for later occupations after 1000 BC. Since a short period of overlap between these styles cannot be ruled out, the occurrence of these styles in combination could represent one or more occupations within a few hundred years either side of 1000 BC. Considering the radiocarbon dates derived for the three clusters that yielded projectile points, either of these scenarios is possible. Thus, while the types of projectile points recovered from LA 159879 are mostly consistent with the radiocarbon dates obtained from features, they do not permit a further refinement of those dates.

Tool Use at LA 159879

As noted earlier, only 27 formal and informal tools were identified in the LA 159879 assemblage, with most coming from Cluster 4, which also produced the largest number of chipped stone artifacts. Cluster 4 contained 43.4 percent of the entire chipped stone assemblage and 57.7 percent of the tools. These percentages are close enough to suggest that the percentage of tools for Cluster 4 is not out of proportion to the percentage of the total assemblage from that part of the site.

All three tools from Cluster 1 are formal, and consist of only two basic types: projectile points and scrapers. These tools are made from various cherts, none of which seem to be of exotic origin. The San Pedro point exhibits fractures that may be indicative of use-related breakage, though this remains uncertain. The tool-using activities represented in this part of the site include hide processing (scrapers) and possibly hunting (projectile points), especially if the San Pedro point was returned to the site in a meat package. Two reduction-related tasks can be suggested: core reduction (cores and core flakes) and biface reduction (biface flakes).

In contrast to Cluster 1, all tools from Cluster 2 are informal, and include a utilized chalcedony flake, a utilized silicified wood flake, a utilized metaquartzite core, and a rhyolite core-hammerstone. Four edges on the two utilized flakes and core exhibit unidirectional wear, and all measure over 45 degrees. In experiments conducted to examine the results of cutting and scraping on debitage edges, Schutt (1980) concluded that edges that measured over 40 degrees were poorly suited for cutting and were better for scraping. Thus, we assume that edge angles smaller than 40 degrees were best for cutting, and those larger than 40 degrees were better for scraping. This suggests that the utilized flakes and core from this cluster were used for scraping, most likely in leather-working. The last informal tool from Cluster 2 is a chopper-hammerstone. This tool would have had a dual purpose, and was probably used for chopping vegetal materials and pounding hard materials. Thus, the tool-using activities that can be documented for this cluster include leather working (utilized flakes and core), chopping, and pounding (chopper-hammerstone). The only reduction-related activity that can be suggested is core reduction (cores and core flakes).

Both formal and informal tools were found in Cluster 3. The formal tool is a chert San Pedro point, and the informal tools include a utilized chert core flake, a utilized rhyolite core, and a chert core-hammerstone. The San Pedro point has an impact fracture at its distal end, indicating that it was broken during use and the foreshaft was returned to the site for refurbishing. The utilized core flake and core both exhibit unidirectional wear and have edge angles over 60 degrees. Thus, both of these tools were probably used for scraping, possibly during leather processing. Despite the fact that the core-hammerstone is made from a brittle material it was used for pounding, and was probably used in core reduction. Two reduction-related activities can be suggested for this cluster including core reduction (core flakes, cores, core-hammerstone), and biface reduction (biface flakes).

The 15 tools recovered from Cluster 4 include four formal and 11 informal specimens. All four formal tools are projectile points, including two chert San Pedro points and two Pelona point (chert and aphanitic rhyolite). One San Pedro point is a medial section that exhibits use-related breaks at both ends, indicating that it fractured during hunting and was returned to the site in a meat package. The informal tools include seven utilized core flakes (5 chert, 1 rhyolite, 1 unknown), a utilized chert core, a chert graver, a chert scraper-graver, and a basalt core-hammerstone. Edge angles on all seven utilized core flakes are over 40 degrees, five exhibit unidirectional use-wear and two exhibit bidirectional use-wear. All seven of these tools were probably used for scraping, possibly in leather working. Similarly, the utilized core also has a steep edge angle and exhibits unidirectional wear, suggesting use as a scraping tool. The graver and scraper-graver were probably used in wood-working, though they could also have been used to carve bone. Finally, the core-hammerstone was used in pounding activities, probably related to core reduction. The presence of cores and core flakes indicate that core reduction occurred in this area. Biface reduction also occurred, as indicated by the presence of biface flakes.

Since no tools of any kind were found in Clusters 5–7, only reduction-related activities can be suggested for those parts of the site. The presence of cores and core flakes in all three clusters suggests that core reduction occurred in those areas. A single biface flake apiece was recovered from Clusters 5 and 7, indicating that limited biface reduction may have occurred there as well.

As Table 4.18 shows, at least nine activities are represented in the chipped stone assemblage. Notably absent is evidence for cutting. No cluster contains evidence for the full range of activities, and Cluster 4, with the largest assemblage, also contains evidence for the largest number of activities. Figure 4.6 graphs the relationship between number of artifacts per cluster and number of activities represented, and shows that these characteristics are closely related, with the number of activities per cluster steadily declining as the number of artifacts decreases. The larger the assemblage, the better the chance that evidence of stone tool use will be represented. Still, comparatively few tasks that used chipped stone tools can be documented using the data presented here.

Considering the three projectile points and single middle stage biface illustrated in Figure 4.4 modern collection of tools from the surface of this site is unfortunately a factor that must be taken into

Table 4.18. LA 159879, probable activities defined for each cluster based on chipped stone data.

Cluster	Core Reduction	Biface Reduction	Hunting	Shaft Refurbishing	Leather Working	Wood Working	Chopping	Pounding
1	x	x	x	–	x	–	–	–
2	x	–	–	–	x	–	x	x
3	x	x	–	x	x	–	–	x
4	x	x	x	–	x	x	–	x
5	x	x	–	–	–	–	–	–
6	x	–	–	–	–	–	–	–
7	x	x	–	–	–	–	–	–

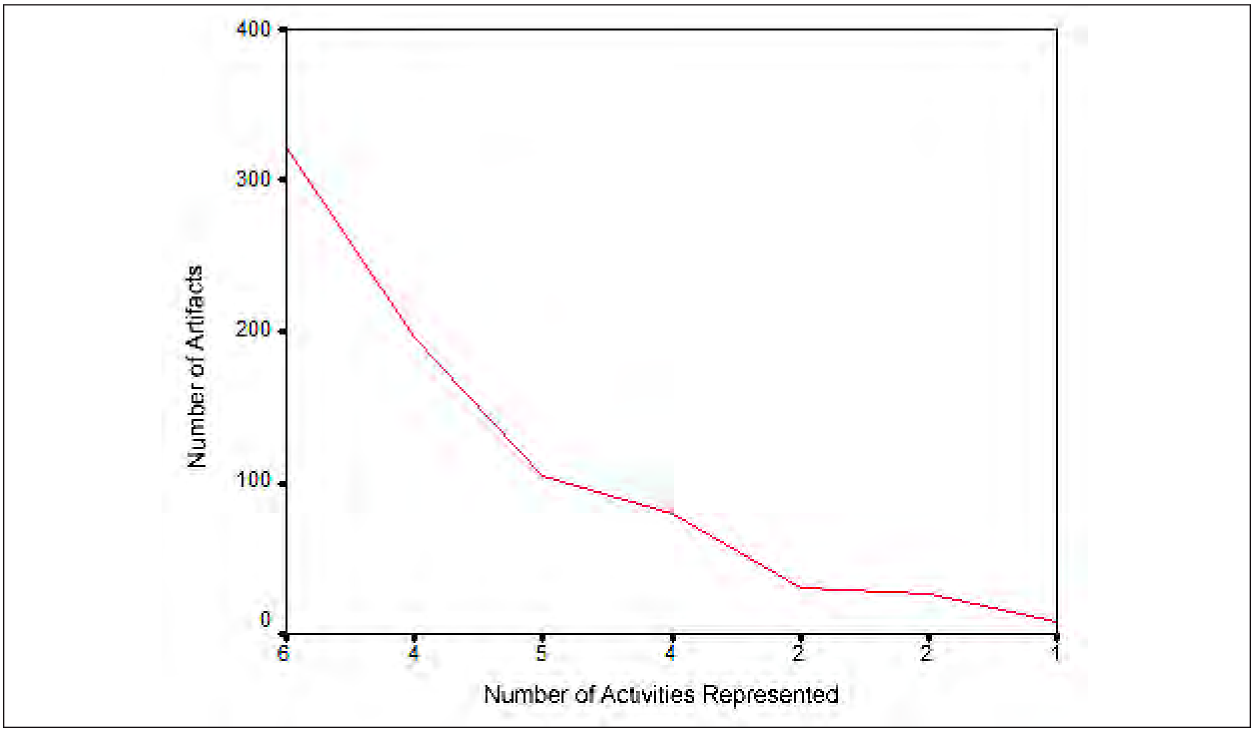


Figure 4.6. Number of activities represented in clusters graphed against the corresponding number of artifacts.

consideration. With modern impact to the assemblage factored in, the comparative dearth of formal tools is more easily understood. A similar rarity of informal tools cannot be explained in the same way, but our analysis is not geared toward identifying all informal tools. Rather, only those debitage and cores that exhibit definite evidence of tool use are classified as such. There are two reasons for this. First, not all informally used debitage tools are visibly damaged during that use, as discussed earlier. The second reason is that debitage edges can be damaged during removal and by environmental processes occurring after deposition, necessitating a fairly strict definition of the type and extent of scarring that constitutes evidence of cultural use. This eliminates many specimens from consideration, because the edge damage seen on them cannot be assigned to a cultural source. Thus, the presence of informal tools in an assemblage is qualitative evidence of tool-using activities, but the level of use cannot be quantified.

CONCLUSIONS

This study has addressed three main topics for LA 159879: material selection parameters, evidence for reduction strategy, and tool use. During the course of this analysis, various attributes related to material selection and reduction strategy were tested to determine whether there was any statistical relationship between cluster assemblages. Unfortunately, such testing was not possible for every attribute because in many cases there were empty cells or several cells containing too few examples for any accurate assessment of relationship. The results of all these tests are shown in Table 4.19. Various combinations of cluster assemblages formed statistical populations for each attribute, with little consistency from attribute to attribute. Indeed, different combinations of clusters represent statistical populations in almost every test. Matrices comparing the correspondences between the various clusters are shown in Table 4.20, with the exception of Cluster 6, which contained too few artifacts for comparison. Overall, the best correspondences are between Clusters 2 and 3 and Clusters 3 and 5. When only

Table 4.19. LA 159879, populations formed by clusters during chi-square analysis for various assemblage attributes.

Category	Material Selection			Reduction Strategy			
	Material Type Composition	Material Texture	Material Toughness	Cortical Coverage	Platform Lipping	Bulb of Percussion	Thermal Alteration
Populations	1 & 4	1, 2, 3, 4, 5, & 7	1 & 6	1 & 2	4, & 7	2, 3, & 4	2, 4, & 7
	2, 3, 5, & 7		4 & 7	2 & 4	1, 2, 3, & 5	1, 5, & 7	3 & 5
			2, 3, & 5	3 & 5			
Outliers		4					1
Eliminated	6			6 & 7	6	6	6

Table 4.20. LA 159879, matrices showing the correlation between clusters for statistically tested attributes.

Material Selection and Reduction Strategy Attributes Combined

Location	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 7
Cluster 1	2	2	2	3	2
Cluster 2	–	5	4	4	3
Cluster 3	–	–	2	6	2
Cluster 4	–	–	–	1	4
Cluster 5	–	–	–	–	3

Material Selection Attributes

Location	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 7
Cluster 1	1	1	2	1	1
Cluster 2	–	3	1	3	2
Cluster 3	–	–	1	3	2
Cluster 4	–	–	–	1	2
Cluster 5	–	–	–	–	2

Reduction Strategy Attributes

Location	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 7
Cluster 1	1	1	0	2	1
Cluster 2	–	2	3	1	1
Cluster 3	–	–	1	3	0
Cluster 4	–	–	–	0	2
Cluster 5	–	–	–	–	1

material selection is considered, Clusters 2, 3, and 5 correspond for all three attributes. No clusters correspond for all four of the reduction strategy attributes that were tested, but Cluster 3 and 5 and Clusters 2 and 4 each correspond for three apiece.

The best correspondence for these attributes is between Clusters 2, 3, and 5. Cluster 1 is, for the most part, very different from the others. There is a resemblance between Clusters 4 and 7, but to a lesser extent than occurs between Clusters 2, 3, and 5. As Figure 4.1 shows, Clusters 4 and 7 are contiguous, as are Clusters 3 and 5. The resemblances between these two groups of contiguous clusters may be an indication of the artificial nature of the dividing lines between clusters, and suggests that there was continuity in the range of reduction and material selection activities occurring in those two larger areas.

Perhaps the most important aspect of the correspondences between clusters for the various assemblage attributes in Table 4.19 is their inconsistency. With rare exceptions, corresponding cluster assemblages change from one attribute to the next. This is undoubtedly a demonstration of the nature of LA 159879. The range of radiocarbon dates from features indicates that the site is a multi-occupational locale. In cases where there are multiple dated features within a cluster (Clusters 3 and 4), multiple occupations are likely. This, in addition to the variation in correspondences between cluster assemblages for various attributes, indicates that LA 159879 represents a palimpsest, in which multiple occupations overlap and materials from them are mixed to the extent that they cannot be separated with any degree of certainty. The fact that there are various degrees of correspondence between many cluster assemblages for the material selection attributes suggests that selection parameters probably did not vary greatly between occupations. The biggest differences appear to have been in the reduction strategy that was pursued, but for the most part those differences may not have been too great. Cluster 4, which contains both the largest number of artifacts and features, also exhibits the largest amount of evidence for tool manufacture. While these characteristics may indicate that occupations in this area lasted longer than those represented by other parts of the site, it could also reflect a larger number of individual uses. Because of the overlapping nature of the various occupations, there is no way in which to determine which of these suppositions (if either) is correct.

Thus, we conclude that there were multiple periods of occupation at LA 159879, and that the various occupants tended to collect similar ranges of materials for reduction. The reduction strategy pursued appears to have been broadly similar between occupations, but differed somewhat in the amount of biface reduction that occurred. Materials appear to have been exclusively (or almost exclusively) obtained from gravel deposits, and from the amount of core reduction that occurred across the site, those sources were probably fairly nearby. Cherts were most commonly selected for use, making up 51 percent of the assemblage by count and 44.6 percent by weight. The assemblage was dominated by nearly equal proportions of coarse- and fine-grained materials (48.2 percent and 45.7 percent, respectively). In terms of toughness, brittle and strong materials make up over three-quarters of the assemblage, suggesting that most materials were selected to provide sharp edges.

While expedient core-flake reduction dominated the assemblage as a whole, there is also evidence for biface reduction across the site. It was difficult to gauge just how much biface reduction occurred at LA 159879, because some of the data were confusing. While definite biface flakes were comparatively rare, core flakes with modified platforms were fairly common. This either suggests that cores were reduced in a careful, systematic manner, or that early stage biface manufacture was common. Since there is no other evidence for the systematic reduction of cores, we can suggest that early stage biface reduction was fairly common, but by no means dominant.

Evidence for chipped stone tool-using activities was comparatively sparse, but occurred in most areas of the site. The paucity of evidence for chipped stone tool use can probably be attributed to a combination of amateur surface collection of formal tools combined with the difficulties in identifying informal tools. Despite these problems, several activities were defined for the site, including hunting, leather-working, wood-working, shaft refurbishing, and general pounding and chopping tasks.

The character of this assemblage suggests that LA 159879 was occupied as a short-term camp on multiple occasions by mobile hunter-gatherers who collected most of their materials from local gravel beds. The types and range of activities performed during those camping episodes probably varied considerably, as did the lengths of occupation. The overlapping nature of the various occupations make it impossible to sort out individual use areas, but the relative similarity of artificially defined assemblages across the site suggest that they were mostly of a similar nature.

5 ▵▿ Ground Stone Analysis

Karen Wening

Introduction

Several factors compromise the integrity of the LA 159879 assemblage. First and foremost, the site has been subjected to intensive, long-term amateur collection, which renders the project assemblage only partially representative. Second, ground stone artifacts outside of the project area were point provenienced, but not collected. Third, a significant portion of artifacts collected in the field were not ground stone, but fire-cracked rock. These may, however, be ground stone fragments, as it is clear that broken tools were used as heating elements in thermal features (37 percent; n = 67). Much of the uncollected rock in thermal features may be broken or discarded ground stone tools.

Of all these factors, amateur collection has had the most impact. In particular, the field crew observed numerous large slab metates in private collections; they are completely absent in the assemblage. As such, the dominant characteristics noted for the project ground stone are actually not representative of the frequency or range of ground stone used at this site prehistorically. Thus, the assemblage reflects a narrow slice of the full range of processing methods used.

Basin metates, one-hand manos, and abraders dominate the food-processing assemblage. Locally available tool stone was probably procured from lag gravels or possibly, alluvial gravels of the Mimbres River; this idea is addressed further below. Most raw material was selected for its low or minimal abrasion quality. Use surfaces commonly display moderate to high use, accompanied by little surface rejuvenation.

Perhaps most exciting, grass, corn, and sedge-seed phytoliths were recovered from four tools (Appendix 3). Cummings' analysis revealed some unexpected tool and plant associations, providing evidence that planted and gathered foods were processed with the same tools, at least in these particular instances. Corn and cottonseed may have been processed with the same tools used for grass, sedge, and cheno-am seeds.

Several ground stone artifact clusters are present. Based on high numbers of fragmentary tools and heat-fractured artifacts, which likely served as thermal elements, repeated use is indicated. Whole ground stone artifacts may have been cached as site furniture for future use at this foraging locale. Stored milling stones may reflect a high degree of efficiency, degree of use, and expenditure reflecting intensity of site use and planned anticipation of site reuse (Nelson and Lippmeier 1993).

Analysis Methods

OAS standard analysis was employed for the ground stone assemblage (OAS 1994), with some modifications and additions. New attributes are based on Adams' studies (1999, 2002, 2010), and are primarily concerned with use-surface morphology and wear. Adams' ground stone terminology is also heavily used. This analysis includes and expands on all attributes proposed for the ground stone analysis in the LA 159879 research design (Greenwald et al. 2009:37).

All artifacts are analyzed for material type, texture and induration, function, condition, raw material form, production input, plan shape, transverse and longitudinal cross-section shapes, shaping methods, number of functions, number of wear surfaces/edges, heat exposure, adhesions, use of cortical surface, artifact dimensions and weight.

Each tool can be analyzed for up to three distinct functions on the analysis sheet. Artifacts with more than three functions are analyzed in the "comment" section for each artifact, but none were encountered.

Several attributes are focused specifically on the use-surface. Each wear surface is analyzed for contour, stroke/netherstone companion type, macroscopic and microscopic wear patterns, and degree of use. These are further defined below. These attributes figure significantly in determining tool configuration, which informs on processing strategies used at the site. Wear patterns, in particular, have great information potential. The contour of the wear surface can inform on the stroke used to manipulate the tool, the type of companion tool used, multiple functions, motor habits, and degree of use (Adams 1993, 1999, 2002:41–42, 98–114). Micro- and macroscopic wear type and location can distinguish artifacts that appear to have identical functions (Adams 1988, 2002, 2010). The ground stone analysis is designed with these factors in mind, with the goal of determining artifact function(s) as accurately as possible. Wear-pattern analysis aids in the definition not only processing strategies, but greatly enhances the identification of multifunctional tools.

Attributes and Definitions

Measurements:

Length in centimeters is recorded for each artifact. If the original long axis of the artifact could be determined, this measurement is recorded as length even if it is not the longest dimension. If the long axis cannot be identified, the longest dimension is recorded. If metate fragments display parallel striations on the use surface, this axis is assumed to be the length.

Width in centimeters is recorded for each artifact. As with length, if the length and width orientation can be determined, measurements are taken along this axis even if the width is not the second largest dimension.

Thickness in centimeters is recorded for each artifact.

Weight in grams is recorded for all artifacts. If fragments can be determined to be part of the same artifact, they are weighed together.

Material Type: All artifacts were monitored for material type, color, and degree of cementation. Any combination of these three characteristics denotes a specific material type. For instance, gray, friable sandstone is a specific material type.

Material Texture: Texture is recorded as fine (grains of less than 1 mm), medium (grains 1–2 mm), or coarse (2–4 mm) (Adams 2002:233). Materials without macroscopically visible grains are cryptocrystalline.

Raw Material Form: This variable records the form of the ground stone source material. Artifacts were recorded as having been manufactured from a rounded cobble, a flattened cobble, a thick slab (10+ cm), a thin slab (5–10 cm), or a very thin slab (<5 cm). Artifacts whose manufacturing techniques completely obscured the raw material form were recorded as indeterminate.

Plan Shape: Plan is the outline of the top, or dorsal, view of the artifact. If the artifact is fragmentary, this attribute is indeterminate.

Transverse Cross-Section Shape (TXS): TXS defines the outline shape of the mano or metate across the width axis. For some wedge and truncated wedge shaped manos in the assemblage, these shapes did not appear to be solely the result of use, but of intentional shaping. This is discussed in detail with the analysis results.

Longitudinal Cross-Section Shape (LXS): LXS is the outline shape of the mano or metate across the length axis. Both TXS and LXS attributes were added to the standard OAS ground stone analysis, as was Use Surface Contours, below.

Use Surface Contour: This variable is a biaxial attribute that records the transverse and longitudinal contour of each wear surface (i.e., biaxially convex). If each axis is differently contoured, an appropriate value is used. Following Adams' designations, "ventral" and "dorsal" are used to specify use surfaces (2000:45). Modified and utilized edge angles are measured.

The more heavily used surface is labeled the ventral surface, and the more lightly worn surface, the dorsal. This applies to all other tool types as well. In the case of equally worn surfaces, a random assignment is made. For tools with more than two use surfaces, the two most heavily worn are the ventral and dorsal, and subsequent surfaces are numbered according to relative degree of use. If both surfaces display identical use, the assignment is arbitrary.

Ventral Stroke: The ventral stroke refers to motion used to manipulate handstones when the ventral surface is in contact with the netherstone. It is also used to define the stroke used on a metate. As with the contour attribute, the most heavily worn surface is termed the ventral. These terms are based on Adams' terminology (2002:45) so that the location of all cultural modification is clear.

Dorsal Stroke: Dorsal stroke is the identical attribute applied to the least used surface of a tool. For unifacial or fragmentary tools with a single surface remaining, this attribute is inapplicable.

Production Input: The level of manufacturing effort expended on a specific tool is recorded in this variable. This is defined by the percentage of a tool's surface area that has been shaped. "Fully shaped" refers to 100 percent, "mostly modified" to 50–99 percent, and "slightly modified" is considered less than 50 percent of the surface area. This breakdown was applied subjectively to fragments. If a fragment exhibited a high degree of shaping, the artifact was recorded as "mostly modified" even though the missing portions could not be observed. This was done to obtain the maximum information possible from fragmentary artifacts.

Shaping: Shaping refers to the methods used to shape a ground stone tool. Grinding, flaking, pecking, and combinations of these methods were recorded. Pecking to shape an artifact is differentiated from pecking to rejuvenate a grinding surface, which is recorded under "Wear Surface Rejuvenation." If shaping is present on a fragment, it is coded as "shaped on extant portions."

Heat Alteration: This variable describes the degree heat exposure an artifact has received. Attributes consist of reddened, crazed, fractured, burned, and sooted, and combinations of these attributes.

Adhesions: Adhesions are any foreign substance on the artifact such as pigment or other residue. Caliche is coded as an adhesion only where it precludes analysis of the use surface.

Function: This is the general tool-type category. Manos are classified as handstones, metates as netherstones. Handstones are identified using Adams' definitions for this artifact. The first describes handstones as all tools held in the hand (2002:142). The second includes all handheld tools that do not display attributes that define them as manos, such as abraders, polishing stones, pestles, etc. These are primarily "small stones used to process pigments or mix other substances on lapstones and netherstones" (Adams 2002:142). All netherstones, or base stones (Adams 2002:98), are recorded as metates. If the tool function(s) is unidentifiable, as with small fragments, the function is indeterminate. Reworked and reshaped artifacts with multiple functions are coded individually for all identifiable functions. Functions are coded in the reverse order of use, with the most recent function first. In some cases, as with reused and/or reshaped fragments, the primary function cannot be fully analyzed because it is obscured by consequential use(s).

It should be noted here that the function is based on broad sets following Adams' diagram (2002:Figure 4.6, 13, 98). Handstones are active, hand-held tools used to alter a contact surface or intermediate substance. Netherstones are passive tools upon which a contacting surface of intermediate substance is altered. Lapstones are identical to netherstones, but may not be worked with a handstone. Subgroups of these categories are defined by tool morphology, motor habits, and wear.

Number of Functions and Number of Wear Surfaces: These two variables record the number of identifiable functions and wear surfaces that an artifact has had. For metates, if the base is worked only to shape, then that surface is not analyzed as a wear surface.

Condition: Condition describes the artifact as whole, end fragment, medial fragment, corner fragment, internal fragment and corners only missing. Use wear surface attributes are analyzed to the furthest extent possible with ground stone flakes.

Wear Surface Rejuvenation: The presence or absence of pecking to resharpen the grinding surface is recorded for all wear surfaces.

Wear Surface Degree: The extent of use of each utilized ground stone surface is recorded as light, moderate, or heavy. While this is an admittedly subjective attribute, an attempt was made to objectify the values. "Light" refers to grinding wear that occurs only on the high points of a surface, leaving unused areas. The boundaries of the use surface are not well defined. The unmodified raw material texture is still visible after light use. "Moderate" refers to wear that is extensive enough to grind down most of the use surface, obliterating most of the original raw material texture. "Heavy" wear obliterates the raw material texture, resulting in a smooth, unbroken, often macroscopically striated surface. The use surface is well defined. Very fine-grained or cryptocrystalline materials can become polished and striated from heavy use. For rejuvenated tools, degree of wear is based on remaining ground areas, if any.

Wear Type: This variable refers to every individual type of wear observed on each ground surface. Adams has repeatedly stressed that tool form does not necessarily determine function, and that artifacts of identical morphology can be functionally distinguished only when macro- and microscopic wear patterns are carefully examined (1988, 2002, 2010). The location of wear is also essential to determining function, and may also indicate the nature of the substance being processed (Adams 2010:132).

Use surfaces are examined macroscopically and with 40X power magnification. Wear patterns are based on Adams' observations during use-wear experiments and employ her terminology (2002). Macroscopic values consist of grinding, striations, pitting, battering, and polishing. Microscopic values are grain shearing, melting, rounding, polishing and striations. The "melting" term is borrowed from Adams (1988:308) and is used to describe areas ground flat with the surrounding matrix, virtually eliminating all interstices and creating a melted effect. Utilized surfaces are compared to unmodified surfaces to eliminate confusion with natural erosion. Striations are additionally monitored for location and orientation.

MATERIAL TYPES

Material type categories defined for the ground stone assemblage (Table 5.1) include vesicular basalt, tuff, sandstone, limestone, quartzitic sandstone, igneous/volcanic (rhyolite, diorite, granite, and non-vesicular basalt), quartzite, and andesite. These are described in order of their abrasive quality with vesicular basalt the highest and andesite the lowest. Subtypes within these categories are defined by color and grain size. Hematite inclusions are ubiquitous in many materials, including basalt, quartzitic sandstone, quartzite, and sandstone.

Table 5.1. LA 159879, ground stone tools by material type.

		Abrasiveness								
		High							Low	
		Vesicular Basalt	**Tuff**	**Sandstone**	**Limestone**	**Quartzitic Sandstone**	**Igneous and Volcanic**	**Quartzite**	**Andesite**	**Total**
Handstones	Manos	11		6	1	14	22	10	–	**64**
	Abraders, smooth	–	–	–	–	2	2	10	24	**38**
	Abraders, coarse	3	–	1	–	–	1	–	–	**5**
	Pestles and crushers	–	–	1	–	2	–	–	1	**4**
	Polishing stones	–	–	–	–	–	–	–	2	**2**
Netherstones	Metates	2	–	8	–	7	8	–	5	**30**
	Lapidary	–	–	–	–	–	–	–	1	**1**
	Mortars	1	1	–	–	–	–	–	–	**2**
Miscellaneous	Shaped or painted stone	–	1	–	–	1	–	–	1	**3**
	Drilled stone ball	–	1	–	–	–	–	–	–	**1**
	Ornamental	–	–	–	–	–	–	–	1	**1**
	Raw material	–	1	–	–	–	–	–	–	**1**
Indeterminate		5	–	1	1	4	6	2	6	**25**
Total		**22**	**4**	**17**	**2**	**30**	**39**	**22**	**41**	**177**

No tool stone was observed on the surface of the site or in the fill of the backhoe trenches or excavated areas. The closest source was probably in or near the Mimbres River about a half mile (0.8 km) south of the site. The Mimbres River itself is sourced in the snowpack of the southwestern slopes of the Black Range, northwest of the project area. Successive flooding of the Mimbres River has formed thick, expansive fluvial deposits in the Mimbres Basin (Love and Seager 1996:81). These repeated, massive flooding episodes deliver gravels that tap from a variety of outcrops in the mountains bordering the basin. Most of the materials found in the LA 159879 assemblage outcrop within the Black Range, where a variety of volcanic, igneous, and sedimentary rocks occur. This and other mountain ranges on the north and east sides of the basin, such as the Pinos Altos Range, Cookes Range, and Big Burro Mountains, provide the materials that funnel into drainages coursing downslope into the project area.

Geologic studies in the area suggest that the volcanic and igneous materials found as tools or fire-cracked rocks at LA 159879 are most reliably sourced in the lag or alluvial gravels of the Mimbres River [Mimbres River]. Love and Seager (1996:84) note that gravels in the Deming area consist of well-rounded volcanic and granitic materials that are large compared to those found further south and east. Kuellmer (1954) provides an analysis of a geologic section of the Black Range near Kingston, New Mexico, in an area about 22.5 km (14 miles) east of the Mimbres River in the southwest portion of the mountains. The mapped zone lies a short distance east of an area where numerous creeks and unnamed drainages flow southwest toward the Mimbres River. These drainages cut through numerous and varied outcrops of volcanic, igneous, and sedimentary rocks. Later deposits in these higher elevation drainages have a high gravel content, some of which are specified as andesitic (Kuellmer 1954:86, Plate 1). Rhyolite is also ubiquitous in the Kingston area, found in "abundant intrusive bodies" (Kuellmer 1954:1). Sedimentary rocks occur here as well, consisting of massive gray to black limestone and sandstone. However, sandstones at LA 159879 are not likely to be sourced in the Black Range; this is discussed further below. Only one limestone artifact can be assigned to a secondary source based on its waterworn cortex; the second artifact does not retain cortex.

Vesicular Basalt

Vesicular basalt (n = 22) occurs almost exclusively as cobbles. Although this material is the most abrasive in the assemblage, most tools of this material utilize the unmodified cortical surface of the cobble, which is considerably less abrasive than a shaped, pecked surface. The vesicles of most basalt cobbles are small, measuring about 1–2 mm in diameter. Most basalt is gray or grayish-brown, with a few grading to brown and reddish-brown. The water worn cortex on vesicular basalt artifacts suggests the material was likely procured from the Mimbres River. Though specific sources for vesicular basalt were not found, basaltic andesites outcrop in the Black Range (Kuellmer 1954; Eggleston and Norman 1986) where the Mimbres River is sourced.

Pumice

This fine-grained, poorly indurated material is unsuitable for ground stone tools, and is likely being reduced to powder for an alternative function. All artifacts of this material (n = 3) are small, slightly rounded, angular lumps ranging from white to light tan in color. This volcanic pumice may be the "sugarlump tuff" constituent of the Mimbres Formation found in Cookes Range (McLemore et al. 1996:5). Tuff also outcrops along Iron Creek, a southwest-flowing drainage in the Black Range near Kingston that empties into the Mimbres River (Kuellmer 1954:Plate 1), suggesting that these particular pieces may derive from the Mimbres River. Tuff materials also outcrop in the Black Range (Kuellmer 1954:29) and may erode into the Mimbres River as a constituent of alluvial gravels.

Sandstone

The sandstone tools are remarkably uniform in texture and induration (n = 17). Virtually all sandstone material is fine-grained and very well indurated. While sandstone is typically considered a highly abrasive rock, those from LA 159879 are low to moderate in asperity. This is due to both natural and cultural factors, such as the fine texture, high induration, heavy tool use and low surface rejuvenation. The combination of these traits results in smooth, almost polished use surfaces on most tools. Sandstone occurs primarily as slabs, contrasting with the cobble form of other material types. Brown and gray sandstone dominates this material group, with single occurrences of red and white materials. Two tools are of indeterminate color due to heavy sooting. A wide variety of sandstone material outcrops in the Black Range, but the mountain sandstones are coarse-grained (Love and Seager 1996), and project sandstone is fine-grained. Also, tabular pieces of stone eroding from the Black Range and transported in the Mimbres River would presumably be unsuitable for metate manufacture. Perhaps the most likely sandstone source is within the Deming fan itself. Love and Seager (1996:91) state that coarse- and fine-grained sandstones occur in the "shallow stratigraphy" of the Mimbres River fans. It is not clear how proximate these outcrops may be to LA 159879, but the site is situated within the Deming fan of the Mimbres River, and may have been proximate to sandstone materials.

Limestone

Of the two limestone artifacts, one displays a very fine-grained, indurated character. No cortex is visible to indicate raw material form. The other is limestone breccia, very densely packed with a variety of macroscopically visible fossils. The limestone breccia is in cobble form, indicating a secondary source. Fossiliferous limestone occurs in the Kingston area, primarily in the Lake Valley limestone, which outcrops at the surface along Middle Percha and Iron Creeks, the latter emptying into the Mimbres River (Kuellmer 1954:20).

Quartzitic Sandstone

This material occurs almost exclusively in cobble form, with gray, tan, white and brown colors represented (n = 30). It is fine-grained and extremely well indurated, and may be identical to silicified sandstone. While it is slightly more abrasive in texture than quartzite, this material is not highly abrasive. Based on the predominance of waterworn cortex, it is likely derived from Mimbres River gravels. Orthoquartzite, "silica-cemented quartzose sandstone," occurs in the Bliss sandstone in the Black Range (Kuellmer 1954:12), where the Mimbres River and much of the gravel material originates.

Igneous and Volcanic

This category combines rhyolite (n = 8), diorite (n = 5), granite (n = 2), and non-vesicular basalt (n = 25) for a total of 39 ground stone artifacts. Each material is specified in the analysis, but all are combined here due to similar abrasion quality (referred to hereafter as igneous). Most of these materials are extremely dense and fine-grained, with smooth, non-abrasive cortical surfaces; however, none exhibit the conchoidal fracture qualities of andesite (below). Both rhyolite and granite outcrop in the Black Range, though granite is confined to "three small, isolated areas north and north-west of Kingston" (Kuellmer 1954:7). Rhyolite is more abundant, occurring in dikes in the Black Range (Kuellmer 1954).

Quartzite

Quartzite materials (n = 22) are very fine-grained or cryptocrystalline. It is exclusively present in cobble form, occurring in gray, brown, black, and tan colors, with one piece an unusual tan with orange banding. The source for quartzite could not be conclusively identified, but an outcrop known as Beartooth Quartzite is exposed in at least three areas in the higher elevations of the northern Mimbres Basin, one of which is proximate to the Mimbres River (Finch et al. 2008:193, Figure 2). Possibly, quartzite materials eroding from this outcrop may find their way into the Mimbres River and flow downslope into the project vicinity. Beartooth Quartzite also outcrops in the upper elevations of Cookes Peak (Kuellmer 1954:193).

Andesite

The project andesite is a dense, cryptocrystalline material (n = 44). It displays good conchoidal fracture, owing to the uniform, homogenous texture. These qualities make it suitable for chipped stone tools, but this low-abrasion material is used for ground stone tools as well. The vast majority of the andesite materials are cobbles (n = 41, 93 percent). Andesite materials are a prime constituent of outcrops in the Black Range (Love and Seager 1996), and may erode into the Mimbres River, which is sourced in these mountains.

MATERIAL SELECTION

Two trends are evident among the materials chosen for ground stone tools. First, materials with low abrasion qualities are preferred. This includes the andesite, quartzite, igneous, quartzitic sandstone, and limestone material groups, all of which are dense, highly indurated, fine-grained rocks with very low asperity. This material distribution is similar to ground stone from the San Pedro phase Donaldson Site in southeastern Arizona (B. Huckell 1995:61).

Secondly, most tool stone derives from lag or alluvial gravels of the Mimbres River. Where raw material form could be identified, cobbles predominate over slabs by a huge margin. This is true for each material group except sandstone, which occurs primarily in slab form.

While most materials are nearly identical in their low abrasion quality, this results not only from the inherent material qualities, but also from the cobble raw material form, the degree of use and virtual absence of surface rejuvenation. For example, quartzitic sandstone is coarser-grained and more abrasive than andesite, yet the two materials share identically textured smooth cortical surfaces. The cultural use of each material also illustrates the preference for low asperity. This is interesting in light of Adams' use wear experiments with vesicular basalt and more granular materials (1999:487). The vesicular basalt has the advantage of requiring little rejuvenation and adding very little grit to the material being processed. Grinding efficiency is quickly reduced by the vesicles filling with processed material, but is easily restored when the vesicles are swept clean. More granular materials, in contrast, retain grinding efficiency longer, even for a variety of foodstuffs, but add considerably more grit to the flour.

Based on the high percentage of waterworn cortex in the assemblage (n = 109, 60.5 percent), most raw material was probably procured from the Mimbres River. The size and weight of ground stone raw material doubtless factors into a preference for nearby sources. Love and Seager (1996:81) describe the huge fluvial fans deposited in the Deming basin by the Mimbres River during flooding episodes. Given the array of materials outcropping in the Black Range where the river is sourced and the extensive fluvial deposits in the project vicinity, some tool stone was likely to have been more readily available, while others may have been procured proximate to the Mimbres River. Virtually all of the project ground stone materials occurs as cobbles, with the notable exception of sandstone. Most sandstone is in slab form, indicating procurement from a primary source.

GROUND STONE ASSEMBLAGE

Considering the number of factors influencing the integrity of the assemblage, site excavations yielded a surprising number of artifacts complete enough to provide significant information. The ground stone assemblage totals 177 tools. The handstone tool group consists of manos (n = 64), smooth abraders (n = 38), coarse abraders (n = 5), pestles/pestles (n = 4), and polishing stones (n = 2). The netherstone tools consist of metates (n = 30), a lapidary stone (n = 1), and mortars (n = 2). The miscellaneous tools are shaped or painted stones (n = 3), a possible pendant (n = 1), a raw material fragment (n = 1), a drilled stone ball (n = 1), and indeterminate fragments (n = 25).

Handstones

Manos (n = 64)

The mano assemblage has an interesting mix of traits. In some respects, the mano tool group is quite uniform, and in other respects, is quite variable in intriguing ways. The most obvious similarity among manos is that virtually all are one-hand tools (Fig. 5.1). This is true of whole tools and appears to be the case for many fragments based on the edge curvature. There is also a clear preference for materials with low to minimal abrasion qualities. However, as noted in the introduction, these minimally abrasive types may not reflect the full range of materials used at the site.

Manos are manufactured from vesicular basalt, sandstone, limestone, quartzitic sandstone, and igneous/volcanic rocks (Table 5.1). The igneous/volcanic category includes non-vesicular basalt (n = 19), diorite (n = 1) and brown rhyolite (n = 2). These material groups are listed in order of abrasive quality, demonstrating that the majority of manos are made from low abrasion materials.

Raw materials are primarily cobble forms (n = 48; 75 percent). Even the vesicular basalt manos are cobbles and used on less abrasive cortical surfaces. The preference for rather smooth, low abrasion surfaces is interesting in view of the grass and sedge seed phytoliths found on ground stone tools (Appendix 3). These materials may be more suitable for processing of fragile seeds, as seeds become lodged in the vesicles or interstices of coarser-grained materials; however, vesicular basalt also adds less grit

Figure 5.1. One-hand manos.

to the food and the surface is more easily restored during use (Adams 1999:487).

An interesting dichotomy exists in terms of mano shaping modification. Whole manos tend to be either fully shaped or completely unmodified. Only a handful of tools are partially shaped. Many fragments could not be analyzed for shaping. Though both shaping extremes characterize the mano group, the majority of tools employ natural, unmodified forms. Manos that are shaped display carefully pecked and ground round or oval forms. Only one subrectangular mano is present, and about half could not be analyzed for plan shape.

Less than one-quarter of all manos are whole (n = 14, 22 percent). Most are fragmentary, over half of which are fractured from heat exposure. This may indicate that manos were cached in or near thermal features, used secondarily in thermal feature construction following mano use, or discarded in thermal features as trash.

Manos at LA 159879 are generally small, even for one-hand forms (Table 5.2). Mean dimensions are 10.7 by 9.2 by 5.4 cm, and weight 823 grams. There is considerable range in length, with cobbles as small as 7.3 cm used as manos; although this is based on a single sandstone tool. However, the standard deviation is below 2 cm for all dimensions, indicating a considerable degree of size uniformity.

Eight of the manos have secondary functions. Five manos display hematite stains, though resulting from different functions. Four of these have pigment stains on the broad surfaces and/or sides of the tool apparently the result of processing pigment. Two of these also have battering wear on the ends where the pigment stains are found, possibly from crushing hematite, seeds, or from hammerstone use. One fragmentary tool, however, appears to have been painted, as hematite stains reside over most of the broken and ground surfaces. One mano was used as a hammerstone on the ends. One vesicular basalt mano retains unidentified rounded brown particles inside the vesicles that appear to be remains of processed material. Two manos have battering and crushing wear on the perimeter. This wear could result from seed crushing or hammerstone use.

Interestingly, the majority of manos are unifacial (n = 35, 55 percent), with fewer bifacial tools (n = 26, 41 percent). Two bifacial manos are also ground on the perimeter, and one atypical cobble mano has four adjacent wear facets. This tool appears to have functioned both as a mano and abrader.

Mano surfaces (n = 63) tend to be very similarly contoured. Most are biaxially biconvex on both the ventral and dorsal sides (88 percent). Others are biaxially flat (9 percent), convex on one, flat on the other (3 percent), or indeterminate (n = 1). This suggests two things: that most manos were moved with a rocking stroke, and that the companion tool was a basin metate. Convex widths indicate a rocking stroke where the edges of the mano are lifted at the end of each stroke (Adams 2002:41). This lifting motion breaks mano contact with the metate. Similar rocking strokes were noted on Middle Archaic–period manos from Ventana Cave and Picacho Reservoir (Morris 1990; Haury 1950, cited in Morris 1990). The wear surface morphology led Haury (1950) to propose that the manos were rocked laterally, possibly as the best method of reducing hard native seeds. Flat contours result from use with a slab metate, but also occur on new tools that have not developed marked convexity. Length contours can inform on the type of metate used. Markedly

Table 5.2. LA 159879, measurements of whole manos.

	Length (cm)	Width (cm)	Maximum Thickness (cm)	Minimum Thickness (cm)	Weight (g)
Mean	10.7	9.2	5.4	3.1	823.2
N	14	14	14	8	14
SD	1.9	1.3	1.3	1.3	416.9
Minimum	7.3	7.4	3.3	1.4	251.0
Maximum	14.2	11.4	7.6	4.8	1657.0
Range	6.9	4.0	4.3	3.4	1406.0

SD = Standard Deviation

convex contours are associated with basin metates, though they also indicate heavier use. Basin manos also lack the ground ends resulting from grinding against a trough metate.

Use surface striations are also critical in determining the type of mano manipulation. Linear striations overwhelmingly dominate tools displaying this wear type (n = 59, 91 percent) denoting the preference for a reciprocal stroke. These linear striations extend unbroken across the entire use surface. Random striations (n = 6, 9 percent) are evident on very few manos, and are more characteristic of abrading tools. Most linear striations are parallel to the mano width, but several tools are striated lengthwise. These lengthwise striations denote an atypical movement, with the mano moved at two angles perpendicular to one another. This type of stroke occurs most often on rounder manos with length and width nearly equal, though one oblong tool displays this wear. The lengthwise striations are usually paired with a second surface that is striated along the width. These differentially striated manos may have been used for two different tasks related to processing a single substance. For instance, the lengthwise striations may result from hulling fragile grass seeds against the sides of the basin, and the width striations from seed grinding. A stroke of this type may resemble one illustrated by Adams (1999:Figure 2, 482). The predominance of linear striations on mano surfaces is reflected in basin wear patterns as well, which are exclusively linear. Random striations, while very infrequent in the mano group, may also result from a circular stroke in a basin metate.

Surface rejuvenation is virtually absent in the mano assemblage. Virtually all mano surfaces are unrejuvenated, regardless of the degree of wear. Tools with light, moderate or heavy use are uniformly void of this feature. The lack of rejuvenation is also constant among material types as well. It is possible that some variety in abrasion levels of tools was achieved through material quality. This may be partially demonstrated by the use degree of various materials (Table 5.3). More abrasive materials such as vesicular basalt and sandstone have light to moderate wear, while finer-grained, less abrasive materials are typically more heavily worn.

Obviously this is related in part to the way certain materials wear, as coarser-grained materials require longer use to show heavy wear compared to finer-grained materials. However, it is also possible that manos of different materials were used for stages of processing. This may be evidenced by the presence of grass phytoliths on variously textured and contoured tools. This also points out problems with classifying function based on wear surface attributes and material qualities. Grass seed was processed with tools that differ in all of these attributes, with the latter two not even in the mano category. Then again, the phytolith analysis identified a range of possible grasses that may have been processed; these seeds may have required different tools.

Some characteristics of the mano assemblage may inform on site use patterns. A study of architectural sites in the Black Range area north of Deming concluded that ground stone at regularly used architectural sites differ from those at fortuitously occupied rockshelter sites (Nelson and Lippmeier 1993). Ground stone tools cached at regularly used sites were more likely to be manufactured from durable materials such as quartzite, granite, basalt, and rhyolite. Shaped manos that remained at the site between foraging trips were also more likely to conform to a standardized design (Nelson and Lip-

Table 5.3. LA 159879, mano wear surface use degree by material.

	Wear Surface Use Degree			
Material Group	**Light**	**Moderate**	**Heavy**	**Total**
Vesicular basalt	6	8		**14**
Sandstone	4	3	1	**8**
Limestone		1		**1**
Quartzitic sandstone	3	7	15	**25**
Igneous and volcanic	10	10	11	**31**
Quartzite	2	6	9	**17**
Total	**25**	**35**	**36**	**96**
Percent	**26%**	**36%**	**38%**	**100%**

pmeier 1993:301). The LA 159879 mano assemblage reflects this material selection. Shaped manos at LA 159879 also reflect a great degree of uniformity, but expedient tools are used as well.

A one-hand mano-pestle was submitted for starch and phytolith analysis (FS 449-1). The use surface of this tool retained corn and sedge seed phytoliths, indicating the tool was used to process these materials. The functional roles of tools with positive starch and phytolith analysis are addressed in a separate section below.

In summary, LA 159879 manos display consistency in dimension, material abrasion quality, and use-surface contours and wear patterns. One-hand manos manufactured from minimal to moderately abrasive materials predominate. Wear surfaces indicate that most manos were manipulated with a rocking reciprocal stroke and used on a basin metate. This is corroborated by the dominance of basin metates with reciprocally worn basins.

Smooth Abraders (n = 38)

Based on the preceding discussion, it is evident that there is functional overlap between manos and abraders; or perhaps more specifically, similar foodstuffs may be processed with differently textured tools. That said, manos and abraders exhibit such a great degree of difference in material type, use-surface morphology, and wear, that it is important to separate these tools for analysis purposes.

The primary difference between abraders and manos is a combination of material type and wear (Fig. 5.2). The abrader group is typified by these dense, fine-grained or cryptocrystalline materials: andesite, quartzite, quartzitic sandstone, rhyolite (n = 1), and diorite (n = 1) (Table 5.1). The quartzitic sandstone tools are included based on small size and wear, which appears to be tribochemical. Tribochemical wear is an accumulation of films and oxides deriving from the processed material that adheres to the use surface, resulting in polish (Adams 2002:31–32).

Abraders are also distinguished from manos based on use-surfaces that are almost invariably polished and striated, even on lightly worn tools (Fig. 5.2[d, g]). Smooth abraders tend to be slightly smaller than manos and weigh considerably less, with mean weight about a third that of manos (Table 5.4).

These tools have some characteristics of Adams' abraders. She notes that the most important attribute is texture, as these tools are used for abrading and polishing (2002:81). Adams suggests that some tools of this type may have been used in axe manufacture based on use-wear experiments as were the occurrence of abraders with axes in various stages of manufacture at Turkey Creek Pueblo. While Adams describes a specific morphology and manner of manipulation for these tools, she also stresses that artifact form is of far less importance than texture. Wear patterns resemble those produced from working wood, which produces rounded grains that are visible with 40X power magnification.

Smooth abrader wear differs from mano wear in several ways. Smooth abraders are much more likely than manos to display random striations. Where mano striae tend to be deep and extend across the entire use surface, abrader striae are shallow and fine. Abrader striae are more likely to occur in short, multidirectional patches resulting from a random stroke. Full-length linear striae also occur, but in nearly equal numbers to random striae (46.6 percent and 53.3 percent respectively). Microscopic examination indicates that grain rounding, polishing, and melting are prevalent. Grain rounding results from processing softer materials such as wood or green bone (Adams 2002:37–41). Grain melting and grains sheared even with the matrix can result from tribochemical wear, which results from grinding oily substances such as sunflower seeds or hide processing. One possible example of tribochemical wear is shown in Figure 5.2[b].

Abrader surface morphology also contrasts significantly with that of manos. Unmodified cortical surfaces are ground on most abraders (n = 36, 94.7 percent), as opposed to under half for manos (n = 31, 48.4 percent). This prevalence of utilized cortical surfaces indicates a selection for comparatively smooth textured materials. Most abraders were made from unmodified cobbles. Shaped abraders were modified exclusively by flaking. Interestingly, these abraders appear to be flaked to prepare the grinding surface, rather than to shape the entire tool (Fig. 5.2[a]). The flake ridges of these tools are heavily striated and polished, suggesting that this uneven surface was the most efficient for some type of processing. Though these surfaces appear prepared, it is also possible that serviceable flakes were produced as well.

Other abraders appear to have been used in scraping activity (Fig. 5.2[c, e]). Three tools were

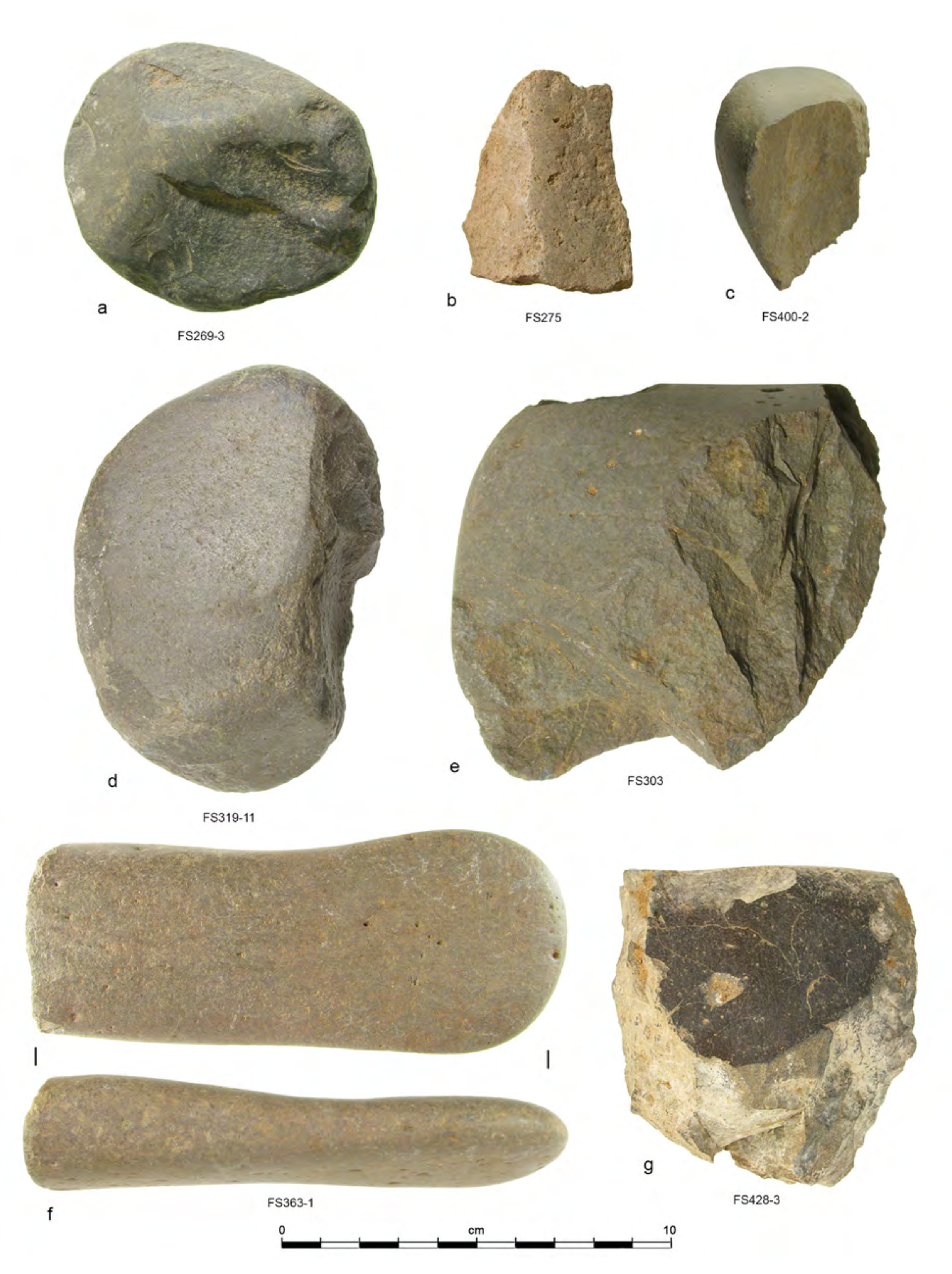


Figure 5.2 [a–g]. Abraders.

Table 5.4. LA 159879, measurements for whole smooth abraders.

	Length (cm)	Width (cm)	Maximum Thickness (cm)	Minimum Thickness (cm)	Weight (g)
Mean	8.6	5.9	3.82	1.4	272.7
N	15	15	15	1	15
SD	2.1	1.5	1.1	?	157.7
Minimum	5.3	3.3	1.9	1.4	81
Maximum	12.8	9.9	6.2	1.4	564
Range	7.5	6.6	4.3	0	483

SD = Standard Deviation

flaked to form 60-, 65-, and 76-degree edge angles. These edges were flaked and ground, and the adjacent cortical surface was heavily ground, striated, and polished. The convex cortical surfaces of these tools were also polished and striated. The location and type of wear on these tools may result from scraping relatively soft materials such as hide, wood, or green bone.

Abraders were also more likely than manos to serve multiple functions based on wear patterns. While all abraders were used most recently to grind, almost one-third (n = 13, 31.7 percent) were also used as hammerstones (n = 8), pestles (n = 2), edge scrapers (n = 2), or combinations of these functions. One cobble abrader was completely pigmented on one surface, while the reverse was devoid of hematite (Fig. 5.2[f]). The pigmented surface of this same tool is heavily striated from the rounded end about halfway across the length of the tool. Most tools display biaxially convex use surfaces, with flaked surfaces, flat and irregular contours representing the minority. As with manos, abraders are more likely to be used on a single surface, but differ from manos in that three, four, and five surfaces are more frequent (n = 6, 14.6 percent). In contrast, less than 5 percent of all manos are utilized on more than two surfaces (n = 3, 4.6 percent).

Eighteen abraders are whole, including two reshaped and reused fragments. One of the reshaped tools was formed from a metate fragment. As with manos, the majority of fragmentary abraders was heat fractured, and likely from the same possible causes.

Coarse Abraders (n = 5)

These tools share some traits with smooth abraders, primarily their small comparative size with manos. Coarse abraders, as the name implies, were made from more roughly textured materials such as vesicular basalt and non-vesicular basalt (Table 5.1). All but one of the vesicular basalt tools is fragmentary. Coarse abraders also differ from smooth abraders in that all five tools are either lightly or moderately worn.

While the sample size is quite small, it is interesting to note that none are heavily ground, which is interesting in view of the phytolith analysis. One of these tools from the Feature 3 activity area had grass-seed phytoliths. Although fragmentary, this tool was probably used to process grass seed based on the presence dendriform phytoliths (Appendix 3). Dendriforms occur in the bract material that surrounds the seed of some native and wild grasses and can remain on the surface of a tool used to process the seed. A second tool fragment from Feature 7 retained dendriform phytoliths from grass and corn phytoliths (Appendix 3).

Also of note is the presence of light polish on four of the five tools, which is uncommon on tools with light or moderate wear. As noted above, this may result from oily substances contained in the processed grass seed. Unlike smooth abraders, coarse abraders do not display evidence of multiple functions, but because most tools are broken, this may not reflect the full range of use.

While most coarse abraders are fragmentary, they share several morphological traits. All five tools were made from unmodified cobbles and used on one or two biconvex cortical surfaces. The single whole tool is small, measuring 5.4 by 4.8 by 3.8 cm and weighing 92 g. Two coarse abraders were submitted for starch and phytolith analysis (FS 299 and 425). The use surface of both tools retained grass dendriform phytoliths, indicating the tool was used to process this material. FS 425 also had corn phytoliths. The functional roles of tools with positive starch and phytolith analysis are addressed in a separate section below.

Crushers (Mesquite Pestles) (n = 2)

These two artifacts are among the most distinctive of the assemblage, one from the Feature 3 activity area and the other from near Feature 5. Both tools were shaped from large, heavy, oblong, brown quartzitic sandstone cobbles. The Feature 5 tool was used on both ends, and the Feature 3 tool was used on one end. The ends have crushing and grinding wear, possibly from pulverizing resistant foodstuffs such as mesquite seeds.

The Feature 5 pestle is the smaller, but heavier, of the two, measuring 28.3 by 9.8 by 6.8 cm, and weighing 3200 g. The entire surface was shaped by shallow, evenly spaced pecking, creating a smooth, elongated oval form that is biaxially convex on both surfaces. The cross-section is nearly spherical. Both ends of the cobble have been used in crushing activity. The pestle ends display well defined, markedly convex facets. Their intersection with the broad surface is easily traced around the tool. Microscopic examination shows that the highest grains are rounded and polished, possibly from the buildup of residue from processed materials. This is coupled with fatigue wear, which shears grains off at varying elevations, leaving deeper interstices. The striations on the use ends provide clear evidence that the tool was rocked reciprocally, either side-to-side or back and forth. These striations are linear, running lengthwise along the sides and continuing around the convex end (Fig. 5.3.). The tool may have been held vertically inside a mortar and rocked reciprocally. This has resulted in fairly deep grooves on the sides of the ends where the tool contacted the mortar sides. There is no evidence of rotary motion.

The wear on the broad surfaces of the Feature 5 pestle differs from that on the ends. The entire tool is striated lengthwise from end to end. These striations intersect with the edge of the crushing facets at each end, running down the entire length and circumference. They are notably present even in slightly concave areas, and continue right down to the edge of the crushing facet. It is not clear if these striations are the result of manufacture or use and suggests contact with a malleable substance such as hide. This would mean the tool was always manipulated parallel to the length. These lengthwise, linear striations could be produced using a vertical pounding motion in a cylindrically shaped mortar.

Russell notes that the pestles used by the Pima "varies in size from the small stone the size of one's finger to the great cylinder weighing 9.1 kg (20 lb) that requires both hands to yield it" (1908:109–110). Wood mortars are used for pounding mesquite pods, but the hard seeds require a stone pestle (Russell 1908:74–75). The illustrated stone pestle

Figure 5.3. Quartzitic sandstone pestle (FS 361-1).

resembles that from Feature 3 (Russell 1908:109–100, 109, Figures 13c, 29). According to Russell, the mortar is the most important tool for the Pima and mortars and pestles are used to process a range of materials. These include mesquite, cotton, quail plant, wild gourd root, pimeria seeds, and medicinal worms (1908:99, 75, 77, 79, 191, 265). Any one or all of these materials contain residue that could create tribochemical wear on pestles.

The broad surfaces of the Feature 5 tool display strong evidence of tribochemical wear (e.g., Adams 2002:31–32). Material grains are sheared flat, "melted" into a flat, almost glassy, polished surface. This polished, glassy sheen may also result from handling, as the tool would have been grasped in two hands and used in a pounding motion. The sheen completely encircles the tool at one end, and about 75 percent of the circumference at the other end.

The plan shape and end wear on the Feature 5 tool appear similar to a pestle found at the Wood Canyon site, an Early Agricultural–period settlement south of Silver City. The Wood Canyon tool is pecked to a cylindrical cross-section shape with a tapered end (Van Hoose 2000:434, Figure 17.14). The tapered end is extensively ground and battered. The Wood Canyon artifact is slightly smaller (27.7 by 10.2 by 10.1 cm; 2774 g) than the Feature 5 Deming site artifact. Although the weight and dimensions of the tool seem to be ideally suited for use as a rocker mano, the wear does not support this.

The second pestle from the Feature 3 activity area is the larger, but lighter of the two tools (Fig. 5.4). It also differs morphologically. Where the Feature 5 tool reflects the cylindrical form typical of pestles, the Feature 3 pestle is an elongated, somewhat flattened, triangular form. The quartzite river cobble from which it is made is bimarginally flaked along the sides and base. The ground wear-facet at the end is well defined and striated parallel to the length. Thus, wear patterns of the two project pestles indicate similar use despite some differences in morphology. Further corroboration is provided by the presence of a large quantity of mesquite pollen in a sample taken from fill beneath the tool (Appendix 3, FS 294). It is also interesting to note that the tool stands vertically in a very stable position on the shaped base.

The variations between the two pestles from LA 159879 are not unusual given the wide variation documented for this tool type in ethnographic studies (Schroth 1996:66 and references therein). Pestles range from unmodified cobbles to fully shaped, polished, cylindrical forms. Wooden pestles are also common, but are generally more club-like in form, particularly those used in perforated gyratory mortars. Such tools are used for mesquite processing in the Piñacate region of Sonora, Mexico, near the northernmost coast of the Gulf of California (Hayden 1969:Figure 1). The indigenous Areneños Pinacateños processed mesquite

Figure 5.4. Quartzitic sandstone pestle (FS 304).

with perforated mortars, which evolved from flat to conical forms over thousands of years until their use ceased about AD 1100–1200 (Hayden 1969:160). The wooden pestles developed projections from use in the perforated mortars which provided leverage against the sides of the mortar. A very large stone pestle is photographed in use by a Pima woman, but the cross-section shape cannot be viewed in the image (Hrdlicka 1908:Plate VIII, 42).

A detailed study of bedrock mortar and pestles at the Los Morteros Site in the Tucson Basin revealed interesting characteristics of both tools (Wallace 1983). The Los Morteros pestles are similar in size and shape (Wallace 1983:Figures 14–15, 162–164) to the Feature 5 pestle. The pestles were consistently manufactured from materials that are harder than the bedrock mortars in which they were used. This contrasting hardness resulted in differential wear between the two tools, creating a "poor pestle-to-mortar fit," which decreases the efficiency of the grinding (Wallace 1983:160, 166). The length of the wear on the Los Morteros pestles varies; in some it was restricted to the ends, and in others the wear extended up the length of the tool. Wallace refers to wear striations that indicate vertical pounding use, though the orientation is not specified (1983:165). Yuman pestles are also similar morphologically to the Feature 5 tool, but are considerably larger (Schneider 1996:Figure 3, 301), as are those of the Pima (Russell 1908:Figure 29, 109).

Paint Pestles (n = 2)

Both of these tools are tentatively classified as paint pestles based on the presence of hematite stains. The tools are made from unmodified cobbles of andesite and indurated gray sandstone. Both are medial fragments and do not retain the cobble ends, which may have displayed battering wear from pigment processing. The sandstone pestle was moderately ground on two opposing surfaces, both of which retain pigment. The andesite tool was lightly ground and randomly striated on a single surface. Microscopic examination indicates that the grains of both surfaces are sheared. The andesite tool is burned and sooted, and the sandstone tool is fractured from heat exposure.

Polishing stones (n = 2)

The small size, andesite material, and polished surfaces of these artifacts identify these tools as polishing stones. Both were made from unmodified cobbles. The whole tool is ground and polished on a single slightly concave surface (5.3 by 3.0 by 1.5 cm; 27 g). The fragmentary tool is bifacially ground, polished, and randomly striated on convex surfaces (6.9 by 2.7 by 1.9 cm; 56 g).

Netherstones

Metates (n = 30)

Most of the Deming metates are small and either edge or internal fragments, where a type could not be identified (n = 23). Of those that can be typed, all are basin metates including a possible preform (n = 7). While basin metates are the only type in the recovered assemblage, larger, slab metates were observed in private collections near the site. This may indicate that the LA 159879 metate assemblage was more variable but the larger forms were taken from the site surface, which could suggest they are not contemporaneous with the basin metates recovered during excavation.

Basin Metates (n = 7)

Basin metates were manufactured from indurated sandstone (n = 2), quartzitic sandstone (n = 1), granite (n = 1), nonvesicular basalt (n = 1), andesite (n = 1), and vesicular basalt (n = 1). Four basin metates are whole, including the possible preform (Fig. 5.5) and three are small edge or internal fragments. Two of the basin metates have hematite pigment stains on the ground surfaces. All of the whole basin metates were shaped to some degree, though with far less attention than the manos were. All of the basin metates are made from fairly thick slabs that, though somewhat angular, display waterworn cortex suggesting the Mimbres River gravels was their source. Shaping modification is minor, restricted to flaking portions of the perimeter. Only the basin use-surfaces display more meticulous shaping modification, in the form of pecking.

With a single exception, all of the basin metates are bifacial. The exception is a basin/flat slab combination. The flat surface is hematite-stained (Fig. 5.5[a]). Perhaps the most distinctive aspect of basin metates is the linear striations on the grinding surfaces. Every basin metate was ground using a reciprocal stroke; a rocking stroke is evident in lengthwise concavities. One possible exception is where the small, shallow basin of a unifacial metate

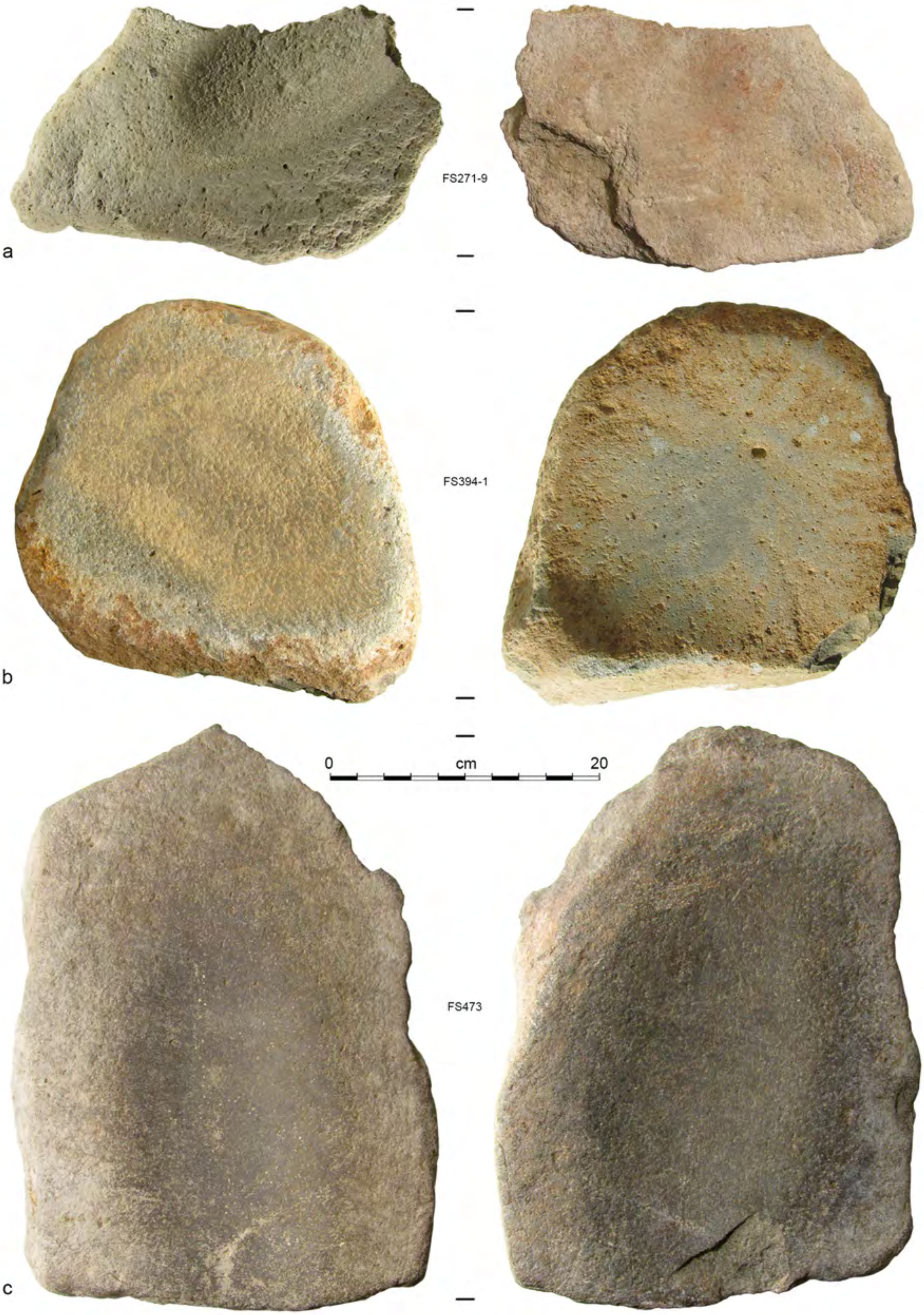


Figure 5.5 [a–c]. Basin metates.

would probably not accommodate a rocking stroke, although it has linear striations that denote a reciprocal stroke.

Linear striations invariably extend the full length of the basin, sometimes slightly overlapping the edges. This pattern changes on the basin borders where a flat ground area is randomly striated. This border varies in width depending on the size of the metate, but usually measures about 3 cm. Basin borders could reflect shaping modification or they could have served as small use areas.

The shape and wear patterns of the LA 159879 basin metates may result from seed-processing methods similar to those used by Australian Aborigines. Large quantities of grass and sedge seeds are collected and husked by rubbing the seeds between the hands (Cane 1989:105). Both dry and soaked seeds are ground using rounded or domed water-rolled pebbles (Cane 1989:112–113). The rocking reciprocal stroke used to grind the seeds produces a long, narrow groove in the metate that is deepest in the center. The wear surface progresses from a broad, flat area to a deeply concave groove. The task becomes increasingly difficult, as the user's hands rub against the metate, and the ground seeds do not flow down off the surface as when the basin is shallow. This necessitates shaping a new groove into the metate, which results in concentric, layered grooves. While layered basins are not represented at LA 159879, other aspects of the aboriginal seed processing method appear to compare functionally.

Surface rejuvenation is more prevalent on basin metates than manos. Four of the six ground basins are rejuvenated. One additional basin has rejuvenation only on the borders, with the basin ground smooth. This tool was clearly rejuvenated at some point, but was heavily used without modification afterwards. Interestingly, all bifacial basin metates have one rejuvenated and one unrejuvenated surface, and none of these tools are identically rejuvenated on both sides (Fig. 5.5[b, c]). This may indicate a preference for varied surface texture, or simply an alternating use sequence. Only the unifacial granite metate is freshly rejuvenated, overlain with very light wear.

One bifacial basin metate also served as a palette. One ground basin has hematite stains combined with an oily residue, possibly the pigment binding agent. The bifacial metates are deeply worn, some to thin cross-sections ranging from 1.1 to 4.2 cm thick. Basin depth does not vary greatly, ranging from 0.6 to 1.8 cm. Basins of bifacial metates are invariably ground parallel to one another, which would increase ease of use and provide most efficient use of available surface area. Dimensions of the four complete metates illustrate the preference for small size (Table 5.5).

Basin metates may have been preferred as the most efficient means of processing a wide variety of cultivated and wild plant materials. Use-wear experiments with basin, slab, and trough metates and manos led Adams to conclude that basin metates are best suited for grinding a range of materials. The basin keeps material from sliding off the metate, permitting more efficient grinding (Adams 1999:485–486). However, basin manos and metates are also the least efficient in terms of time required to process seeds into flour and also the most physically tiring (Adams 1993:338, 1999:485–486).

Basin Preform

The basin preform (n = 1) is somewhat dubious. It is a large angular piece of vesicular basalt with a very large flake removed from one edge that does not appear to be the result of shaping. The stone is heavily coated with caliche except for one irregular, flaked oblong concavity (7 by 20 cm) where raw material is exposed beneath the caliche. The irregularity and the somewhat decomposed nature of this area suggest that it may be natural, but the chipped area is restricted enough to suggest possible cultural modification.

Metate Fragments

Metate fragments (n = 23) are primarily internal portions of the ground surface (n = 18). Five are edge fragments too small to be further typed. Metates are more likely to be manufactured from more abrasive materials than are manos, though by a slim margin. Vesicular basalt (n = 1), sandstone (n = 6), quartzitic sandstone (n = 6), rhyolite (n = 3), nonvesicular basalt (n = 3), and andesite (n = 4) are represented among fragments. Metates also differ from manos in that unmodified cortical surfaces are rarely used; most of the wear is on shaped surfaces. Two of the metate fragments were shaped by flaking on the extant edge. Most are too fragmentary to be analyzed for shaping.

Most fragments have a single concave ground surface (n = 14), while a minority are bifacially worn (n = 9). Heat fracturing has removed the opposing surface on many fragments, so bifacial metates may

Table 5.5. LA 159879, whole basin metate dimensions.

FS	Provenience	Material Type	Metate Type	Length (cm)	Width (cm)	Maximum Thickness (cm)	Minimum Thickness (cm)	Weight (g)
270	257.36N 651.41E, Strat 2	Vesicular basalt	preform	40	24.4	13.2	not used	12100
394	Feature 9 area	Nonvesicular basalt	bifacial	30.6	26.0	8.3	4.2	6800
436	General surface	Granite	unifacial	24.6	22.2	7.9	na	6500
473	382.37N 542.37E	Andesite	bifacial	39.4	29.0	7.5	3.1	10600

be underrepresented. Of the 30 use-surfaces represented among fragments, most are biaxially concave (n = 20) and a minority are biaxially flat (n = 10). Heavy use dominates (n = 18), with moderate (n = 10) and light (n = 2) wear less frequent. Only one had surface rejuvenation, but this attribute may be underrepresented as the entire surface is not represented in fragments. Among striated surfaces (n = 23), most are linear, denoting reciprocal strokes (n = 20), with three that are randomly striated. One bifacial sandstone fragment has impact scars on one surface that appear to be from use as an anvil. Six metate fragments are fractured from heat exposure. One additional metate fragment has hematite stains on the ground surface.

One sandstone metate fragment (FS 226) from a hand-excavated grid unit in the southern portion of the site produced the only grass-seed starch found at the project (Appendix 3). The starch was on a surface displaying parallel striations, indicating a reciprocal stroke. As with manos, evidence of grass-seed processing occurs on slightly more abrasive materials. Functional implications of ground stone with positive starch and phytolith remains are addressed below.

Lapidary Stone or Polisher (n = 1)

This tool from near Feature 5 was tentatively classified as a netherstone based on the size (23.7 by 18.2 by 5.3 cm; 4200 g), and a concave use surface (Fig. 5.6). However, the wear on this surface suggests that it may have been manipulated as a handstone. The tool is made from a large, subrectangular basalt cobble that is slightly wedge-shaped in both cross-sections. The smooth, unmodified cortical surface was used on both sides.

The most extensively used surface has a slightly concave center bordered by convex edges that form the cobble sides. Wear occurs in both the concavity and the bordering convex edges. The entire surfaces is randomly striated and polished, most heavily on the convex edges. This suggests that the tool was used as a handstone to work a soft material such as hide. This type of use may be more likely to overlap the convex edges as the stone pushes down into the softer material. However, the concavity is also clearly worked, as the grains are sheared, rounded and polished, possibly reflecting a combination of fatigue and tribochemical wear.

The reverse side has identical, but more extensive wear. This surface also has a small, shallow concavity, though it is more heavily striated than the above concavity. As with the first surface, polish and striations are most evident on the edges and sides. The tool is considerably larger than hide-working tools identified by Adams (2002:96). Wear inside the interstices is the distinguishing characteristic of the tool type, and is present on the Deming tool. The size and weight of the tool would presumably make for difficult maneuvering, as no ergonomic features are present. While the tool seems to have functioned as a netherstone, the edge wear seems incompatible with this function.

Mortars or Cupules (n = 2)

Both of these tools are small edge fragments, possibly from mortars (Fig. 5.7). Both artifacts were recovered in and around the Feature 3 structure, and Features 10, 11, and 12 fire pits. One is from the surface, the other from Stratum 3. The vesicular basalt artifact is roughly flaked inside the mortar bowl, presumably for shaping. The exterior is smooth and polished, possibly from shaping and handling.

The white tuff mortar fragment has vertical

Figure 5.6. Lapidary stone/polisher (FS 361-2).

gouges inside the mortar bowl, probably from shaping. No rim portions remain. Both of these fragments are markedly concave, suggesting a diameter of less than 5 cm. The small diameter of these tools is comparable to cupules found at Los Morteros in the Tucson Basin, ranging from 0.5 to 2.0 cm in depth and from 1.0 to 7.0 cm in diameter (Wallace 1983:144). The Los Morteros project documented bedrock processing areas riddled with mortars, cupules and metates, with the former two most often associated. Some of these areas were intensively used, with the individual features thought to be associated with mesquite processing during the Tanque Verde phase (AD 1225–1350) (Wallace 1983:148, 171). They are irregularly shaped, sometimes with a pointed tool. While the Los Morteros cupules are formed in bedrock, there are similarities in morphology and dimension. Cupules are thought to have been used for pestle manufacture or for grinding or pounding wild plant resources such as herbs or medicinal plants (Wallace 1983:179–180).

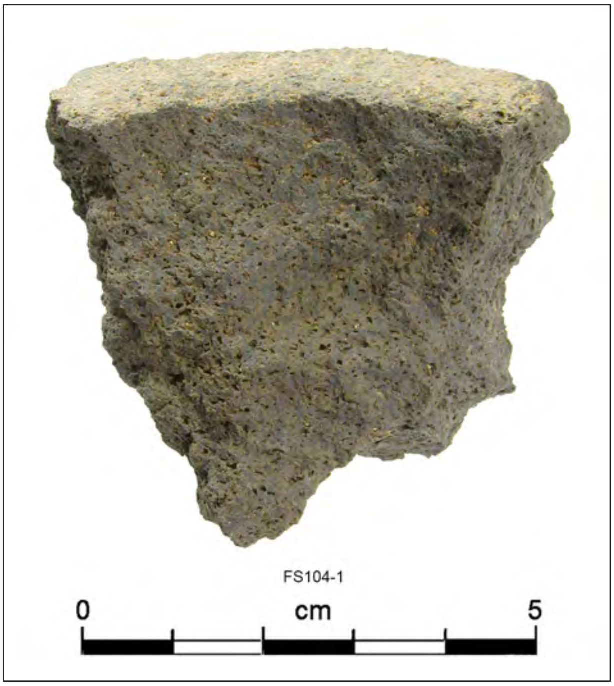


Figure 5.7. Possible mortar, edge fragment (FS 104-1).

Miscellaneous

Shaped and Painted Stone (n = 3)

These three artifacts differ considerably from one another, but are identical in that all appear to represent ritual function. The artifact from grid-unit excavations near Feature 3 is a white tuff stone (7.7 by 5.9 by 4.7 cm; 169 g) that was ground over most of the surface into an oblong shape. It is cracked and flaked, but otherwise intact.

An artifact recovered in general collection of the central site area is a whole, elongated, andesite cobble (23.0 by 3.1 by 2.2 cm; 1566 g) that is lightly ground and striated parallel to the length axis. The grinding appears to be the result of shaping, rather than use. The reverse side is unmodified. It was recovered in general collection.

The last example is from the fill of Feature 3 and is an end fragment of a small gray quartzitic sandstone cobble (4.1 by 1.9 by 1.2 cm; 12 g). The entire surface of the stone, except for the broken edge, is coated with hematite pigment. The cortical surface is also polished, likely from handling, as the grains are not sheared or rounded from grinding wear.

Drilled Stone Ball (n = 1)

This artifact from a hand-excavated unit in the southern part of the site is ground into a spherical shape and drilled about halfway into the sphere (Fig. 5.8). It is split roughly in half. The cylindrical hole is drilled into a slightly flattened facet on one side of the sphere (1.7 cm depth, 1.6 cm diameter; 17 g). The entire exterior surface is covered with deep, random striae that appear to have been scratched into the surface after the stone was shaped. The scratches are spaced too widely to result from shaping, and many are curved, suggesting that they were added to texturize the stone or as decorative embellishment. The material is lightweight, tan-colored welded tuff. Several small vesicles are visible in the interior of the hole and the exterior or the sphere. The hole appears to have been formed by gouging and drilling, as both rotational and vertical striae occur on the interior. No exterior wear is present. The outside dimensions of the ball are 3.2 by 2.8 by 2.4 cm; 17 g). The stone may have been shaped to fit over a wooden shaft, but the diameter of the hole seems small for such a function. The artifact resembles historically traded stone club heads from Papua, New Guinea (McNiven 1998:94, 100, Figure 2F), which were fitted onto wooden shafts.

Ornament (n = 1)

This artifact was tentatively classified as an ornament. It is a small, triangular andesite cobble (5.4 by 1.4 by 1.3 cm; 15 g) with a biconvex cross-section

Figure 5.8. Welded-tuff drilled stone ball (FS 259).

(Fig. 5.9). Most of the cobble cortex is randomly striated. The striations are unusual, consisting of sets of short, parallel, curved or straight scratches. Random striations are present as well. This type of wear seems more likely to result from handling or use as an ornament, as with a pendant. The lengthwise cross-section shape is an isosceles triangle, narrowing considerably at the apex. The apex is much thinner than the base, suitable for drilling, although no drill holes or notches for stringing are present. It was recovered from Stratum 3 in the vicinity of Features 3, 10, 11, and 12.

Raw Material (n = 1)

A small, tabular, subrectangular piece of white tuff (4.9 by 4.6 by 1.9 cm; 65 g) was lightly ground and striated on one surface. It is otherwise unmodified. It was recovered from the fill of Feature 9.

Indeterminate Fragments (n = 25)

Twenty-five ground stone artifacts are too small to determine tool type. Most have a single, flat ground surface that was lightly or moderately worn. Materials of low abrasion quality are the most numerous, consisting of igneous and volcanic rocks, quartzite, and andesite (Table 5.1). Abrasive materials account for 11 fragments, most of which are vesicular basalt, sandstone, limestone, and quartzitic sandstone. One indeterminate fragment was submitted for phytolith analysis due to its association with the Feature 8 hearth, but the results were negative (Appendix 3). Fragments weigh from 2 to 98 g; mean is 30 g.

Figure 5.9. Possible ornament, made from a basalt pebble (FS 397-2).

Spatial Distribution

Nearly 70 percent of the ground stone at LA 159879 came from one of six clusters (Table 5.6) of tools and 28 percent of it was recovered from unprovenienced backhoe fill. Ground stone tools tend to be clustered around structure and fire pit features. These clusters are compared and contrasted in terms of frequency, condition, thermal alteration, tool type, and feature association followed by a summary of spatial distribution (Figs. 5.10–5.13; Table 5.7).

Cluster 1 (Features 3, 10, 11, and 12) (n = 36)

Cluster 1 encompasses a structure (Feature 3), an adjacent activity area with three fire pits (Features 10, 11, and 12), and 16 hand-excavated units. This cluster appears to represent the greatest concentration of ground stone-related activity at LA 159879. Cluster 1 has the highest frequency of whole tools (Fig. 5.10), the highest number of heat-fractured fragments (Fig. 5.11), and the greatest variety of tools (Fig. 5.12). An unusually high number of manos and abraders were found in or near every feature in this area. Polishing stones, shaped stone, mortars, the drilled stone ball, and the partially shaped ornament were found here, suggesting that multiple tasks took place in this area.

Cluster 1 also yielded the highest number of tools directly associated with features (Fig. 5.13); most of these tools were adjacent to the Feature 3 structure and a few were from the Features 10 and 11 fire pits. Perhaps the most intriguing aspect of Cluster 1 is the presence of grass or corn and sedge phytoliths on two tools, one adjacent to Feature 3 and the other from Feature 10, and the presence of a single grain of cotton pollen beneath FS 299 (Appendix **3, Figure 1**; Fig. 5.14[b]). Both tools are fragments, and neither exhibits evidence of exposure to heat. One of the large stone pestles (Fig. 5.4) was found near Feature 3, which matches well with the botanicals. Feature 3 and the adjacent activity area yielded an interesting mix of plant remains, including mesquite, cheno-ams, amaranth, dropseed grass, and cotton, suggesting a broad range of processing activities at this location (Table 5.7).

Table 5.6. LA 159879, feature and hand-excavated grids by cluster assignment.

Cluster	Feature	North	East	Count
0	no feature association	general surface		49
		178.00	714.00	1
		257.36	651.41	1
		316.33	560.17	1
		362.18	544.58	1
	Total			**53**
1	no feature association	275.00	617.00	2
		275.65	630.57	1
		276.00	615.00	4
			616.00	1
			617.00	1
		277.00	615.00	3
			617.00	1
		278.00	615.00	1
			616.00	2
			617.00	2
		279.00	615.00	4
			616.00	2
			617.00	1
	Feature 3	276.80	616.40	2
	Feature 3 activity area	275.08	615.40	1
		275.32	615.48	1
		275.48	615.45	1
		275.92	615.88	1
		276.00	615.60	1
	Feature 10	271.56	628.48	3
	Feature 11	276.96	634.10	1
	Total			**36**
2	no feature association [Feature 5 vicinity]	Feature 5 vicinity		3
		207.71	672.67	10
		209.32	680.38	1
		215.00	703.00	1
		215.59	664.76	1
		216.00	702.00	3
			703.00	1
			704.00	1
		217.00	703.00	1
			704.00	1
			705.00	1
		218.00	703.00	1
			704.00	3
		220.20	661.98	1
		228.86	679.09	1
		230.00	665.00	1
			667.00	1
	Total			**32**
3	no feature association	306.64	614.65	1
		312.00	597.00	1
		313.00	596.00	1
			598.00	1
		314.00	598.00	1
		315.00	597.00	1
			598.00	1
		316.21	583.83	1
		331.71	598.11	1
	Feature 6	305.23	591.57	1
	Feature 7	303.00	593.00	1
	Feature 8	316.61	596.61	3
	Feature 9	320.30	604.51	7
	Total			**21**
4	no feature association	381.99	528.48	1
		382.37	542.37	1
		382.56	537.67	1
		386.00	527.00	1
		387.00	526.00	1
			527.00	3
			528.00	1
		388.00	529.00	2
		389.00	527.00	1
		390.00	532.00	1
	17	372.84	534.46	2
	Total			**15**
5	no feature association	335.42	580.92	1
		335.49	577.31	1
		337.66	558.90	1
		339.13	573.00	1
		342.31	581.21	1
		346.00	572.00	1
		347.00	572.00	1
		348.54	569.67	1
		349.00	572.00	1
		350.01	573.75	1
	13	352.00	552.00	1
	Total			**11**
6	no feature association	244.00	636.00	1
			638.00	1
			639.00	1
		245.00	637.00	2
		246.00	637.00	1
		247.00	636.00	1
			637.00	1
			638.00	1
	Total			**9**

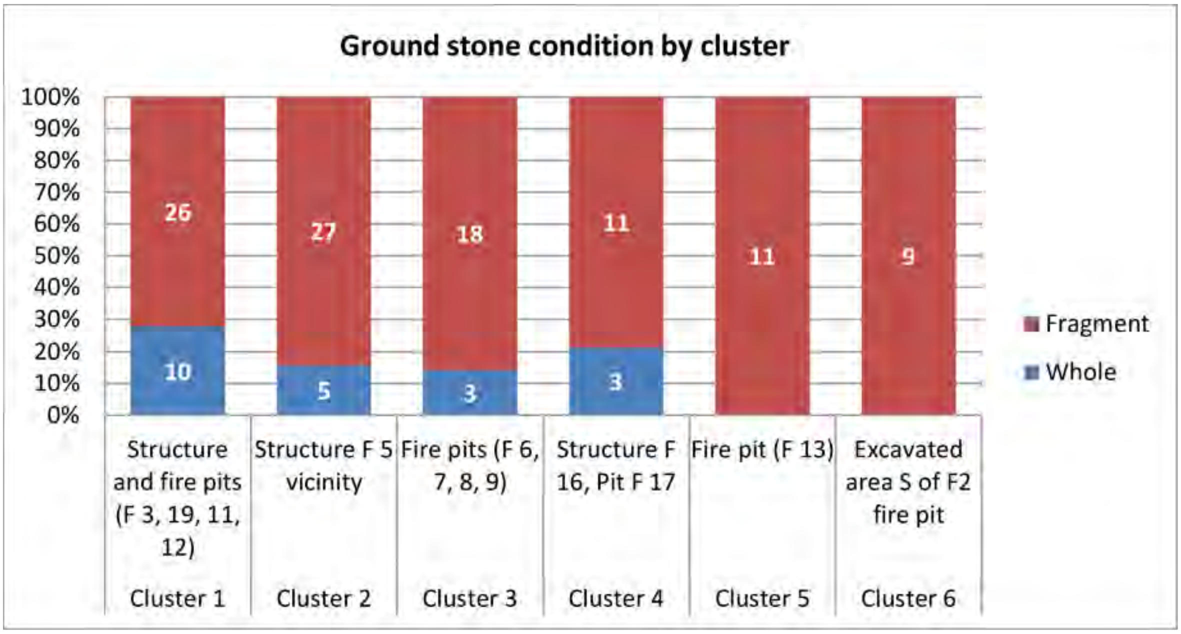


Figure 5.10. Ground stone condition by cluster.

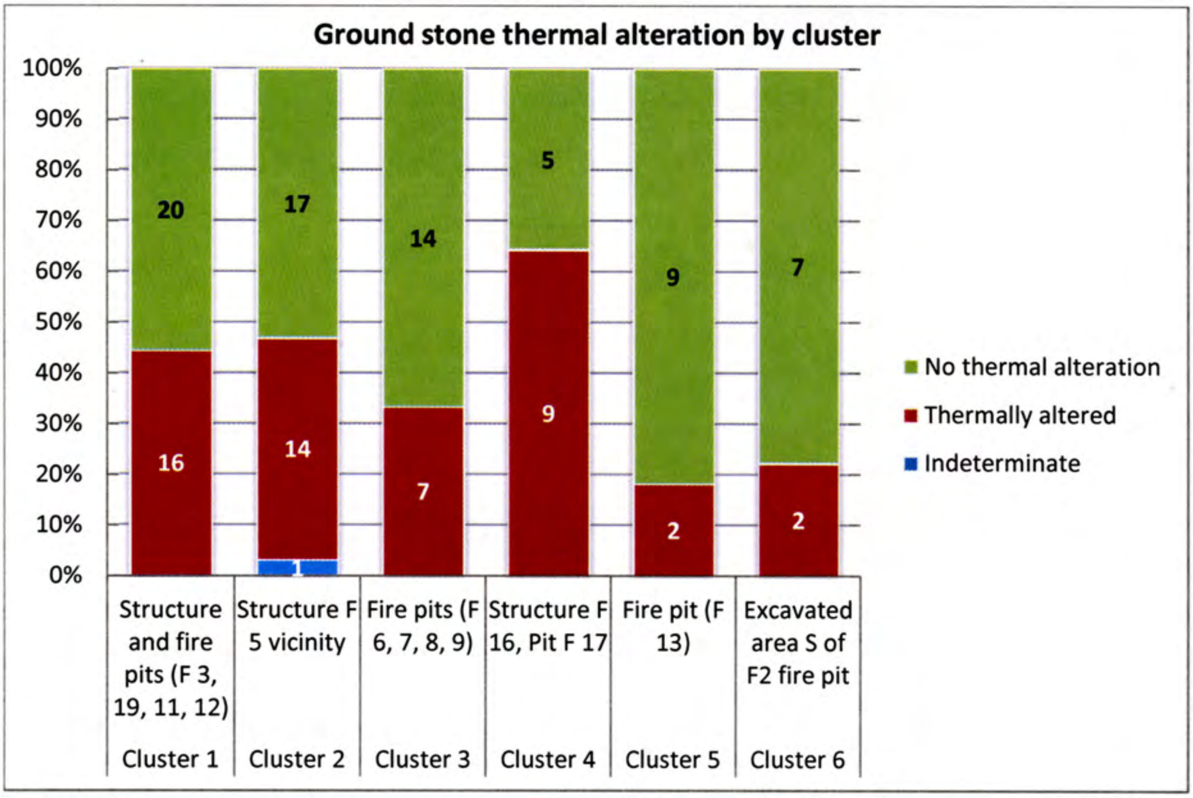


Figure 5.11. Ground stone thermal alteration by cluster.

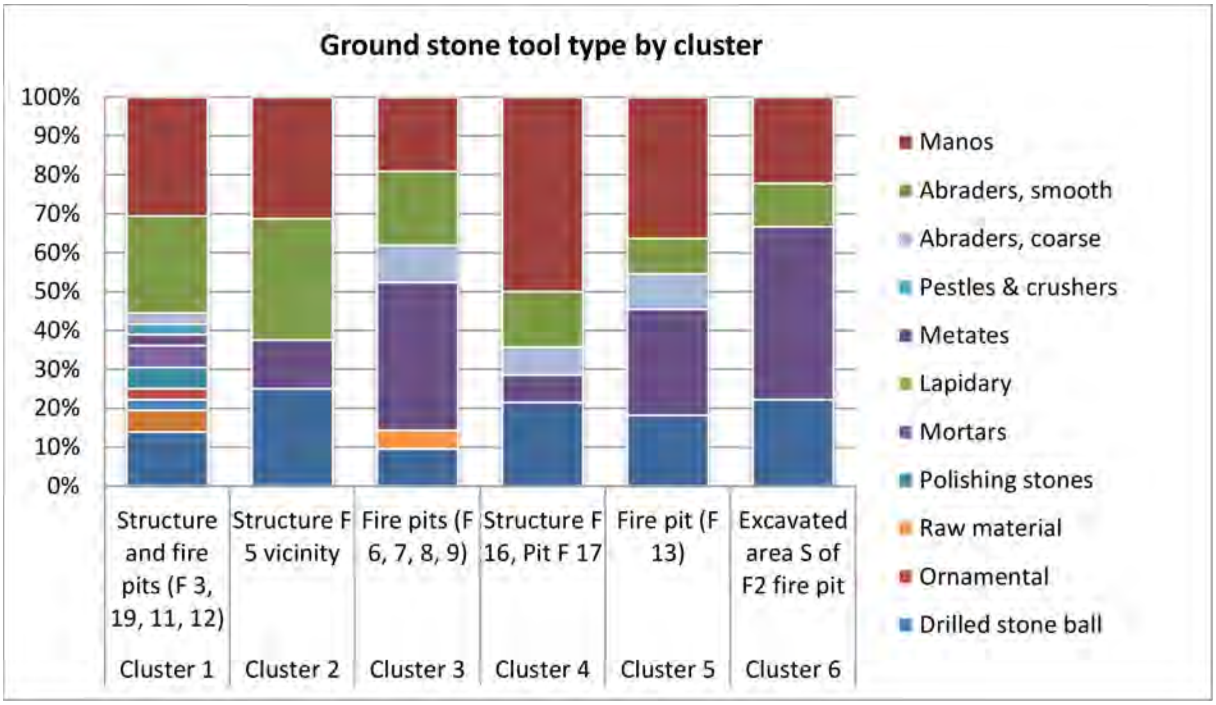


Figure 5.12. Ground stone tool type by cluster.

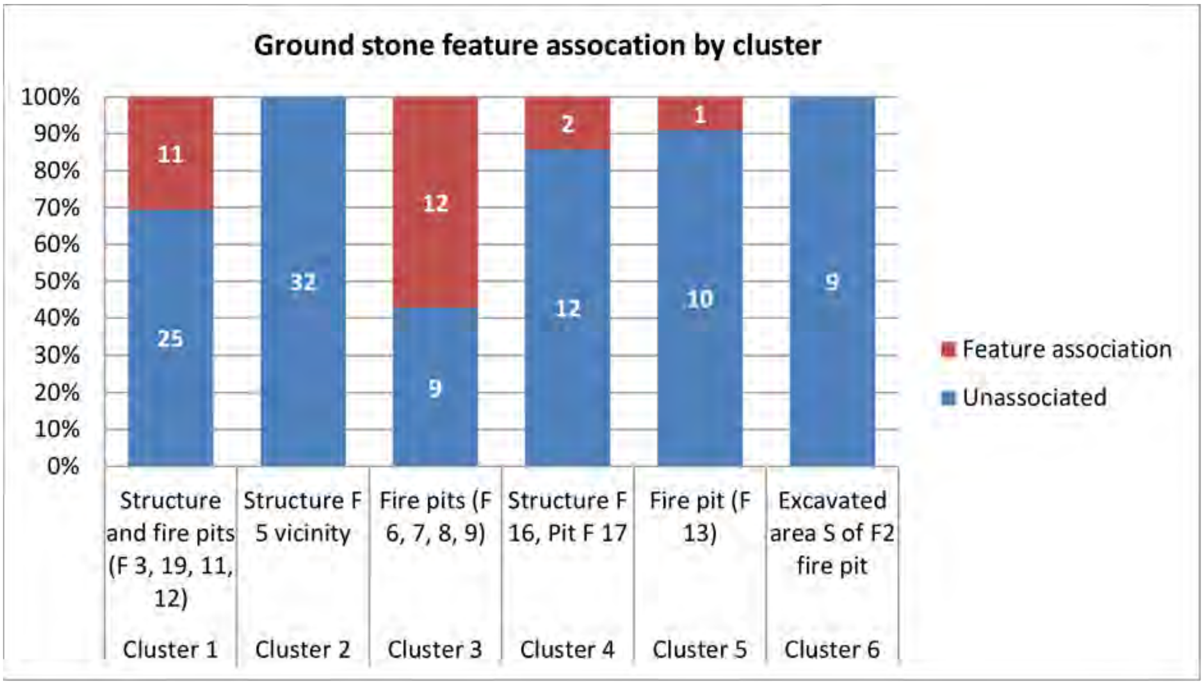


Figure 5.13. Ground stone feature association by cluster.

Table 5.7. LA 159879, ground stone phytoliths, pollen, and feature botanical data.

Feature	Feature Type	FS	Ground Stone Tool	Material Group	Ground Stone Phytoliths or Starch**; Economic Pollen **	Cultigen	Feature Samples: Flotation***
2	hearth	na	–	–	–	–	amaranth, cheno-am and goosefoot, dropseed grass
3 (activity area)	structure	299	Abrader fragment, coarse*	nonvesicular basalt	3 dedriform grass phytoliths; mesquite and cotton pollen	cotton?	mesquite seeds, dropseed grass, cheno-am, amaranth
5 (vicinity)	structure	226	Metate fragment, nfs*	sandstone	Grass seed starch; no phytoliths	–	cheno-ams, goosefoot
6	fire pit	422	One hand mano	nonvesicular basalt	not submitted for analysis; no economic pollen	–	melon loco, possible mesquite
7	fire pit	425	Abrader fragment, coarse*	vesicular basalt	3 disarticulated grass dendriforms; grass dendritic sheet element; corn pollen; no starch; corn phytolith	corn	goosefoot
8	fire pit	427	Indeterminate fragment	basalt	None	–	no cultural botanicals
9	fire pit	393-1	Abrader fragment, smooth	andesite	None; no economic pollen	–	cheno-ams
10	fire pit	449-1	One hand mano-pestle* fragment	quartzite	Corn phytoliths; sedge seed phytolith; no starch; no economic pollen	corn	monocot stem
		449-2	Abrader fragment, smooth	andesite	No starch; no phytoliths		
11	fire pit		–	–	–	–	cheno-ams, goosefoot
13	fire pit	432-1	Metate fragment, nsf	andesite	Ground stone not submitted for analysis; corn pollen	corn	mesquite seeds, possible corn kernels
15	fire pit	na	–	–	No economic pollen	–	goosefoot
16	structure	na	–	–	No economic pollen	–	goosefoot
17	pit	489-1 & 2	One hand mano fragment, smooth abrader fragment	–	Walnut pollen	–	goosefoot

*ground stone with positive starch or phytolith

**See Chapter 7.

***See Appendix 3.

nfs = not further specified

Cluster 2: Feature 5 vicinity (n = 32)

The ground stone tools in Cluster 2 are more dispersed than those in Cluster 1, and none were directly associated with Feature 5, a possible structure, and the only feature in this cluster. The vast majority of Cluster 2 tools are fragments (Fig. 5.10), though only half are fire-cracked (Fig. 5.11). Cluster 2 is less diverse than Cluster 1, as manos and abraders account for most of the tools (Fig. 5.12), though a significant number of indeterminate fragments may obscure some functional variability. This was the only cluster with tools that yielded grass starch, which was found on the surface of an indeterminate metate fragment found about 9 m east of Feature 5. Cheno-am and goosefoot pollen were recovered from feature fill.

Cluster 3: Features 6, 7, 8, and 9 (n = 21)

Cluster 3 has four fire pits (Features 6, 7, 8, and 9) and a hand-excavated unit. This cluster yielded the highest number of ground stone tools directly associated with features (n = 12) (Fig. 5.13). Most of these feature-associated tools were from Feature 9, which yielded a majority of broken tools, a few of which were heat-fractured. Tool counts in Feature 8 (n = 3), Feature 7 (n = 1), and Feature 6 (n = 1) were comparatively low. Three broken tools were recovered from the surface. The remaining six artifacts originated from Stratum 2 in the hand-excavated unit. Virtually all ground stone in Cluster 3 was fragmentary (n = 18), though only one-third was heat-fractured, suggesting that broken tools were not often reused as thermal elements in this area. This does not preclude their having been collected and deposited here for future use as thermal elements, however. The entire Cluster 3 assemblage contained three whole tools, a one-hand mano from Feature 6, and a basin metate and partially worked tuff fragment from Feature 9.

Cluster 3 contained mostly manos, abraders, and metates (Fig. 5.12), nearly all of which were broken and burned (Figs. 5.10, 5.11). A substantial number of metate fragments originated in Cluster 3, each of a different material type. The surface of a fragmentary coarse abrader from Feature 7 retained grass and corn phytoliths, and goosefoot botanicals were recovered from flotation samples. A second smooth abrader from Feature 9 and an indeterminate fragment from Feature 8 were submitted for analysis but did not yield any starch or phytolith remains.

Cluster 4: Features 15, 16, and 17 (n = 14)

Cluster 4 encompasses a structure (Feature 16), fire pit (Feature 15), two postholes (Features 20 and 21), and a possible large pit (Feature 17) or animal burrow. Only two tools were recovered from feature context, both from Feature 17. The remaining 12 ground stone tools from this cluster originated from hand-excavated units. As with most clusters, whole tools are in short supply (Fig. 5.10), consisting of a basin metate, a one-hand mano, and an abrader. Most tools here are broken, and most broken tools were thermally altered (Fig. 5.11). This contrasts with other clusters, where fragments are typically fire-cracked as often as not. The only two tools in feature context are two fragments that were recovered from Feature 17, one of which was heat-fractured. Burned goosefoot seeds were recovered from all features in this cluster.

Cluster 5: Feature 13 (n = 11)

This cluster includes ground stone found in and around a fire pit, Feature 13. All of the tools found here were broken, but only one was heat-fractured. Mano, abrader, and metate fragments litter the area around Feature 13, with only one in the feature itself. Burned mesquite beans and possible corn kernels were found in floatation samples from Feature 13. No ground stone tools were submitted for phytolith analysis.

Cluster 6: Feature 2 (n = 9)

The Feature 2 fire pit—which dates to the historic era—and the surrounding area yielded a small number of ground stone artifacts. All tools here are fragmentary (Fig. 5.10), but as with Cluster 5, only one is fire-cracked. Tool types here mirror those of Cluster 5 as well, including mano, metate, and abrader fragments (Fig. 5.12). No tools were found in the fire pit itself. No ground stone tools from this cluster were submitted for phytolith analysis. Macrobotanical remains include amaranth, cheno-ams, goosefoot, and dropseed.

Summary

Clusters differ in the number of tools present and the proportion that were heat-fractured, but they all

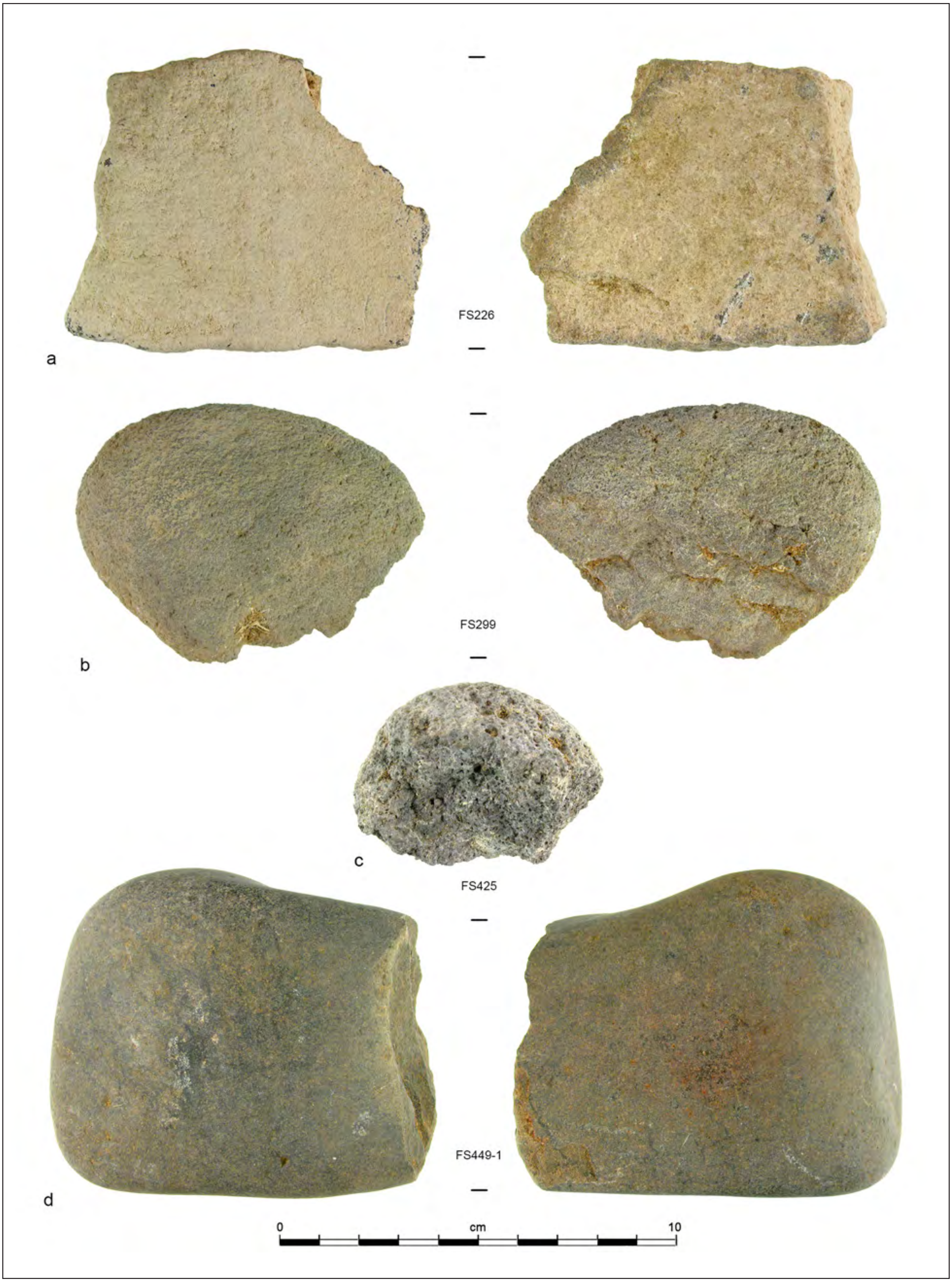


Figure 5.14 [a–d]. Ground stone associated with plant starch or phytoliths.

have similarly high proportions of broken tools. The presence of whole, broken, and heat-fractured tools suggests that the full lifecycle of many tool types are represented at the site. Tools may have been used until they were broken or expended, at which point they became heating elements in fire-pit features. Not all broken tools ended up in the fire, however; in many cases they were simply discarded, as no evidence of thermal alteration is present. It is also possible that broken tools were collected from around the site and placed near the thermal features for future use.

An obvious reason for the high numbers of ground stone near features is that food processing occurred there, either in the form of preparation (for roasting or parching), or grinding (following cooking); alternatively, the high ground stone presence in these contexts is simply a factor of areas sampled for excavation.

With the exception of Cluster 3, tools were rarely found in feature context at LA 159879. Where they do occur, they are usually fragmentary. However, broken tools are only slightly more likely to be heat-fractured (52 percent) than not (48 percent). This is true of tool fragments both inside and outside of features.

SEED PROCESSING AND THE LATE ARCHAIC/EARLY AGRICULTURAL PERIOD

The Late Archaic/Early Agricultural period is marked by a number of significant changes that signal the transition from hunting and gathering to a mixed farming and foraging economy (B. Huckell 1996:343). Foraging involved the gathering and storage of a wide variety of wild seeds, which in turn, required the development of grinding tools to process these resources, including one-hand manos, basin metates, small and large mortars, and pestles. Though wild seeds were not the only resources exploited by Archaic foragers, the increased focus on seed gathering and processing is considered a salient characteristic of the period that distinguishes it from the preceding Paleoindian period (Dello-Russo 2008:18). The array of wild seeds and plants exploited during the Late Archaic is described as having impressive breadth and balance (L. Huckell 1994, cited in B. Huckell 1996:344).

Gathered plants continued as a staple throughout the Archaic, but were supplemented by corn by 3000 BP. Though researchers are virtually unanimous on the increasing importance of cultigens over time, there is much debate regarding the rate at which this occurred (Huckell et al. 2002:137–138). Some researchers posit that cultigens had an immediate impact, assuming a primary role quickly upon their introduction into the Southwest (Hard et al. 2006). Others (Blake 2006:57) view the reliance on cultigens occurring more gradually, with planted foods serving only as supplemental resources until about AD 500. One point that emerges consistently is that foraging provides a better subsistence return over farming in terms of energy expenditures, and that wild resources are sought first before farming is pursued (cf. Cordell 1984; B. Huckell 1995; Dello-Russo 2008:19).

Regardless of the degree of reliance on cultivated foods in the Late Archaic, there is general agreement regarding stability in ground stone tool design. Food-processing tools were altered little when agriculture was introduced and remained constant for 2,000 years (B. Huckell 1995:4, Huckell et al. 2002:138, Morris 1990:186). The continuity of ground stone tool morphology is noted by others as well (Wills 1988, Adams 1999). One-hand manos and basin metates are characteristic of the Archaic, though these forms continue into the Formative periods in many areas of the Southwest (Adams 2002:122, Figure 5.15). This has led some to suggest that these are functionally specific tools related to the continued use of a particular resource (Wills 1988:16–17). Others link the later changes in tool design to the use of new recipes and food-processing methods (Adams 2002:121). Still others have chronicled numerous ethnographic studies that conclude a single tool can be used to process a vast array of plant materials, precluding fixed associations of tool types with specific foods (Wright 1994). Hard has linked an increase in mean mano size with greater reliance on agriculture based on the need for more efficient grinding. Increased reliance on agriculture occurred more slowly in more arid environments where farming would likely be less productive. These areas have a much greater consistency in use of small manos over time than more mesic environments, where farming is more likely to succeed (Hard 1986).

Archaeobotanical remains and ethnographic studies also reflect continuity in the use of many wild plant resources over time. Ethnographic studies have repeatedly documented the importance of wild grasses as a staple food source for many Southwestern groups (Doebly 1984) and are considered an especially important resource in arid environments. Even in groups where agriculture is the primary food source, several wild grasses are an essential dietary element, as with the Hopi (Whiting 1939:18, cited in Doebly 1984) and Yuman (Castetter and Bell 1951:180).

Grass, Sedge, and Goosefoot

Grass was doubtless far more abundant and varied in the Late Archaic environment than it is today (Chapter 7). Grass seeds are but one of the diverse group of wild seeds exploited, evidenced by numerous ethnographic studies. Among the Yuma, an impressive array of seeds is processed by grinding (Castetter and Bell 1951:179–211). Mustard, mesquite, sunflower, panic grass, goosefoot, and pigweed seeds are among these, all of which represent possible resources at LA 159879. Based on Kelly's ethnographic studies of the Yuma between 1940 and 1952 (Michelini 2009:2; Kelly 1977, cited in Castetter and Bell 1951), these seeds are parched and ground, with the flour eaten dry or cooked into a mush by the Mojave, Yuma, and Maricopa groups. Sedge seeds are commonly exploited by many groups as well, including Laguna and Acoma (Castetter 1935:25). Parched goosefoot seeds were ground into meal by Navajo (Elmore 1944:44), the Pima (Russell 1908:73), and Havasupai groups (Whiting 1985:67), to name only a few.

Dello-Russo notes that the ratio of gathered to cultivated foods varied during the Archaic, "function(ing) effectively as opposite ends of the storable food spectrum along which forager-farmer groups positioned themselves" (2008:19). Based on the flotation and phytolith analyses, a similar flexible adaptive economic ratio may have prevailed at LA 159879 (Table 5.7). Corn and cotton cultigens were recovered, as well as a variety of wild food sources (Chapter 7, Appendix 3).

Wild resources include cheno-ams such as goosefoot, pigweed, and saltbush (Table 5.8). Possible grass resources found in Luna County include several species of dropseed, grama, panic, and deer grass (Pamela McBride, personal communication, 2012). Within the grass (Poaceae) family, several species of wild grass seed may have occurred prehistorically in the project area (Pamela McBride, personal communication, 2012). While ricegrass is not among these, several species of dropseed and other varieties may have been exploited. Table 5.8 provides a potential list, many of which are noted as dietary staples of several Southwestern groups. Virtually all of these seeds are processed using ground stone tools, either by hulling or grinding into flour, often after parching. The flour or meal is used in a wide variety of recipes. Grass phytoliths found on ground stone from LA 159879 clearly indicate that grass seeds were processed with these tools. Late Archaic sites often yield botanical remains similar to those found at LA 159879, including grasses, mesquite, cheno-ams, mustard, amaranth, and sedge, the latter indicating a somewhat mesic site environment (Roth and Wellman 2001:72).

The presence of sedge-seed phytoliths at LA 159879 is particularly interesting, as its preference for disturbed soils led to its proliferation in the agricultural fields of some groups in the southern Southwest and northern Mexico (LaFerriere et al. 1991; Lawton et al. 1976). Sedge, or yellow nut grass (*Cyperus Esculentis*), is commonly referred to as a gathered food in the more northerly areas of the Southwest. However, for many groups in the xeric southern areas, it is a cultigen. The Yuma, Mojave, Maricopa, and Paiute groups either cultivate sedge or take advantage of its tendency to grow in fields tilled for other foods (Haynes 2010:317; LaFierriere et al. 1991:107; Lawton et al. 1976:36). Both the tubers and seeds are eaten. The dried tubers, which have a high carbohydrate and moderately high fat content, were ground into a meal by the Mountain Pima of Chihuahua, Mexico (LaFerriere et al. 1991:107).

The combination of hulling and parching of many wild resources may also explain the presence of ground stone tools and fire-cracked fragments in or near thermal features at the site. As many seeds are processed with a combination of parching and hulling or grinding, these might be most efficiently carried out with tools near a fire pit or pit. The benefit of this type of processing is further addressed below.

Cotton

Cotton seeds may have been exploited by site occupants, as they are rich in oil and protein (L. Huckell 1993:176). The Pima cultivated the seeds and fiber until the late nineteenth century. Cottonseed meal

Table 5.8. Wild grass food resources in Luna County.

Grass Type	Common Name	Use	Harvest Months	Reference
Sporobolus cryptandrus	Sand dropseed	Seeds ground to make dumplings, rolls, griddle cakes, tortillas	April–September	Hough 1897
–	–	"Seeds ground with corn to make a kind of cake greatly enjoyed by the Hopi"; "seeds used for food"	–	Hough 1897:37
		"Seeds used for food"		–
Sporobolus giganteus	Giant dropseed	Staple for the Hopi	June–October	–
Sporobolus airoides	Alkalai sacaton	Staple grain for the Hopi and Paiute	April–October	–
Sporobolus contractus	Spike dropseed	Staple grain for the Hopi	August–October	–
Panica obtusum	Vine mesquite	Semicultivated grain for the Hopi, Paiute and Cocopa; "seeds eaten with corn"	May–October	Hough 1897:37
Panicum capillare	Cushion witchgrass	"The Navajo eat the seeds of this plant"	July–October	Elmore 1944:25
Muhlenbergia rigens	Deer grass	Paiute and Apache	July–October	–

*Doebly 1984:54-58, Table 1; Pamela McBride, personal communication 2012

may have been mixed with mesquite or corn meal, as with the Pima and Tohono O'odham, who likened the taste to tallow (L. Huckell 1993:176, citing Castetter and Bell 1942:103). The Pima also parched and consumed the seeds without grinding (Castetter 1935:29), or pounded cottonseed and mesquite pods in a mortar together (Russell 1908:77; Castetter 1935:29). Interestingly, both mesquite and cotton pollen were found near Feature 3 (Appendix 3), indicating they may have been processed together or separately. The single cotton pollen grain recovered from near Feature 3 structure fill does not necessarily denote the cultivation of this plant, as wild cotton occurs in the project area.

Mesquite

Mesquite was an essential staple for many Southwestern groups both prehistorically and historically. The significance of mesquite and screwbean food sources is difficult to overstate, as Castetter and Bell have noted: "Mohave, Yuma, and Cocopa informants agreed that no other wild food compared in importance with these two; that they were more important that maize and later wheat; and that they virtually supplied the living through the winter and until the next cultivated crop was ready" (1951:179–180). Mesquite and screwbean were deemed to be of equal value by these same groups in several other ethnographic studies (Castetter and Bell 1951:181). Obviously, this food continued to be a staple for many groups well into historic times.

In Mojave and Yuma territory, mesquite pods ripen in late June, and earlier in more mesic biotic settings (Castetter and Bell 1951:182). Full days were spent gathering mesquite, extending to "sojourns of several days' duration on which they camped" (Castetter and Bell 1951:182). The Pima travelled for this as well, relying on mesquite when other resources failed, and trading mesquite pods and meal roasted in mud-lined pits (Russell 1908:94).

Mesquite processing methods are extensively documented for many Southwestern groups. Ethnographic studies and later synthesis repeatedly highlight the elevated importance of this wild resource. Rendering of mesquite pods and seeds was carried out in many ways. Some appear to be almost universally employed, and others may be unique to specific groups. Pods were pulverized fresh and dried, processed into meal, flour, and pulp to produce many different recipes.

Possibly the most extensively documented processing is for the Yuma and Pima. The gathered mesquite pods were processed differently by the Yuma depending on maturation. Ripe pods were dried and stored for later processing. Dried pods were first crushed in a mortar, then sometimes ground on a metate to produce a finer meal (Castetter and Bell 1951:184). Unripe pods were immediately mashed in a mortar to produce a pulp mixed for beverages. Interestingly, the Mojave and Yuma discarded the fiber and seeds.

The Pima use both pods and seeds, sometimes grinding them separately, and other times combining them. The mashed pod juice is also combined with corn meal, and the leaves and bark powdered for numerous medicinal uses (Hrdlicka 1908). The combined seeds and pods are ground into various textures ranging from fine flour to coarser meal to pulp, as with the White Mountain Apache (Bell and Castetter 1937:25, citing Reagan 1929:145).

While mortars and pestles figured prominently, manos and metates are often the tools of choice to pulverize these materials. This is particularly true for mesquite, which is processed with both sets of tools by the Pima and Yuma. Wood and stone are used for both mortar and pestle, with the intriguing distinction of stone tools being used to produce lesser amounts (Russell 1908:75). Numerous groups also employ both tool sets as stages of processing, with wooden mortars and stone pestles used first to pulverize, and manos and metates used for finer grinding (Schneider 1996:302). The Walapai use the two tool sets interchangeably (Hrdlicka 1908b:260; Bell and Castetter 1951:25, citing Kroeber 1935:53). The Pima pound the seeds and pods in a mortar, as they are "too sticky for the metate" (Bell and Castetter 1937:23).

The Havasupai dispensed with the mortar altogether, pounding the dried pods on a metate (Bell and Castetter 1937:25). Wallace, summarizing Hayden's experimental study, suggests that mesquite processing actually involves a two-step process, first pulverizing the softer, outer pods, and then crushing the much harder seeds once separated from the pods (1983:149). These processes require wood and stone tools, respectively, based on differential hardness.

Mesquite is also processed in earth mortars, a cylindrical hole dug into the ground, sometimes lined with a basket of arrowweed twigs and split roots (Castetter and Bell 1951:184). Earth and wood mortars may not survive in the archaeological record, possibly explaining the few mortars at LA 159879. As grain dehusking experiments have revealed, wood pestles may be more efficient as they do not crush the seeds into the bran as with stone pestles (Foxhall and Forbes 1982:77). The absence of battering wear on manos and metates suggest that hard materials such as mesquite or seed corn are probably not being crushed using a pounding motion with these tools. Possibly, harder seeds such as corn and mesquite are cracked by rocking the mano, rather than pounding. The presence of a stone pestle and mesquite botanical remains suggests that mortars were in use at LA 159879. These ethnographic comparisons suggest that while manos and metates may be used to process a variety of wild seeds and cultigens, mortars and pestles appear to be specialized tools used almost exclusively to pound mesquite seeds and pods.

A single tool type can possess extreme versatility in the number of materials processed, and it may be equally flexible in processing strategies. Many foods can be prepared without grinding or pounding, while others—including wild cereals, chenopods, and other fibrous plants— require it. Even the force applied for particular seeds may vary depending on specific food, volume and ripeness. For example, light pounding of a volume of wheat and barley accomplishes dehusking with little damage to the seed (Wright 1994:242–243). Possibly, an assortment of methods was applied to seeds gathered at LA 159879. This may include treatment of seeds and grains prior to grinding. Seed corn can be dried, soaked, parched, or cooked depending on the recipe used (Adams 1999:Table 1). While all are ultimately ground, the texture of the food is obviously quite variable depending on which of these initial methods are used. In addition to this, the harvested seed corn may also vary, including flour, sweet, dent, flint, or pop varieties.

Stahl notes that foods can be exposed to a variety of heat treatments, including parching and roasting with dry heat, boiling, steaming or simmering with moist heat. Heating can also facilitate hulling, prepare foods for storage, or chemically alter foods to reduce toxins and/or increase digestibility. Moist heat, in particular, increases digestibility (1989:181–183). Although nutrients can be lost through heat exposure, "substantial gains in nutritive value may also occur" (Stahl 1989:183). Grinding, pounding, and grating processing methods increase the nutritional value of foods by reducing particle size, which eases digestion (Stahl 1989:172–175). A variety of processing methods can be employed for a single food, and this, in itself, can be considered an intensification of specific resource use (Stahl 1989:185).

Implications for Ground Stone Function Based on Pollen, Phytolith, and Starch Analysis

Seven ground stone tools were submitted for pollen, phytolith, and starch analysis (Appendix 3). Four of these tools yielded exciting positive results, linking each one with specific seed types. This allows us to examine the characteristics of a certain tool with at least one food that was processed with that tool. The most intriguing result of this combined data is that there appears to be no single way of grinding some seeds and that seeds of very different quality were pulverized with the same tool. The salient data for these four tools, along with the plant remains found on their use surfaces, are summarized in Table 5.9 and illustrated in Figure 5.14[a–d].

The phytolith analysis results are surprising in some aspects, and expected in others. Perhaps the most obvious result, particularly in view of the preceding ethnographic discussion, is that ground stone tools were multifunctional, at least in terms of the variety of food being processed (Table 5.7). For example, two tools retained phytoliths from both cultivated and wild seeds (FS 425 and 449-1). A third tool is also possible, though the cultigen in that case is based on the presence of single grain of cotton pollen from fill beneath a coarse abrader fragment (FS 299), which could also represent processing of a foraged, rather than cultivated, plant. The first is a one-hand mano fragment with corn and sedge remains, and the second is an abrader fragment with corn and grass remains. The most fascinating aspect of these two tools is that though they were both used for corn and wild seed, only some traits are shared between them. In short, they resemble each other morphologically, but differ in texture and wear. One is smooth and polished, the other comparatively rough and unpolished. Wear pattern differences could simply owe to varying degrees of use, but contrast in material texture is likely related to a specific method or stage of processing. Only two identical traits occur in corn tools: convex use surfaces and one-hand morphology. The latter, of course, applies to grass and sedge tools as well.

Grass-processing tools vary also, though generally display more consistency than those used for corn. Grass tools are more abrasive than those used for corn and sedge. Processing strategies are difficult to determine from these small broken tools, but a flat reciprocal stroke is clearly indicated on the metate fragment. Polish wear on one coarse abrader may result from seed oil content.

The variation in tools used to process the same food may owe to a variety of factors. While corn, sedge, and grass seed can all be processed by grinding, only the latter two require hulling. Sedge and grass hulling could have been accomplished in a manner similar to that used by the Australian Aborigines, in which seeds are rolled between the hands and the husked seeds ground on a metate (Cane 1989:105–106). The seeds are sometimes soaked before grinding. The initial hulling step, if executed with tools, may have required different tools than those used for cracking, crushing, and grinding activities, or simply a different stroke using the same tool. While corn kernels did not require husking, the dried kernels may have been considerably harder, requiring crushing or cracking using tools other than those used to grind. Also, the handstone artifacts chosen for phytolith analysis all appear to be unshaped, informal tools that represent expedient use only.

Whatever the reason for the variation in tools used to process the same food, it would seem that two general statements can be made: that morphology alone is an insufficient indicator of the nature of the food being processed, and that many, if not most, ground stone tools were multifunctional, corroborating the numerous ethnographic studies that stress the versatility of such tools.

Discussion

Based on the small sampling of ethnographic plant uses examined above, it is easy to assume that the botanical remains from LA 159879 represent a fraction of the wild resources used at the site. Wright notes that while seeds are an important food, they are also better preserved than other dietary items (1994:239). Pima, Yuma, Cocopa, Walapai, Havasupai, and Maricopa groups pulverize seeds, bark, leaves, roots, pods, and fruits of countless plants using mortars and pestles, and manos and metates. Use of these tools was not restricted to plant processing, as meat is often pounded on metates as well.

Ethnobotanical remains from LA 159879 indicate a focus on a few annual plants, dropseed grass, corn, and mesquite (Chapter 7). Pollen and phytolith analysis results suggest that this selection may be expanded to include sedge and corn (Appendix

Table 5.9. LA 159879, wear data for ground stone tools with phytolith remains.

FS/ Feature	Material Type	Material Texture	Raw Material	Tool Type	Wear Pattern	Wear Surface Contour	Wear Degree	Residue Analysis
226/F5 vicinity	Gray sandstone, indurated	High	Slab	Metate, nfs fragment	Grinding, parallel striations	Biaxially flat	Moderate	Grass starch
299/F3 activity area	Nonvesicular basalt	Moderate	Cobble	Abrader (coarse) fragment	Grinding and polish	Biaxially convex	Light	Grass phytoliths
425/F7	Vesicular basalt	High	Cobble	Abrader (coarse) fragment	Grinding	Biaxially convex	Light	Grass and corn phytoliths
449-1/F10	Quartzite, black	Low	Cobble	One hand mano-pestle fragment	Grinding, random striations, polishing	Biaxially convex	Moderate	Corn and sedge phytoliths

3). Many of these wild resources may have been semi-cultivated in the Archaic by burning, broadcasting seeds, or transplanting (Roth and Freeman 2008:340). The tendency of sedge to sprout in the disturbed soil of agricultural fields led to its exploitation as a semi-cultivated crop (Haynes 2010:317; LaFierriere et al. 1991:107; Lawton et al. 1976:36).

While the botanical remains and ground stone phytoliths likely represent only a small portion of the full spectrum of exploited resources and processing tools, some ideas may be put forth. Among the plant remains from LA 159879, the processing methods may be variable. Mesquite and grasses, in particular, may be the most likely to be processed using multiple techniques, based on ethnographic documentation. How does this square with a ground stone assemblage that is not highly variable, either in the character of the stone, or the manner in which most have apparently been used? One explanation is that at LA 159879, many of the resources are being processed in a similar way. Grinding tools are light and easily manipulated. Tool stone is fine-grained or even cryptocrystalline. Use surfaces are smooth with little rejuvenation. Tools of similar character may be used to grind mesquite pods and grass seed, but with mesquite pods first pounded using pestles and wooden mortars. Partially reduced mesquite pods could be transferred to the metate, while grass or sedge seed could be processed completely with this tool. Based on the dominant tool character, it seems likely that a finer meal or simply hulled seeds were being produced.

Restricting a particular tool type to a specific food is precluded by ethnographic studies not only in the Southwest, but around the world. Wright outlines an impressive list of the huge assortment of food and non-food items processed with manos and metates, clearly asserting that ground stone tools are not food-specific (1994:241). While tool morphology cannot be reliably linked to a specific function or dietary emphasis, it can suggest "overall strategies" (Wright 1994:242). The versatility of a single tool is evident in the starch analysis results from tests conducted on a basalt slab from the Upper Paleolithic site Ohalo II, on the southwestern shore of the Sea of Galilee in Israel; the impressive array of plant materials that were found dated the tool's use to about 22,500 to 23,500 years ago (Piperno et al. 2004:670). While the Ohalo II site metate is considerably older and was used to process foods collected from more mesic environs than Southwestern Archaic sites, it illustrates the potential variable uses for a single tool.

Does form follow function? Several researchers suggest that the adoption of agriculture required no change in grinding technology. Adams states that "tool configuration has nothing to do with whether the seeds were gathered or planted, but does have everything to do with determining how they were processed to achieve a desired end product" (1999:487). The development of trough metates reflects a change in processing habits based on an increased reliance on flour (Adams 1993, 1999:478–479). Fixed associations between tools and food often lead to assumptions about the degree of reliance on wild or planted resources, when only the processing method has changed (Adams 1999:476). In other words, metate morphology alone cannot be used to infer the degree of dependence on cultigens; metate design is driven by the processing method used. Corn agriculture began centuries before trough mano and metate designs were developed in the Southwest (Adams 1999). Wills (1988:37, 119) suggests that corn cultivation was not likely to have required the modification of existing tools. Hayden reiterates this point, stating that the tools needed to process domesticated crops, in this case cereals, were developed prior to the advent of farming (1995:278).

Others differ, viewing a clear association between increasing agricultural dependence and specific mano and metate forms, suggesting that milling stone design is specialized and can be directly linked to relative dependence on wild versus planted foods. Mauldin's 1993 examination of ground stone assemblages from the Pine Lawn Valley in west-central New Mexico led him to identify several characteristics that develop with agricultural intensification. Mano length and use surfaces increase dramatically from Early Pithouse to late Pueblo phases in this area, concomitant with reliance on cultigens. From AD 400–1300, large, bifacial manos are the dominant handstone for most, but not all, time periods, leading Mauldin to conclude that agricultural intensification may have waned during some phases (1993:325–328).

Hard (1986), observing these same attributes of mano length and number of use surfaces advances this position further by applying ethnography, coprolite evidence, and climate data. For dozens of Southwestern groups, larger mano size is clearly correlated with greater dependence on cultigens (Hard 1986:114–118, Table 10). Perhaps the most compelling correlation between mano size and subsistence is demonstrated by Hard's use of climate data in which he compares mean mano length for a wide range of climate locations (1986:128–196). Three of these areas have high "PB" ratings (an indirect measure of plant food availability) identical to Chihuahuan desert environs: Big Bend, Fort Irwin, and Death Valley (Hard 1986:154, 160, Tables 14, 16). These high P/B environments have greater wild plant food availability, but are less reliable for rainfall-dependent agriculture (Hard 1986:130). For all hunting and gathering periods in these drier areas, mean mano length is nearly identical to that of LA 159879, differing by only 1 mm (10.6 and 10.7 cm respectively). Generally, Hard's studies link smaller manos with foraging lifestyles and larger manos with farming-dominant subsistence; though it should be noted that the earliest dates considered in his study postdate the LA 159879 occupation by about one millennium. However, mean mano size would likely remain consistent with site occupation dates based on similar, longstanding subsistence practices and ground stone assemblages in these arid areas. This relationship is reiterated in a later study linking increases in mano size with corn ubiquity for the Southern Jornada area from the Archaic to the El Paso phase, while stressing the need for additional multiple lines of evidence (Hard et al. 1996:304).

Diehl (1996) arrives at a similar conclusion based on a large mano assemblage from upland Mogollon pithouse villages spanning four occupation phases from AD 200–1000. Mean mano surface area increases over time, thought to be based on higher per capita maize consumption (Diehl 1996:110). In his study of Mimbres Valley Salado ground stone, Lancaster (1986:190) concludes that two-hand manos and trough metates are likely "created to grind corn," while emphasizing that the frequency of basin manos and metates cannot be used to determine the degree of reliance on wild foods.

Murrell (2007) also sees a positive relationship between abrasive material types, increased mano size, and agricultural dependence. Interestingly, he notes a dramatic increase in the use of vesicular basalt and sandstone milling stones with the introduction of Maiz de Ocho, a hybrid corn variety that produces higher grain yield (2007:44–45). This hybrid corn becomes the dominant cultigen following the Chapalote maize exploited throughout the Archaic, possibly requiring larger, more abrasive processing tools. The reverse is also true, that the "smallest metamorphic manos" dominate assemblages during hunting and gathering economies, possibly concurrent with the introduction of Chapalote and Proto-Maiz de Ocho (Murrell 2007:49). The latter has special significance for LA 159879, where small, durable manos prevail and wild plants and domesticates are evident in the diet.

One of the most compelling indications that the basin manos and metates used at LA 159879 functioned primarily as seed-grinding tools comes from an ethnographic study of Australian Aborigines (Smith 1986). Detailed descriptions of milling-stone morphology and wear closely mirror those from LA 159879. Grass seeds are ground on long, narrowly grooved metates that are nearly identical in dimension to project basins. Even more fascinating, the wear surfaces resulting from grass-seed grinding are "finely abraded and very smooth. A fine reflective polish, recently identified as silica, is commonly present on the ground surfaces" (Smith 1986:32–33). Small quartzite handstones are used, some of which are carefully manufactured. These also display silica polish, and are "occasionally" rejuvenated by light pecking. As in the Southwest during the Holocene, these distinctive tools were developed in response to the need for intensified seed exploitation.

However, Smith's study is challenged by others (Gorecki et al. 1997), who claim that pounding and milling occur on the same metate, and that the concave groove is simply the end product of this use of a slab metate. These two views taken together suggest that while these tools are indeed used for seed grinding, they are also quite versatile in terms of processing method.

The botanical remains at LA 159879 mirror the forager-farmer subsistence economy, which is thought to dominate the San Pedro phase. Bruce Huckell notes that "maize farming was a critical component…but extensive use of hunted and gathered wild resources from the surrounding biotic communities continued to be indispensable" (1995:119). This dependence on gathered foods continued into the later Cienega phase, where the dietary importance of cheno-ams and grass resources were in evidence (B. Huckell 1995:122). San Pedro–phase sites in northwestern Mexico are located on valley floodplains ideal for cultigens and agrestals. Ground stone tools are "dominated by utilitarian seed milling equipment (manos, metates, pestles, mortars), and a few other forms with less obvious functions (cruciforms and small disks)" (B. Huckell 1995:119). The LA 159879 assemblage mirrors this distribution, reflecting a predominance of manos and metates used for food processing. The high numbers of fragmentary and fire-fractured tools also suggest that the site served as a long-term foraging location. Whole, functional manos and metates may have remained at the site between foraging visits, cached for future use after each visit. The proximity to the Mimbres River may have offered an ideal floodplain environment for seeds of many varieties. A similar long-term floodplain occupation is associated with the Valley Farms site in the northern Tucson Basin, which yielded a deeply buried San Pedro–phase component with radiocarbon dates ranging from 2700–3100 BP (Roth and Wellman 2001:74).

Conclusions

Though the ground stone assemblage from LA 159879 contains a limited number of tool types that display several remarkably uniform characteristics, the phytolith remains from four tools coupled with the botanical analyses suggest that this seemingly simple toolkit was extremely versatile and multifunctional. A diverse assortment of wild and planted foods was exploited at the site using milling tools that do not vary greatly from one another with the notable exception of mesquite, which required specialized tools.

Various combinations of corn, grass, and sedge were ground using single tools, suggesting at least some degree of functional versatility in milling equipment. Even greater flexibility in tool function is implied by the wide range of food resources identified from feature fill, many of which would have been processed by grinding. However, tools with identical phytoliths both compare and contrast, which may owe to a number of factors including different processing strategies, the expedient nature of some tools, varying degree of use, or the oil content in some foods. The multifunctional nature of the LA 159879 assemblage appears to echo the conclusions reached by a number of ethnographers who stress that no single tool type can be assigned to a specific food based on morphology alone.

6 Faunal Analysis

Nancy J. Akins

Excavations at LA 159879 recovered few faunal remains (102 bones and 1 piece of egg shell) representing a small range of animals. The only animals specifically identified are cottontail rabbit, jackrabbit, and turtle. Seven of the feature and non-feature excavations produced fauna during excavation or from flotation samples.

GENERAL METHODS

The Deming project bone was identified using the OAS comparative collection. Recording followed the established OAS computer-coded format that identifies the animal and skeletal element, how and if the animal and part was processed for consumption or another use, and how taphonomic and environmental conditions have affected the specimen. The following describes and defines the variables.

Provenience Related Variables: Provenience and stratigraphic information was linked to the data file through the Field Specimen (FS) number. Each line contains the area within the site (northern, central, southern), the north and east coordinates of the grid or the feature number and feature division, the stratum and/or level, and the starting and ending depths.

Specimen Control Number and Counts: A lot number identifies a specimen or group of specimens that fit the description recorded in that line and the count indicates how many specimens are described by that line of data. A bone broken into a number of pieces during excavation or cleaning is counted as a single specimen.

Taxon and Common Name: Taxonomic identifications were made to the most specific level possible. Identifications that were less than certain were flagged in the certainty variable. Specimens that cannot be identified to the species, family, or order were assigned to a range of indeterminate categories based on the size of the animal and whether it is a mammal, bird, other animal, or cannot be determined. Unidentifiable fragments often constitute the bulk of a faunal assemblage. Identifying these as precisely as possible supplements the information gained from the identified taxa.

Element Characteristics: When possible, the skeletal element (e.g., cranium, mandible, humerus) is identified then described by side, age, and the portion recovered. Side is recorded for the element itself or for the portion recovered when it is axial, such as the left transverse process of a lumbar vertebra. Body-part information is crucial for examining whether complete or partial animals are represented and can aid in determining site function.

Post-occupational burrowers tend to be represented by the larger parts that will not pass through screens, and parts that are complete. Small animals, such as rabbits, are generally returned to a site complete so that all parts are found and the processing needed to render small animals into cooking or consumptive units is fairly minimal. Artiodactyls, with their larger body sizes, can be treated differently depending on how far from the site the animal was killed, how much of the animal was returned to a site, whether processing of complete animals took place at the site, or only high-yield parts were returned and processed, and whether the parts were consumed.

Age was estimated at a general level as: fetal or neonate, immature (up to two-thirds mature size), young adult (near or full size, with unfused epiphysis or young-textured bone), and apparently mature. The criteria used to assign the age is also recorded, generally, the size, epiphysis closure, or whether the texture of the bone is compact as in mature animals or porous as in less than mature animals. Aging based on texture alone is not absolute since most growth in mammals takes place near the articular ends so that diaphyseal bone can be compact and dense while the bone near an end retains a roughened or trabecular structure (Reitz and Wing 1999:73). As a result, fragments from the same bone can be coded as different ages and juvenile bone is probably under-numerated. Age information can be useful for determining the seasons a site was occupied. While small animals have long breeding seasons that can sometimes rule out some seasons of use, artiodactyls such as deer have a fairly restricted breeding and calving season and aging by size, epiphyseal union, and tooth wear can provide information on the season an animal died.

The portion of the skeletal element represented by a specimen was recorded in detail for estimating the number of individuals represented in an assemblage and to aid in discerning patterns related to processing. Indeterminate fragments were recorded as either long-bone shaft or end fragments or as flat bone.

Completeness: Completeness refers to how much of the skeletal element is represented by the specimen (analytically complete, more than 75 percent complete but not analytically complete, between 50 and 75 percent complete, between 10 and 50 percent, or less than 10 percent complete). Completeness is used in conjunction with the portion represented to estimate the number of individuals present. It also provides information on whether a species was intrusive and on the degree of processing, environmental deterioration, animal activity, and thermal fragmentation.

Taphonomic Variables: Taphonomy, or the study of preservation processes and how these effect the information obtained, has the goal of identifying and evaluating some of the non-human processes effecting the condition and frequencies found in a faunal assemblage (Lyman 1994:1). Taphonomic processes monitored in this analysis include environmental, animal, and some types of burning. Environmental alteration includes pitting or corrosion from soil conditions, sun bleaching from extended exposure, checking or exfoliation from exposure or soil conditions, root etching from the acids excreted by roots, polish or rounding from sediment movement, a fresh or greasy look, and damage caused by the soil or minerals

Animal alteration was recorded by source or probable source. Choices include carnivore (gnawing, punctures, and/or crushing), probable scat, rodent gnawing, carnivore and rodent, and altered but the agent is uncertain. Bones recorded as probable scat have rounding on edges and portions of the inner and outer tables can be partially dissolved.

Burning, when it occurs after burial, is also a taphonomic process. Furthermore, burning influences the preservation and completeness of individual bones. Heavily burned bone is friable and tends to break more easily than unburned bone (Lyman 1994:389–391; Stiner et al. 1995:223).

Burning: Burning can occur as part of the cooking process, part of the disposal process when the bone was discarded into a fire, or after it was buried. Burn color is a gauge of burn intensity. A light brown, reddish, or yellow color or scorch occurs when bones are lightly heated, while charred or blackened bone becomes black as the collagen is carbonized. When the carbon has been oxidized, it becomes white or calcined (Lyman 1994:384–388). Calcination requires direct exposure to live coals while bone buried up to 6 cm below a bed or coals can exhibit carbonization (blackening) (Stiner et al. 1995:223). Burns can be graded, reflecting the thickness of the flesh-protecting portions of the bone; they may be dry and light on the surface and black at the core or blackened on only the exterior or interior, indicating the burn occurred after disposal when the bone was dry. Graded or partial burns can indicate a particular cooking process, generally roasting, while complete charring or calcined bone do not. Uniform degrees of burning are possible only after the flesh has been removed (Lyman 1994:387) and generally indicate a disposal practice. While a wide range of colors and intensities occur, this information is summarized in the burn type variable, which identifies the intent rather than a more detailed visual description of the specimen. Complete and some graded burns represent discard processes and were recorded as discard. Patterns that suggest the part was roasted (e.g., graded burns that are scorched where the flesh is thick and burned black at the end where there is little or no flesh) were recorded as roasted. Bone that is only scorched can be problematic. It can be the result of roasting but can also occur from proximity to a heat source unrelated to cooking (e.g., buried beneath a thermal feature). In other cases, the burn appears accidental or intentional (e.g., dry burns or a burned tip) and is recorded as such. Potential boiling was recorded as boiled (color change, waxy, rounded edges) or boiled(?) when it is less clear.

Butchering and Processing: Evidence of butchering was recorded as a combination of morphology, tool type, and intent. Variables identify substantial cuts, chops, fine cuts (defleshing), impact breaks, spiral breaks, marrow breaks, snaps, and saw cuts. The location of these on the element is also recorded. A conservative approach was taken to the recording of marks and fractures that could be indicative of processing animals for food, tools, or hides since many natural processes result in similar marks and fractures. Spiral fractures were recorded based on morphology, while recognizing there are other causes and that these can occur well after discard. Impacts require some indication of an impact, generally flake scars or evidence of percussion. These were not recorded when they were ambiguous or accompanied by carnivore gnawing. The condition of the bone in many faunal assemblages often obscures or destroys much of the evidence of processing.

Modification: Tools or ornaments, manufacturing debris, utilized bone, possible modification, and pigment stains were identified as modified. Categories are fairly broad, as a worked bone analysis defines the item type.

Comments: The comment section was used to flag specimens recovered from flotation and to make verbal comments. For example, when a more specific age can be assigned it would be recorded as a comment.

Data Analysis: The data was entered and checked and the provenience information added. Data were tabulated and analyzed using SPSS (pc version 11).

LUNA COUNTY FAUNA

A wide variety of animals inhabit Luna County. Searching the New Mexico Fish and Game list of species in the Biota Information System (BISON-M, October 12, 2011) and selecting for those found in Luna County that live in a Chihuahua desert vegetative zone characterized by tarbush, mesquite, and ocotillo, results in at least 178 species (Table 6.1). Many of those on the list are unlikely sources of food or raw material (amphibians, most reptiles, many of the birds, and bats), however, the list is an indication of the range of fauna that could have been available for prehistoric groups. The floodplain may support additional species and other species may have inhabited the area in the past and in times when moisture was more abundant.

Even though a wide range of animals were present, prehistoric groups tend to focus on only a few of these, mainly rabbits, deer, and pronghorn. Peccary are currently found in only the southwest corner of the county (Findley et al. 1975:325) and may have spread north of Mexico in only the last 300 years (Martin and Szuter 2004:68).

Cottontail rabbits (*Sylvilagus audubonni minor*) favor open country with a sufficient cover of weeds, brush, or cactus and the protection provided by burrows of other animals such as badgers and prairie dogs (Bailey 1971:56). Their primary advantage is the ability to reproduce abundantly and rapidly. These short-lived prolific breeders produce up to five litters of three to four a season. Young are born from late March into September, becoming sexually mature at 80 days. Gestation is 25 to 35 days and the young are ready to leave the nest at two weeks of age and disperse at three weeks (BISON-M, October 12, 2011). While no numbers are available for this species of cottontail it probably falls within the range represented by other cottontail species. A female Nuttall's cottontail can produce 22 young per year while an eastern cottontail in Oregon can produce 39 young per year (Chapman et al. 1982:96). Rapid breeding makes cottontail rabbits an ideal food animal. Their relatively small ranges and propensity to feed, hide, bask, and rest in vegetation or near burrows (BISON-M, October 12, 2011) made them a fairly predictable resource and one that was susceptible to capture with snares and nets.

The much larger black-tailed jackrabbit (*Lepus californicus texianus*) is widespread. These rabbits are not only abundant but able to inhabit desert valleys where there is little or no water by obtaining moisture through food plants (Bailey 1971:49). Jackrabbits are not as prolific as cottontails, with females in southern Arizona producing about 16 young annually. Also in southern Arizona, the breeding season lasts for 300 days and the mean litter size is 2.24. Gestation is about 45 days. Most females do not

Table 6.1. Animals present in Luna County, Chihuahua Desert ecozone.

Taxonomic Group	No. of Species*	Comments
Amphibians:	**6**	
Salamanders	1	–
Spadefoot toads	3	–
Toads	2	–
Reptiles:	**39**	
Lizards	21	–
Snakes	17	–
Turtles	1	*Terrapene ornata* , ornate box turtle
Birds:	**88**	
Falconiformes	12	vultures, hawks, falcons
Galliformes	2	quail, grouse, turkeys
Charadriiformes	1	shorebirds (killdeer)
Columbiformes	3	pigeons and doves
Cuculiformes	1	cuckoos and roadrunners
Strigiformes	3	owls
Caprimulgiformes	3	goatsuckers
Apodiformes	3	swifts and hummingbirds
Piciformes	2	woodpeckers
Passeriformes:	**58**	
Tyrannidae	4	tyrant flycatchers
Alaudidae	1	larks
Hirundinidae	1	swallows
Corvidae	5	jays, magpies, crows
Paridae	2	chickadees, titmice, verdin, bushtits
Sittidae	1	nuthatches
Troglodytidae	4	wrens
Mimidae	5	mockingbirds and thrashers
Turdidae	1	thrushes, solitares, bluebirds
Ptilogonatidae	1	silky flycatchers
Laniidae	1	shrikes
Parulidae	2	wood warblers
Icteridae	7	blackbirds and orioles
Thraupidae	1	tanagers
Fringillidae	22	grosbeaks, finches, sparrows
Mammals:	**45**	
Bats	8	–
Rabbits	2	cottontail, jackrabbit
Rodents:	**20**	
Sciuridae	2	squirrels
Geomyidae	2	pocket gophers
Heteromyidae	3	pocket mice
	3	kangaroo rats
Cricetidae	4	*Peromyscus*
	2	grasshopper mice
	1	harvest mouse
	1	cotton rat
	2	wood rats
Carnivores:	**12**	
Canidae	4	coyote, foxes
Procyonidae	2	racoon, ringtail
Mustelidae	4	skunks
Felidae	2	bobcat, mountain lion
Ungulates:	**3**	
Tayassuidae	1	peccary
Cervidae	1	deer (mule)
Antilocapridae	1	pronghorn

*BISON-M, accessed October 2011

breed during their first year. Adult size is reached by seven months (BISON-M, October 12, 2011; Dunn et al. 1982:128). Jackrabbits usually rest during the day in grass or vegetation and avoid the heat and sunlight in hot weather. When well hidden, they may lie still until nearly stepped on before bounding away at great speed (Bailey 1971:49). Dietary items, including mesquite leaves and seedpods, soaptree yucca, and various grasses (Dunn et al. 1982:131), may have put jackrabbits in direct competition with human foragers. Abundance in areas that are otherwise dry and hiding in clumps of vegetation are traits that would have been noted by prehistoric hunters.

Mule deer (*Odocoileus hemionus*) range throughout all elevations and habitats in New Mexico. As browsers, their most important foods are shrubs and trees (Findley et al. 1975:328–329). Like the jackrabbit, mule deer in the arid Southwest rely on the moisture found in plants or the dew on plants to meet their metabolic needs (Mackie et al. 1982:866–867). In some areas, deer move to higher altitudes in hot weather, returning to the foothills and valleys in the winter. In the Deming area, fawns are probably born in late May to early June and have a gestation period of seven months; litters range from one to three. Carrying capacity in chaparral is 4 to 30 and averages about 10 per square mile (2.5 km) state-wide depending on weather and habitat (Bailey 1971:34; BISON-M, October 12, 2011). Body weight fluctuates between 19 and 22 percent seasonally, increasing summer into early fall and declining in fall and winter. Weight in both males and females peaks during October and is lowest in March. Deer tend to be widely dispersed, living alone or in small groups, but may be forced to congregate on winter ranges. Dispersal is greatest in summer during the fawning period. Females drive yearlings off and groups comprise males or yearlings. After about two months, yearlings rejoin the does and fawns so that group size increases through late summer and fall into winter (Mackie et al. 1982:863, 868). Located in a valley setting, we would expect deer to have a greater presence in the site area during the cold season, but they would not necessarily be in the best condition.

The Mexican pronghorn (*Antilocapra americana mexicana*) was once numerous but their population has declined. Bailey reports a "good many on the plains south of Deming" in 1908 (Bailey 1971:28). In Arizona, pronghorn prefer areas with grass and scattered shrubs in rolling or dissected hilly or mesa areas. In southwestern Arizona fawning peaks in March and April, and from April to June in central Arizona. Gestation is 230 to 240 days (BISON-M, October 12, 2011). Again, like other desert dwellers, pronghorn can survive where free water is not available, probably by obtaining moisture from desert succulents. Pronghorns are a herd animal, especially during winter. After winter, the herds break up into smaller groups by age and sex. Young males form bachelor herds, females form herds that may associate with older males. Does leave the herd and scatter to give birth, forming nursery herds once the fawns are three to six weeks old. In some areas, pronghorns migrate between summer and winter ranges. Daily movements are shortest in spring, when food is abundant, and longest in fall, when plants are dry and less abundant. Both males and females generally weigh less in May, possibly into winter for females, but weight gain is probably correlated with the rainy season (Kitchen and O'Gara 1982:963–965). For prehistoric hunters, the advantage of herds was probably partially offset at least somewhat by the speed at which pronghorn can flee.

LA 159879 Faunal Assemblage

A fairly small sample of fauna was recovered from LA 159879 (Table 6.2), with nearly a third found in flotation samples. Almost all are small fragments (90.3 percent) that are consistent with small mammals and most are probably from two of the identified taxa, cottontail rabbit and jackrabbit. None could be from small rodents and if rodents are represented at all, these were large-sized rodents (e.g., squirrels). The only other animal bone that could be identified was an unburned piece of turtle carapace, probably from a box turtle. The eggshell fragment was white and thin (0.17 mm). It was from Strata 3 of a grid excavation and may be a result of the bioturbation in this stratum. In addition to the fragmentation, all of the unburned and a few of the burned specimens are heavily etched from soil conditions or etched and checked from soil conditions and exposure. No animal alternation is evident but gnawing could be obscured by the deep etching. Etching also obscures all but epiphyseal evidence

Table 6.2. LA 159879, summary of fauna by area and feature.

	Northern				Central														Southern		Total	
	Non-Feature		Feature 15		Non-Feature		Feature 3		Feature 6		Feature 7		Feature 9		Feature 11		Feature 12		Non-Feature			
Common Name	**N**	**Col. %**	**N**	**Col. %**	**N**	**Col. %**	**N**	**Col. %**	**N**	**Col. %**	**N**	**Col. %**	**N**	**Col. %**	**N**	**Col. %**	**N**	**Col. %**	**N**	**Col. %**	**N**	**Col. %**
Small mammal	3	100	26	83.9	8	66.7	23	63.9	3	42.9	1	100	2	100	1	33.3	–	–	3	42.9	**70**	**68.0**
Cottontails	–	–	1	3.2	2	16.7	7	19.4	2	28.6	–	–	–	–	–	–	–	–	–	–	**12**	**11.7**
Black-tailed jack rabbit	–	–	4	12.9	1	8.3	6	16.7	1	14.3	–	–	–	–	2	66.7	1	100	4	57.1	**19**	**18.4**
Eggshell	–	–	–	–	1	8.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**1**	**1.0**
Turtles and tortoises	–	–	–	–	–	–	–	–	1	14.3	–	–	–	–	–	–	–	–	–	–	**1**	**1.0**
Total	**3**	**100**	**31**	**100.0**	**12**	**100.0**	**36**	**100.0**	**7**	**100.0**	**1**	**100**	**2**	**100**	**3**	**100.0**	**1**	**100**	**7**	**100.0**	**103**	**100.0**
From flotation	–	–	**15**	**48.4**	–	–	**8**	**22.2**	**1**	**14.3**	**1**	**100**	**2**	**100**	**3**	**100.0**	**1**	**100**	–	–	**31**	**30.1**
Completeness																						
<10%	3	100	30	96.8	12	100.0	33	91.7	4	57.1	1	100	2	100	3	100.0	–	–	5	71.4	**93**	**90.3**
10–50%	–	–	1	3.2	–	–	2	5.6	2	28.6	–	–	–	–	–	–	1	100	2	28.6	**8**	**7.8**
Complete	–	–	–	–	–	–	1	2.8	1	14.3	–	–	–	–	–	–	–	–	–	–	**2**	**1.9**
Burning																						
Unburned	3	100	8	25.8	12	100.0	26	72.2	6	85.7	1	100	–	–	1	33.3	1	100	4	57.1	**62**	**60.2**
Discard burn	–	–	22	71.0	–	–	8	22.2	1	14.3	–	–	1	50	2	66.7	–	–	3	42.9	**37**	**35.9**
Scorched	–	–	1	3.2	–	–	2	5.6	–	–	–	–	1	50	–	–	–	–	–	–	**4**	**3.9**

for immature animals and none of the bones have unfused epiphyses. Bone was presumed mature because the surfaces could not be examined for subtle indications that the animal was young. The only potential processing is two spiral breaks on small mammal long-bone shafts and this type of break can be attributed to a variety of taphonomic processes (e.g., carnivores, foot traffic).

Taken as a whole, the small sample of rabbit bones represents an array of body parts from head to toe. While cranial, lower limb, and foot bones are often considered waste products, it is likely that in this early period all parts of small mammals were utilized. More of the small mammal (42.9 percent) and jackrabbit (47.4 percent) bone is burned than cottontail (16.7 percent) bone is (Table 6.3).

Grid excavations in all three portions of the site and the fill of seven features contained bone (Table 6.2). All but Feature 3 are fire pits; Feature 3 was a small, shallow structure. Cottontail rabbit remains were found in four of the provenience divisions and jackrabbit in six. However, when both occur, only one has more jackrabbit than cottontail. By area, northern and southern areas have more jackrabbit specimens relative to cottontail, with 2.9 percent cottontail to 11.8 percent jackrabbit in the northern area. The small southern area sample has no cottontail. Counts are equal in the central area. More of the northern area bone is burned (67.6 percent), followed by the southern area (42.9 percent), then the central area (24.2 percent). Most of the bone is highly fragmented, with only the larger sample from the central area containing complete specimens (2 or 3.2 percent).

Northern Area

Excavations in the northernmost area produced fauna in a single grid unit (6387N/526E, Stratum 2) and in Feature 15. A radiocarbon date on wood from Feature 15 is late (most accurate AD 1520–1670, most precise AD 1635–1666; Beta-307898). Specimens from the grid are all small mammal, long-bone shaft fragments; none are burned. Feature 15, a large but fairly shallow fire pit has one of the larger feature samples for this site (n = 31). Nearly half of the bones (n = 15) were recovered in the southern half flotation sample. None of the flotation bone was identifiable beyond small mammal. All are very small fragments; more are burned (n = 10) than unburned (n = 5), and all are evenly divided between long and flat bones (n = 7 each) plus a piece of cranium.

Table 6.3. LA 159879, body part distribution and burning for small mammal and rabbit taxa.

	Small Mammal		**Cottontail**		**Jack Rabbit**		**Total**		**Percent Burned**	
	Count	**Col. %**	**Count**	**Col. %**	**Count**	**Col. %**	**Count**	**Col. %**	**Count**	**Row %**
Long bone	49	70.0	–	–	–	–	**49**	**48.5**	20	40.2
Flat bone	19	27.1	–	–	–	–	**19**	**18.8**	9	47.4
Cranium	2	2.9	6	50.0	2	10.5	**10**	**9.9**	2	20.0
Mandible	–	–	–	–	4	21.1	**4**	**4.0**	2	50.0
Rib	–	–	–	–	1	5.3	**1**	**1.0**	1	100.0
Scapula	–	–	1	8.3	–	–	**1**	**1.0**	–	–
Humerus	–	–	–	–	4	21.1	**4**	**4.0**	1	25.0
Radius	–	–	–	–	1	5.3	**1**	**1.0**	1	100.0
Femur	–	–	–	–	1	5.3	**1**	**1.0**	–	–
Tibia	–	–	2	16.7	5	26.3	**7**	**6.9**	3	42.9
Astragalus	–	–	–	–	1	5.3	**1**	**1.0**	–	–
First phalanx (pes)	–	–	1	8.3	–	–	**1**	**1.0**	1	100.0
Metapodial	–	–	1	8.3	–	–	**1**	**1.0**	1	100.0
First phalanx	–	–	1	8.3	–	–	**1**	**1.0**	–	–
Total	**70**	**100.0**	**12**	**100.0**	**19**	**100.0**	**101**	**100.0**	**41**	**40.6**

Those not recovered by flotation (n = 16) include a cottontail metapodial shaft fragment and jackrabbit mandible (n = 2), cranium, and rib fragments. All of the identified specimens are burned. The rest are small mammal and include pieces of long bone (n = 8, 6 burned), flat bone (n = 2, both burned), and an unburned piece of cranium.

Central Area

Much (60.2 percent) of the faunal assemblage was recovered from the central area of the LA 159879 site excavations. Five grids around one of the small structures (Feature 3) contained bone (n = 12), and all were found in Stratum 3. None of the grid-unit bone was recovered from flotation, and none are burned. The eggshell and a jackrabbit mandible fragment were found in 275N/616E. A small mammal long-bone shaft fragment was found in the grid unit 2 m to the north. Grid unit 277N/617E contained three pieces of long-bone shafts and a cottontail tibia shaft fragment. The grid unit just to the north has a near identical assemblage comprising two small mammal long-bone shaft fragments and a cottontail tibia fragment. North and west in grid unit 279N/615E were two small mammal long-bone shaft fragments.

Only Feature 3, a possible structure with three radiocarbon dates falling between 900 and 790 ± 30 cal BC (2 sigma; Beta-307890–307893), has an appreciable amount of bone (n = 36). Some (n = 8, 22.2 percent) were recovered from two flotation samples. Half of the flotation specimens are small mammal long-bone shaft fragments (half burned, half unburned) with fewer unburned flat-bone fragments (n = 3).Two jackrabbit specimens (mandible and tibia fragments) are unburned. Fauna that was not from the flotation sample is predominantly small mammal (n = 17), including burned (n = 4) and unburned (n = 7) long-bone shaft fragments and burned (n = 2) and unburned (n = 4) flat-bone fragments. Of the cottontail specimens (n = 7), none of the cranial pieces (n = 6) are burned but a complete first phalanx from a hind foot is burned. The jackrabbit parts include an unburned maxilla fragment, a burned and an unburned humerus fragment, and a scorched tibia shaft fragment.

Feature 6, a small informal fire pit with a radiocarbon date of 980 to 830 ± 30 cal BC (2 sigma; Beta-307894), has the next largest sample (n = 7) for this area. An unburned fragment of a cottontail phalanx was recovered in a flotation sample. Unlike most of the feature assemblage, only one specimen is burned, a small mammal long-bone shaft fragment. Other specimens include unburned small mammal long-bone shaft fragments (n = 2), a partial cottontail scapula, a complete jackrabbit astragalus, and the piece of turtle carapace.

The bone found in the other central area features was all recovered from flotation. Feature 7, a small fire pit, had an unburned small mammal long-bone shaft fragment. Feature 9, another small fire pit with one of the earlier radiocarbon dates (1020–900 ± 30cal BC (2 sigma; Beta-307895), had burned pieces of small mammal long bone and flat bone. Feature 11, a shallow fire pit with a radiocarbon date of 920–810 ± 30 cal BC (2 sigma; Beta-307897), held an unburned long-bone shaft fragment from a small mammal and burned pieces of a jackrabbit radius and tibia. Feature 12, also a shallow fire pit, had a piece of an unburned jackrabbit humerus.

Southern Area

The fauna from the southern portion of the site was recovered from four grid units. None were from flotation samples. Two burned small mammal long-bone shaft fragments were found in 204N/704E. Grid unit 215N/702E produced an unburned jackrabbit tibia fragment in Stratum 3. The grid unit just to the east had an unburned small mammal long-bone shaft fragment in the same stratum. The grid unit east of that had three jackrabbit bones, unburned pieces of a humerus and a femur, and a burned piece of a tibia, also from Stratum 3.

LATE ARCHAIC/EARLY AGRICULTURAL–PERIOD FAUNAL EXPLOITATION

Most of the radiocarbon dates from features at LA 159879 date to the Late Archaic/Early Agricultural periods, as early as 1050 BC and as late as 429 BC (Chapter 8 most accurate dates). Before turning to the specific research questions for the Deming project, a sample of the literature on Late Archaic/ Early Agricultural–period subsistence and generalizations regarding hunting are reviewed.

Theoretical Perspective

Faunal subsistence data is often viewed through the framework of a variety of foraging models grounded in human behavioral ecology. One of these, termed the prey choice or diet breadth model, assumes that foragers will try to maximize their rate of energy acquisition by adding resources from the highest (i.e., large mammals) to lowest return rate. Predictions that follow from this model include: 1. foragers will always pursue high-ranked resources when they are encountered; 2. lower-ranked resources are not added to the diet due to their own abundance, rather they are added when the higher-ranked resources are not as abundant; and 3. resources are added or deleted by rank order. However, recent studies have demonstrated that energy return does not always determine the rank of a resource. For example, hunting high-risk prey may be costly and inefficient but it confers benefits, such as status, that are not related to consumption. Furthermore, prey choice varies by the age, sex, and composition of the task group. Women and children often target low-ranking resources that are easy to handle (Lupo 2007:145–155). Models such as these have some utility but often ignore the contribution of other resources, such as plants, to the diet and assume that that animal acquisition is independent of plant acquisition and that changes in plant acquisition, including reliance on storable vegetal products, could influence the ranking of some smaller prey (Lupo 2007:173).

Given the scale of most research projects, few have the resources to effectively identify, quantify, rank, and explore resource choices based on archaeological data within an entire catchment. Yet, most explicitly or implicitly utilize some variation of this model for examining the archaeological remains left by Archaic hunter-gatherers in southern New Mexico. Most begin by examining the relationship between site location and aspects of the environment identifying potential plant and animal resources and assessing the potential for cultivation (Hogan 2006:4–23). For example, Mauldin's study of small non-diagnostic lithic scatters in the southern Tularosa valley east of Deming describes the central valley as one with no permanent water sources except for playas that could hold water after intense storms. The valley is enclosed by north–south trending mountain ranges with springs and some small streams flowing out of those to the east. Rainfall is variable and highly seasonal, and temperatures extreme. As a result, he proposes that temperature and rainfall patterns would have made deer and pronghorn some of the few foods available from winter to early spring. Late spring resources would include cool season grasses, rabbits, rodents, as well as agave, sotol, and yucca. Summer monsoons bring warm season grasses, yucca, mesquite, rabbits, rodents, and some large mammals. His research suggests that the central valley sites are small, short-term residential sites that date from the Late Archaic into the Early Ceramic period and appear to focus on hunting and gathering. Flotation samples from excavated sites contain few charred seeds from wild plants and the faunal remains are invariably from cottontail and jackrabbits or animals in that size range (2004:87, 89, 95).

Analyzing excavations at nine sites on the McGregor Guided Missile Range, Bury and colleagues were unable to determine the basis for procurement decisions in that region based strictly on an optimum foraging model (Bury et al. 2009). Ranked by return in calories for the procurement time expended, deer were by far the highest-ranked resource. Deer are followed by jackrabbit (cottontails are not on their list), mesquite, saltbush seeds, rye grass seeds, then corn. Yet the archaeological evidence indicates that rye grass provided more of the calories than the higher-ranked resources. Seasonal abundance is suggested as the main reason for the high rank of the rye (Bury et al. 2009:299–300). This study demonstrates another problem with trying to apply a broad catchment-based model to a single or small sample of sites that reflect only a portion of the routine subsistence behavior of highly mobile groups. It is not so much the failure of a model but of our attempts to address complex subsistence systems by looking at only a small piece of the evidence.

Summary of Late Archaic Subsistence

Miller and Kenmotsu (2004) summarize subsistence in the Jornada Mogollon and Eastern Trans-Pecos regions during the Late Archaic as a mixed economy characterized by some dependence on corn agriculture, a broad spectrum of plants, and a variety of animals. Diverse environmental and topographic zones were utilized, including interior basins. Rock shelter sites with Late Archaic deposits contain mainly large- or medium-sized animal remains while open-air site assemblages have mainly rabbits. Sites tend to be more numerous than in the Middle Archaic and are small, with thermal features and occasional structures. Group mobility may have decreased and the land-use pattern intensified (2004:228–230, 235). Cultigens continued to play a minor role into the early Formative period, where a mobile hunter-gatherer adaptation continued (Miller and Kenmotsu 2004:237).

The early part of the Formative period (AD 200–1000) was characterized by a dispersed settlement system, exploitation of several environmental zones, and ephemeral semi-circular house structures. Alluvial fan use increased gradually, along with the construction of more substantial pit structures and a decrease in the use of central basin landforms. Detailed studies of fauna, while rare, suggest rabbits are common in assemblages from lowland settings, with some medium artiodactyls and indications for the use of riverine resources. Projectile points are rare in Formative-period habitations, an observation that is consistent with the reduced importance of large mammals in the diet (Miller and Kenmotsu 2004:236–238, 247, 250, 255).

One of the themes seen here and elsewhere is that, given the modern climate and environments, Archaic groups in southern New Mexico probably employed a foraging strategy that emphasized residential mobility. Mobility continued to be the primary option until greater population levels led to decreases in the territories that could be utilized and leading to cultivation (Hogan 2006:4–51).

Another theme is the contrast between the fauna recovered at rockshelter versus open-air sites, which might be better characterized as more of an upland (woodland) and lowland (desert scrub and grassland) dichotomy. Given that ethnographically documented groups depending primarily on plants are invariably foragers and that these groups move and average of 12.6 ± 9.9 times annually an average of 24.49 ± 13.7 km (15.2 miles) per move (Binford 2001:254, 278), the same groups could easily be responsible for the range of sites found in both upland and lowland settings (e.g., B. Huckell 1996:350–352).

Southern New Mexico Faunal Subsistence

The Late Archaic/Early Agricultural phase (ca. 1500 BC–AD 400) was a time of population growth and major changes in settlement and technology. These include the first evidence of agriculture, brown ware ceramics, and a more diverse array of feature types, as well as substantial occupation of interior basins landforms and nearly all environmental and topographic zones. Much of the evidence for plant and animal use comes from rockshelter sites. Open air sites, like LA 159879, generally have poor preservation and small samples of fauna (Miller and Kenmotsu 2004:226, 228).

With little comparative faunal data for the Deming area, assemblages from neighboring basins and river valleys in southern New Mexico are examined for insights into subsistence in the greater region. Recent work at Fort Bliss, in the northern Tularosa Basin, in the Sacramento Mountains, and in the Pecos Valley are reviewed for consistency with the generally accepted views on the Late Archaic/Early Agricultural and Early Formative periods. In each area, we see the contrast between upland and lowland, and occasionally river valley, faunal assemblages.

Northwest of Deming, excavations at the Late Archaic/Early Agricultural sites of Wood Canyon and Forest Home in the Big Burro Mountains produced good samples of fauna. While neither is a rockshelter, both are upland sites with more substantial occupations than LA 159879. Pit structures, storage features, human burials, corn, and substantial trash were found at the Forest Home site, which also has components dating to the Early Pithouse period (AD 200–550) (Turnbow and Reycraft 2000). The Wood Canyon site had the same suite of features as Forest Home, indicating a mixed farming, hunting, and foraging economy. The site also has minor Middle Archaic, Late Pithouse, Mimbres, and Protohistoric components (Turnbow 2000a). Faunal results for these two sites are mainly presented at the site level without breaking the assemblage into components. Forest Home has an assemblage size of 907 that includes both species of rabbit, a squirrel, two rodents, porcupine, coyote, deer, and pronghorn. Rabbits comprise relatively little of the assemblage: 1.4 percent cottontail, 2.1 percent jackrabbit, and 4.1 percent all rabbit, with only 5.2 percent small mammal. Artiodactyls are more common, 6.1 percent are deer and 0.1 percent are pronghorn, with a total of 6.6 percent for all artiodactyls, and an additional 15.4 from large mammals and 34.7 percent classified as medium-to-large mammal, for a total of between 6.6 and, potentially, 56.7 percent. Wood Canyon has a larger sample (n = 2,820), with turtle, lizard, red-tailed hawk, roadrunner, both rabbits, at least three rodents, a fox, a larger canid, raccoon, bobcat, elk, deer, pronghorn, and bighorn sheep. Again, rabbits are relatively rare with1.8 percent cottontail, 3.2 percent jackrabbit, 6.8 percent for all rabbit, and an additional 12.7 percent that are small mammal. Artiodactyls are more common, with 1.6 percent deer, 0.6 percent elk, 0.2 percent pronghorn, 0.1 percent bighorn, and all artiodactyl 4.0 percent; an additional 12.3 percent are large mammal and 17.2 percent are medium-to-large mammal (Duncan 2000), for a range of 4.0 percent to a maximum of 33.5 percent artiodactyl. These larger samples contain a greater diversity of fauna and both indicate substantially more reliance on artiodactyls in the more upland areas around Deming.

South-central New Mexico, including the Tularosa Basin and Fort Bliss, has had considerably more excavation but there is relatively little faunal data. Exceptions include upland shelter sites. The Late Archaic assemblage from High Rolls Cave (Stratum 2, n = 1653) has mainly artiodactyls bones (71.7 percent), especially deer (12.1 percent), but it also has pronghorn (0.8 percent) and bighorn (1.0 percent), and a little more rabbit (3.4 percent). Aged immature artiodactyl specimens indicate the shelter was mainly used during the late spring and summer (Akins 2006:110, 117, 125). The latest of the Late Archaic deposits produced a fairly small and similar assemblage (n = 142). Small mammals, including cottontail rabbit (5.8 percent), increase but remain rare, as are woodrats (0.7 percent) and birds (very large bird 0.7 percent) compared to artiodactyl remains (66.9 percent medium artiodactyl, 17.6 percent deer, and 0.7 percent each for pronghorn and bighorn). The range of ages in deer specimens indicates at least summer and winter deposition. (Akins 2006:110, 123, 125). Nearby Fresnal Shelter is a larger shelter, and field-school excavations in 1969–1971 collected about 28,000 pieces of bone. The array of species recovered is similar to High Rolls and it, too, included large quantities of artiodactyl bones that are or probably are deer (Wimberly and Eidenbach 1981:21; Witter 1972:appendix 3). The Archaic stratum in Hooper Canyon Cave in the Guadalupe Mountains' upper piñon-juniper zone also has an assemblage that is predominantly large mammal, mainly deer (Hogan 2006:4–32).

This abundance of artiodactyl remains at higher elevation shelter sites contrasts with more lowland shelter assemblages such as the Late to Middle Archaic assemblage from Todsen Shelter in the Las Cruces area. That assemblage comprises mainly rabbit remains along with some aquatic species (Miller and Kenmotsu 2004:228). The same is true for Honest Injun Cave where rabbits and some rodents were the most commonly utilized taxa (Hogan 2006:4–32).

While some variability is evident for shelter sites, the same is not true for the lowland open sites where faunal subsistence was centered around rabbits. Bone is decidedly sparse in these sites but most reach this conclusion (e.g., Church and Sale 2003:161–168). A sample consisting of the most likely subsistence remains from 33 central Hueco Bolson sites dating to the Late Archaic and Mesilla phase (n = 1,317) were largely unidentifiable (n = 931), but cottontail (n = 73) and jackrabbit (n = 51) were the most abundant of the identifiable specimens (Mauldin et al. 1998:134). In the El Paso area, Archaic assemblages (n = 3) were very small (less than 100 specimens each) and have both cottontail and jackrabbit but most are mainly small mammal remains and none are from larger animals. Three Mesilla-phase assemblages were also small (n = 12, 30, and 38 specimens) and one has a good sample size (n = 816). Cottontail was found in all of the assemblages but jackrabbit at only one. No large mammal bone is listed for the large assemblage (Presley and Shaffer 2001:416, 418–419). Two Mesilla-phase sites in the Tularosa Basin produced a sample of 119 identifiable and 571 unidentifiable elements. Of a sample selected from seven features, most are from rabbits (n = 115), with a few rodents (n = 5) and artiodactyls (n = 3) (Church and Sale 2003:141–142).

Researchers in the southern Tularosa Basin have proposed a bi-seasonal settlement model where small family groups spent warm seasons in the basin and aggregated along alluvial fans during cold weather. These groups would have pursued a broad spectrum of resources that favored small mammals, grasses, and seed-bearing plants moving to a new residence when resources were depleted. The same strategy would have been used in winter but they were able to acquire large game and acquire firewood (Bury et al. 2009:43–44). Finding that the archaeological remains (including 159 bones from nine sites) do not reflect rankings for local resources, they conclude that the main recovered resource (wild rye) was seasonally available in large quantities making it a high ranking resource and that rabbits would always be taken at an opportunistic level (Bury et al. 2009:295–300).

Fauna recovered during recent work in the Pecos Valley suggests a similar pattern. Lowland sites contain significant amounts of rabbit bone, and these sites appear to represent groups with a more plant-based and a more diverse and small animal focus as compared to upland sites with an overwhelming emphasis on artiodactyls. Sites along the Pecos show early use of aquatic resources, such as mussel shell, combined with rabbits. The Brantley Reservoir project just north of Carlsbad on the Pecos River investigated sites dating to three local phases of the Archaic. Fauna was generally sparse and the report lacks information on the size of the animal for unidentifiable fragments and little attempt was made to identify the burned bone or isolate components in multicomponent sites. Taxa that were identified are apparently unburned and include cottontail, jackrabbit, pocket gopher, woodrat, a few fish bones, modern domesticates (Robertson 1985:A-19-A-23), and three species of freshwater mussels (Murray 1985:A-20-a-27). Middle Archaic or Avalon Phase (3000–1000 BC) investigations at five sites described as campsites located along major water courses included one site with a living surface, rock-lined thermal pits, and concentrations of large mussel shells demonstrating an aquatic aspect to the diet. Four sites dating to the Late Archaic or McMillan Phase (1000 BC to AD 1) were characterized by burned-rock concentrations. These were considered campsites and the presence of projectile points as an indication of utilization of upland faunal resources. The final Archaic or Brantley phase (AD 1–750) was found at eight sites and commonly includes burned rock rings. A mixed plant and animal economy and upland orientation were proposed for this period (Katz and Katz 1985:396–410).

Farther north, the most recent OAS studies at the lowland Townsend site near Roswell, an upland rockshelter in the Sacramento Mountains, and a lowland open-air site, add to our knowledge of subsistence during this period. The Late Archaic occupation of the Townsend site, located on Salt Creek, a tributary of the Pecos River, consists of areas with thermal features, sparse fire-cracked rock, and moderate amounts of lithic and ground stone artifacts. The fauna suggests a balanced use of large and small animal forms. A sample of 152 specimens from a non-feature grid location produced more bones from small mammals (59.2 percent) than artiodactyls (37.5 percent), and includes some rodents (4.6 percent), but no mussel shell. The other area has a very small sample (n = 5) (Akins 2003:276, 304). Fallen Pine Shelter is located in the Sierra Blanca Mountains on a convenient route between the Hondo Valley and the Tularosa Basin. Fauna recovered from the shelter itself (n = 158) and the talus in front of the shelter (n = 321) was highly fragmented artiodactyl (67.7 and 62.3 percent) and deer (9.5 and 9.3 percent) with virtually no rabbit (0.6 and 0.9 percent) and no small mammal bone. Most of the deer and medium artiodactyl bone was from mature animals (Akins 2004:108, 112). The Sunset Archaic site overlooking the Hondo River had evidence of early agriculture (corn) and storage. The fauna (n = 1,018 pieces) is mainly from small forms (cottontail 23.3 percent, jackrabbit 8.2 percent, small mammal 53.5 percent) with few artiodactyl (3.9 percent) and potential artiodactyl remains (large mammal 5.4 percent). A small number of bird and other rodent bones were also recovered (Mick-O'Hara 1996:159–160; Wiseman 1996).

Projects in the Pecos Valley also contribute to our understanding of early Formative subsistence, in at least that area and indicate a continuation in the patterns observed for the Late Archaic. The Townsend site has a Mesilla-phase component (radiocarbon dates of AD 570 ± 40 to 940 ± 70) with structures. The faunal assemblage (n = 1316) is mainly small mammal (56.4 percent) and rabbit (14.2 percent) with very little bone from artiodactyls (1.7 percent) or large mammals (3.0 percent). Prairie dog is fairly common (2.5 percent), and the assemblage contains a range of other rodents, turtle, fresh-water mussel shell (8.3 percent), and a small amount of fish (0.5 percent) (Akins 2003:270, 276).

Fallen Pine Shelter fauna from slightly later ceramic levels (n = 274; equivalent to the Dona Ana Phase) are mainly artiodactyls (50.4 percent medium artiodactyl; 9.5 percent deer) with few rabbit (3.0 percent) or small mammal (1.1 percent), and considerable turkey (10.6 percent) and large bird (6.9 percent). Aspects are consistent with a short-term base camp occupied by small groups of foragers rather than a logistic camp produced by more settled groups who largely relied on agriculture (Akins 2004:112, 131). Other Pecos Valley sites have not been as productive for faunal remains.

Formative sites in the Southern Mesilla Bolson at the Santa Teresa Port-of-Entry have produced little or no fauna (Moore 1996). A Mesilla-phase site at Fort Bliss (LA 126396) with a sample size of 119 was largely rabbit (n = 51 jackrabbit, n = 64 cottontail) with a few possible rodent and three artiodactyl bones (Church et al. 2003:142–143). An assemblage from the Mesilla-phase site of Los Tules near Las Cruces was mainly rabbit, while the Sandy Bone site located just north of Anapra had rabbits as well as riverine resources like duck, fish, and softshell turtle. The sample of 1,510 specimens has a single deer bone along with 43 from cottontails and 318 from jackrabbits (O.Laughlin 1977:27–30).

For the most part, assemblages from these three areas suggest some variability during the Archaic and Formative periods depending on area and especially on elevation. Formative-period sites along the Pecos River and its tributaries show a high dependence on rabbits and small forms, on more diverse forms, and greater use of riverine resources than in the Archaic. Highland sites show that artiodactyls were still an important resource and may document the shift from more mobile groups acquiring artiodactyls as part of their seasonal movements to more targeted logistic hunts by groups that were more sedentary. How the central basin sites fit into the overall picture during the Formative is less clear. In some areas the trends in animal subsistence may resemble that in the Pecos Valley, that is, little artiodactyl, significant amounts of rabbit, and increased use of riverine resources. In other areas, and most likely the Deming area, the sites may be more like logistical bases from which plant resources are gathered and where the fauna could represent encountered species rather than targeted ones.

RESEARCH QUESTIONS

The primary research questions for the fauna data are in Problem Domain 2 (subsistence and economy) where only some apply and can be addressed. Question 1 asks what resources were exploited by the site occupants and whether these were locally available. Both of the rabbits and the turtle could have been found in close proximity. Cottontails and jackrabbits were probably ubiquitous and, while turtles may have been fairly rare, they could be obtained locally. Rabbits were a logical choice because short-lived species that reproduce rapidly and mature rapidly provide long-term stability in food supply (Binford 2001:367).

Question 3 asks what resources were obtained through hunting or trapping and what strategies were used when game animals were procured. The technologies used to hunt small and large animals differ significantly. Hunting small animals involves simple expedient technologies and can be embedded with other activities. Hunters need not be specialists so that all ages could participate in the capture of small animals. Techniques include nets, snares, traps, probing or flooding burrows, stoning, clubbing, and the use of bows and arrows. When bows and arrows are used, the tips can be wood or reed rather than investing energy in manufacturing stone points. This contrasts with hunting larger animals where there is more variety in technology. In historic era groups, males did much of the large animal hunting and it was often accompanied by ceremonies and rituals. Coincident with ceremonies and rituals is the manner in which large animal remains were treated. These tend to receive special treatment rather than simply thrown in the trash. Traps, snares, and pitfalls may have been used as well as the stone projectile points needed to kill larger animals (Szuter 2000:200–206, 210–211).

The small sample of fauna recovered from LA 159879 is insufficient to directly answer questions concerning hunting strategies. Furthermore, the excavation area included only a sample of the site and the features at the site, and the assemblage may not be representative of the site as a whole. Preservation and differential deposition of waste based on body size could easily influence our perception of what resources were utilized. The consistent presence of both rabbits in the features and excavated areas certainly suggest that rabbits were a regular food item but does not rule out the possibility that other animal resources were equally or more important. The presence of large projectile points indicate that large game was hunted but does not reveal whether these were hunted from this locale or this locale was used to refurbish and manufacture tools for use elsewhere.

Since the tools used to procure small mammals are either highly perishable or consist of no more than rocks or sticks, it is not surprising that we find no evidence of how these animals were taken at LA 159879. Instead we have to turn to generalizations that may best fit the patterns observed when all aspects of the site contents are examined. Here it is most likely that small animals were taken as an embedded strategy rather than a focused effort. Certainly, the dichotomy between animal resources represented in upland and lowland sites suggests that different resources were exploited in different contexts and finding mainly rabbit bones is consistent with results from similar sites and settings.

The final question involves scheduling and seasonality. Again, the faunal assemblage does not allow for directly addressing these issues. Not only is the sample size small, but much of the bone is heavily etched, thus obscuring most evidence for young animals. Furthermore, given the long reproductive season and rapid growth, even a substantial sample of rabbit bones might not provide information on seasonality.

7 Flotation and Wood Sample Analysis

Pamela J. McBride

Introduction

LA 159879 is about 0.8 km (0.5 mi) north of the Mimbres River within the northern reaches of the Mimbres Bolson in the Chihuahuan Desert Scrub biotic community (Brown 1994). The Mimbres River in this area is an intermittent stream, swelling or shrinking depending on the intensity of precipitation. Honey mesquite (*Prosopis glandulosa*), four-winged saltbush (*Atriplex canescens*), sand sagebrush (*Artemisia filifolia*), soaptree yucca (*Yucca elata*), and cholla (*Opuntia imbricata*) are the predominant shrubby species. Chihuahuan Desert Scrub upper and lower contacts are normally with Semi-Desert Grassland. Grasses like tobosa (*Hilaria mutica*) and sacatons (*Sporobolus wrightii, S. airoides*) are prolific in this biotic community in areas where overgrazing has not impacted the vitality of grassland species.

LA 159879 is mainly a Late Archaic/Early Agricultural–period site; most of the features date between 1020 and 410 BC. At the end of this period, agricultural pursuits are starting to become more important in certain areas, particularly in the Rio Grande and Mimbres River valleys where broad, flat floodplains would have offered greater potential for placement of agricultural fields (Barbour and Lentz 2011). Rather than focusing on agriculture, groups that utilized more constrained areas within basins such as the Deming Plain, where the Mimbres River crosses the Mimbres Bolson (and where LA 159879 is situated), may have concentrated on foraging for seasonal resources such as mesquite pods, cactus fruits, or grass seeds, or on incipient agriculture using various methods of water diversion (Dello-Russo 2008).

Flotation Methodology

Archaeobotanical analysis included flotation processing and identification of plant material encompassing reproductive and non-reproductive parts and charcoal. The methods used are described, followed by a description of analysis results and a discussion of possible interpretations of the data.

Flotation Processing: The 29 soil samples collected during excavation were processed at the Museum of New Mexico's Office of Archaeological Studies using the simplified "bucket" version of flotation (see Bohrer and Adams 1977). The volume of flotation soil samples ranged from 0.16 to 9.0 liters. Each sample was immersed in a bucket of water, and a 30–40 second interval allowed for settling out of heavy particles. The solution was then poured through a colander lined with a square of chiffon fabric, which would catch organic materials floating or in suspension. The squares of fabric were lifted out and laid on coarse-mesh screen trays until the recovered material had dried. Flotation sample summary information, including the presence of roots, insects, bone fragments, and insect or rodent scats is reported along with sample volumes (before flotation) in Table 7.1.

Full-Sort Analysis: Each of the 29 samples was sorted using a series of nested geological screens (4.0, 2.0, 1.0, 0.5 mm mesh), and then reviewed under a binocular microscope at 7–45X power. Charred and uncharred reproductive plant parts (seeds and fruits) were identified, counted, and placed in labeled polypropylene capsules. Flotation data are reported as a standardized count of seeds per liter of soil, rather than an actual number of seeds recovered. Relative abundance of non-repro-

Table 7.1. LA 159879, flotation sample summary information.

Feature	FS	Volume (l)	Roots	Insects	Bone	Feces	No Cultural Material
2	266	3.00	+	+	–	–	–
3	325	1.90	+	+	–	–	–
3	326	1.65	+	+	–	+	–
3	327	1.80	+	+	+	+	–
3	349	1.65	+	+	–	–	–
3	350	1.90	+	+	–	+	–
5	356	2.00	+	+	–	–	–
5	357	6.45	+	+	–	–	–
9	389	1.65	+	+	–	+	–
6	422	6.00	+	+	+	–	–
7	425	3.55	+	+	–	–	–
8	427	4.80	+	+	–	–	–
8	428	2.50	+	+	–	–	–
13	430	6.85	+	+	–	+++	–
4	434	4.70	+	+	–	++	+
12	438	4.58	+	+	–	–	–
11	440	9.00	+	+	–	+	–
10	449	3.30	+	+	–	++	–
15	468	3.80	+	+	–	–	–
15	469	3.15	+	+	–	–	–
16	478	2.40	+	+	–	+	–
16	479	1.76	+	+	–	–	–
16.3	482	0.80	+	+	–	–	+
16.4	483	0.16	+	+	–	+	–
16.1&16.2	484, 485	0.36	+	+	–	+	–
20	486	1.75	+	+	–	+	–
21	487	1.90	+	+	–	++	–
17	492	7.16	+	+	–	+	–
Feature 3 area	517	1.56	+	+	–	+	–

+ = 1–10/sample, ++ = 11–25/sample, +++ = 26–100/sample

ductive plant parts such as monocot stem fragments was estimated per sample.

To aid the reader in sorting out botanical occurrences of cultural significance from the considerable noise of post-occupational intrusion, data in tables are sorted into categories of “Cultural” (all carbonized remains), “Possibly Cultural” (unusual unburned remains that have known economic uses), and “Noncultural” (unburned materials or burned introduced species, especially when of taxa not economically useful, and when found in disturbed contexts together with modern roots, insect parts, scats, or other signs of recent biological activity).

Charcoal Identification: Wood charcoal was extremely rare in flotation samples, so that any specimens encountered that were of sufficient size and condition were identified. Each piece was snapped to expose a fresh transverse section, and then identified at 45X power. Identified charcoal from each taxon was weighed on a top-loading digital balance to the nearest tenth of a gram and placed in labeled polypropylene capsules. Low-power, incident light identification of wood specimens does not often allow species—or even genus-level precision, but can provide reliable information useful in distinguishing broad patterns of utilization of a major resource class. Wood samples were identified and treated in the same manner as flotation charcoal except that identified specimens were placed in foil packets labeled with the weight and taxon in preparation for possible submission to a radiocarbon laboratory for dating.

Results

Archaeobotanical remains from features will be discussed by their occurrence from north to south, beginning with the most northerly feature, Feature 4—a stain in a backhoe trench wall that could be the remains of a disturbed fire pit. Based on field notes documenting the presence of heavy rodent disturbance in Feature 4 and the absence of oxidation, together with the recovery of only unburned seeds (hackberry, goosefoot, puncture vine, and purslane), the feature is probably noncultural. Burned mesquite was found in Stratum 2 of the grid unit of the feature. Feature 16, a small, shallow pit structure, contained goosefoot seeds, while the three postholes in which plant material was found (one posthole, Feature 16.3 lacked floral remains), produced unidentifiable seeds and unburned modern annual and dropseed grass seeds (Tables 7.2a–e). Charred goosefoot seeds were recovered from the nearby fire pit (Feature 15) originally thought to be associated with the structure. Wood charcoal was absent from the structure and postholes, but wood collected from the fire pit consisted of mesquite and saltbush (Tables 7.3a–b).

Feature 17 was also questionable because of a large animal burrow within the feature, but burned goosefoot seeds, a monocot stem, an unknown stem and plant parts were found in the feature, suggesting either the pit was used for trash disposal or these minimal numbers of plant materials washed in or were brought in by the burrower during construction of the burrow. Features 20 and 21 were postholes that probably served to support a temporary lean-to or windbreak adjacent to the pit structure. Plant material from the postholes was limited to unburned annual, dropseed grass, and crownbeard seeds and mesquite leaves.

Table 7.2a. LA 159879, Features 15, 16, 16.1–16.4, 20, and 21, northern portion of site; flotation sample plant remains.

Context	**Northern Portion of Site**							
	Feature 16 Pit Structure		**Features 16.1, 16.2 Postholes**	**Features 16.3, 16.4 Postholes**	**Feature 15 Fire Pit**		**Feature 20 Posthole**	**Feature 21 Posthole**
	S 1/2	**N 1/2**			**S 1/2**	**N 1/2**		
FS	**478**	**479**	**484, 485**	**483**	**468**	**469**	**486**	**487**
Cultural Annuals: Goosefoot	0.4	–	–	–	2.1	6.3	–	–
Other: Unidentifiable seed	–	–	2.8	–	–	–	–	–
Noncultural Annuals: Amaranth	–	–	8.3	6.3	0.5	–	0.6	1.1
Goosefoot	–	–	–	–	–	–	–	–
Puncture vine	–	–	–	–	–	–	–	–
Purslane	0.8	–	2.8	–	0.5	–	–	–
Spurge	–	–	–	–	–	–	0.6	–
Tansy mustard	–	1.1	5.6	–	–	–	–	1.1
Tumbleweed	–	–	–	–	–	–	–	2.1
Grasses: Dropseed grass	–	–	77.8	–	–	0.6	4.0	–
Crownbeard	–	–	–	–	–	–	0.6	–
Other: Unidentifiable seed	–	–	–	–	–	0.3	–	–
Perennials: Globemallow	–	–	–	–	0.3	–	–	–
Mesquite	–	–	–	+ leaf	+ leaf	–	+ leaf	

+ = 1–10/sample

Table 7.2b. LA 159879, Features 13 and 17, northern portion of site; flotation sample plant remains.

Context	Northern Portion of Site	
	Feature 13 Fire Pit	Feature 17 Pit?
	N 1/2	N 1/2
FS	**430**	**492**
Cultural Annuals: Goosefoot	–	0.1
Other: Monocot	–	+ stem
Unknown taxon	1.6 pp, possible maize	0.3 pp, + stem
Perennials: Mesquite	0.1	–
Noncultural Annuals: Amaranth	0.7	5.4
Caltrop	0.1	–
Goosefoot	–	11.3
Puncture vine	–	1.7
Purslane	0.4	24.0
Spurge	–	6.8
Tansy mustard	1.0	–
Tumbleweed	0.6	–
Grasses: Dropseed grass	6.7	1.0
Other: Aster family	0.1	0.3
Bean family	0.4	–
Crownbeard	–	–
Perennials: Mesquite	+ leaf	–

+ = 1–10/sample, pp = plant part

The last of the features from this part of the site was Feature 13, a large, shallow fire pit (5 cm deep), that produced the only positively identified specimen of carbonized possible mesquite seed fragments (n = 4) at the site. Mesquite seed remains are often extremely fragmentary and probably demonstrate the practice of pounding pods to either release the seeds or pulverize them so that the whole seed can be ground into flour. The carbonized seed fragments could represent seeds that were discarded or spit out into the fire during consumption of the ground meal. The unknown plant parts from this feature could be fragments of a maize kernel (the endosperm morphology resembles that of maize; Fig. 7.1) and were submitted for radiocarbon dating analysis. The delta ^{13}C ratio was consistent with that of maize (-11.4 0/00) and dated to between 672 and 429 cal BC (2 sigma; Beta-319043; OxCal 65.9 percent probability). Maize pollen, also identified in the feature fill (Chapter 8; Appendix 3), lends support to the identification of the carbonized plant parts as maize.

Features in the central portion of the site consisted of two clusters of features: one consists of fire pits (Features 6, 7, 8, and 9), and the other includes a probable small structure (Feature 3) and four additional fire pits (Features 2, 10, 11, and 12. The possible structure (Feature 3) and associated activity area and one of the fire pits (Feature 6), contained the other three instances of mesquite seeds. Feature 3 also yielded the majority of dropseed grass seeds along with cheno-ams (present in all five samples) and amaranth. In addition, large quantities of mesquite pollen and a single cotton pollen grain were identified, as well as grass dendriforms found on the use surface of a ground stone fragment associated with the feature, indicating grasses were processed using this tool (Appendix 3).

Feature 6 produced a fragment of an unknown plant part previously described by L. Huckell (1987, 1998, 2000). Referred to as columnar-celled seed coats (CCSC), these rarely measure more than 2 mm at their maximum dimension and the specimen from LA 159879 is no exception. When viewed in cross-section the seed coat displays a thick zone of elongated columnar cells that form a palisade wall, a characteristic shared by several taxa like mesquite, palo verde (*Parkinsonia* spp.), acacia (*Acacia* spp.), soapberry (*Sapindus saponaria*), and sumac (*Rhus* spp.). After methodically examining the seed coats of these taxa along with others, L. Huckell tentatively identified the CCSCs as *Apodanthera undulata* or melón loco (2002), a member of the Cucurbitaceae family. *Apodanthera undulata* is a vining perennial that grows on dry plains and mesas in southern New Mexico with fruits that are very odoriferous (Martin and Hutchins 1980:1932, 1935).

The columnar-celled seed coat from LA 159879 could be a fragment of a melón loco seed. Fragments of melón loco have been found at a variety of sites in southeastern Arizona with occupations ranging from the Paleoindian period through the Classic Hohokam as well as sites in southern New Mexico and northern Texas (L. Huckell 1987, 1998, 2000, 2002; McBride 2003).

Features 7, 9, 2, and 11 yielded charred ama-

Table 7.2c. LA 159879, Features 6–9, central portion of site; flotation sample plant remains.

Context	**Central Portion of Site**					
	Feature 6 Fire Pit	**Feature 7 Fire Pit**	**Feature 8 Fire Pit**		**Feature 9 Fire Pit**	
	N 1/2	**S 1/2**	**N 1/2**	**S 1/2**	**N 1/2**	**S 1/2**
FS	**422**	**425**	**427**	**428**	**389**	**517**
Cultural Annuals: Cheno-am	–	–	–	–	2.4	0.6
Goosefoot	–	0.3	–	–	–	–
Other: Columnar-celled seed coat	0.2	–	–	–	–	–
Perennials: Possible mesquite	0.2	–	–	–	–	–
Noncultural Annuals: Amaranth	–	0.3	–	–	–	–
Goosefoot	–	–	–	–	–	–
Puncture vine	0.5	–	–	–	–	0.6
Purslane	0.5	0.6	0.2	–	–	–
Spurge	–	–	–	0.4	–	0.6
Tansy mustard	–	–	0.2	–	–	–
Perennials: Globemallow	0.3	–	–	–	–	–
Grasses: Dropseed grass	–	–	1.3	–	0.6	8.3
Grass family	–	–	0.6	–	–	–
Other: Aster family	–	–	0.2	–	–	–

ranth, cheno-am, and goosefoot seeds; dropseed grass seeds were also recovered from Feature 2. Although carbonized monocot stems and unknown plant parts were the only floral materials recovered from Feature 10, maize and sedge phytoliths were identified from ground stone tools. Maize phytoliths and pollen were also recovered from Feature 7 fill samples and grass dendriforms from ground stone (Appendix 3).

One fragment of mesquite wood was identified in the flotation sample from Feature 3. Other flotation wood from features in this part of the site included one piece of saltbush from the Feature 11 fire pit, three of mesquite and two of saltbush in Feature 6, and seven fragments of saltbush in the Feature 9 fire pit. Macrobotanical wood was primarily mesquite, with five samples containing small amounts of saltbush; Feature 9 was an exception to this where the majority of wood specimens were saltbush (Tables 7.3a–b).

Two flotation samples from Feature 5, a possible structure in the southernmost portion of the site, produced carbonized cheno-am and goosefoot seeds; nine fragments of unknown non-conifer wood were present in the flotation sample from the north half of the feature. In addition to mesquite and saltbush, the macrobotanical wood samples had two pieces of what compare favorably to piñon, quite a surprising diversion from taxa found in other features. It is possible that the piñon was collected as driftwood in the Mimbres River, carried down from the Pinos Altos Range, the Black Range, or the Mimbres Mountains to the north. Alternatively, it could have been collected in the nearby Tres Hermanas or Florida Mountains to the south.

Table 7.2d. LA 159879, Features 3, 10, and 11, central portion of site; flotation sample plant remains.

Context	**Central Portion of Site**						
	Feature 3 Structure					**Feature 10 Fire Pit**	**Feature 11 Fire Pit**
				S 1/2			**N 1/2**
FS	**325**	**326**	**327**	**349**	**350**	**449**	**440**
Cultural Annuals: Amaranth	–	–	0.5	1.8	–	–	–
Cheno-am	1.1	4.2	2.1	4.2	2.1	–	0.3
Goosefoot	–	–	–	–	–	–	0.2
Grasses: Dropseed grass	0.5	1.2	1.1	0.6	–	–	–
Other: Monocot	–	–	–	–	–	+ stem	–
Unknown taxon	–	–	2.1 pp	–	0.5 pp	0.3 pp	0.3 pp
Perennials: cf. mesquite	–	–	–	3.0	–	–	–
Possible mesquite	–	–	0.5	–	–	–	–
Noncultural Annuals: Amaranth	1.6	0.6	3.7	0.6	–	5.2	–
Goosefoot	0.5	–	–	0.6	–	–	–
Puncture vine	–	–	–	3.6	0.5	–	–
Purslane	0.5	–	0.5	–	–	0.9	–
Spurge	–	–	–	–	–	0.3	–
Tansy mustard	–	0.6	1.6	–	–	2.4	–
Tumbleweed	–	–	–	–	–	0.9, 0.3*	–
Grasses: Dropseed grass	–	0.6	–	–	1.6	0.9	–
Other: Groundcherry	–	–	–	–	–	0.3	–
Plantain	–	–	–	–	–	0.6	–
Unknown taxon	–	–	–	–	–	+ leaf	–
Perennials: Globemallow	–	–	–	–	–	–	0.1
Mesquite	–	–	–	–	–	+ leaf	–

* = charred, + = 1–10/sample, pp = plant part
cf. = resembles taxon

Discussion

Research questions pertaining to archaeobotanical investigations included determining the economic floral resources used by site occupants, whether resources were procured locally or from elsewhere and brought to the site, and how resource procurement and use were scheduled.

Inhabitants of LA 159879 seemed to have focused on a small suite of annual plants, dropseed grass, and mesquite. There is evidence in the pollen and phytolith record indicating maize agriculture was part of the subsistence regime. Further, unknown plant parts from Feature 13 also resemble maize kernel fragments and the delta ^{13}C ratio is consistent with that of maize. The biotic community in which the site is located was probably grassland during prehistoric occupation. Overgrazing has caused forbs and shrubs to replace grasses such as grama (*Bouteloua* spp.) and bush muhly (*Muhlenbergia porter*) over much of New Mexico that is now classified as Chihuahuan Desertscrub or Desert Grassland (Dick-Peddie 1993:107). So, it is possible that during the use of

Table 7.2e. LA 159879, Features 2, 5, and 12, central and southern portions of site; flotation sample plant remains.

Context	**Central Portion of Site**		**Southern Portion of Site**	
	Feature 2 Fire Pit	**Feature 12 Fire Pit**	**Feature 5 Structure?**	
		S 1/2	**S 1/2**	**N 1/2**
FS	**266**	**438**	**356**	**357**
Cultural Annuals: Amaranth	0.3	–	–	–
Cheno-am	0.3	–	0.5	0.6
Goosefoot	6.3	–	2.5	1.9
Grasses: Dropseed grass	7.7	–	–	–
Other: Unknown taxon	–	0.9 pp	–	–
Noncultural Annuals: Amaranth	11.0	0.2	1.5	0.8
Goosefoot	0.3	–	1.0	0.2
Purslane	1.3	–	1.0	0.5
Spurge	0.3	–	–	0.6
Sunflower	–	–	–	0.2
Tansy mustard	6.0	–	–	–
Grasses: Dropseed grass	2.7	–	–	–
Other: Aster family	0.3	–	–	–
Plantain	0.3	–	–	–
Perennials: Mesquite	+ leaf	–	–	–
Saltbush	0.3 fruit, + leaf	–	–	–

+ = 1–10/sample, pp = plant part

Table 7.3a. LA 159879, Features 4, 5, and 15, northern and southern portions of site; wood sample taxa.

Context	**Northern Portion of Site**		**Southern Portion of Site**	
	390N/532E, Feature 4 Area, Stratum 2	**Feature 15 Fire Pit**	**Feature 5 Structure?**	
FS	**505**	**472**	**358**	**359**
Nonconifers: Mesquite	1/.07 g	8/.51 g	3/.06 g	1/.01 g
Saltbush	–	3/.23 g	3/.09 g	4/.05 g
Unknown nonconifer	–	–	1/.01 g	–
Conifers: cf. *Piñon*	–	–	2/.09 g	–
Total	**1/.07 g**	**11/.74 g**	**9/.25 g**	**5/.06 g**

cf. = resembles taxon

Table 7.3b. LA 159879, Features 2, 3, 6, 9, and 11central portion of site; wood sample taxa.

Context	**Central Portion of Site**									
	Feature 6 Fire Pit	**Feature 3 Structure**						**Feature 9 Fire Pit**	**Feature 11 Fire Pit**	**Feature 2 Fire Pit**
FS	**421**	**328**	**329**	**330**	**331**	**332**	**345**	**348**	**391**	**440**	**266**
Nonconifers: Mesquite	11/.26 g	4/.05 g	–	1/.07 g	6/.19 g	10/.42 g	5/.05 g	1/.01 g	1/.01 g	16/.67 g	1/.99 g
Saltbush	6/.07 g	–	4/.04 g	–	–	–	–	1/.01 g	22/.53 g	5/.18 g	–
Unknown wood	–	–	–	–	–	–	–	–	2/.05 g	–	–
Total	**17/.33 g**	**4/.05 g**	**4/.04 g**	**1/.07 g**	**6/.19 g**	**10/.42 g**	**5/.05 g**	**2/.02 g**	**25/.59 g**	**21/.86 g**	**1/.99 g**

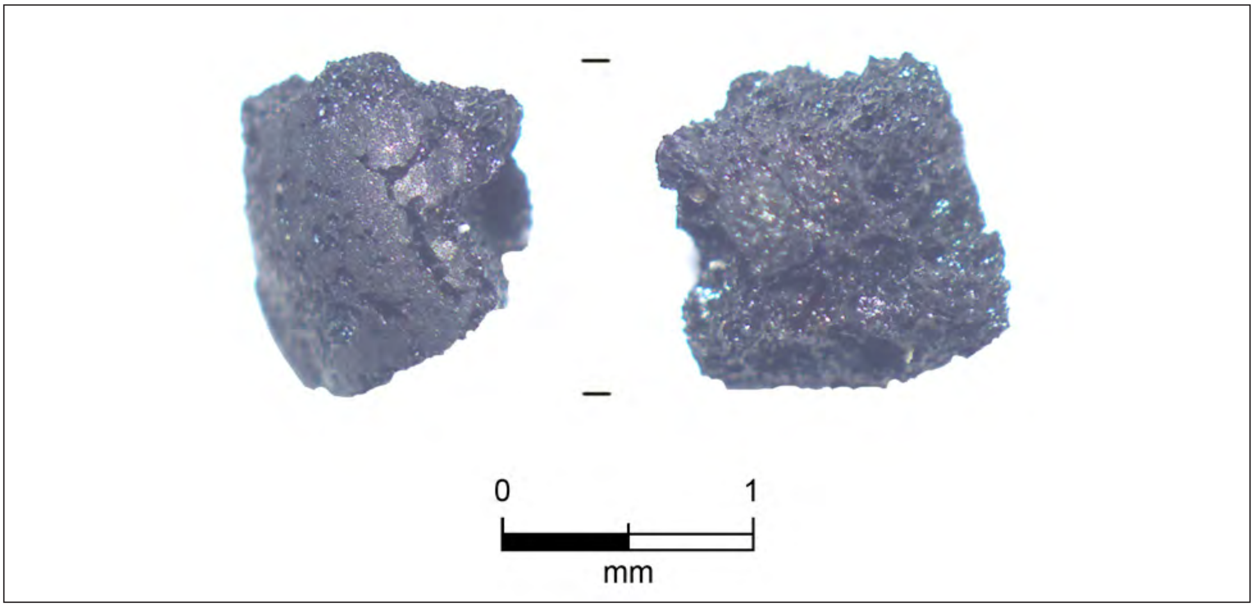


Figure 7.1. Possible maize kernel, from Feature 13.

the site, grasses were more in evidence than the mesquite-dominated landscape today. Grass use at LA 159879 is well-documented in the pollen and phytolith record, particularly in the form of dendriforms found on ground stone that indicate tools were used for grinding grass seeds.

Annuals like amaranth and goosefoot are weedy taxa that are part of a wide variety of plants defined as agrestals and/or ruderals. These are plants that favor disturbed habitats such as roadsides, habitation sites, or field margins (Stuckey and Barkley 2000). These taxa are found in virtually any disturbance situation and are widespread throughout the Southwest and have been found at sites from all time periods and often provide the only evidence of economic plant use. The leaves of goosefoot were prepared as greens much like spinach, while the seeds were parched, ground into meal, and often made into a thick gruel (Castetter 1935:16, 23, 30) or mixed with cornmeal and made into balls or cakes and steamed (Stevenson 1993:33).

The ground seeds of dropseed grass were

used by the Navajo to make dumplings, rolls, and griddle cakes, and the Hopi ground the seeds and mixed them with cornmeal (Castetter 1935:28). Even though dropseed grass grains are very small, the positive qualities of abundant seed production and the retention of the grains by the plant after maturation, preventing their loss before harvesting, (Doebley 1984) probably outweighed the problem of small seed size.

Although there are a few accounts of indigenous groups utilizing mesquite seeds, for the most part, the pods were ground into meal and the seeds winnowed out before storage or cooking. The meal was often made into cakes, eaten raw or baked, or dried for easy transportation (Bell and Castetter 1937). If the beans were to be stored whole, they were dried, and then placed in baskets or sealed pots, on platforms or on roofs.

Pods were ground on a metate, in bedrock mortars near collection loci, or pounded in a mortar of wood or stone with a pestle of either material. Julian Hayden (1969) described conical ground stone artifacts with a hole punched or worn in the bottom found in the Sierra Pinacate of northwestern Sonora, Mexico, that he labeled "gyratory crushers." By manipulating a heavy wooden pestle to grind mesquite pods in the gyratory crusher, the indurate seeds are separated from the fibrous mesocarp (the seeds cannot be crushed with a wooden pestle as they are harder than the wood) and the seeds can easily be removed from the crushed material exiting the hole at the bottom of the mortar. Although two pestles that display crushing and grinding wear were recovered at the site, they "bear little resemblance" to the gyratory crushers described by Hayden (1969; Chapter 5). However, other accounts of mesquite processing and the resulting wear patterns on pestles do resemble that found on one of the pestles and could have been used to process mesquite pods and /or seeds.

Based on flotation remains, LA 159879 was probably occupied at least from mid-late summer into the early autumn months. Amaranth, goosefoot, and dropseed grass seeds mature in mid-late summer at approximately the same time that mesquite pods are ready for harvesting, although pods can be collected as late as October or November if they haven't been consumed by other animals. Evidence of occupation in the spring is absent from the record; plants with herbage or seeds that appear in April or May like tansy mustard (*Descurainia* spp.) were not recovered. The site might have been a campsite where a limited amount of domesticates were grown, and that was part of a seasonal round, visited repeatedly over many years by hunter/gatherer or semi-sedentary groups.

LA 159879 plant taxa are compared in Table 7.4 with those from the NM 90 project (LA 99631, the Wood Canyon site, and LA 78089, the Forest Home site), the only other known project with significant components from the Late Archaic/Early Agricultural period in the area (approximately 56 km or 35 mi to the northwest of LA 159879, in the Burro

Table 7.4. LA 159879 and NM 90, plant taxa ubiquity by number of samples in which taxon is found.

	LA 159879[1]	**NM 90 LA 99631, LA 78089[2]**
Sample Count	**27**	**87**
Annuals: *Amaranthus*	11.1%	3.5%
Chenopodium	51.8%	40.2%
Cheno-Am	40.7%	25.3%
Corispermum	–	8.1%
Cycloloma	–	3.5%
Descurainia	–	5.8%
Helianthus/Viguiera	–	1.2%
Mentzelia	–	6.9%
Nicotiana	–	1.2%
Portulaca	–	4.6%
Cultivars: *Zea mays*	–	50.6%
Grasses: Poaceae	–	5.8%
Sporobolus	18.5%	3.5%
Other: Brassicaceae	–	2.3%
Columnar-celled seed coat	4.0%	91.0%
Physalis/Solanum	–	1.2%
Perennials: *Juglans*	–	4.6%
Juniper	–	55.2%
cf. *Pinus*	–	1.2%
Prosopis	14.8%	
Quercus	–	13.8%
Rumex/Polygonum	–	2.3%
Yucca	–	1.2%
Total Taxa	**5**	**21**

cf. = resembles taxon

[1] current project

[2] Huckell 2000

Mountains). This is a somewhat futile comparison because not only was the sample size from the NM 90 project two-thirds larger, but the two sites from NM 90 were much more complex than LA 159879, consisting of pit structures, thermal features, various unburned pits, and several burials. The more substantial structures with internal features along with the considerable presence of maize at the NM 90 project indicate the community may represent year-round habitation or at least one that was more sedentary in nature. Further, LA 99631 and LA 78089 are in an area where three biotic communities intersect, offering access to a large variety of resources within a 3 km radius of the sites.

Not surprisingly then, a total of 21 taxa were recovered from the NM 90 sites (L. Huckell 2000) compared to a mere five from the current project. The most common plant materials from the NM 90 project were fragments of columnar-celled seed coats (found in 91 percent of samples from Wood Canyon and Forest Home) that may be, as discussed earlier, the seed coats of *Apondonthera undulata*. In contrast, only one sample from LA 159879 contained a fragment that looked like columnar-celled seed coats encountered in previous investigations (McBride 2003).

The seeds of melón loco are roasted and eaten in Jalisco and Zacatecas (Lira and Caballero 2002). In Mexico, the mashed pulp of the fruit is used to treat urinary ailments and the seeds are eaten roasted (Merrick 1991, cited in Lira and Caballero 2002). The ancient use of this taxon has been documented by the recovery of seeds in caves of the Tehuacan Valley in Puebla and Guila Naquitz in Oaxaca (Cutler and Whitaker 1967). The seeds have a high nutritional value, containing 21.2–29.4 percent fat and 62.1–79.3 percent protein (Bemis et al. 1967, cited in Lira and Caballero 2002), so it is not remarkable that the seeds have been identified at a number of southern New Mexico and Arizona sites.

Comparison of wood taxa recovered from the two projects demonstrates the use of locally available genera in both areas: oak, mountain mahogany, and juniper were the most common taxa from Wood Canyon and Forest Home, while mesquite and saltbush were the dominant taxa encountered at LA 159879.

SUMMARY AND CONCLUSIONS

LA 159879 was probably a campsite used during the Late Archaic/Early Agricultural period as a base from which to collect and process annual seeds, dropseed grass, melón loco, and mesquite in the mid-late summer and possibly early fall. Maize and cotton as evidenced in the pollen and phytolith records were grown in a limited way, possibly as a supplement in years of less than optimal wild plant production. Locally available wood or, to a very limited extent, driftwood was utilized for firewood. This portion of the site probably represents a fraction of the cultural signature of what may constitute a larger settlement outside the project limits, offering tantalizing possibilities for further insights into prehistoric subsistence in this area of the Deming flood plain.

8 Dating Analysis

Dates for LA 159879 were established using three methods: projectile point typology, AMS radiocarbon dating, and optically stimulated luminescence (OSL) dating. Projectile points recovered from the site include San Pedro points dating from the Late Archaic from Clusters 1, 3, and 4 and Pelona points dating from the Middle into the Late Archaic from Clusters 1 and 4 (Chapter 4). A past property owner collected a Bajada point and Hueco/San Pedro points.

Most of the radiocarbon samples returned dates in the Late Archaic/Early Agricultural period. However, two of the samples, both on wood, date to the Protohistoric and Early Historic era. No record was kept of the specific material types that were sent for dating to Beta Analytic, Inc., but McBride (Chapter 7) identified mesquite wood in botanical samples identified as a radiocarbon sample with the same FS number from Feature 2 and mesquite and saltbush from the radiocarbon sample from Feature 15.

Feature 2 was located in the central part of the site and was a fairly large (80 cm diameter), but shallow (5 cm) fire pit. No artifacts were recovered in the 2 by 2 m area surrounding the feature but burned amaranth, goosefoot, dropseed grass, and the mesquite wood were recovered as flotation and radiocarbon samples. The most accurate date range is AD 1470–1640. This feature could well indicate early Historic-period use of the site area, but there is no corroborating evidence.

Feature 15's most accurate date of AD 1520–1670 is more difficult to explain given that its location near Feature 16 (a small pit structure) with a radiocarbon date of 1027–891 BC (Chapter 2). Chipped stone artifacts found in the two structures are similar materials and types, but the Feature 15 pollen sample was fairly distinctive. Again, this feature could indicate Protohistoric or early Historic use of the site area but the only evidence is the radiocarbon sample.

Ten OSL samples were collected and submitted to Ronald J. Goble at the Luminescence Geochronology Laboratory, Department of Earth and Atmospheric Sciences, University of Nebraska, for analysis. Methodology and results are described in Appendix 1 and Chapter 3. The relevance of these dates is discussed below.

ANALYZING RADIOCARBON DATES FROM LA 159879

JEFFREY L. BOYER

Introduction

Thirteen samples were collected from LA 159879 and submitted to Beta Analytic, Inc., for accelerator mass spectrometry (AMS) radiocarbon analysis and dating. They included 11 samples of burned organic material and two samples of wood, at least one of which was probably not burned. The samples came from 10 different features at the site; seven were fire pits, two were defined as structures, and one was a possible structure. Three samples were collected from two fire-pit features and a structure in the northern area of the site; eight samples were collected from four fire-pit features and a structure in the central area; and two samples were collected from a possible structure in the southern area. This discussion presents the results of radiocarbon dating and analyses of the dates.

Methodological Background

Radiocarbon analysis results for each sample include the measured radiocarbon age in years BP (before AD 1950), which is corrected for $\delta^{13}C$—the ratio of ^{13}C to ^{12}C in ‰ ("isotopic fractionation")—in the sample, producing the conventional radiocarbon age, also in years BP. Inherent variability in the presence of carbon isotopes in each sample as well as in detection and counting procedures produces an error factor that is represented in the results as a single standard deviation (1 sigma) value before and after the mean age. Beta Analytic, Inc., also provides dates calibrated to calendar years as 1-sigma and 2-sigma "calibrated results" (in this case, atmospheric curve IntCal09; Reimer et al. 2009). The Beta Analytic calibration process uses the conventional radiocarbon age (BP) as a single value—the mean age without its 1-sigma range—and follows that single value as it intercepts the calendar-year curve—or, more accurately, one or more points comprising the curve—and assigns one or more calendar-year values to the conventional age. Those values are presented as "intercept dates." The calibration process then provides 1-sigma and 2-sigma ranges of calibrated dates that account for the intercept date(s) and the range of the conventional age about its mean as it intercepts the calibration curve. The calibrated results are presented as BP and calendar-year date ranges and can include, for a single sample, multiple 1-sigma and 2-sigma ranges derived from the slope of the calibration curve and its interception with the conventional age. Beta Analytic, Inc., results are presented in Table 8.1).

For each sample, the conventional age (BP) and its 1-sigma error value calculated by Beta Analytic, Inc., were then used with two applications, OxCal (v. 4.2; https://c14.arch.ox.ac.uk/oxcal/OxCal.html, first accessed May 30, 2014; atmospheric curve IntCal13) and Calib (v. 6.1.0; http://calib.qub.ac.uk/calib, first accessed May 30, 2014; atmospheric curve IntCal09) for additional calendar-year recalibrations. OxCal and Calib recalibrations are also presented in Table 8.1, which shows that calendar-year calibrations produced by Beta Analytic, Inc., and by OxCal and Calib applications are usually very similar and often identical. Differences are related to variations in calculation algorithms and in ways that the three processes present their results. Recalibrations using OxCal and Calib provide results that allow estimation of probability of accuracy and, depending largely on the slope of the calibration curve in relation to specific conventional radiocarbon ages, precision. The Beta Analytic process uses the conventional radiocarbon age as a point with a 1-sigma standard deviation error that creates a range of dates within which any single date has the same probability of accuracy as any other single date. Precision is based on the width of the 1 sigma. Beta Analytic calibration involves the "interception" of the range of conventional ages with the calibration curve (Fig. 8.1). "Intercept dates" are the points at which the mean conventional age intersects the calibration curve. Ranges of calibrated dates result from the interception of the range of conventional ages with the calibration curve, which is constructed as a best-fit line following data points. Since every conventional age within a range has equal probability of accuracy, every range of calibrated dates also has equal probability of accuracy. Consequently, the Beta Analytic calibration process cannot assign differential probabilities of accuracy to multiple ranges of calibrated dates for a single sample.

For each conventional radiocarbon age with its 1-sigma error, on the other hand, OxCal provides one or more 1-sigma and 2-sigma calendar date ranges with percentage numbers (Table 8.1) that represent the portions of overall 1-sigma and 2-sigma ranges comprised of smaller ranges. The conventional radiocarbon age is used, not as a single point with a standard deviation, but as a normal probability distribution curve (Fig. 8.2). Additionally, any location on the calibration curve is identified as a range of values rather than a single value. The curve, therefore, is not a single best-fit line; visually, the curve resembles a ribbon rather than a single line:

> The OxCal plot…displays a thick blue line. A similar thick line, in grey, is displayed in [a] Calib plot. The thick line is the "calibration curve." The calibration curve represents the tree-ring ^{14}C concentrations used in the calibration procedure. There are at least two issues here. First, the calibration "curve" is not a curve in the common sense; rather, each point on the curve has a potential error, which is usually specified by the standard deviation of the measurement… the top of the thick line indicates the upper 1σ bound,

Table 8.1. LA 159879, radiocarbon samples in order from oldest to youngest.

Feature	Site Area	FS	Sample Material and Condition	BETA-ANALYTIC DATA						OXCAL* Calibration Data**					CALIB*** Calibration Data**	
				Sample	**δ13C (0/00)**	**Convent-ional Radi-carbon Age (BP)**	**2σ Calibrated Age**	**1σ Calibrated Age**	**Radio-carbon Age-Cali-bration Curve Intercept Dates**	**2σ Calibrated Age**	**1σ Calibrated Age**	**Mean Date**	**Mean Range 1σ Years**	**Med-ian Date**	**2σ Calibrated Age**	**1σ Calibrated Age**
9 Fire Pit	Central	391	mesquite, saltbush, unknown wood, burned	307895	-25.1	2810±30	1020–900 BC	1000–920 BC	970 BC 960 BC 940 BC	**1050–895 BC (95.4%)**	**1000–925 BC (68.2%)**	962 BC	39	962 BC	**1050–896 BC (99.7%)** **864–860 BC (0.3%)**	**999–925 BC (100.0%)**
5 Structure?	South	358	mesquite, saltbush, unknown conifer, piñon, burned	307893	-24.1	2800±30	1010–900 BC	1000–910 BC	970 BC 960 BC 930 BC	**1027–891 BC (91.4%)** **879–848 BC (4.0%)**	**996–915 BC (68.2%)**	952 BC	40	953 BC	**1026–892 BC (95.6%)** **878–847 BC (4.5%)**	996–985 BC (12.3%) 980–915 BC (87.7%)
16 Pit Structure	North	477	"charred material" (from Beta Analytic form)	307899	-24.4	2800±30	1010–900 BC	1000–910 BC	970 BC 960 BC 930 BC	**1027–891 BC (91.4%)** **879–848 BC (4.0%)**	**996–915 BC (68.2%)**	952 BC	40	953 BC	**1026–892 BC (95.6%)** **878–847 BC (4.5%)**	996–985 BC (12.3%) 980–915 BC (87.7%)
5 Structure?	South	359	mesquite, saltbush, burned	307894	-24.4	2770±30	1000–840 BC	970–960 BC 930–900 BC	910 BC	**997–839 BC (95.4%)**	970–958 BC (10.2%) 940–892 BC (40.8%) 877–848 BC (17.3%)	915 BC	43	914 BC	**997–839 BC (100.0%)**	973–958 BC (18.9%) 938–893 BC (58.9%) 875–848 BC (25.3%)
6 Fire Pit	Central	421	mesquite, saltbush, burned	307896	-24.5	2760±30	980–830 BC	920–890 BC 880–850 BC	900 BC	992–989 BC (0.5%) 980–830 BC (94.9%)	**929–844 BC (68.2%)**	901 BC	42	901 BC	994–989 BC (0.9%) 979–830 BC (99.1%)	967–965 BC (2.8%) 928–889 BC (53.4%) 882–843 BC (43.8%)
11 Fire Pit	Central	440	mesquite, saltbush, burned	307897	-23.9	2730±30	920–810 BC	900–830 BC	890 BC 880 BC 850 BC	**930–812 BC (95.4%)**	**901–836 BC (68.2 %)**	872 BC	32	871 BC	967–965 BC (0.2%) 928–812 (99.8%)	**900–837 (100.0%)**

Table 8.1 (continued)

Feature	Site Area	FS	Sample Material and Condition	BETA-ANALYTIC DATA						OXCAL* Calibration Data**					CALIB*** Calibration Data**	
				Sample	δ13C (0/00)	Convent-ional Radi-carbon Age (BP)	2σ Calibrated Age	1σ Calibrated Age	Radio-carbon Age-Cali-bration Curve Intercept Dates	2σ Calibrated Age	1σ Calibrated Age	Mean Date	Mean Range 1σ Years	Med-ian Date	2σ Calibrated Age	1σ Calibrated Age
3 Structure	Central	332	mesquite, burned	307891	-23.6	2680±30	900–800 BC	840–810 BC	820 BC	**897–802 BC (95.4%)**	890–881 BC (7.1%) 844–804 BC (61.1%)	841 BC	28	832 BC	**896–801 BC (100.0%)**	889–881 BC (11.0%) 843–804 BC (88.9%)
3 Structure		346	unidentified wood, burned	307892	-23.6	2660±30	840–800 BC	830–800 BC	810 BC	895–867 BC (9.8%) 859–794 BC (85.6%)	**832–801 BC (68.2%)**	827 BC	25	820 BC	895–868 BC (10.2%) 861–855 BC (1.7%) 850–793 BC (88.1%)	**831–800 BC (100.0%)**
3 Structure		331	mesquite, burned	307890	-25.0	2630±30	830–790 BC	810–800 BC	800 BC	**838–777 BC (95.4%)**	**816–794 BC (68.2%)**	808 BC	17	806 BC	**837–774 BC (100.0%)**	**815–793 BC (100.0%)**
7 Fire Pit	Central	425	"charred material" (from Beta Analytic form)	319042	-10.8	2510±30	790–700 BC 700–540 BC 530–520 BC	770–740 BC 690–660 BC 650–550 BC	760 BC 680 BC 670 BC	791–701 BC (27.7%) 696–540 BC (67.7%)	772–747 BC (13.4%) 685–666 BC (10.5%) 642–556 BC (44.3%)	653 BC	76	639 BC	788–697 BC (27.5%) 696–538 BC (72.5%)	796–746 BC (16.9%) 688–665 BC (18.3%) 646–587 BC (45.3%) 583–553 BC (19.5%)
13 Fire Pit	North	430	maize, burned	319043	-11.4	2460±30	760–680 BC 670–410 BC	750–690 BC 660–640 BC 590–580 BC 570–510 BC	730 BC 690 BC 660 BC 650 BC 540 BC	758–678 BC (29.5%) 672–429 (65.9%)	751–683 BC (27.0%) 668–637 BC (11.7%) 623–616 BC (2.0%) 591–509 BC (26.9%) 497–495 BC (0.7%)	607 BC	97	614 BC	756–684 BC (27.9%) 669–606 BC (18.6%) 603–478 BC (39.1%) 472–414 BC (14.4%)	750–687 BC (37.0%) 667–640 BC (14.7%) 593–509 BC (41.8%) 437–421 BC (6.6%)

Table 8.1 (continued)

Feature	Site Area	FS	Sample Material and Condition	BETA-ANALYTIC DATA						OXCAL* Calibration Data**					CALIB*** Calibration Data**	
				Sample	δ13C (0/00)	Conventional Radiocarbon Age (BP)	2σ Calibrated Age	1σ Calibrated Age	Radiocarbon Age-Calibration Curve Intercept Dates	2σ Calibrated Age	1σ Calibrated Age	Mean Date	Mean Range 1σ Years	Median Date	2σ Calibrated Age	1σ Calibrated Age
2 Fire Pit	Central	266	mesquite, burned	307889	-24.0	340±30	AD 1450–1640	AD 1480–1530 AD 1540–1550 AD 1550–1630	AD 1520 AD 1590 AD 1620	**AD 1470–1640 (95.4%)**	AD 1490–1525 (23.2%) AD 1557–1603 (30.7%) AD 1610–1632 (14.3%)	AD 1555	51	AD 1560	AD 1470–1639 (100.0%)	AD 1490–1526 (33.8%) AD 1556–1603 (45.2%) AD 1609–1632 (21.0%)
15 Fire Pit	North	472	unidentified wood, burned	307898	-23.3	260±30	AD 1520–1560 AD 1630–1670 AD 1780–1800 AD 1950–1950	AD 1640–1660	AD 1650	AD 1520–1593 (28.3%) AD 1619–1670 (53.1%) AD 1780–1800 (12.3%) AD 1943–1950 (1.6%)	AD 1530–1541 (9.0%) AD 1635–1666 (50.4%) AD 1785–1795 (8.8%)	AD 1642	87	AD 1647	AD 1519–1593 (29.3%) AD 1619–1670 (56.8%) AD 1779–1799 (12.6%) AD 1943–1951 (1.4%)	AD 1529–1542 (14.3%) AD 1634–1666 (71.9%) AD 1784–1795 (13.8%)

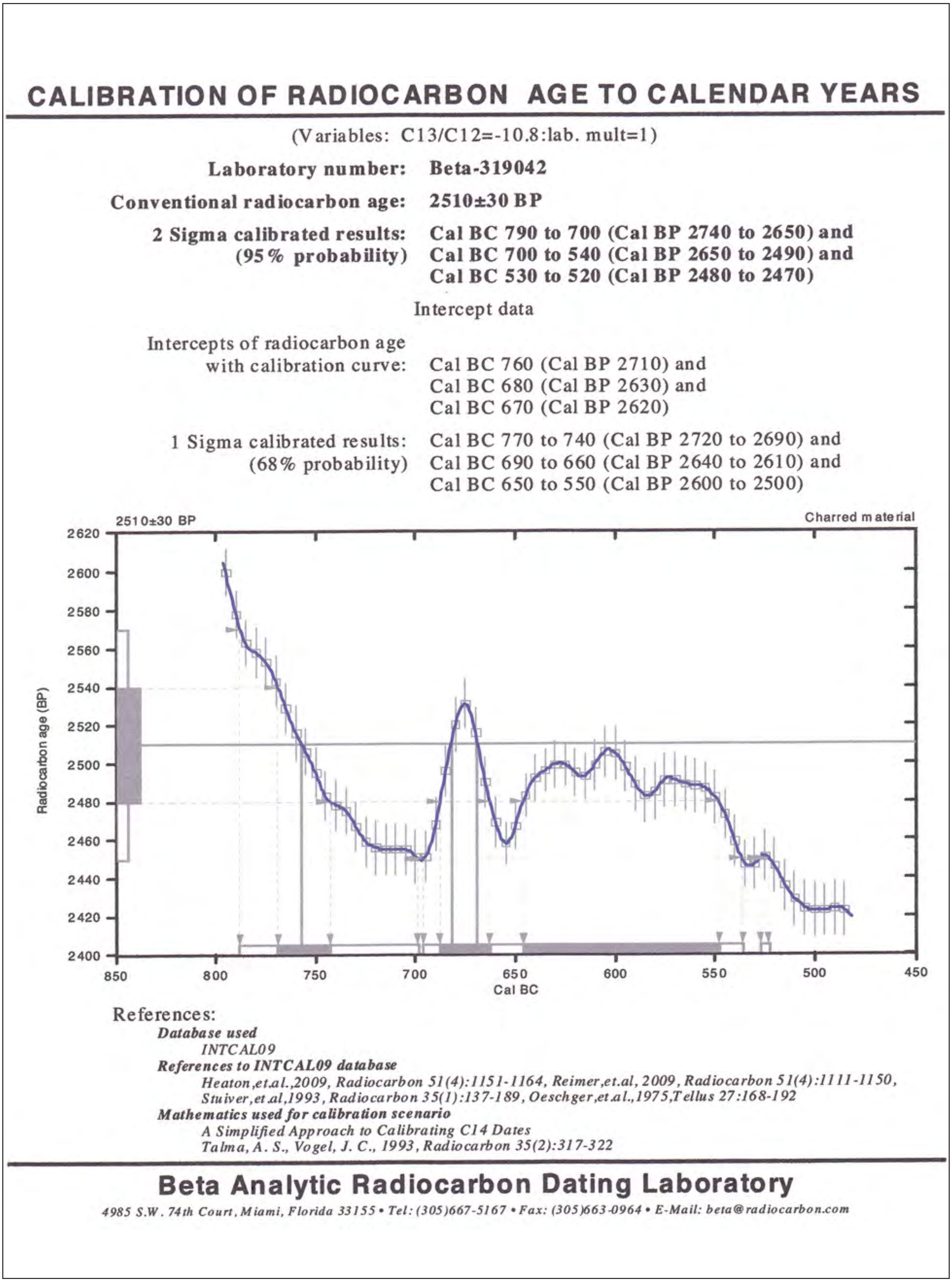
* OxCal v. 4.2; https://c14.arch.ox.ac.uk/oxcal/OxCal.html, accessed May 28, 2014; atmospheric curve IntCal13.

OxCal calibrations: Percentage numbers represent the portions of 1-sigma (68.2% total) and 2-sigma (95.4% total) ranges comprised of smaller, internal ranges.

Calib calibrations: Percentage numbers represent the proportions of 1-sigma (100.0% total) and 2-sigma (100.0 % total) ranges comprised of smaller, internal ranges.

** Dates in **bold** font have the highest-percentage probabilities (more than half of the total range) of being the most accurate dates.

*** Calib v. 6.1.0; http://calib.qub.ac.uk/calib, first accessed May 28, 2014; atmospheric curve IntCal09.14c.



CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-10.8:lab. mult=1)

Laboratory number: **Beta-319042**

Conventional radiocarbon age: **2510±30 BP**

2 Sigma calibrated results: **Cal BC 790 to 700 (Cal BP 2740 to 2650) and**
(95% probability) **Cal BC 700 to 540 (Cal BP 2650 to 2490) and**
Cal BC 530 to 520 (Cal BP 2480 to 2470)

Intercept data

Intercepts of radiocarbon age
with calibration curve: Cal BC 760 (Cal BP 2710) and
Cal BC 680 (Cal BP 2630) and
Cal BC 670 (Cal BP 2620)

1 Sigma calibrated results: Cal BC 770 to 740 (Cal BP 2720 to 2690) and
(68% probability) Cal BC 690 to 660 (Cal BP 2640 to 2610) and
Cal BC 650 to 550 (Cal BP 2600 to 2500)

References:

Database used
INTCAL09

References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

Figure 8.1. Example of Beta Analytic, Inc., curve plot: LA 159879, Feature 7, FS 425 (Beta-319042).

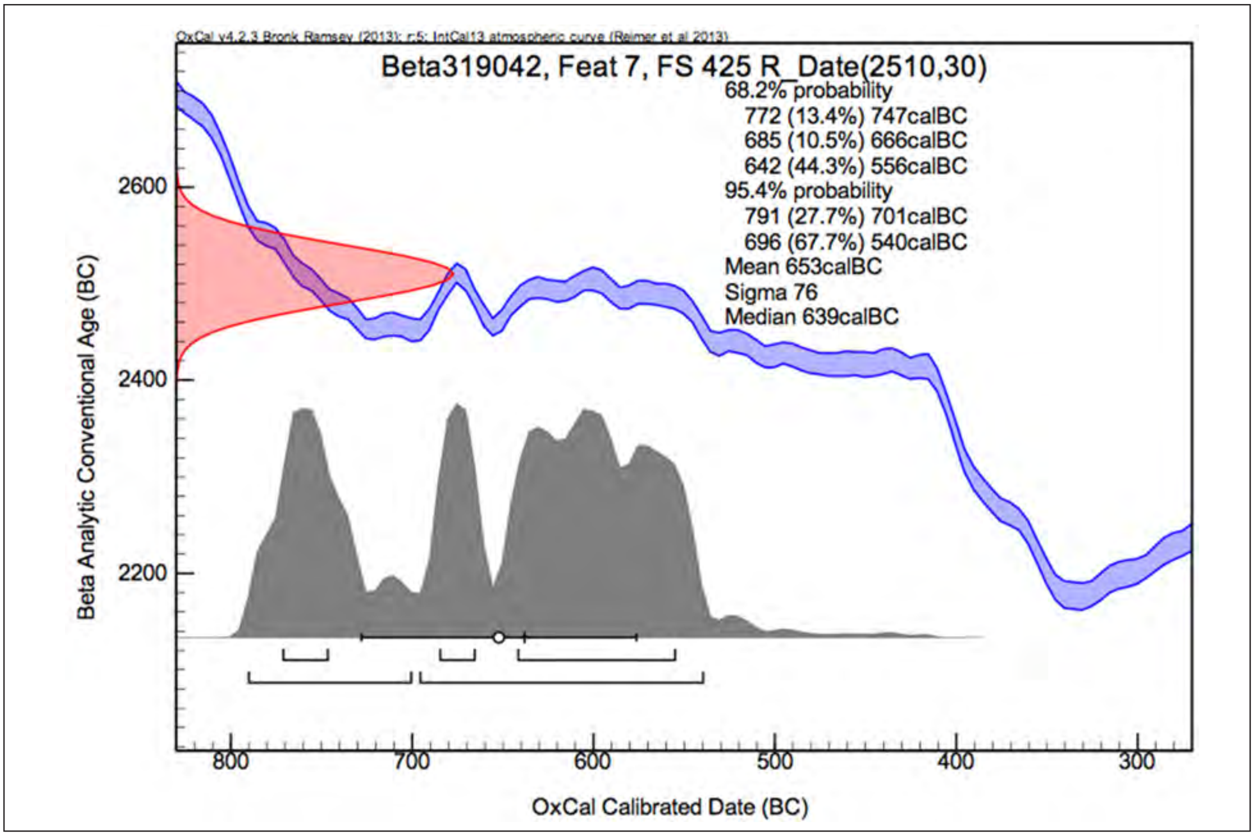


Figure 8.2. Example of OxCal curve plot: LA 159789, Feature 7, FS 425 (Beta-319042).

> and the bottom of the thick line indicates the lower 1σ bound. Second, both OxCal and Calib treat the curve as continuous; doing so requires interpolation, because we do not have ^{14}C measurements in continuous time, only for each tree ring, i.e., for each calendar year (Keenan 2012:346).

Thus, there is no single point or set of single points at which the mean conventional age intercepts the calibration curve. Rather, the conventional age distribution curve intersects the “ribbon” of calibration curve values and the OxCal calibration process determines ranges of calendar-year values that result from that intersection. In doing so, OxCal determines how much of the conventional age distribution curve intersects the calibration curve at one or more locations along the latter, and presents those data as 1-sigma and 2-sigma calendar-year ranges with percentages of the distribution curve intersecting the calibration curve. This is what Keenan (2012:346) calls, “the main output of the calibration process,” whether of OxCal, Calib, other calibration applications, or Keenan’s own process. Because it determines the portions of overall 1-sigma and 2-sigma date ranges that are made up of smaller ranges, the OxCal percentage values for 1-sigma ranges add up to 68.2 percent, while the percentage values for 2-sigma ranges add up to 95.4 percent (Table 8.1). The OxCal percentages can be interpreted as probabilities of accuracy and, depending on the shape of the calibration curve, as the precision of date ranges because higher percentage values represent date ranges within which a sample’s actual age is more likely to fall.

OxCal analyses also provide mean and median calendar dates, as well as the 1-sigma standard deviation value for each mean date (Table 8.1). Telford and others (2004) point out problems with single-year calibration-curve intercept dates. The problems focus on difficulties determining single points at which dates, expressed as ranges of values within confidence limits, intersect a calibration curve also made up of ranges of values. Further, because the calibration curve is subject to revision as new atmospheric data are acquired, intercept dates are directly related to the version of the curve in use at the time of analysis. Consequently, Telford and others (2004) conclude that mean and median dates, calculated as they are from ranges of dates representing the intersection(s) of conventional age curves and calibration curves, are more accurate single-year values than intercept dates. It is important to remember, however, that inherent variation in samples and in calibration processes mean that single-year values represent specific dates within ranges of dates and that, excepting the precision provided by percentage values, no one year within those ranges is more likely than any other to be "the" year. That is, single-year precision is not possible. Still, because analytical results from Beta Analytic include intercept dates, they are reported here.

Like OxCal, Calib also provides one or more 1-sigma and 2-sigma calendar date ranges representing the intersection(s) of a conventional age distribution curve with the calendar-year calibration curve, and provides percentage values for each range. Unlike the OxCal percentages, though, Calib percentages represent the proportions of overall 1-sigma and 2-sigma ranges comprised of smaller ranges. Consequently, the Calib percentages associated with each range, whether 1-sigma or 2-sigma, add up to 100.0 percent. Like OxCal percentage values, Calib percentage values can be interpreted as probabilities of accuracy and, potentially, as the precision of date ranges, also because higher percentage values represent date ranges within which a sample's actual age is most likely to fall. Differences between OxCal and Calib calibration dates are likely related to equational differences between the applications.

To determine whether groups of dates are present, we first used Grubbs' test to determine whether the assemblage contains dates that are statistical outliers (Table 8.2). For this test, we used the Beta Analytic conventional radiocarbon age for each sample because this value is the common basis for Beta Analytic, Calib, and OxCal calibrations. Because no dates are determined by Grubbs' test, it was not necessary to use calibrated ages. Grubbs' test assigns a standardized Z value to each conventional radiocarbon age that represents the distance of each age from the group mean; it then compares each individual Z value to a critical Z value determined by the number of ages in the group. Ages whose Z values exceed the critical Z value are statistical outliers. For each group, the test also identifies the conventional age that is furthest from the group mean but is not a statistical outlier.

The protocol for identified outliers was to remove the outlier age from the group and re-run the Grubbs' test. If the second test identified another outlier, that age was then removed and the test was run again, and so on until all outliers were identified and removed. Outliers were grouped together and tested to determine whether they were a cohesive set of dates. Identification of statistical outliers does not, in itself, tell us why they are outliers, which can only be determined in light of archaeological context, material integrity, and material suitability for radiocarbon dating, as well as comparison with other dates from related samples and proveniences.

The protocol for those mean conventional ages that were identified by Grubbs' test as furthest from their group means was the same as for outliers, realizing that those ages were not actually statistically different from the others in their groups. The results, therefore, cannot be used to securely identify different groups of dates within a site assemblage; they are, however, used to suggest intra-site groups of dates that can be examined with other tests. In part, this is because the group mean and standard deviation calculated for any group of ages by the Grubbs' test reflects both the number of individual ages and their range or span of years.

In addition to calendar-year calibrations, Calib was used to calculate mean pooled conventional radiocarbon ages, including 1-sigma standard deviations (Table 8.3). Calib was then used to convert mean pooled conventional ages to calibrated radiocarbon ages to make them more comparable with other calibrated ages (Table 8.3). Mean pooled calibrated ages are not, however, accorded the same weight in this analysis as comparing 1-sigma and 2-sigma dates from site features because the process of combining (pooling) any series of mean dates and their standard deviation values and calculating a mean value and mean standard deviation value for that pooled group necessarily minimizes differences within the group and, therefore, results in smaller standard deviation values and shorter ranges of dates than are evident when simply comparing the values within the group. Further, the

Table 8.2. LA 159879, radiocarbon dates: Grubb's outlier test results.

Conventional ^{14}C Age (BP)	Z Value	Mean Conventional Age (BP)	Standard Deviation	Sample Count	Critical Z Value for Sample Size	Outlier at 95% Confidence Level
All samples		2323.85	904.89	13	2.46	
2810	0.54					no
2800	0.53					no
2800	0.53					no
2770	0.49					no
2760	0.48					no
2730	0.45					no
2680	0.39					no
2660	0.37					no
2630	0.34					no
2510	0.21					no
2460	0.15					no
340	2.19					no
260	2.28					no*
* Not an outlier but highest Z value, thus furthest from group mean. The Z value is only 0.18 less than critical Z score, so the date is a near outlier. Calibration T-test shows that this not a single group of dates.						
Remove youngest sample		2495.83	688.31	12	2.41	
2810	0.46					no
2800	0.44					no
2800	0.44					no
2770	0.40					no
2760	0.38					no
2730	0.34					no
2680	0.27					no
2660	0.24					no
2630	0.19					no
2510	0.02					no
2460	0.05					no
340	3.13					yes*
* Removing the youngest date, which is nearly an outlier, results in this date becoming an outlier by increasing the group mean and thereby increasing the distance of this date from the mean. This is called "masking".						
Remove next youngest		2711.67	67.35	7	2.36	
2810	0.99					no
2800	0.91					no
2800	0.91					no
2770	0.66					no
2760	0.57					no
2730	0.32					no
2680	0.10					no
2660	0.27					no
2630	0.52					no
2510	1.53					no
2460	1.95					no*
* Not an outlier but highest Z value, thus furthest from group mean. Calibration T-test shows that this not a single group of dates.						

Table 8.2 (continued)

Conventional ^{14}C Age (BP)	Z Value	Mean Conventional Age (BP)	Standard Deviation	Sample Count	Critical Z Value for Sample Size	Outlier at 95% Confidence Level
Note: Removing the two youngest dates from the assemblage, which are much younger than the other eleven dates, does not result in a single statistical group of dates.						
Remove youngest sample		2715.00	95.60	10	2.29	
2810	0.99					no
2800	0.89					no
2800	0.89					no
2770	0.58					no
2760	0.47					no
2730	0.16					no
2680	0.37					no
2660	0.58					no
2630	0.89					no
2510	2.14					no*
* Not an outlier but highest Z value, thus furthest from group mean. Note that Z value is only 0.15 less than critical Z score so the date is a near outlier. Calibration T-test shows that this not a single group of dates.						
Remove next youngest		2737.78	66.67	9	2.22	
2810	1.08					no
2800	0.93					no
2800	0.93					no
2770	0.48					no
2760	0.33					no
2730	0.12					no
2680	0.87					no
2660	1.17					no
2630	1.62					no*
* Not an outlier but highest Z value, thus furthest from group mean. Calibration T-test shows that this not a single group of dates.						
Remove next youngest		2751.25	56.68	8	2.13	
2810	1.04					no
2800	0.86					no
2800	0.86					no
2770	0.33					no
2760	0.15					no
2730	0.37					no
2680	1.26					no
2660	1.61					no*
* Not an outlier but highest Z value, thus furthest from group mean. Calibration T-test shows that this is not a single group of dates.						
Remove next youngest		2764.29	46.50	7	2.02	
2810	0.98					no
2800	0.77					no
2800	0.77					no
2770	0.12					no
2760	0.09					no
2730	0.74					no
2680	1.81					no*
* Not an outlier but highest Z value, thus furthest from group mean. Note that Z value is only 0.15 less than critical Z score so the date is a near outlier. Calibration T-test shows that this is not a single group of dates.						
Remove next youngest		2778.83	30.61	6	1.89	
2810	1.03					no

Table 8.2 (continued)

Conventional ^{14}C Age (BP)	Z Value	Mean Conventional Age (BP)	Standard Deviation	Sample Count	Critical Z Value for Sample Size	Outlier at 95% Confidence Level
2800	0.71					no
2800	0.71					no
2770	0.27					no
2760	0.6					no
2730	1.58					no*
* Not an outlier but highest Z value, thus furthest from group mean. Calibration T-test shows that this is a single group of dates but with a 10.49% probability that the group is formed by chance.						
Note: It is necessary to remove the seven youngest dates from the assemblage before the remaining six dates comprise a single statistical group.						
Remove next youngest		2788.00	21.68	5	1.72	
2810	1.01					no
2800	0.55					no
2800	0.55					no
2770	0.83					no
2760	1.29					no*
* Not an outlier but highest Z value, thus furthest from group mean. Calibration T-test shows that this is a single group of dates but with a 39.10% probability that the group is formed by chance.						
Remove next youngest		2795.00	17.32	4	1.48	
2810	0.87					no
2800	0.29					no
2800	0.29					no
2770	1.44					no*
* Not an outlier but highest Z value, thus furthest from group mean. Note that Z score is very close (0.04) to critical Z score and is a near outlier. Calibration T-test shows that this is a single group of dates but with a 94.77 percent probability that the group is formed by chance.						
Remove next youngest		2803.33	5.77	3	1.15	
2810	1.15					yes*
2800	0.58					no
2800	0.58					no

* Date is an outlier because the other two dates are the same. Calibration T-test shows that this is a single group of dates but with a 96.44 percent probability that the group is formed by chance.

Table 8.3. LA 159879, radiocarbon dates: mean pooled radiocarbon ages and student's t-test results.

Mean Pooled 14C Age				Square Root of Variance	Sample Count	Student's T-Test				Result Summary
Conventional (BP)	Uncalibrated (BC/AD)	Calibrated (BC/AD) Summed Probability Age				T Value	P Value (2-tail)	χ2 (0.05)	Degrees of Freedom	
		2-Sigma	1-Sigma							
All samples										
2323.846	373.846 BC	**1019-522 BC (85.3%)** AD 1486-1605 (8.0%) AD 1606-1666 (5.9%) AD 1783-1796 (0.8%)	**1005-793 BC (96.9%)** AD 1643-1656 (3.1%)	8.321	13	10917.680	0.000	21.00	12	Samples are different at 95 percent confidence level. There is no probability (0.00%) that this result happens by chance. They are not a single group of dates and their summed probability ages are irrelevant.
Remove youngest sample (based on outlier test results)										
2495.833	545.833 BC	**1023-518 BC (92.0%)** AD 1481-1533 (2.7%) AD 1536-1635 (5.3%)	996-984 BC (4.2%) **980-795 BC (95.8%)**	8.660	12	5790.546	0.000	19.70	11	Samples are different at 95 percent confidence level. There is no probability (0.00%) that this result happens by chance. They are not a single group of dates and their summed probability ages are irrelevant.
Remove next youngest sample (based on outlier test results)										
2691.818	741.818 BC	**1042-514 BC (100.0%)**	976-951 BC (12.6%) **949-796 BC (87.4%)**	9.045	11	157.071	0.000	18.30	10	Samples are different at 95 percent confidence level. There is no probability (0.00%) that this result happens by chance. They are not a single group of dates and their summed probability ages are irrelevant.
Remove next youngest sample (based on outlier test results)										
2715	765 BC	**1045-730 BC (92.6%)** 692-659 BC (1.7%) 652-543 BC (5.7%)	975-955 BC (11.1%) **942-845 BC (53.6%)** 842-797 BC (35.3%)	9.487	10	91.389	0.000	16.90	9	Samples are different at 95 percent confidence level. There is no probability (0.00%) that this result happens by chance. They are not a single group of dates and their summed probability ages are irrelevant.
Remove next youngest sample (based on outlier test results)										
2737.778	787.778 BC	**1049-766 BC (97.4%)** 764-744 BC (0.4%) 689-675 BC (0.2%) 673-664 BC (0.2%) 647-551 BC (18.4%)	974-956 BC (11.4%) 941-893 BC (31.1%) 889-850 BC (21.1%) 839-797 BC (36.4%)	10.000	9	39.506	0.000	15.50	8	Samples are different at 95 percent confidence level. There is no probability (0.00%) that this result happens by chance. They are not a single group of dates and their summed probability ages are irrelevant.
Remove next youngest sample (based on outlier test results)										
2751.25	801.25 BC	**1050-776 BC (96.7%)** 764-734 BC (0.6%) 690-680 BC (0.2%) 673-662 BC (0.2%) 649-546 BC (2.1%) AD 1644-1651 (0.1%)	974-956 BC (12.9%) **941-849 BC (59.7%)** 839-802 BC (27.4%)	10.607	8	24.986	0.000	14.10	7	Samples are different at 95 percent confidence level. There is no probability (0.00%) that this result happens by chance. They are not a single group of dates and their summed probability ages are irrelevant.

Table 8.3 (continued)

Mean Pooled 14C Age				Square Root of Variance	Sample Count	Student's T-Test				Result Summary
Conventional (BP)	Uncalibrated (BC/AD)	Calibrated (BC/AD) Summed Probability Age				T Value	P Value (2-tail)	χ2 (0.05)	Degrees of Freedom	
		2-Sigma	1-Sigma							
Remove next youngest sample (based on outlier test results)										
2764.286	814.286 BC	**1050-776 BC (96.1%)** 766-731 BC (0.7%) 691-660 BC (0.6%) 651-544 BC (2.4%) AD 1643-1653 (0.2%)	976-952 BC (16.9%) **946-844 BC (67.8%)** 832-807 BC (15.3%)	11.340	7	14.413	0.000	12.60	6	Samples are different at 95 percent confidence level. There is no probability (0.00%) that this result happens by chance. They are not a single group of dates and their summed probability ages are irrelevant.
Remove next youngest sample (based on outlier test results)										
2778.333	828.333 BC	**1051-774 BC (95.5%)** 768-728 BC (0.9%) 693-658 BC (0.8%) 654-542 BC (2.6%) AD 1642-1654 (0.2%)	**996-888 BC (76.5%)** 883-844 (23.5%)	12.274	6	5.204	0.0035	11.10	5	Samples are the same at 95 percent confidence level. There is a very low probability (0.35%) that this result happens by chance. The six oldest dates are a single group of dates.
Remove next youngest sample (based on outlier test results)										
2788	838 BC	**1051-724 BC (95.9%)** 694-540 BC (3.8%) AD 1641-1656 (0.3%)	**1000-892 BC (79.2%)** 877-847 BC (15.7%) 814-805 BC (5.1%)	13.416	5	2.089	0.1049	9.49	4	Samples are the same at 95 percent confidence level. They are a single group of dates. However, there is a 10.49 percent probability that this result happens by chance.
Remove next youngest sample (based on outlier test results)										
2795	845 BC	**1051-716 BC (95.5%)** 695-539 BC (4.1%) AD 1641-1658 (0.4%)	**1002-894 BC (78.7%)** 872-850 BC (11.0%) 822-802 BC (10.3%)	15.000	4	1.000	0.3910	7.81	3	Samples are the same at 95 percent confidence level. They are a single group of dates. However, there is a 39.10 percent probability that this result happens by chance.
Remove next youngest sample (based on outlier test results)										
2803.333	853.333 BC	**1052-701 BC (94.9%)** 698-538 BC (4.5%) 526-526 BC (0.02%) AD 1638-1660 (0.5%)	**1003-895 BC (78.4%)** 869-854 BC (6.7%) 829-801 BC (14.9%)	17.321	3	0.074	0.9477	5.99	2	Samples are the same at 95 percent confidence level. They are a single group of dates. However, there is a 94.77 percent probability that this result happens by chance, likely because the group size is very small. Outlier test results show that the oldest of the three dates is a statistical outlier because the other two conventional ages are the same.
Remove next youngest sample (based on outlier test results)										
2805	855 BC	**1051-537 BC (99.2%)** 528-524 BC (0.08%) AD 1530-1536 (0.1%) AD 1635-1660 (0.6%)	**1002-895 BC (73.8%)** 871-851 BC (9.3%) 831-800 BC (14.9%)	21.213	2	0.056	0.9644	3.84	2	Samples are the same at 95 percent confidence level. They are a single group of dates, perhaps because the group size is small. There is a 96.44 percent probability that this result happens by chance.

Table 8.3 (continued)

Mean Pooled 14C Age				Square Root of Variance	Sample Count	Student's T-Test				Result Summary
Conventional (BP)	**Uncalibrated (BC/AD)**	**Calibrated (BC/AD) Summed Probability Age**				**T Value**	**P Value (2-tail)**	**χ2 (0.05)**	**Degrees of Freedom**	
		2-Sigma	**1-Sigma**							
Two youngest samples										
300	AD 1650	**AD 1472-1667 (94.2%)** AD 1782-1797 (5.7%) AD 1950-1950 (0.1%)	AD 1521-1578 (41.2%) AD 1581-1591 (5.5%) AD 1620-1665 (47.5%) AD 1785-1793 (5.8%)	21.213	2	3.556	0.1745	3.84	1	Samples are the same at 95 percent confidence level. They are a single group of dates, perhaps because the group size is small. There is a 17.45 percent probability that this results happens by chance.
Feature 5 samples										
2785	835 BC	**1009-841 BC (100.0%)**	995-987 BC (7.0%) **980-899 BC (93.0%)**	21.213	2	0.500	0.7048	3.84	1	Samples are the same at 95 percent confidence level. They are a single group of dates, perhaps because the group size is small. There is a 70.48 percent probability that this result happens by chance.
Feature 3 samples										
2656.67	706.67 BC	895-867 BC (11.1%) **864-788 BC (88.9%)**	**833-796 BC (100.0%)**	17.321	3	1.407	0.2947	5.99	2	Samples are the same at 95 percent confidence level. They are a single group of dates, perhaps because the group size is small. There is a 29.47 percent probability that this result happens by chance.

Conventional mean pooled ages (BP) are calculated by Calib 6.1.0 using conventional ages provided by Beta Analytic, Inc. Uncalibrated mean pooled ages (BC) are calculated by subtracting conventional mean pooled ages from AD 1950. Calibrated mean pooled ages (BC/AD) are calculted by submitting conventional mean pooled ages to Calib 6.1.0 (Intcal09.14c). Dates in bold type have the highest probabilities of accuracy (2 sigma) and precision (1 sigma).

process of calibrating the conventional pooled mean ages produces both 1- and 2-sigma standard deviation ranges that represent proportions of 1-sigma ranges for the conventional ages, that is 68.2 and 95.4 percents, respectively, of a 68.2 percent range. Consequently, we are not confident of the apparently increased precision provided by pooled mean ages. Therefore, when assessing the dates from features and sites, emphasis is placed on comparison of the calibrated 1-sigma and 2-sigma radiocarbon ages; the results are compared with pooled mean ages and their similarities are observed but the latter are not given the same weight when identifying most accurate and most precise dates.

Additionally, Calib calculated Student's T-test values (Table 8.3). The results of these tests show whether the dates make up a single group, that is, whether they are statistically the same at a 95.4 percent confidence level. If they are not the same, however, these tests do not necessarily confirm whether more than one group of dates are present or whether the dates are all different from each other. They do, however, provide information important for identifying the strength of group identities. Thus, intra-site groups identified or suggested by outlier testing were examined by calculating mean pooled ages and standard deviations and with Student's T-tests to determine whether the groups could be confirmed. It was, therefore, the interplay of outlier testing with t-testing and mean pooled ages that identified and confirmed or denied groups of site dates.

LA 159879 Radiocarbon Dates

Table 8.1 shows that calibrated radiocarbon dates from LA 159879 range from about 1050 BC to AD 1670 (2 sigma). Figure 8.3 shows the 13 dates in a single OxCal multiple plot, ordered from oldest to youngest. Showing them all in a single curve plot (all samples plotted along the calibration curve) is needlessly difficult to read. Curve plots are presented later for the historic dates, the prehistoric dates, and each individual date. Table 8.4 summarizes the "most accurate" and "most precise" dates for each sample. A discussion of these distinctions follows.

"Most accurate" refers to the range of calibrated dates with the highest probability—expressed as a percent value—of including the actual age of the sample. It is obtained from OxCal and Calib calibrated, 2-sigma dating results since those calibrations include percent probabilities while Beta calibrations do not. Beta calibrations use the conventional age and its 2-sigma range as a simple range of values that intersect the calibration curve, resulting in a simple range of calendric dates. OxCal and Calib calibrations use the conventional age and its 2-sigma range as a bell curve with the highest probability at the conventional age and decreasing probabilities moving away from the conventional

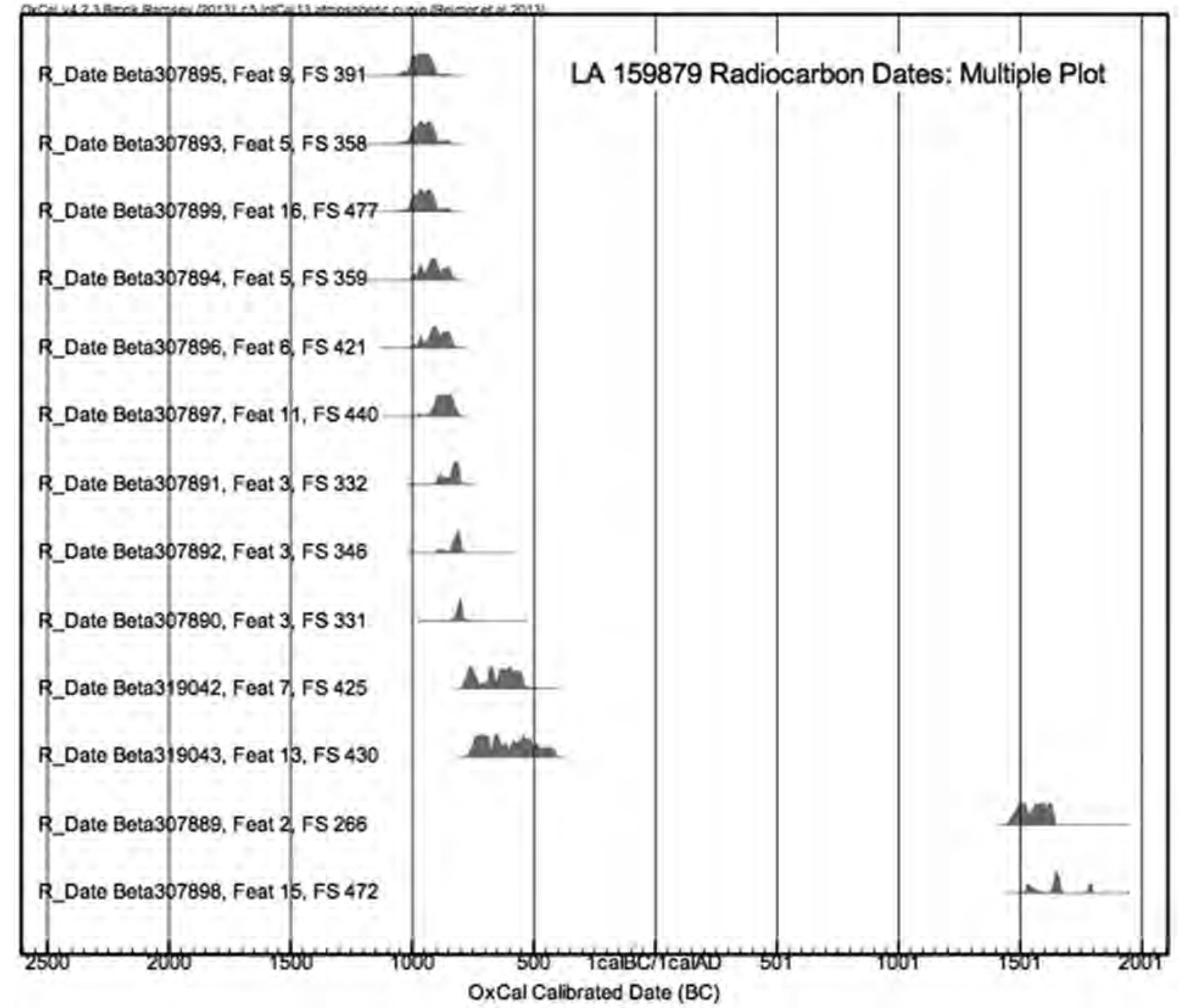


Figure 8.3. Radiocarbon date, multiple plot.

Table 8.4. LA 159879, most accurate and most precise radiocarbon dates by sample.

Site Area	Feature	FS	BETA Sample	Most Accurate Date	Most Precise Date
Central	9 Fire Pit	391	307895	1050–895 BC	1000–925 BC
South	5 Structure?	358	307893	1027–891 BC	996–915 BC
	5 Structure?	359	307894	997–839 BC	973–848 BC
	5 Structure?	pooled age for feature	NA	1009–841 BC	980–899 BC
North	16 Pit Structure	477	307899	1027–891 BC	996–915 BC
Central	6 Fire Pit	421	307896	980–830 BC	929–843 BC
Central	11 Fire Pit	440	307897	930–812 BC	901–836 BC
Central	3 Structure	332	307891	897–801 BC	844–804 BC
	3 Structure	346	307892	859–793 BC	832–800 BC
	3 Structure	331	307890	838–774 BC	816–793 BC
	3 Structure	pooled age for feature	NA	864–788 BC	833–796 BC
Central	7 Fire Pit	425	319042	791–538 BC (only 72 percent)	same
North	13 Fire Pit	430	319043	758–429 BC	same
Central	2 Fire Pit	266	307889	AD 1470–1640	same
North	15 Fire Pit	472	307898	AD 1520–1670	AD 1635–1666

age. As that bell curve intersects the calibration curve, OxCal and Calib calibrate the probabilities that the intersected area or areas, depending on the slope and shape of the calibration curve, includes the actual sample age.

Calibrated 2-sigma ranges frequently do not include multiple individual ranges resulting from multiple, discontinuous intersections of the convention age range with the calibration curve but, again, that is dependent on the slope and shape of the calibration curve. If there are multiple individual ranges within the overall oldest–youngest calibrated, 2-sigma range for a sample, focus is placed first on the individual range or ranges with probabilities greater than half of the overall 2-sigma probability (95.4 percent for OxCal dates, 100 percent for Calib dates). That is, we focus first on the individual range or ranges with probabilities greater than 47.7 percent for OxCal dates and greater than 50 percent for Calib dates. We then assess the separation or discontinuity between individual ranges; ranges separated by more than 10 years are considered to be actually discontinuous. If individual ranges are separated by less than 10 years, the apparent discontinuity is considered not to be real and the ranges are added together, increasing the length of the greater-than-half range and its probability of accuracy. In that way, the most accurate date for a sample might not be the entire calibrated, 2-sigma range, but the nature of calculating a range with 95.4 percent or greater probability means that it will likely be very close to the entire range.

"Most precise" refers to the range of calibrated, 1-sigma dates with the highest probability of including the actual age of the sample, also obtained from OxCal and Calib calibration results. Because 1-sigma date ranges are usually shorter than 2-sigma ranges (but not always, depending on the slope and shape of the calibration curve), they are considered potentially more precise because they further limit the range within which the actual date is probably present. Increased precision comes with the considerable risk of decreased security (68.2 vs 95.4 percent probability), however, so a variety of factors are assessed to determine whether recommending a more precise date based on the 1-sigma results is warranted.

One-sigma results more often include multiple, individual ranges than do 2-sigma results. Again, focus is first directed on the 1-sigma range or ranges that make up more than half the overall 1-sigma oldest-youngest range; in this case that means greater than 34.1 percent for OxCal dates and greater than 50 percent for Calib dates. Length of separation between individual ranges is also checked, again looking for discontinuities of greater or lesser than 10 years. If individual ranges are less than 10 years apart, they are combined, increasing the length of the resulting range and its probability. The results are then checked against the OxCal mean sample date with its 1-sigma range, the OxCal median date and, frequently, the Beta intercept dates, recognizing the hazards of using intercept dates. If there is good correspondence between the date range making up most or all of the overall 1-sigma range and the sample's mean and median dates—and intercept dates, even though less confidence is placed in them—a "most precise" date based on 1-sigma dating results can be recommended with reasonable confidence, recognizing the decreased security inherent in 1-sigma results. If, these conditions are not met, however, the risks of using a 1-sigma range that does not include the sample's actual age are considered to be too great and the "most precise" date is listed as the same as the "most accurate" date derived from 2-sigma results.

Historic Dates

Of the 13 samples, only two yielded dates younger than the third century BC. Both were obtained from wood collected from fire pit features. Figure 8.4 shows these two dates in an OxCal multiple plot.

Feature 2

Sample Beta-307889 consisted of burned mesquite wood collected from Feature 2. It yielded a 2-sigma calibrated date of ca. AD 1470 to 1639/1640, a range of 170 years; a more precise 1 sigma was not identified (Tables 8.2, 8.4). This is because the conventional age curve intersects the calibration curve in the late AD fifteenth century and again in the late AD sixteenth to early seventeenth centuries after the calibration curve reversed its slope in the early AD sixteenth century (Figs. 8.5, 8.6). Had the reversal not happened, the Feature 2 sample might have been more accurately and precisely dated about AD 1500 ± ca. 30 to 40 years, and we can suggest but certainly not demonstrate statistically that the Feature 2 sample dates to the late AD sixteenth or early seventeenth centuries.

Feature 15

Sample Beta-307898 consisted of unidentified, burned wood collected from Feature 15 and produced a 2-sigma calibrated date range of ca. AD 1519/1520 to 1950, with four separate, shorter internal ranges (Table 8.1. These are created because the conventional age curve intersects the

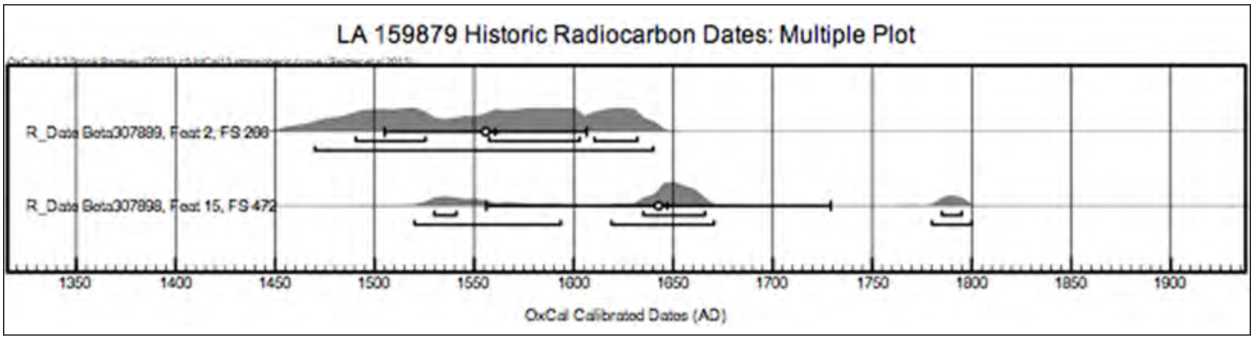


Figure 8.4. Historic radiocarbon dates, multiple plot.

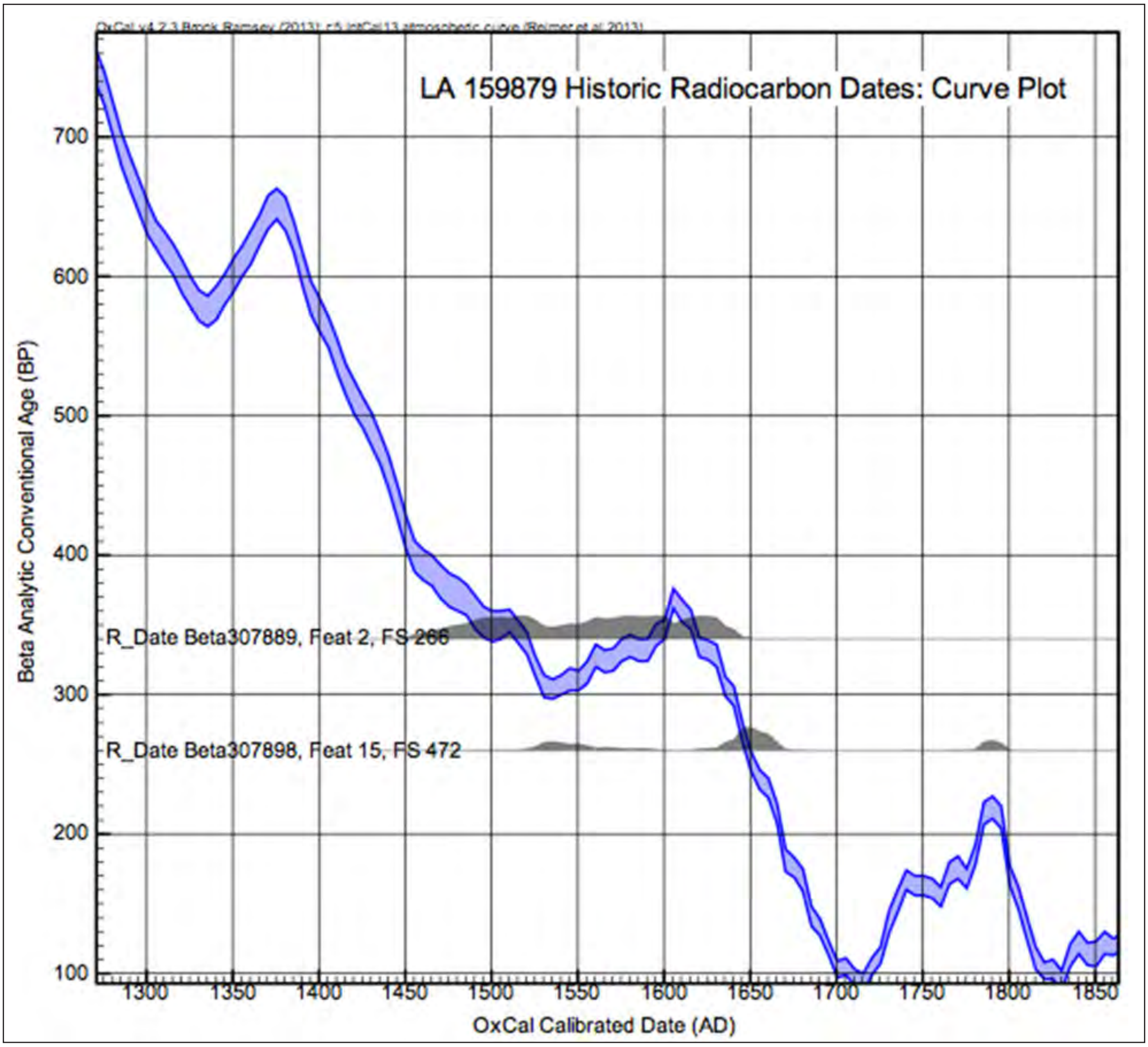


Figure 8.5. Historic radiocarbon dates, curve plot.

calibration curve several times during a period between about AD 1530 and 1820 when the latter reversed its slope twice (Fig. 8.7). One of the internal ranges, ca. AD 1619 to 1670 (51 years), has the highest probability of accuracy but by just over 50 percent. This range as well as a more precise 1-sigma range of AD 1634/1635 to 1666 are both supported by mean and median dates of AD 1642 and 1647, respectively, and an intercept date of AD 1650. The mean date, AD 1642, however, has a long 1-sigma standard deviation range of 87 years—AD 1555 to 1729. Comparing that range to the 2-sigma ranges in Table 8.1 shows that it encompasses half of the earliest 2-sigma range, AD 1519/1520 to 1593 (28 to 29 percent accuracy probability) as well as the AD 1619 to 1670 range (53 to 57 percent) but does not reach the third 2-sigma range, AD 1779/1780 to 1799/1780 (ca. 12 percent). Caution dictates identifying the most accurate date for the Feature 15 sample as ca. AD 1520 to 1670, a range with a combined 85 to 86 percent probability of accuracy. A more precise date of ca. AD 1635 to 1666, however, has a 72 to 74 percent probability of accuracy, is supported by mean, median, and in-

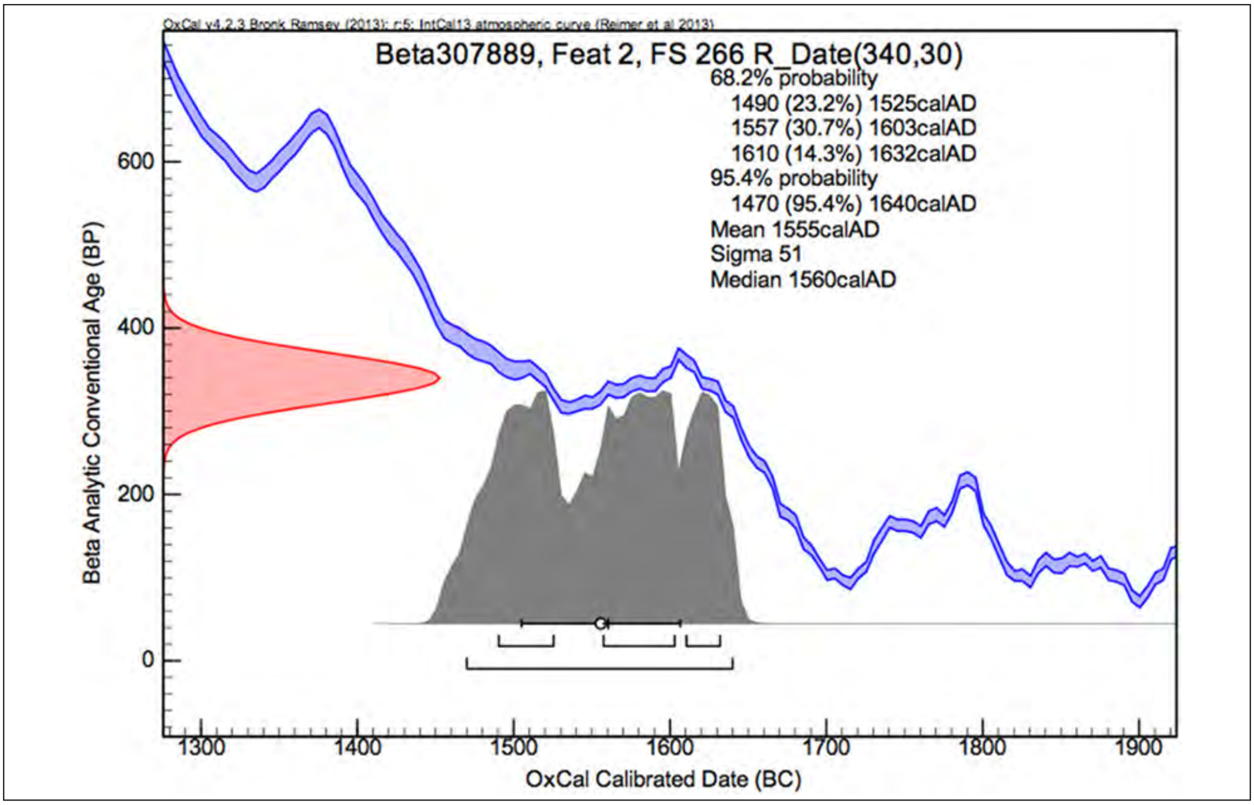


Figure 8.6. Feature 2, FS 266, radiocarbon date, curve plot.

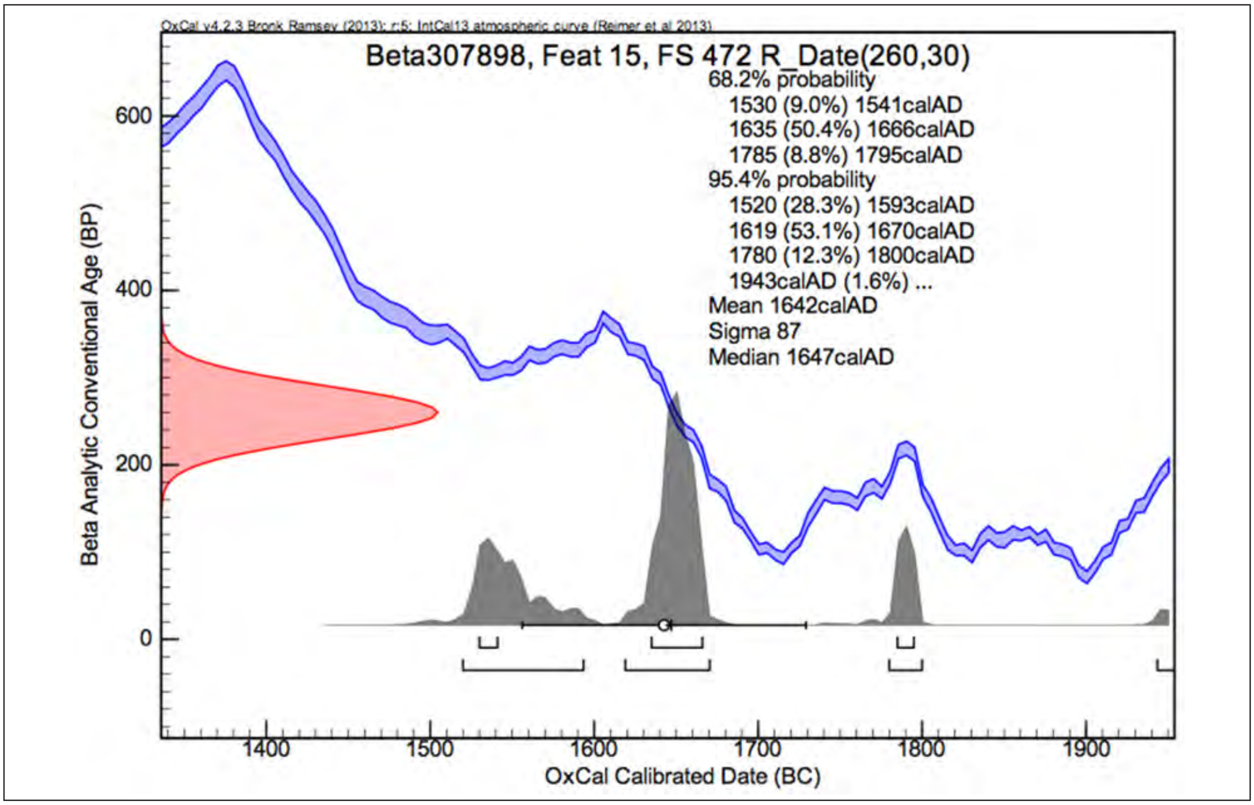


Figure 8.7. Feature 15, FS 472, radiocarbon date, curve plot.

tercept dates, and may be used to date the sample (Table 8.4).

Historic Sample Group

Because the two historic samples are so obviously different than the other 11 samples, Student's T-test results were used to see if they comprise a single group within the entire site assemblage (Grubbs' test cannot be run because there are only two samples). Results (Table 8.3) show that as a group, they are most accurately dated between AD 1472 and 1677 (2-sigma calibrated; 205 years). A single, precise 1-sigma date cannot be determined among the four ranges identified between AD 1521 and 1793. However, two ranges account for almost all of the 1-sigma variability: AD 1521 to 1591 (46.7 percent) and AD 1620 to 1665 (47.5 percent). The two historic samples are statistically the same at the 95 percent confidence level and form a single group, although there is a 17.5 percent probability that the group is formed by chance. It is likely, then, that since the two samples were collected from different features, their pooled 2-sigma date range is over 200 years long, and their pooled 1-sigma ranges are similar to their individual dates, they actually form a single group because there are only two of them.

Prehistoric Dates

The remaining 11 samples from LA 159879 yielded dates ranging between about 1050 and 400 BC (calibrated, 2-sigma; Table 8.1). Figure 8.8 shows the prehistoric dates on an OxCal multiple plot and Figure 8.9 shows them on a curve plot, ordered in both cases from oldest to youngest. In the following discussion, they are presented from oldest to youngest

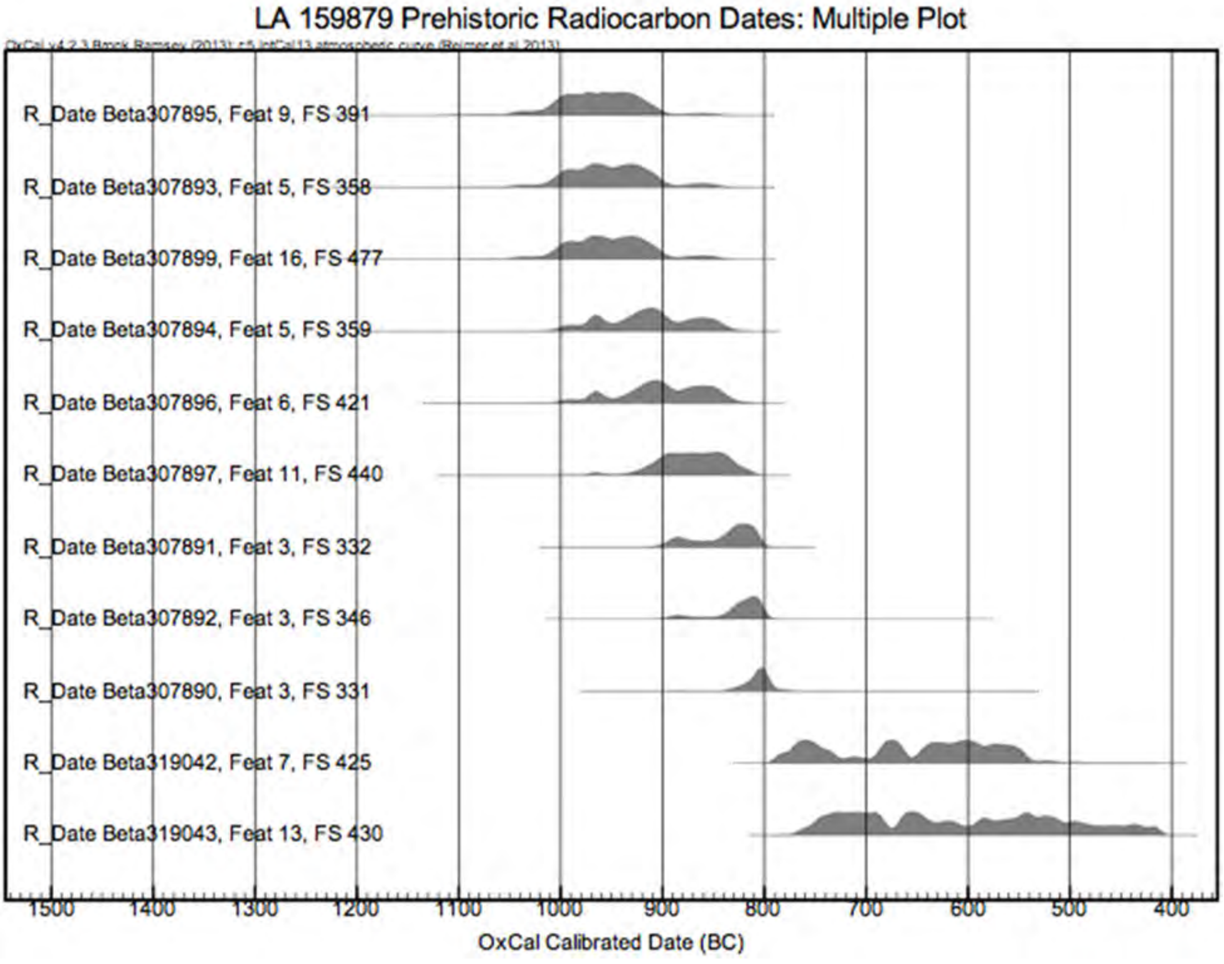


Figure 8.8. Prehistoric radiocarbon dates, multiple plot.

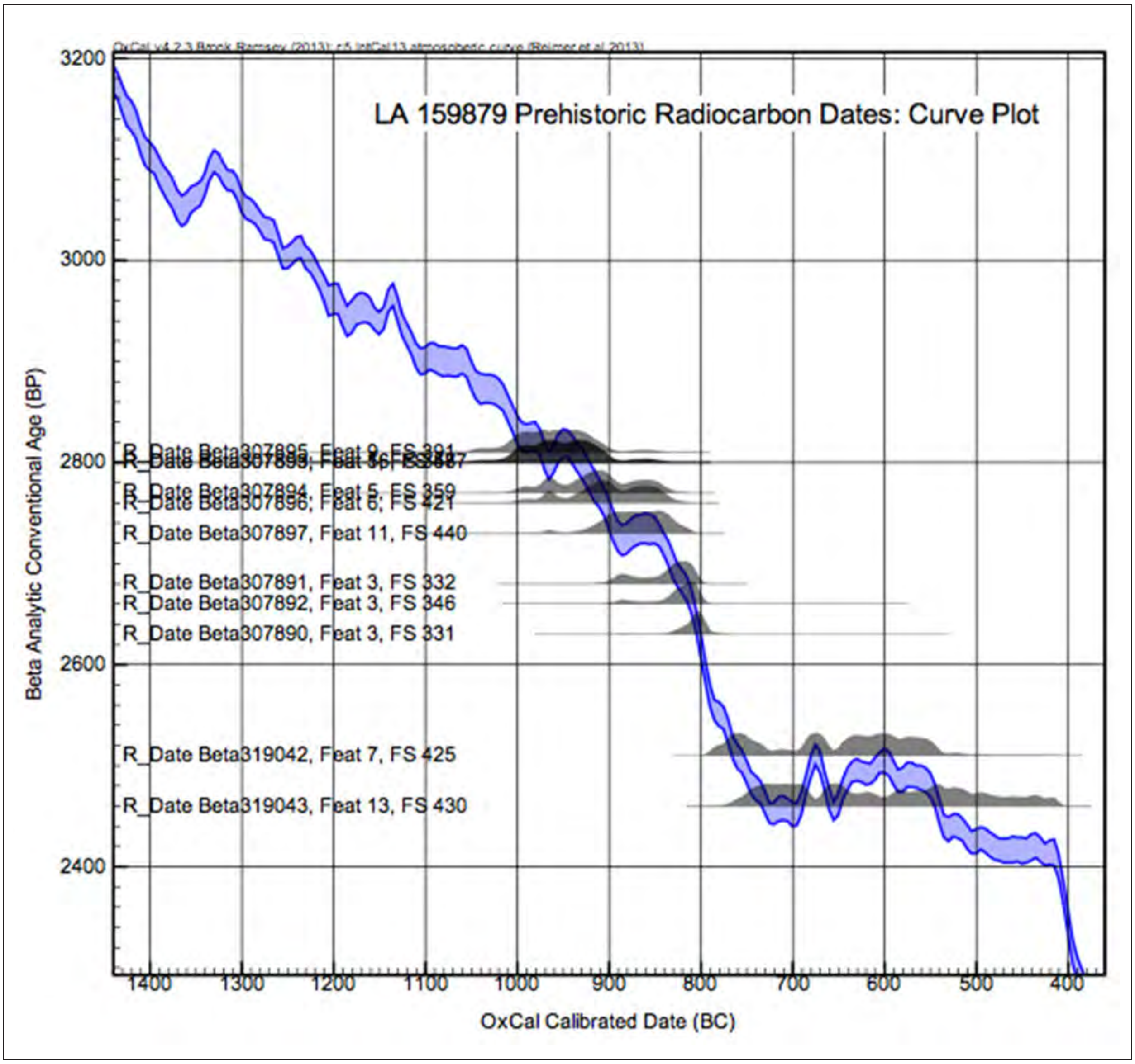


Figure 8.9. Prehistoric radiocarbon dates, curve plot.

with the exception of samples from Features 3 and 5 from which multiple samples were submitted. For those features, the multiple samples are discussed together even if they are not strictly in chronological order within the site assemblage.

<u>Feature 9</u>

Sample Beta-307895 was a collection of burned mesquite, saltbush, and unidentified wood from Feature 9, a fire pit (Table 8.1). Figure 8.10 shows the sample's curve plot. It yielded a calibrated 2-sigma date of 1050 to 896/895 BC (155 years) and calibrated, 1-sigma date of 1000/999 to 925 BC (75 years). The latter is supported by the mean date (962 BC) with its 1-sigma range, 1001 to 923 BC, as well as the median date, also 962 BC, and three intercept dates of 970, 960, and 940 BC. The three intercept dates are the result of a short reversal in the slope of the calibration curve between about 970 and 920 BC. The reversal lengthens the calibrated date ranges, making them less accurate and less precise than had the reversal not happened. The calibrated 2-sigma range is the most accurate date and the 1-sigma

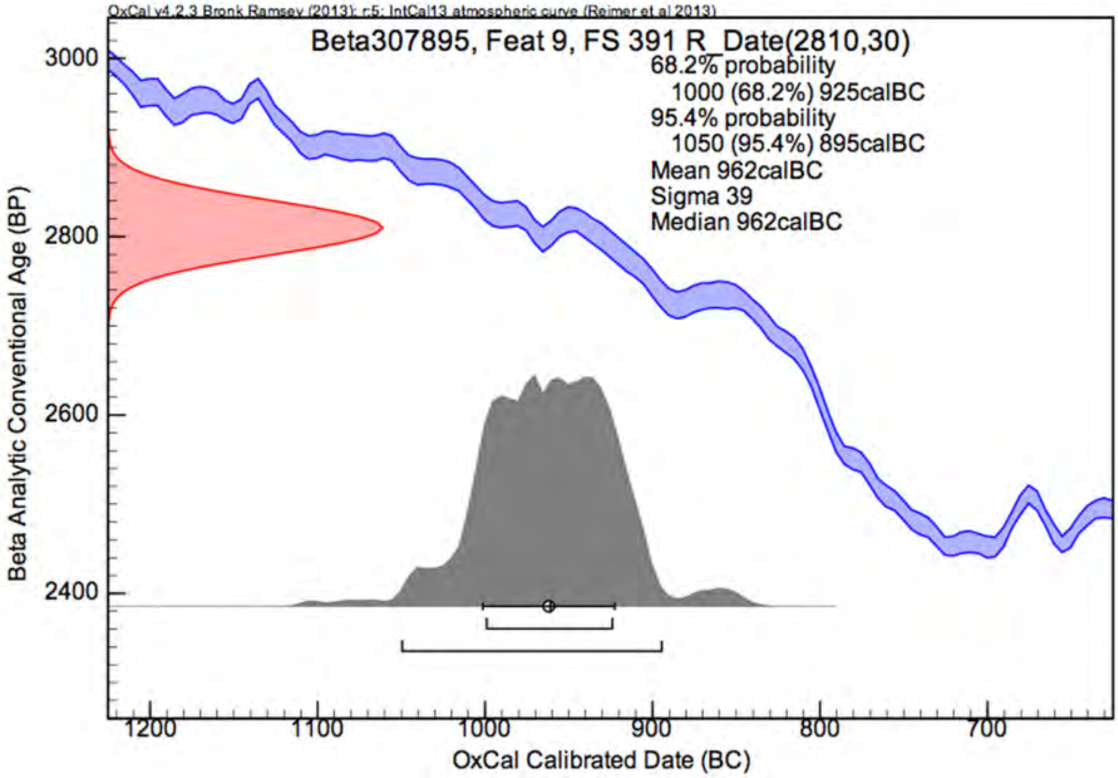


Figure 8.10. Feature 9, FS 391, radiocarbon date, curve plot.

range is the most precise and may be used to characterize the sample.

Feature 5

Two radiocarbon samples were submitted from Feature 5, a possible structure. Sample Beta-307893 consisted of burned mesquite, saltbush, piñon, and unidentified conifer wood from Feature 5 (Table 8.1). Figure 8.11 is the sample's curve plot. The sample yielded a calibrated 2-sigma date of 1027/1026 to 892/891 BC (135 years) and a calibrated 1-sigma date of 996 to 915 BC (81 years). The 1-sigma range is supported by the mean date (952 BC) with its 1-sigma range, 992 to 912 BC. The median date is 953 BC and the sample produced three intercept dates, 970, 960, and 930 BC. The three intercept dates are the result of the same short reversal in the slope of the calibration curve between about 970 and 920 BC that affects the Feature 9 sample. The reversal also lengthens the Feature 5 calibrated date ranges, making them less accurate and less precise than had the reversal not happened. The calibrated 2-sigma range is the most accurate date and the 1-sigma

range is the most precise and may be used to characterize the sample.

The second sample from Feature 5 is Beta-307894 (Table 8.1). Figure 8.12 is the sample's curve plot. Consisting of burned mesquite and saltbush wood, it yielded a calibrated 2-sigma date of 997 to 839 BC (158 years) and a calibrated 1-sigma date of 940/938 to 893/892 BC (47 years). This 1-sigma date has a relatively low probability of accuracy (59 to 60 percent), however. There are two other 1-sigma ranges with lower accuracy probabilities (Table 8.1); they are separated from the higher probability range by 18 to 20 years on the older side and 16 to 18 years on the younger side. The separations are the result of short reversals in the slope of the calibration curve (Fig. 8.12). If the three 1-sigma ranges are combined, ignoring their gaps, the result is a range 122 to 125 years long between about 973 and 848 BC. The mean date for this sample is 915 BC with a 43-year 1-sigma range, 958 to 872 BC. That range encompasses the higher probability 1-sigma range and the two separation periods between it and the other

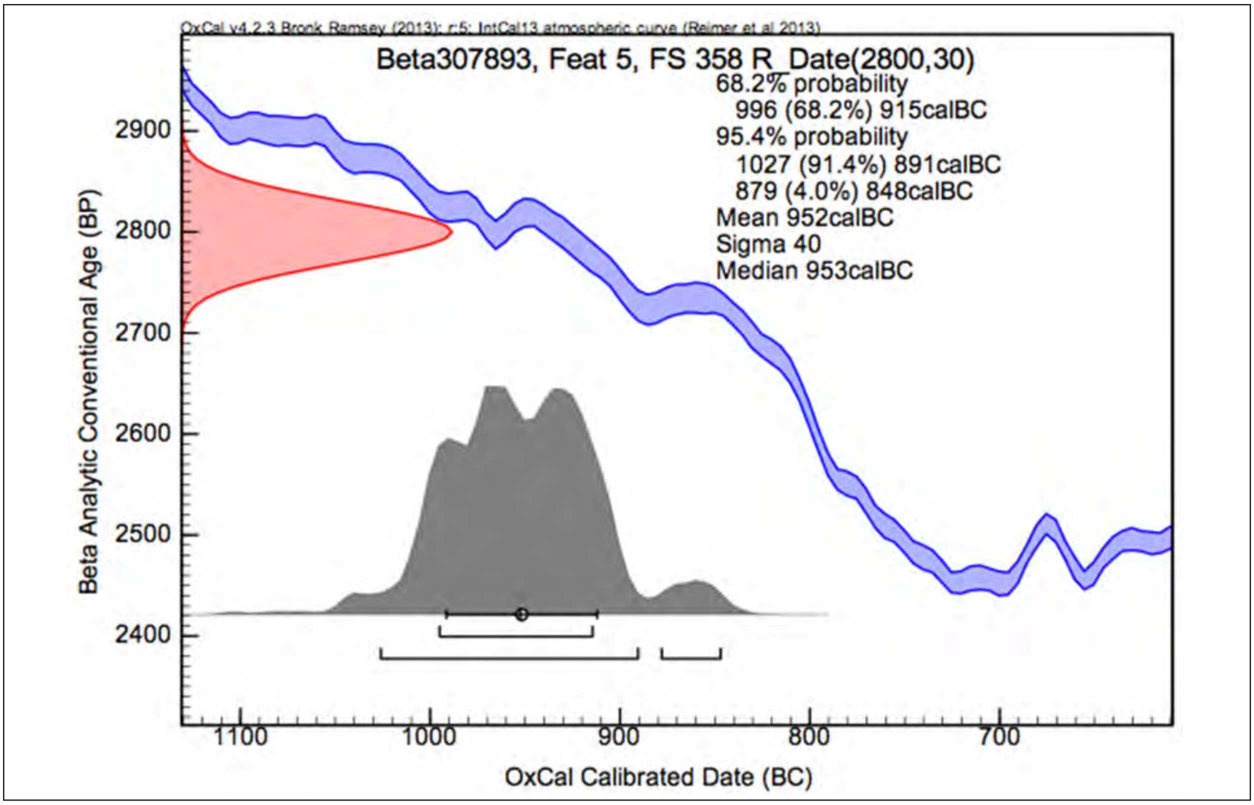


Figure 8.11. Feature 5, FS 358, radiocarbon date, curve plot.

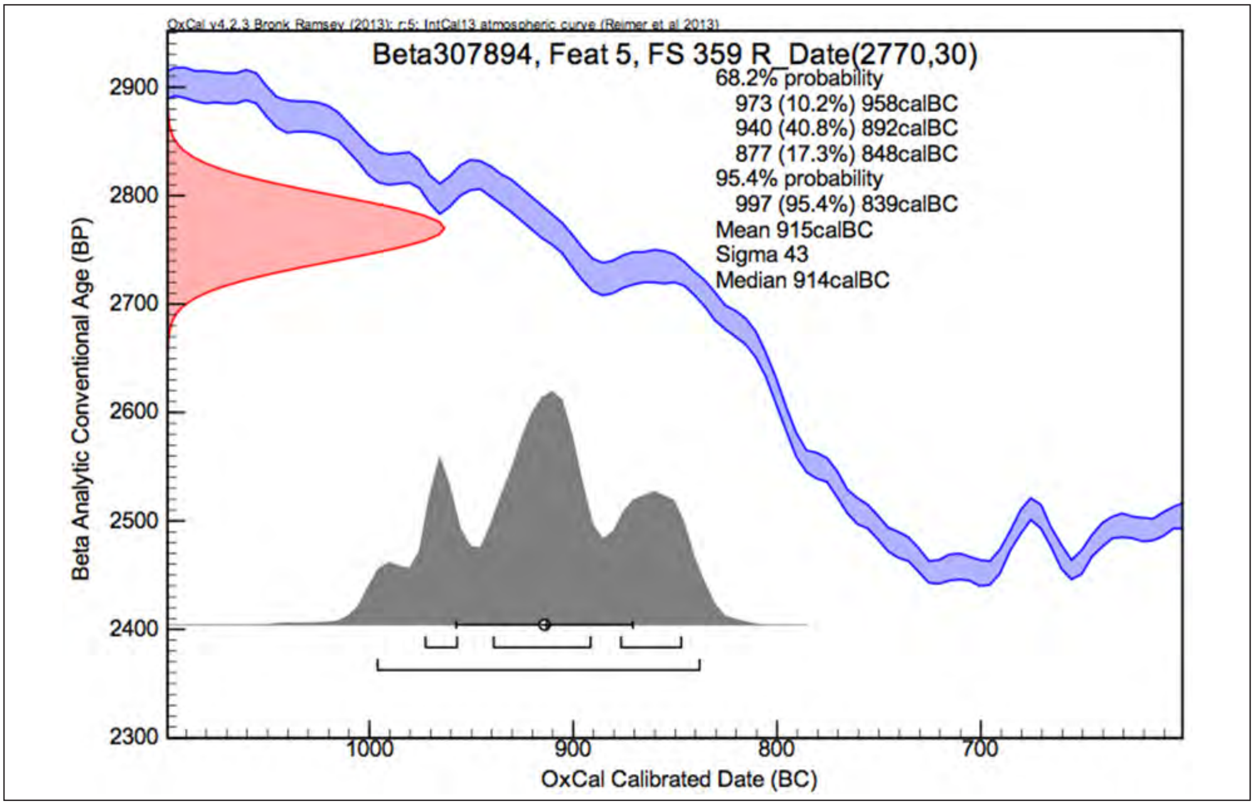


Figure 8.12. Feature 5, FS 359, radiocarbon date, curve plot.

two 1-sigma ranges. Under the circumstances, the 2-sigma range, 997 to 839 BC, is the most accurate date for this sample, and the combined 1-sigma range, 973 to 848 BC, is the most precise date.

Student's T-test results were used to see if the two Feature 5 samples comprise a single group within the entire site assemblage (Grubbs' test cannot be run because there are only two samples). Results (Table 8.3) show that they are statistically the same at the 95 percent confidence level and form a single group. Interestingly, as a group, they provide an accurate, pooled mean date for Feature 5 of 1009 to 841 BC (2-sigma calibrated; 168 years), and a more precise 1-sigma (calibrated) pooled mean date of 980 to 899 BC (81 years).

Feature 16

Sample Beta-307899 was collected from Feature 16, a pit structure, and consisted of unidentified, burned plant material (Table 8.1). Figure 8.13 is the sample's curve plot. A calibrated 2-sigma date of 1027/1026 to 892/891 BC (180 years) and a calibrated 1-sigma date of 996 to 915 BC (81 years) were obtained. The latter is supported by a mean date of 952 BC ±40 years, 992 to 912 BC. The 2-sigma date is the most accurate for the Feature 16 sample, while the most precise date of 996 to 915 BC can be used to characterize the sample.

Feature 6

Feature 6, a fire pit, provided sample Beta-307896 consisting of burned mesquite and saltbush wood (Table 8.1). Its curve plot is shown in Figure 8.14. The most accurate date for the sample is a calibrated 2-sigma age of 980/979 to 830 BC (150 years), while the most precise, calibrated 1-sigma date is 929/928 to 844/843 BC (85 years).

Feature 11

Sample Beta-307897 consisted of burned mesquite and saltbush wood from Feature 11, a fire pit (Table 8.1). Its curve plot is shown in Figure 8.15. Its most accurate date is a calibrated 2-sigma age of 930/928 to 812 BC (118 years) and its most precise, calibrated 1-sigma date is 901/900 to 837/836 BC (64 years).

Feature 3

Three samples were submitted from Feature 3, a structure (Table 8.1). The first is sample Beta-307891, consisting of burned mesquite wood and yielding a calibrated 2-sigma date of 897/896 to 802/801 BC—at 95 years, one of the shorter 2-sigma ranges from the site—and a calibrated 1-sigma date of 844/843 to 804 BC (40 years; Fig. 8.16). In addition to having relatively short date ranges, this sample is unique in that its increased precision is obtained by shortening the 2-sigma range by 23 years on the older side but only four years on the younger side.

Feature 3 also provided sample Beta-307892 that consisted of unidentified, burned wood (Table 8.1). A calibrated 2-sigma date of 859/850 to 794/793 BC (57 to 66 years) and a calibrated 1-sigma date of 832/831 to 801/800 BC (31 years) were obtained from the sample (Fig. 8.17). Like sample Beta-307891, the dates from this sample are relatively short compared to others from the site and increased precision is obtained by shortening the 2-sigma range by 19 to 27 years on the early side and only seven years on the later side.

Finally, sample Beta-307890, comprising burned mesquite wood, was submitted from Feature 3 (Table 8.1). Its most accurate date is a calibrated 2-sigma age of 838/837 to 777/774 BC (64 years), while its most precise date is a calibrated 1-sigma age of 816/815 to 794/793 BC (22 years; Fig. 8.18).

Grubbs' outlier test results (Table 8.2) show that there are no outliers among the Feature 3 samples. Student's T-test results were used to see if the three Feature 3 samples comprise a single group within the entire site assemblage. Results (Table 8.3) show that they are statistically the same at the 95 percent confidence level and form a single group. As a group, they provide an accurate, pooled mean date for Feature 3 of 864 to 788 BC (2-sigma calibrated; 76 years), and a more precise 1-sigma (calibrated) pooled mean date of 833 to 796 BC (37 years).

Feature 7

Sample Beta-319042 consisted of unidentified, burned plant material from Feature 7, a fire pit (Table 8.1). Its $\delta^{13}C$ value, -10.8, shows that the material was from a $\mathbf{C_4}$ pathway plant. The only other sample with a low $\delta^{13}C$ value, Beta-319043 from Feature 13, was burned maize, also a $\mathbf{C_4}$ plant. Figure 8.19, the sample's curve plot, shows that the conventional date intersects the calibration curve first in the eighth century BC when the latter has a relatively steep slope. However, beginning about 725 BC, the calibration curve slightly reverses its slope and become essentially flat for about 300 years, until about 410 BC. This flatness results in multiple intersections of the two curves, reflected in multiple 2-sigma and calibrated Beta, OxCal, and Calib dates, three Beta intercept dates, OxCal mean

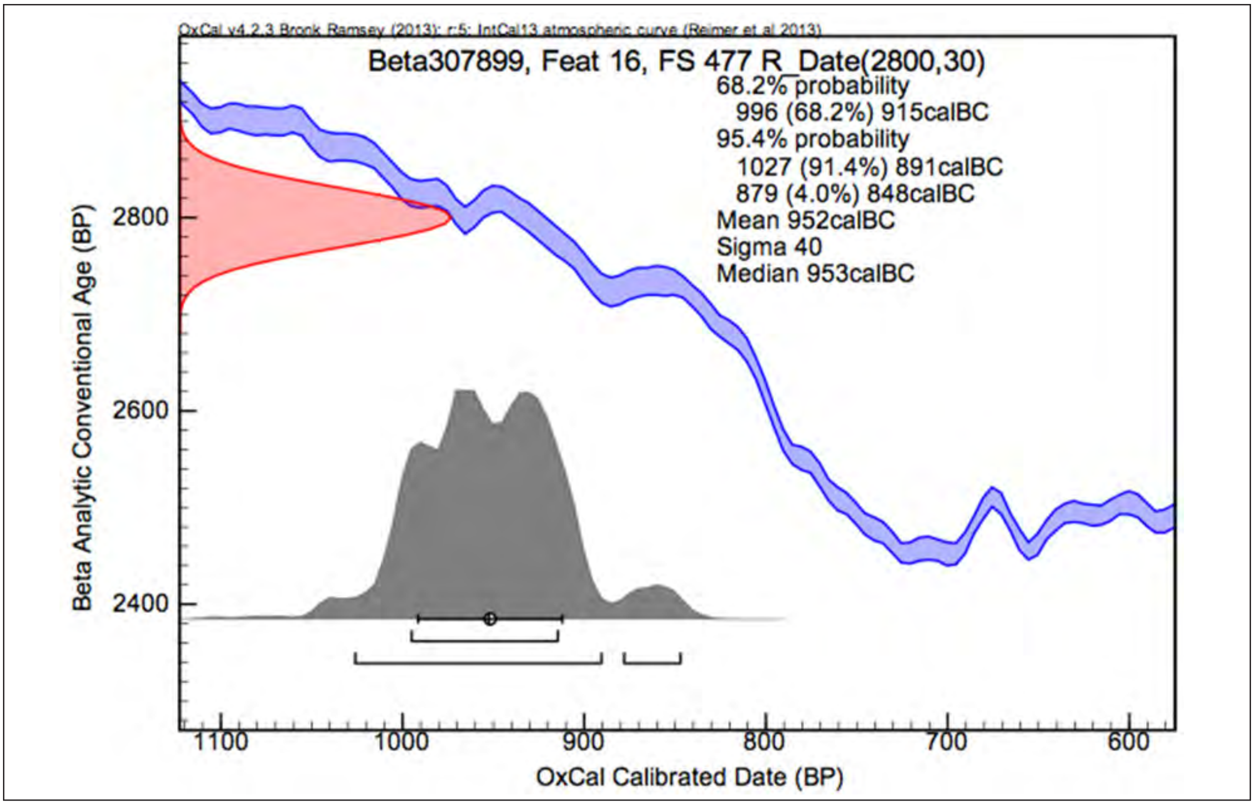


Figure 8.13. Feature 16, FS 477, radiocarbon date, curve plot.

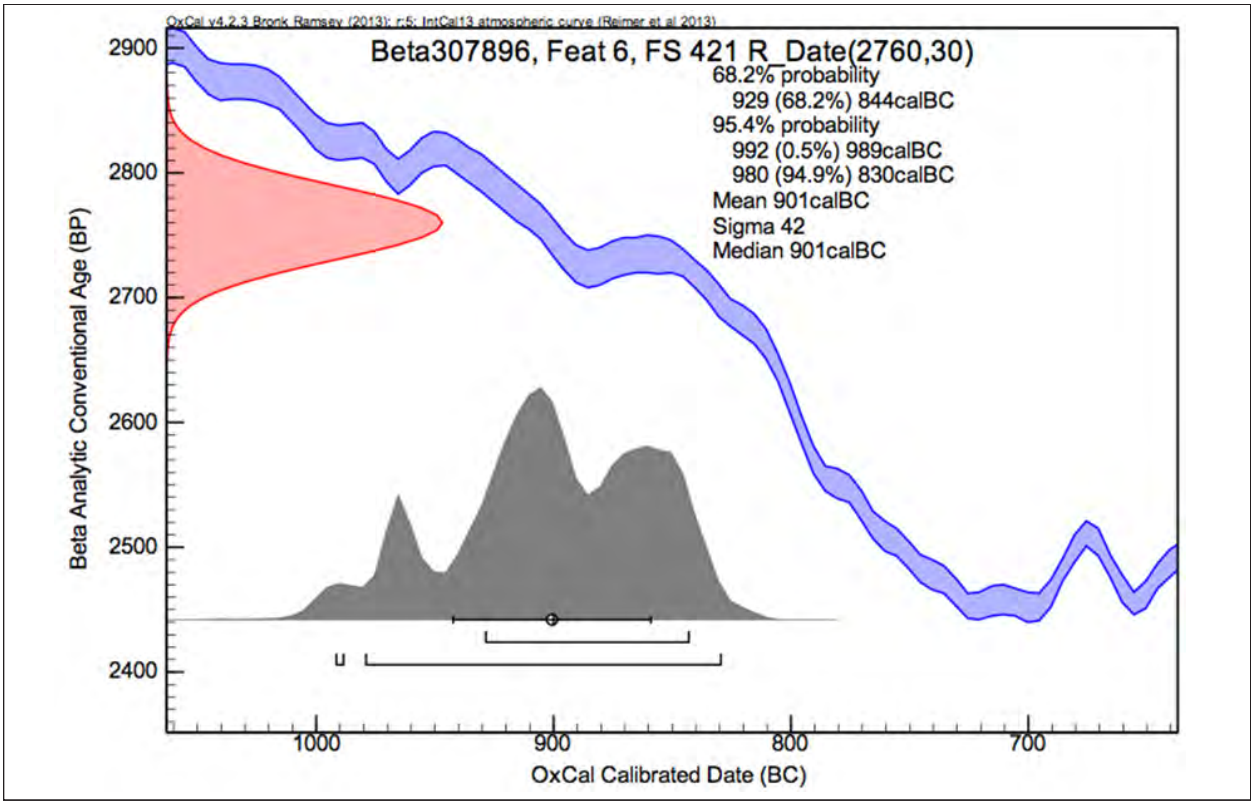


Figure 8.14. Feature 6, FS 421, radiocarbon date, curve plot.

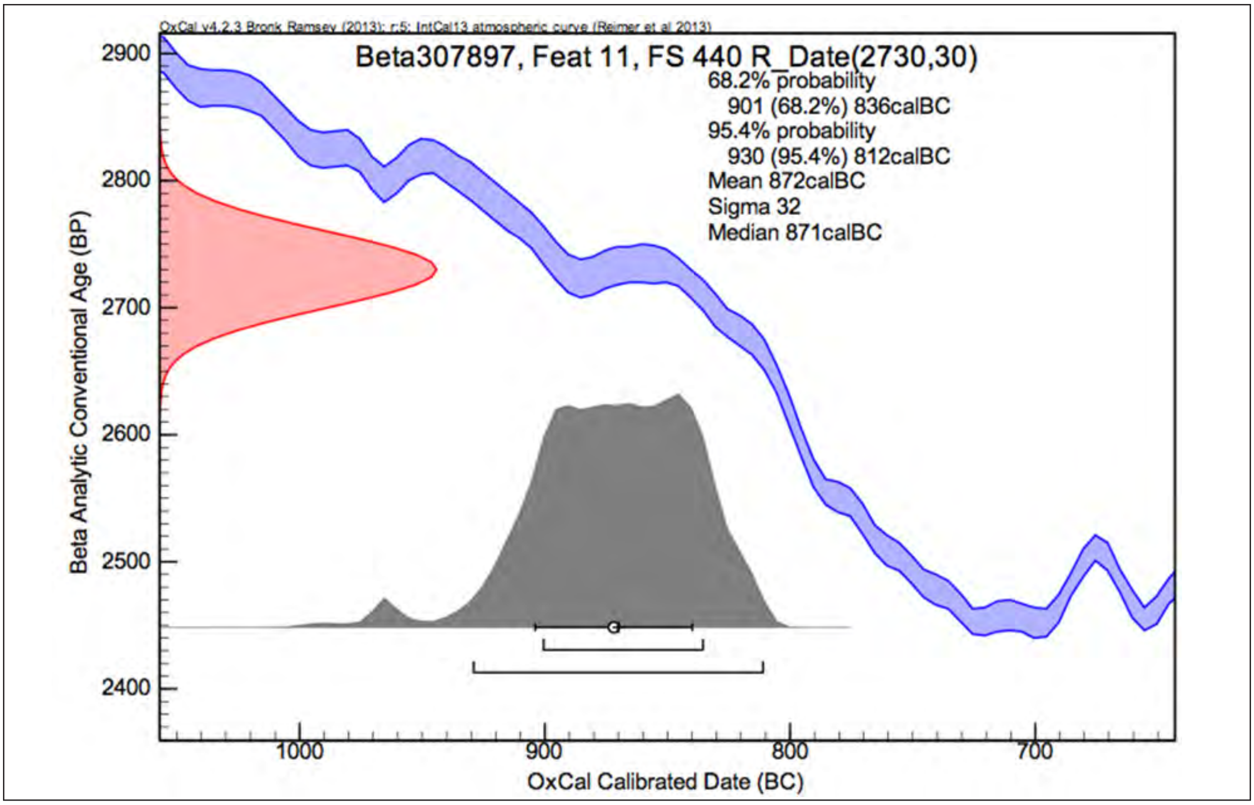


Figure 8.15. Feature 11, FS 440, radiocarbon date, curve plot.

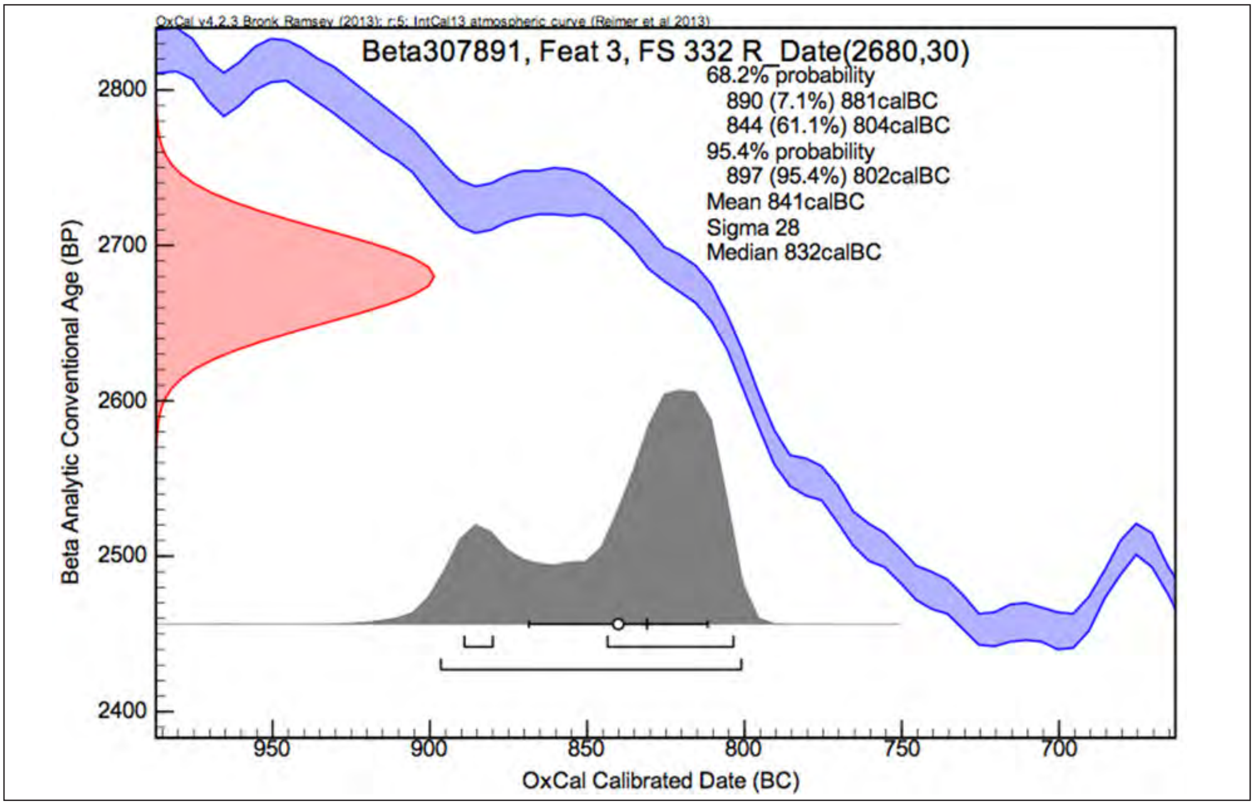


Figure 8.16. Feature 3, FS 332, radiocarbon date, curve plot.

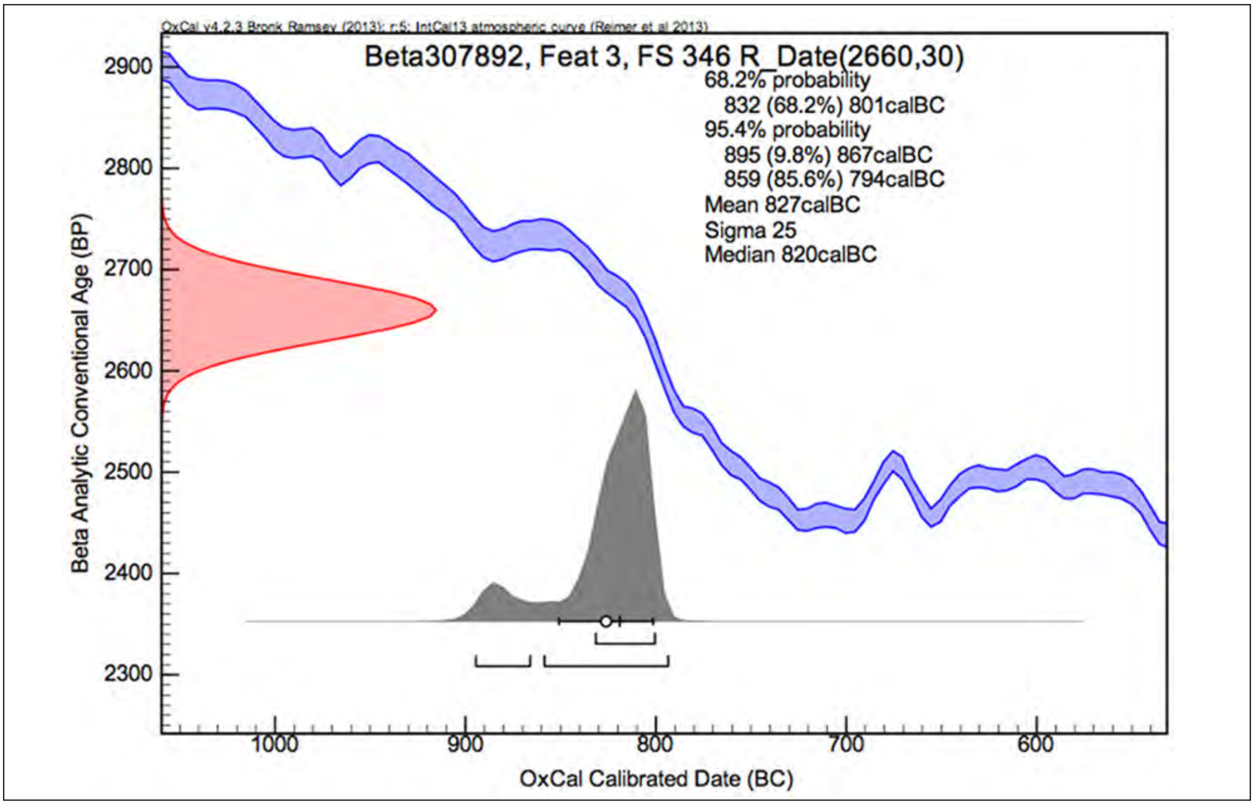


Figure 8.17. Feature 3, FS 346, radiocarbon date, curve plot.

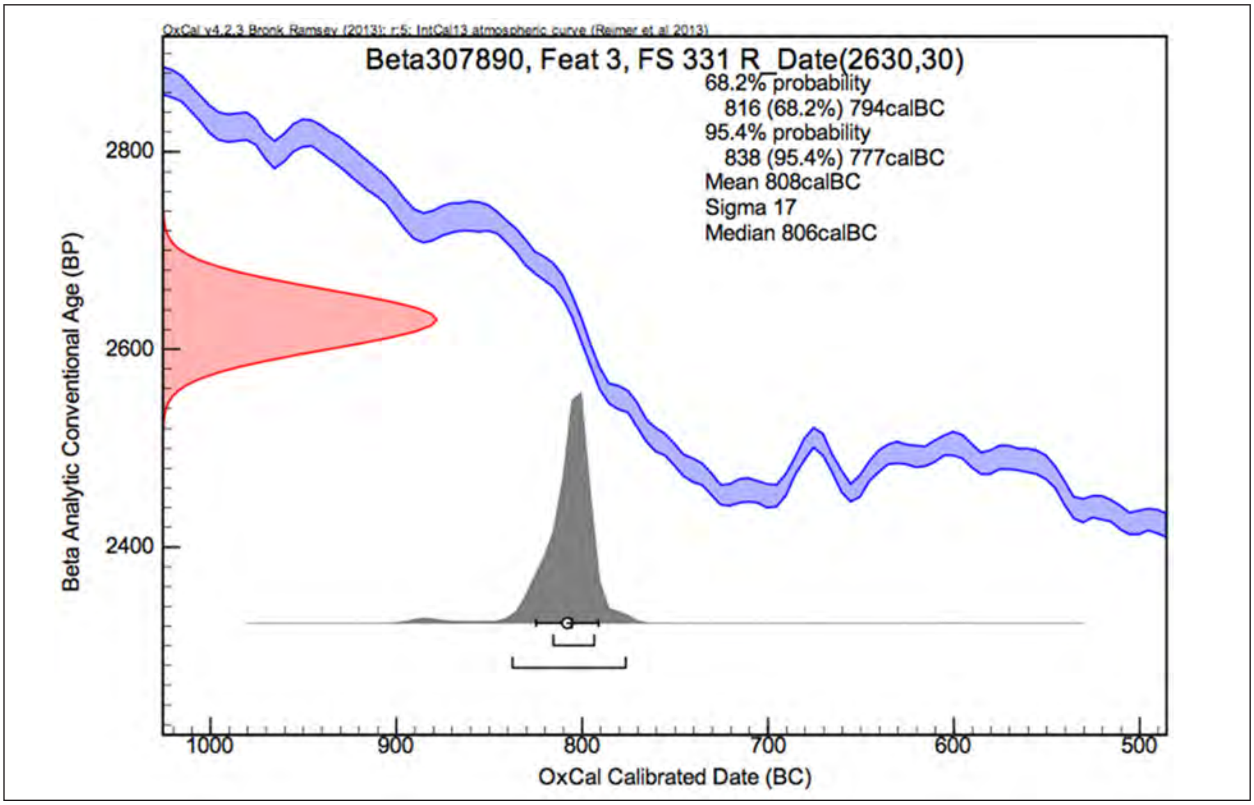


Figure 8.18. Feature 3, FS 331, radiocarbon date, curve plot.

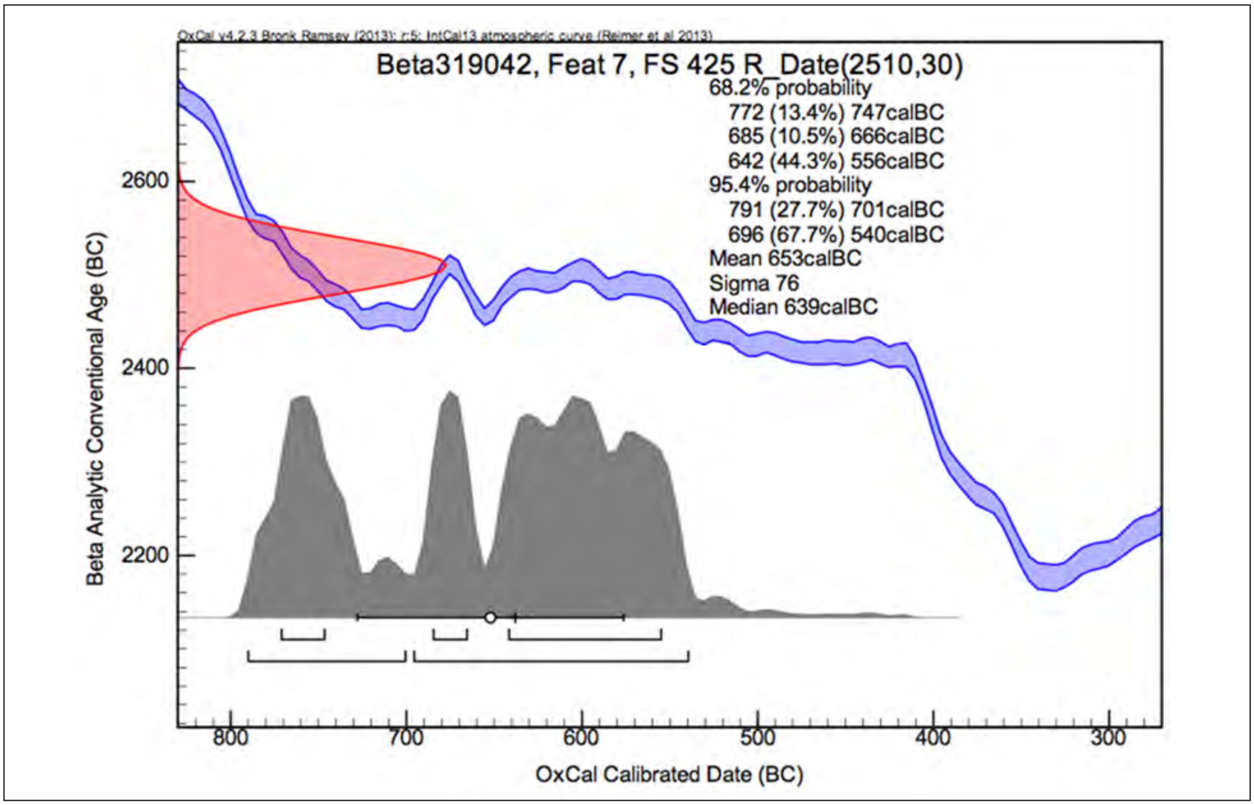


Figure 8.19. Feature 7, FS 425, radiocarbon date, curve plot.

and median dates separated by 14 years (the most difference of all the samples), and a relatively long (76 years) 1-sigma range for the mean date. Consequently, while there is an intercept date at 760 BC, eighth-century BC 2-sigma and 1-sigma calibrated dates have low probabilities of accuracy.

Calibration curve flatness is also shown by relative uncertainty in the OxCal and Calib 2-sigma and 1-sigma calibrated dates. The most accurate date for the sample is a very long, 2-sigma range (250 years) between 791/788 to 540/538 BC, but has only about 71 to 72 percent probability of accuracy. A more precise 1-sigma range of 646/642 to 556/553 BC (90 years) is suggested but has only about 65 percent probability of accuracy. Considering that this is 65 percent of the 1-sigma range that has 68.2 percent accuracy probability, caution requires that it not be used to characterize the sample (Table 8.4).

Feature 13

Sample Beta-319043 from Feature 13 was burned maize (Table 8.1). Like the Feature 7 sample, the Feature 13 sample's conventional date first intersects the calibration curve in the eighth century BC (Fig. 8.20). The Feature 13 conventional age, though, intersects the calibration curve slightly later than the Feature 7 age so that the conventional age curve consistently intersects the relatively flat calibration curve throughout the period between the eighth and third centuries BC. As a result, the Feature 13 sample has five Beta intercept dates between 730 and 540 BC and the OxCal calibrated mean date has the longest standard deviation range (97 years) of the samples from LA 159879 (Table 8.1). Also as a result, the sample has multiple 2-sigma and 1-sigma calibrated dates, with 2-sigma ranges between about 760/756 and 429/410 BC (327 to 350 years) and 1-sigma ranges between 751/750 and 510/421 BC (240 to 330 years). OxCal calibration revealed a range with highest accuracy probability—but only 65.9 percent—between 672 and 429 BC (243 years). With only a six-year gap between this range and the earlier one, the OxCal 2-sigma calibrated date is 758 to 429 BC.

Calib calibration produced a series of four

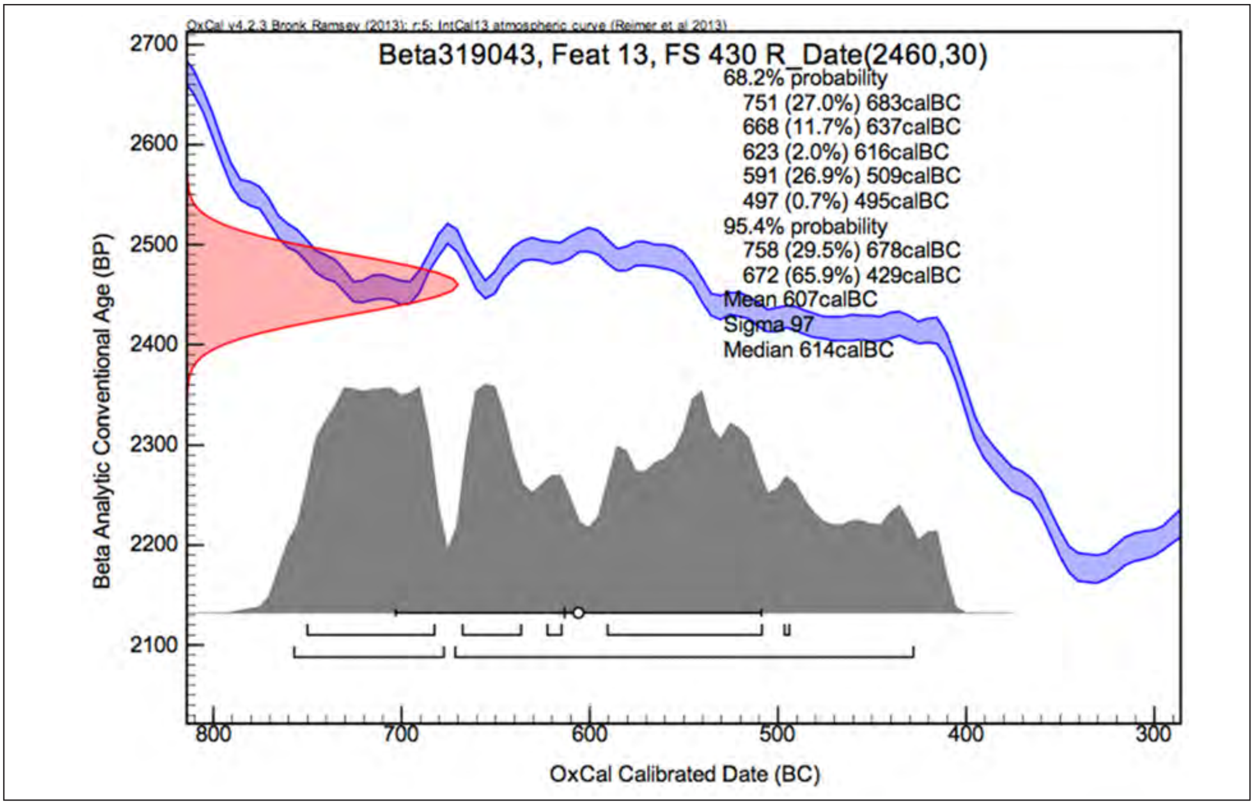


Figure 8.20. Feature 13, FS 430, radiocarbon date, curve plot.

2-sigma ranges. No one range has an accuracy probability greater than 39.1 percent (603 to 478 BC). The combined range of 669 to 414 BC (255 years) has a 72.1 percent probability of accuracy. This range is similar to but longer by 15 years than the most accurate range from the OxCal calibration. OxCal and Calib 1-sigma calibrated dates show an interesting pattern. In both cases, two ranges have highest probabilities of accuracy, even though those probabilities are quite low: 756/751 to 684/683 BC and 593/591 to 509 BC. Due to the slope of the calibration curve, the most accurate date for the Feature 13 sample is ca. 758 to 429 BC. A more precise date cannot be determined.

Groups of Prehistoric Dates

We have seen that the two historic dates as well as the multiple dates from Features 5 and 3 comprise three separate groups of dates. While the results for the Feature 5 and 3 groups are expectable—and convenient—testing suggests that the two historic dates might make up a single group because they are both so different from all the other dates from the site, they are obviously similar, and there are only two of them. Thus, it is not possible to identify their features as representing a single, historic occupation of the site.

In order to determine whether other groups of dates are present within the assemblage, Grubbs' outlier test and Student's T-test were used to determine how closely dates are related. Table 8.2 presents the results of Grubbs' tests; testing began with the entire date assemblage, including the two historic dates, and preceded by re-running the test after eliminating in turn each date that was identified as an outlier or as furthest from the group mean. Beta Analytic conventional ages were used for the outlier tests because they form the basis for all calibrations and recalibrations. Grubbs' test results were then used to structure the performance of Student's T-tests by identifying the dates to eliminate and the order to eliminate them while running and re-running the tests; Table 8.3 presents the results.

Outlier testing revealed only two statistical outliers in the assemblage (Table 8.2). The first test identified the youngest date as furthest from the group mean but not an outlier. The date's Z value, however, is very close to the critical value for the group size so the date is nearly an outlier. When it is eliminated, the next youngest date is identified as an outlier; its Z value exceeds the critical value for the new group size. This situation is known as "masking" and occurs when two sample values are similar to each other and similarly distant from the group mean. When that happens, neither is an outlier because the two similar dates work together to move the group mean toward them. The group mean shifts farther from them, however, when one of them is removed, increasing the distance to the remaining date and making it an outlier.

When the two youngest dates have been removed from the assemblage, interestingly, there is sufficient distance between the individual 11 remaining dates and the group mean that the remaining dates are still not a single group at a 95-percent confidence level. This cannot be explained by the changing slope of the calibration curve. As we have seen, the dates for Feature 7 and 13 samples, for instance, are relatively inaccurate and imprecise because their conventional ages intersect the calibration curve during a protracted period when the latter is relatively flat, resulting in very long date ranges. While those calibrated ranges are derived from the same single-year conventional ages used for outlier testing, the latter uses only the single-year ages so the calibrated ranges do not figure into outlier results.

By sequentially eliminating the youngest dates identified from the assemblage, the third youngest date is identified as a near outlier (Table 8.2), confirming the observation that the 11 prehistoric dates are not a single statistical group; Student's T-test results affirm that this result cannot happen by chance. This result occurs again when the six youngest dates are sequentially removed from the assemblage. In each case, the remaining dates are still not a single statistical group and those results cannot happen by chance.

Indeed, a single group does not appear until the seventh-youngest date is removed (Table 8.3). While there is very little probability that this group formed by chance (0.35 percent), in an assemblage of 13 individual dates, a single statistical group is not found until the seven youngest of those dates—over half—are removed.

Continued elimination of dates furthest from the recalculated group means results in another near outlier when only four dates remain, and an outlier when the assemblage is reduced to its three oldest dates; it is an outlier only because the other two dates are the same. Those results suggest that, although the date assemblage is a single statistical group when reduced below seven samples, that group includes values that are not strongly tied to the others. The suggestion is supported by t-test results (Table 8.3) that show that, as each sequential near-outlier or outlier is eliminated and a new group is formed, the probability that the new group is identified by chance increases from 10.5 to 96.4 percent. At the same time, the number of samples in each succeeding group decreases from five to two, indicating that increasing probabilities of chance are associated with smaller group sizes, regardless of how similar the sample dates.

Summary of Date Groups

The combination of outlier test and t-test results reveals that four groups of dates can be positively identified within the LA 159879 assemblage of 13 dates. One group comprises the two historic samples from Features 2 and 15, which likely form a single statistical group because there are only two of them and they are very different than the other 11 samples. They do not represent a single historic component at the site.

Two groups comprise the two samples from Feature 5 and the three samples from Feature 3. There is a considerable probability—70.5 percent—that the Feature 5 group is formed by chance but this is likely the result of the small group size. There is much lower probability—29.7 percent—that the Feature 3 group is formed by chance. While this is, again, likely the result of small group size, the fact that the three samples are from one feature is reflected in the lower probability of chance for the Feature 3 than for the Feature 5 group.

A fourth statistically significant group is formed by the six oldest dates in the assemblage, which included the two Feature 5 dates. There is very little probability that this group is identified by chance. No groups are identifiable when the seven youngest dates are removed sequentially and these results cannot happen by chance. As the next older dates are removed in sequence, statistically significant groups are identified but those groups are increasingly likely to be identified by chance, apparently because group sizes decrease. Consequently, the group comprising the six oldest dates is not likely to be related to human activity. It is reasonable to conclude, therefore, that there are no groups of prehistoric dates from LA 159879 that represent definable components at the site.

OPTICALLY STIMULATED LUMINESCENCE DATING OF SOILS AT LA 159879 AND PALEOCLIMATIC ASSOCIATIONS WITH EARLY AGRICULTURE DATES IN SOUTHWEST NEW MEXICO

DONALD E. TATUM

Four archaeological features excavated at LA159879 have Late Archaic/Early Agricultural–period dates that are associated with cotton and corn. A single grain of cotton pollen was identified in samples taken from an activity area adjacent to Feature 3, a possible pit structure. Corn pollen and phytoliths were recovered from Feature 7, corn phytoliths from Feature 10, and corn pollen and possible corn kernels from Feature 13. When pooled, the radiocarbon dates obtained from Feature 3, adjacent to the cotton-associated activity area, were most accurately dated to 864–788 BC and most precisely to 833–796 BC (Table 8.4).Most accurate and most precise dates for the corn-associated contexts are 791–538 BC for Feature 7 and 758–429 BC for Feature 13.

Feature 3 was discovered in the west wall profile of BHT 3, which truncated the east end of Feature 3. The activity area southwest of the pit structure was the context for the cotton pollen grain. Feature 3 originated at the abrupt, wavy contact of a weakly structured, weakly developed sandy A-horizon (Aw) with the underlying medium-structured, weakly developed B-horizon (Bw). The pit was intrusive through the Bw-horizon and terminated in the top of the underlying Bk-horizon (Fig. 2.7).

An Optically Stimulated Luminescence sample (OSL-3412) was collected from the top of the Bk-horizon adjacent to the north end of the base of Feature 3 as it appeared in the BHT 3 profile. Sample OSL-3412 yielded a date of 11,800 ± 700 years before present. A second OSL sample, OSL-3411, was collected from the top of the Bw-horizon adjacent to the north end of the top of Feature 3 as it appeared in the BHT 3 profile. This sample yielded a date of 2510 ± 130 years before present (560 ± 130 BC). The OSL data indicate that deposition of the sandy parent material for the top of the Bk dates to the early Holocene (Younger Dryas), while deposition of the sand at the top of the Bw-horizon dates to the late Holocene (late Neoglacial). The geochronologic range for the upper part of the sand unit is roughly contemporaneous with the youngest radiocarbon date obtained for corn at this site and is slightly later (by 200–300 years) than for Feature 3, adjacent to the area where the cotton pollen was obtained.

An extrapolation of the metric distance between the two OSL sampling locations divided by the time span between deposition of the upper and lower sand deposits yields a net depositional rate of 0.0861 mm per year. No disconformities such as stratigraphic breaks, indicators of major erosional episodes such as lag deposits, or major morphological differences in parent material were evident in the Bk/Bw soil profile, indicating a relatively continuous process of deposition and landform stability that changed somewhat abruptly after 2510 ± 130 years.

Several recent paleoenvironment studies provide corroborating evidence of somewhat mesic climate conditions during the time period indicated by dates obtained from radiocarbon samples associated with cotton pollen and corn at LA 159879. Studies of alluvial fan sequences conducted at Playa el Fresnal and Laguna Babicora in the Chihuahuan Desert of northern Chihuahua State, Mexico indicate a period of increasing pluviality occurring near the final centuries of the Neoglacial period. At Laguna Babicora the Late Holocene sediment record indicates a climate fluctuating between periods of soil development and landscape stability with marshes and bogs, and periods marked by erosional events and debris flow deposits. Ortega-Ramirez and colleagues (2004:445–466) determined that a period of greater effective moisture occurred between 2,000–3,000 years ago. This pluvial interval was followed by a lengthy late Holocene period of dramatically decreasing effective moisture. Their observations concurred with those of McFadden and McAuliffe (1997:303–332), who recognized a temporally similar mesic millennial through geomorphological response to climate fluctuation in studies conducted on the southern Colorado Plateau of Arizona.

Studies of carbon isotopes and associated landforms in the Tularosa Basin also indicated a period of greater effective moisture coeval with temporal indicators of corn and cotton agriculture at LA 159879. Geomorphology and geochemistry studies conducted at Fort Bliss identified stable geomorphic surfaces with pedogenic carbon isotopes dating to the Neoglacial, between 2,200 and 4,000 years ago (Buck and Monger 1999).

In the Guadalupe Mountains of southeastern New Mexico, Asmerom and colleagues (2007) have recorded low stable oxygen isotope signatures, indicative of Neoglacial pluvial conditions corresponding to increased speleothem development during moist climate conditions. These pluvial conditions, based on more recent speleothem growth data, were generally similar to the climate during the recent Holocene; that is, lengthy intervals of somewhat more mesic, then less mesic conditions, with intervals of true drought. Speleothem data indicate the onset of a pluvial interval beginning about 2,800 years ago that appears to have lasted for about 500 years, followed by the onset of aridity beginning about 340 BC. This drier, less mesic interval, according to speleothem data, lasted until about 10 BC (Asmerom et al. 2007).

More recently, Hall and Penner published the results of a study in which samples late Quaternary fine alluvium were analyzed for pollen, radiocarbon age, and $\delta\ ^{13}C$ concentration as an indicator of C_3–C_4 vegetation. The samples were collected from thick alluvial deposits at Abo Arroyo east of the Rio Grande and south of the Manzano Mountains. Results of the study indicated a pluvial period between 3,000 and 1,400 years ago, with a sudden climatic vacillation from C_3 to C_4 vegetation, pluvial to dry moisture regime, and cool to warm temperatures occurring just after 2,500 years ago (Hall and Penner 2013:277–278).

9 Addressing the Research Questions

This section addresses the research domains and questions posed by Greenwald and colleagues (2009:18–28) in the research design for this project. Chapter 1 provides the problem domain discussions and the questions that address those domains.

PROBLEM DOMAIN 1: CULTURAL/TEMPORAL AFFILIATIONS

Diagnostic projectile points and radiocarbon dates establish that LA 159879 was occupied during the Late Archaic/Early Agricultural period. Projectile points with age ranges that overlap the Middle Archaic could indicate use during that period and radiocarbon dates hint there was use during the Late Protohistoric to Early Historic period. No ceramics, radiocarbon dates, chipped or ground stone forms indicate use during the region's Ceramic period.

Radiocarbon dates from the site include two from the Protohistoric/Early Historic period and others ranging from about 1050 to 429 BC. Samples from Features 5, 6, 9, and 16 form a statistical cluster as do those from Feature 3 (Chapter 8). Temporally diagnostic projectile points recovered at LA 159879 included a Bajada point observed in a private collection from the site and, Pelona and San Pedro points recovered during this project (Chapter 4).

The geomorphological history of the site (Chapters 3 and 8) indicates that the cultural stratum (Stratum 2) was deposited beginning at least 2,510 years ago (Table 3.1) and covers the range of documented occupations at the site without evidence of stratification (Chapter 3). Rodent burrowing and other natural processes moved artifacts up into more recent sand-dune depositional contexts and down into older deposits. OSL dating of the recent sand deposits suggest these date to the last 100 years and postdate the archaeological deposits at this site. A-horizon deposits (Stratum 2.1) were identified in hand-excavated unit 244N/636E but none of the chipped stone from this area was analyzed and the three pieces of ground stone include a small fire-cracked piece of mano, a fragment of a smooth abrading stone, and an indeterminate fragment, none of which are diagnostic of a particular period. Materials adjacent to Feature 3, a probable structure, probably do represent an activity area associated with the feature, which is well-dated to between 864 and 788 BC. Most of the other features were discovered after the site was bladed, removing similar activity areas and associated artifacts. Since the dated features show no spatial clustering, the site area cannot be used as a proxy for dating the chipped and ground stone artifacts. The evidence for each period is evaluated with respect to current knowledge and is presented below.

Middle Archaic Period (4000–2500 BC)

The mobile foraging adaptation evident in the Middle Archaic is marked by the introduction of limited horticulture toward the end of the period. A wide range of projectile point types–Pelona, Amargosa, Almagra, Shumla, Bat Cave, and Chiricahua types represent this period. Pelona points, which date from the Middle into the Late Archaic, were recovered during the excavation of LA 159879 (Chapter 4). In addition to bifacial and unifacial tools, scraper planes, mullers, milling stones, manos, and metates are found in tool assemblages ascribed to the Middle Archaic period. Faunal resources remained an important part of the resource base, but plant resources appear to have increased in importance based on the appearance of ground stone tools. Shallow, short-term structures were first recognized in the regional archaeological record at the Keystone Dam site toward the end of this phase, suggesting a move toward a more settled lifestyle (Whalen 1994).

None of the dated features at LA 159879 are from this period. Diagnostic projectile points could indicate a Middle Archaic use of the site area, or these could have been curated and lost or discarded by later occupants. Pestles and a single mortar or muller fragment were recovered but these forms were also used during the following periods and are not diagnostic of the Middle Archaic. Thus, while it is possible that Middle Archaic groups spent time at the site, the evidence is far from convincing.

Late Archaic (2500–600 BC)/Early Agricultural Period (ca. 1500 BC–AD 400)

Early corn appears to have been widespread in this portion of the Southwest by 1500 BC. An increased reliance on domesticated plants coincided with a significant change in tool kits, resulting in less variety in tool forms and more focus on plant-processing activities. Furthermore, archaeological evidence suggests that groups became increasingly more sedentary, living in shallow, short-term houses (Carmichael 1984; Gregory 1999), and they began establishing base camps (MacNeish and Beckett 1987:12) along major drainages where logistical forays into adjacent ecological zones could have exploited seasonally available resources.

The Early Agricultural portion of this period was defined in Arizona by B. Huckell (1996) as a period when semi-sedentary agricultural villages developed as upland areas continued to be exploited by hunter-gatherers. During this time groups had a greater reliance on domesticated plants, such as corn, beans, squash, and amaranth. Sites assigned to the Early Agricultural period far outnumber those of the previous phases, and some of these sites appear to have had semi-sedentary or sedentary occupations. It is doubtful that these were full-time agriculturalists, although considerably more importance was placed on crop production. Hunting was still practiced, as indicated by the presence of San Pedro, Hatch, Hueco, Cienega, and Fresnal points. Later in this period, more sophisticated corn varieties began to emerge and the extensive processing of corn is suggested by changes in manos to bifacial/rectangular forms and in metates from slab to trough varieties. Mortars were used increasingly, which also suggests a concomitant intensification in the processing of wild economic plant resources, such as mesquite pods, beans, succulents, and other foodstuffs that could have been prepared and stored for periods of time when fewer food resources were available. Vast geographical basin features, such as the Mimbres Bolson, may have remained primarily broad resource-procurement zones. The Deming Plain—the area in which the Mimbres River traverses the Mimbres Bolson—may have been a focal point of resource procurement during climatically favorable times and of agricultural production during periods of less-than-effective moisture (Chapter 2).

Late Archaic/Early Agricultural–period San Pedro projectile points are the most common type and the only type recovered from excavation contexts (Chapter 4) at LA 159879. Additionally, nearly all of the radiocarbon dates fall within this period (Chapters 3 and 8). Milling tools had not yet reached the size and form that would suggest extensive processing of corn (Chapter 5). The projectile points indicate continued reliance on hunting, but the sparse faunal remains are mainly small forms (Chapter 6) consistent with a gathering focus. The small structures are more consistent with a limited, not even semi-sedentary, occupation of the site area.

Protohistoric/Early Historic Period (AD 1450–1800)

Relatively few sites dating to the Protohistoric and early part of the Historic period have been identified in southern New Mexico and West Texas. Sites representing these mobile groups are notoriously difficult to date and often overlie earlier occupations. Examining the few sites with radiocarbon-dated features (n = 48) for this period, Kenmotsu and colleagues (2009) tentatively note a few trends. Most sites were no more than isolated thermal features containing few artifacts. About half (48 percent) were located away from central basins and chipped stone materials indicate extensive territorial ranges. Distinctive ceramic types do not appear until about 1680 (Kenmotsu et al. 2009:90–93).

More recently, thermal features dating to this period have been reported from two sites located at Spaceport America in the Jornada del Muerto (Moore and Akins 2014:757–758), by Jones and colleagues southeast of Carlsbad, in the Mesilla Bolson, and the Peloncillo Mountains (Jones et al. 2010), and on Fort Bliss (Quigg et al. 2002:207–214).

With the growing body of evidence for Protohistoric and Early Historic mobile groups in southern New Mexico, the radiocarbon dates indicating use during this period are not surprising. No distinct chipped stone assemblages were associated with features dating to this period and no diagnostic artifacts from this period were found, but isolated features with little associated material are typical of this period.

Problem Domain 2: Subsistence and Economy

As noted above, Middle Archaic groups were mobile hunters and gatherers. Late Archaic/Early Agricultural groups depended more on plants, including early corn. Sites and features indicate a more sedentary existence—in at least some areas. Late (Protohistoric and Early Historic) groups were also mobile, possibly even more so than the Archaic groups.

Excavations at LA 159879 produced data that can best address subsistence and economy during the Late Archaic/Early Agricultural period. The small expedient structures and fire pit features at the site (Chapter 2) are typical of those attributed to mobile hunters and gatherers. No storage features or other indications of extended occupation were found. None of the small, shallow structures had internal fire pits, suggesting they were mainly sleeping or shade structures that were occupied during the warmer months. Construction was simple, and only one had small postholes, which suggests a slightly more substantial superstructure.

Flotation, pollen, and phytolith analysis document the use of a fairly narrow range of plants including corn, amaranth, cheno-ams, goosefoot, grass, melón loco, mesquite seeds, and perhaps cotton seeds as food items (Chapter 7, Appendix 3). Of these, cheno-ams (amaranth, goosefoot, cheno-ams) are the most ubiquitous and were found in some form in 70 percent of the features that contained plant remains. Grass was not as common; grass phytoliths were found in only three features. Corn phytoliths and/or pollen were also found in three features, and a kernel fragment was found in one of those that also had corn pollen. Mesquite pollen was found in five features and seeds in two. This array of plants suggests that the occupation may have been limited to mid-summer to early fall. None of the flotation plants suggest the site was used during spring (Chapter 7), when we might expect corn to be planted. As with the recovered plants, the assortment of ground tools was simple but versatile and multifunctional. The milling tools used to process plants do not vary greatly. Only mesquite would have required a specialized tool for processing (Chapter 5). Wood types are similarly limited, with mesquite and saltbush the main types found. Piñon and an unknown conifer, along with mesquite and saltbush, were identified in one of the earlier-dating fire pits; an unknown wood was found in a second early feature (Chapter 7). None of the wood remains are substantial enough or in contexts that would indicate use as construction material.

A relatively small number of projectile points were recovered from the site. Only one of these came from an excavation context; the balance was collected from the site surface. Points are primarily complete or have impact-type fractures. One of the San Pedro points has a break that could indicate it was returned embedded in a meat package, presumably from large game (Chapter 4). Little fauna was recovered from these features and that found was all from small forms (small mammal, rabbit, and turtle). Over a third of the faunal remains are burned, indicating butchering or that food remains were discarded into the fire. While it is possible that bones from larger animals were discarded elsewhere or were not burned and thus not preserved, the evidence points toward the primary utilization of small forms (Chapter 6). Rabbits and most small mammal would have been available year round. Turtles hibernate during at least a portion of the year. The single turtle specimen supports the use of the site during spring through early fall but is insufficient to propose a spring occupation.

Plant and animal remains recovered from LA 159879 suggest the site served as a camp or base from which locally available plant resources were gathered and where the fauna represents species that were encountered rather than targeted. Corn, various grasses, and species that could have been encouraged to grow on the floodplain could also be considered locally obtained resources. Corn could have been planted late and tended by groups that did not inhabit the site area year round. The shallow, probably short-term structures, lack of evidence of extended or multiple use of the fire pits and no evidence of storage features, and a relatively small amount of cultural material that could be considered trash, all argue against a more prolonged occupation of the site area. Amaranth and goosefoot thrive in disturbed areas without human intervention and the corn, mesquite, cotton seed, and other plants could have been brought to the site in small quantities.

Contrast this with the Late Archaic/Early Agricultural–period Wood Canyon site (LA 99631) in the Big Burro Mountains northwest of Deming, where a corn cupule returned a radiocarbon date of 895–505 BC. The earlier of two structures there that dated to this period was large, measuring 4.45 by 3.4 m and 19 cm deep with a hearth and shallow pit. A second structure there, dating late in the period (165 BC to AD 120), was smaller (3.0 by 2.98 m, 24 cm deep) and had numerous postholes around the perimeter and inside the structure, suggesting a more substantial roof than is found in most early structures. It also had two shallow interior pits and two hearths. Storage features were common at Wood Canyon, as was ample evidence of extended residential occupation (Turnbull 2000a:130–144, 150–151). Two structures at the Forest Home site (LA 78089) also date to this period. The earlier structure (380–200 BC) was 3.1 by 3.1 m in diameter and at least 20 cm deep. Interior features include 19 postholes, two hearths, and four storage pits. Corn was found on the floor. A second structure there, dating to about the same time (390–190 BC), was larger, 3.4 by 4.10 m in diameter and at least 15 cm deep. It had six interior postholes, a hearth, five small storage pits, and evidence of corn and squash use. A third Forest Home structure dates to the end of the period (AD 250–430); it was also large, measuring 3.6 by 4.0 m in diameter and at least 4 cm deep. Excavated into granite substrate, it had three to six postholes and a hearth. As at Wood Canyon, exterior storage features were common at the Forest Home site (Turnbull and Reycraft 2000:64–71).

The upland sites described above have far better evidence of more extended, at least seasonal occupation. Structures are larger and more permanent with interior post-supports, hearths, and sometimes storage pits. Human burials, well-developed cultural deposits, and abundant artifacts are typical of these settlements (Turnbull 2000b:631). At LA 157879 the structures are smaller, with insubstantial superstructures, no internal or external storage, no interior hearths, comparatively few artifacts, and a limited array of plant and animal resources, all indicators that it was a short-term camp site. While corn may have been planted and sporadically tended, it is unlikely that it was by full-time or even seasonal residents. Rather, grasses and chenos-ams may have been exploited while corn was grown elsewhere and the evidence of it found at the site could represent stored resources brought from a more substantial residential settlement, like those found at Wood Canyon and Forest Home, whose residents continued to exploit resources in the central basin.

The two features representing the Protohistoric/Early Historic period indicate a similar strategy. Both of the isolated fire pits had few associated artifacts, but the flotation samples held the same taxa as the Archaic features, with amaranth, cheno-ams, goosefoot, and dropseed grass in one and goosefoot it the other. This range of taxa implies similar strategies of mobility, land use, and seasonality.

PROBLEM DOMAIN 3: LAND USE STRATEGIES

In this area, the Mimbres River is an intermittent wash or unreliable stream in an otherwise moisture-deprived area. Both alluvial and eolian soils occur in the general area. Depth of these soils varies, but all are coarse-textured and are susceptible to erosion. Today the area is dominated by Chihuahua Desert vegetation, including mesquite, yucca, salt bush, and dropseed grass. A bimodal precipitation pattern of winter rains with occasional snowfall and summer monsoon-related thunderstorms provides between 20 and 25 cm (8–10 in) of moisture to the area. Winter moisture occurs as gentle showers, whereas summer precipitation can be intense events, occurring sporadically throughout the basin. As a result, heavy rains can transform the basin into a series of shallow playas and the Mimbres River can swell into a ranging torrent.

A variety of lithic materials is present in the nearby Florida and Tres Hermanas mountains to the south, and the Cookes Range to the north, including granite, various sedimentary rocks, and Cretaceous red beds (fine sedimentary materials fused as silicified sandstone and microcrystalline jaspers and cherts), with volcanic materials present further east in the Potrillo Mountains (Chronic 1991). In addition, the Mimbres River serves as a source of stream gravels that were transported from a variety of areas, such as the Pinos Altos Range, the Black Range, and the Mimbres Mountains to the north.

During the Late Archaic/Early Agricultural period, domestic plant production was considerably more important than before. Yet, the processing of wild economic plant resources, such as mesquite pods, beans, succulents and other foodstuffs that could be prepared and stored for periods of time also increased. Hunting was still practiced, as indicated by San Pedro, Hatch, Hueco, Cienega, and Fresnal projectile points. Large geographical basin features, such as the Mimbres Bolson, may have remained broad resource procurement zones. The Deming Plain may have been a focal point of wild resource procurement during climatically favorable times. Plant remains recovered from the LA 159879 flotation samples indicate this portion of the Plain was utilized during mid- to late summer through fall.

If early agriculture was practiced on the floodplain near LA 159879, it could have been a low-investment plant and harvest low-return strategy practiced by highly mobile groups who relied more on shrubs, forbes, succulents, and other native resources. Alternatively, the mainly grassland environment that characterized the site area during the Late Archaic/Early Agriculture period, combined with increasing population densities may have made early farming on the adjacent floodplain a more cost-effective option (e.g., Hard and Roney 2005:172–174). Although, farming in the area would have been a more likely response to less-than-effective moisture after 340 BC—slightly later than the earliest possible dates for corn at LA 159879. Less effective moisture could have decreased wild-plant seed productivity, leading to the introduction of cultivates to counter the loss of wild resources (Dello-Russo 2008:20).

The Late Archaic/Early Agricultural–period occupants of LA 159879 appear to have focused on grass-land resources and plants that favor disturbed environments, which could include the floodplain adjacent to the Mimbres River. As noted for Problem Domain 2, disturbed area plants (cheno-ams) are the most ubiquitous plants and were found in 70 percent of the features with flotation, pollen, or phytoliths (and in 70 percent as charred remains). Fewer features (30 percent) contained grass and corn remains; charred corn was found in 10 percent and there was no charred grass in any of the samples. Mesquite pollen was found in 60 percent and seeds in 20 percent of the features. The recovered plant remains suggest the emphasis was on a range of wild plants and corn late in the period.

The amount of corn at this site is less than that reported for the Big Burro Mountain sites reported by Turnbull and colleagues (2000), where corn was found in 50.6 percent, *Chenopodium* in 40.2 percent, and grass in 5.8 percent (Chapter 7) of the flotation samples. It is also less than at Cerro Juanaqueña, a Late Archaic floodplain site on the Rio Casas Grandes, in Mexico, where charred corn was found in 60 percent, cheno-ams in 45 percent, and grasses in 20 percent of the features (Hard and Roney 2008:150). If early agriculture was practiced at or near LA 159879, it was not as intensive an effort as seen at the sites with more convincing evidence of agricultural production. The site simply does not have evidence of more than short-term, camp-like use. Evidence for Mimbres River overbank flooding is confined to the southern portion of the site where it is found in deposits with OSL dates of 2,100 ± 120 and 2,140 ± 130 years ago (circa 190–150 ± 130 BC) (Chapter 3)—slightly later than the features where corn was found (864–429 BC). If there was farming that took advantage of overbank flooding during the occupation, it could have been at the south end of the site or, more likely, beyond the site closer to the river channel. The relatively small amount of corn could also suggest it was a stored resource carried by mobile groups exploiting grassland resources on a seasonal basis. As an intermittent stream, the Mimbres River would not have supported much of a riverine environment, although alder was found in one and willow in a second pollen sample and could indicate a nearby riparian environment (Appendix 3). There is no direct evidence of use of riparian environments (wood, plants, or animals). Likewise, walnut, aspen, and oak pollen probably represent the regional pollen reign, rather than evidence of use of those resource areas.

Chipped stone material types indicate little use of a greater area, with only San Andres chert as a definite import. Otherwise, much of what was left at the site could have been collected from nearby gravel deposits and discarded during the core reduction and tool manufacturing processes (Chapter 4). The ground stone assemblage is versatile and multifunctional, consistent with processing a range of food resources (Chapter 7). Reuse of ground stone as heating elements suggests that cobbles were not that close or abundant, but most of the materials could have come from the Mimbres watershed and large portions have waterworn cortex consistent with a Mimbres River source (Chapter 5).

PROBLEM DOMAIN 4: SITE FUNCTION AND ACTIVITIES

The more-or-less sequential dates (Fig. 8.8) suggest repeated occupations during the Late Archaic/ Early Agricultural period. The structures (Features 3, 5, and 16) had no evidence of storage or domesticates, rather, the occupation was typical of the limited base camps left by hunting and gathering groups. Small, expedient dwellings like those found at the site were present at many Late Archaic sites (Chapter 2). Evidence of storage—frequently a consequence of intensification and dependence on agriculture—is absent at the site. Fire pits were variable in size but were generally shallow, scooped out pits with little or no fire-cracked rock in the fill. The one exception was relatively small, with 20–25 pieces of rock and fire-cracked rock. The size, expedient construction, lack of indications of multiple uses, and rock content of the site fire pits suggest the foods prepared were those with short cooking times rather than foods that were mass processed for storage, like agave and yucca stems, which require prolonged heating using methods like pit roasting (Chapter 2). What was found is evidence for processing wild plants (cheno-ams, grass, mesquite) using a generalized tool kit (Chapters 5 and 7, Appendix 3). The fauna is typical of a strategy of taking small animals encountered during plant-gathering activities or possibly by snares or traps (Chapter 6). The chipped stone assemblage could not be broken down into occupations, but as a whole it reflects the type of mobile settlement pattern used by local hunting and gathering groups. Exotic materials, which were utilized in a more curated technology, were rare. In contrast, local types (cherts, basalt, rhyolites) appear to have been expediently reduced, but there is also evidence for biface reduction across the site. Discarded projectile points suggest that some of the on-site activities may have included the curation of gear and re-armament (e.g., replacing broken projectile points). Other activities suggested by the chipped stone assemblage include shaft refurbishing, leather working, woodworking, chopping, and pounding (Chapter 4).

Corn phytoliths, pollen, and a corn-kernel fragment were found in some of the latest-dating features, which includes three fire pits, one of which was the undated rock-filled fire pit. Grass, mesquite, and goosefoot were also found, suggesting a continuation of the hunting and gathering economy, with the addition of corn. The absence of structures and storage pits dating to this latest period again suggest the site functioned more as a limited base camp, one that was used by groups who may have practiced agriculture elsewhere in the Mimbres Bolson.

With the lack of stratified deposits and low feature visibility that resulted in discovery during and after mechanical scraping, little information on activity areas was found. Feature 3, a probable small sleeping structure, had an intact activity area to the southwest. A crusher/pestle, with mesquite pollen in a concentration suggesting it was processed, and a complete abrader suggest food processing occurred in this area. The cotton pollen and grass phytoliths were associated with ground stone fragments, and could have been processed elsewhere. A core and core flake could also indicate lithic reduction. Scattered fire-cracked rock and two charcoal stains could be the remains of a small cooking fire. The only other area where the spatial arrangement suggests features were related is the Feature 16 structure and fronting fire pit (Feature 15), with two postholes between the two. Unfortunately, the structure dates to the earliest of the Late Archaic/Early Agricultural–period clusters and the fire pit to the Protohistoric/Early Historic period.

Like the Late Archaic/Early Agricultural–period groups, the limited evidence from this site indicates that Protohistoric and/or Early Historic groups use the site area for short-term camps associated with procuring and consuming locally available resources. The few artifacts that could be associated with this occupation do not provide information on additional activities that could have taken place.

PROBLEM DOMAIN 5: GEOMORPHOLOGICAL ASSOCIATIONS AND IMPLICATIONS

OSL data indicate that the uppermost eolian deposits at LA 159879 (Stratum 1) began forming at least 100 ±10 years ago, probably as a result of intensive cattle ranching and an increasingly xeric climate. The underlying parent soils (Stratum 3) began accumulating during a shift from late Wisconsin mesic conditions into the early Holocene prior to 11,800 ± 700 years ago—the earliest OSL date obtained from the basal Bk parent material. This accumulation appears to have continued until at least 1810 years ago (Table 3.1) and includes the soil horizons within which the archaeological site developed (Chapter 3, Appendix 1).

Artifacts were present on the surface of younger soils and embedded in older soil horizons. Intensive deflation, bioturbation, and erosion resulted in artifacts occurring on the surface and within the recent sand accumulations (Stratum 1). Areas where the Stratum 1 soils where stabilized by shrub vegetation had weak A/B-horizon development. Radiocarbon and OSL data indicates that the site developed on the parent material for the upper Bk and middle-to-upper Bw-horizon. OSL dates indicate that post-occupational sand accumulation continued until at least 1810 ± 120 years ago. Cultural features originating in the Bw-horizon (Stratum 2) intrude into older soil horizons (mainly Stratum 3).

None of the cultural deposits appeared to be significantly stratified. The vast majority of dated features date to between 1020 and 410 BC, with the exception of two features that date to the Protohistoric or Early Historic period. The upper horizon of archaeological deposits appears to be severely eroded to the extent that cultural features were shallow, truncated pits that were not visible until seen in contrast with deeper, lighter-colored calcic soils or somewhat darker-colored Stratum 2 soil. It is possible that erosion of the tops of features obscured or obliterated evidence of stratification.

Variability in depths and elevations of deposits of similar ages indicates that a significant amount of dune-forming erosion and mixing has taken place. This was particularly true in the top of the Bw-horizon, which is the soil of principal archaeological importance. However, a persistent age range of radiocarbon dates obtained from the lower portions of cultural features indicates that these parts of the features remained relatively intact. Support for this observation is further indicated by the recovery of pollen and phytoliths from samples collected from secure contexts, such as underneath ground stone implements in the activity area adjacent to Feature 3.

10 Summary and Conclusions

SUMMARY

Most of the archaeological remains at LA 159879 reflect broad trends in Late Archaic/Early Agricultural–period subsistence, settlement, and land-use patterns for the period roughly between 1050 and 429 BC. The investigated portion of LA 159879 included one and probably two additional small structures. These were semi-subterranean circular shallow pits with little architectural investment in any of the structures, and have no evidence of storage features. Only Feature 16 had interior features—four postholes located at regular intervals along the perimeter—and a perceptible level of formality. The others resemble the expedient dwellings present at many Archaic communities.

Subsistence and chronometric data come from the structures and fire pits investigated during this project. Flotation, pollen, and phytoliths indicate a fairly narrow range of wild plants and corn were processed at the site. Cheno-ams and mesquite were the most ubiquitous plants represented in these features followed by smaller amounts of grass and corn. Evidence of domesticated plants—corn and possibly cotton—was found. Cotton pollen was recovered from an activity area adjacent to Feature 3, which dated to between 864 and 788 BC. Corn from Feature 13 was dated at 758–429 BC and Feature 7 had corn pollen and phytoliths that dated to 791–583 BC (Table 8.4, Fig. 8.8). The ground stone assemblage was geared toward processing wild plants and some corn, and with the exception of pestles used for crushing mesquite pods and seeds, most of the tools were versatile and multifunctional milling tools. The chipped stone artifact assemblage reflects the type of mobile settlement pattern used by local hunting and gathering groups. Exotic materials, which were utilized in a more curated technology and were obtained from extra-local sources and introduced to the site, were uncommon. In contrast, local materials (cherts, basalt, rhyolites) appear to have been reduced expediently. Discarded, broken projectile points suggest that on-site activities may have included making replacement points. Other activities indicated by the chipped stone assemblage include core and biface reduction, shaft refurbishing, leather-working, wood-working, chopping, and pounding. Small animals (rabbits and turtle) were the only animals found in the faunal assemblage.

The features, artifacts, and samples documented and recovered from the site suggest a base camp that served as a focal point for foraging activities during most of its occupation, with a remote possibility for limited agricultural pursuits during the latter portion of the Early Agricultural period. Either way, LA 159879 illustrates the role of incipient agriculture within a seasonal subsistence round that changed in response to population growth, mobility, and climatic variability.

Two features with radiocarbon dates in the Protohistoric/Early Historic period suggest a similar function—a short-term camp that may have served as a base for collecting native plants. Other than the features, no diagnostic cultural material could be associated with this occupation.

AGRICULTURE AS AN EARLY RISK MANAGEMENT STRATEGY

Hunting and gathering systems in New Mexico changed little between about 8,000 and 3,900 years ago, until the arrival of domesticates. Although corn appeared early in the archaeobotanical record, archaeologists generally assume that the deliberate cultivation of domesticates was a minor activity, added on an "as needed" basis, within a subsistence economy still dominated by hunting and gathering.

From an energetic perspective, considerable evidence suggests that foraging provides a better subsistence return than farming and that forager-farmers typically seek to collect wild seed. This suggests that hunters and gatherers would forgo year-round settlement near a perennial food source in favor of a strategy of residential mobility that would allow them to continually collect information about their natural and social environment and prepare for local resource failure (Dello-Russo 2006). Ethnological research on current hunting and gathering groups, such as the !Kung bushmen and the Australian Aborigines, shows that foraging is much less labor-intensive than farming, at times allowing for up to 80-percent leisure time (Binford 1980; 1994:527–566). Given these advantages, forager shifts to a reliance on domesticates requires an explanation, and the causes underlying such a shift are varied and many.

A 2003 study in the Rio Grande Valley, Dello-Russo (2003; 2006) suggested that when the mean regional precipitation falls below a threshold of 20.8 mm per annum, wild plant seed productivity falls off and prehistoric forager-farmers would have altered their subsistence behavior by utilizing domesticates. At that point, cultigens would have been introduced to counter the loss of wild resources. A similar loss of access to wild-plant productivity would occur when demographic thresholds (population packing) occurred, which would have pushed foragers to farm.

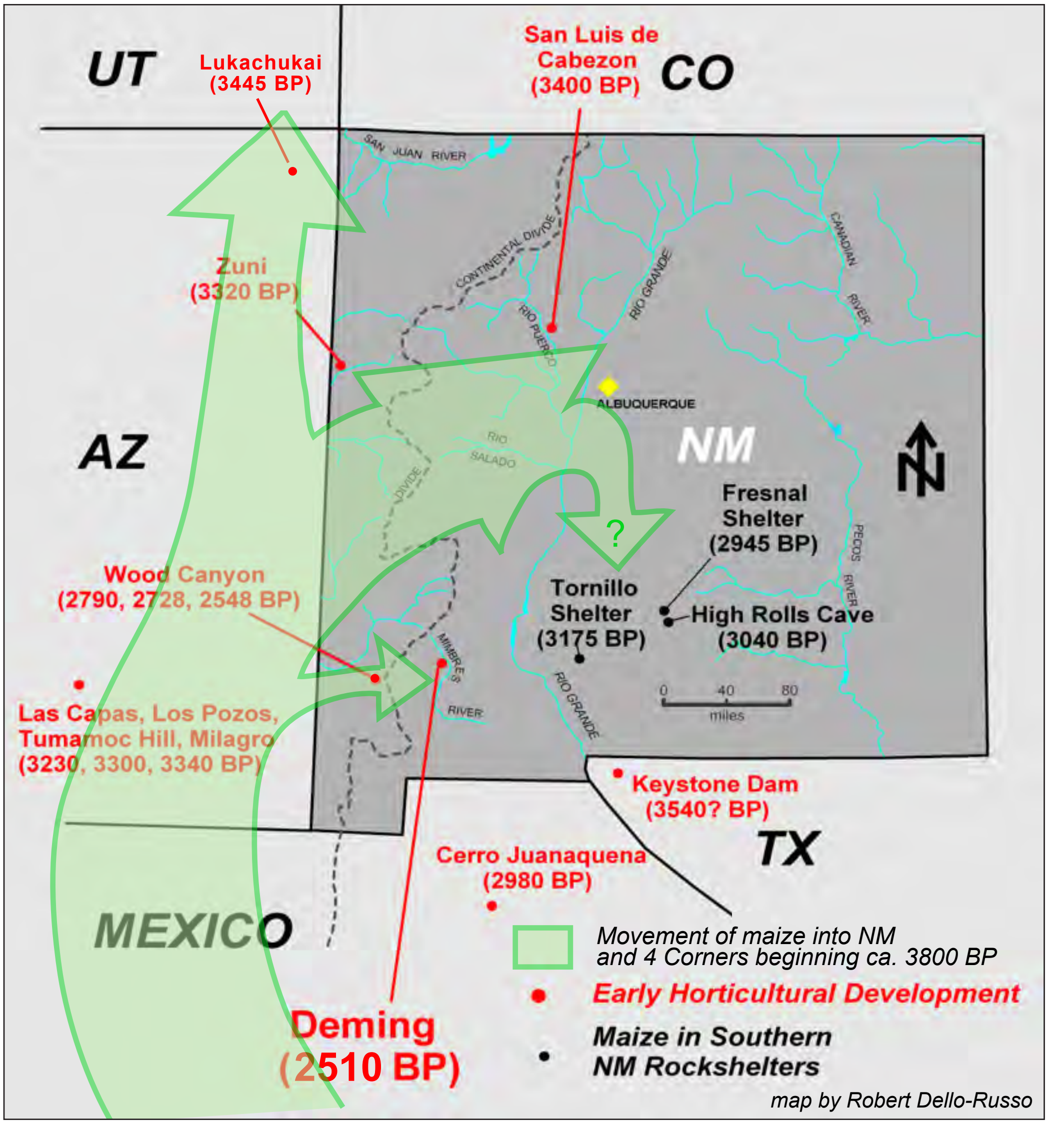
In an earlier study, Hard (1986:128–196) used climate data to show that drier environments produce higher yields of wild resources overall, obviating the need for supplemental agriculture. This has important implications for the incorporation of corn. If corn cultivation has no appreciable economic impact in some environments, the suggestion that corn is not a critical resource until certain environmental or demographic thresholds are breached is well founded, and consistent with Dello-Russo's (2003) argument.

In another study, Wills (1988) proposed that the function of early corn was more to support a continued reliance on a wild-resource foraging economy. This theme is repeated in hunter and gatherer studies worldwide, which suggests that, given the choice, agriculture is practiced only as a supplement to foraging (Hitchcock and Ebert 1984:328–348). In a significant departure from this theme, however, some archaeologists (cf. O'Shea 1989:57–67) suggest the reverse, implying that seasonal crop variation is propped up by foraging.

Early agriculture in the Southwest was not a unitary phenomenon, progressing in different areas at different times. For example, in southeastern Arizona, corn was raised for at least 1,000 years before it became a staple crop between 1200 and 600 BC, when, during a relatively moist period, flood and run-off farming was possible (Mabry 2006:47, 54). This contrasts with southern New Mexico where significant dependence on cultivated crops was considerably later, AD 500–600 in the highlands and AD 1000–1100 in the lowlands. This difference in onset is at least partially due to the absence of perennial water sources in most New Mexico basins, where the resource distribution required more mobility. This high mobility made the southern New Mexico groups less able to abandon mobility for agriculture until later in time (Doleman 2006:114, 123, 132–133; Hard and Roney 2006:173–174).

The closely associated dates from the Sacramento and Doña Ana Mountain sites to the east, including Fresnal Shelter (Tagg 1995), High Rolls Cave (Lentz 2005), and Tornillo Shelter (MacNeish 1993), and at the Early Agricultural sites in the Burro Mountains (Turnbow et al. 2000) to the northwest (Fig. 10.1), indicate that corn was relatively widespread in southern New Mexico by about 2,900 years ago (ca. 880 BC) even though it played a relatively minor role until much later. The role of cotton is more ambiguous. Pollen was found in southeastern Arizona as early as 1200–800 BC and seeds at AD 390–240 (Table 10.1), suggesting seeds were processed for oil.

The combination of geomorphological and paleoclimatic data suggests that, because of the regional xeric conditions, the resource productivity in the Deming area was relatively fragile and variable.



map by Robert Dello-Russo

Figure 10.1. Locations of maize and other horticultural developments during the Early Agricultural period in Arizona and New Mexico.

Lacking a resource "cushion," unsettled conditions, such as those postulated for the area at around 750 BC, may have had adverse consequences for the subsistence pursuits of foragers at that time. An interruption in the seasonal rainfall pattern could have thwarted the early spring growth of annual plants. This in turn could have produced a "ripple effect," in which the fauna and the people dependent on these annuals became destabilized. Too many people were competing for too few resources, and this could either have resulted in agricultural intensification, or could have precipitated an outmigration of the area to search for more reliable plant or animal resources. Proposing that changes in subsistence-resource distributions may have caused substantial shifts in the identification and acquisition of resources, including adding corn to the diet, is not substantially different from diet breadth and central-place subsistence models (Charnov 1976; Kelly 1992; Binford 2001; Dello-Russo 2003, 2008), which deal explicitly with the scheduling of annual economic activities with respect to the distribution of resources.

Mobility could have been maintained if seeds were broadcast opportunistically and left unattended in hopes that they would yield a return the

Table 10.1. Early cotton from archaeological sites in Arizona and New Mexico.

Location	Site	Material	Dates	Reference
Southeastern Arizona	Christiansen Wash (FF:9:10)	Feature 132 (extramural pit); pollen	corn cupule: (820–510 cal BC); mesquite wood: (1310–1050 BC)	Adams and Smith 2009
Santa Cruz River, southeastern Arizona	Valley Farms (AA:12:736)	pollen	San Pedro Phase (1250–800 BC)	Cummings and Moutoux 2000
	Santa Cruz Bend	pollen	Cienega Phase (800 BC–AD 100)	Fish 1998
Gila Bend, central Arizona	Kearney, Arizona (V:12:201)	pollen	Cienega Phase (800 BC–AD 100)	Phillips 2000
	Snaketown trash mounds	cotton seeds	Sweetwater Phase (AD 100–300)	Bohrer 1970
Roosevelt Basin, central Arizona	Eagle Ridge Site	cotton seeds	cotton seeds: (240–390 AD)	Elson and Lindeman 1994
New Mexico	Tularosa Cave	cotton cord	pre-pottery phase (200 BC–AD 1)	Bohrer 1977

following season. This would have been a risky strategy, since young green shoots would undoubtedly attract grazing wildlife. Alternatively, the need to maintain cultivated areas would have required both a time and labor investment where group members would have been assigned to oversee garden plots. A third option is that fairly settled agriculturalists, such as those at the Wood Canyon site, continued to utilize the central basins on a seasonal basis and carried stored resources—such as corn—on these logistical trips to collect wild plants.

An important question for LA 159879 is, which of these strategies is represented? It is fairly clear that the people who occupied the site were not semi-settled agriculturalists who spent much of the growing season at the site. The structures were insubstantial, and both morphologically and functionally, none of the features suggest storage—frequently a consequence of intensification and dependence on agriculture. Quantities and types of artifacts are more consistent with mobile groups and changed little in the resources exploited other than the addition of corn late in the occupational sequence. Ruling out the possibilities that corn was planted and left unattended or brought to the site by seasonally mobile agriculturalists is more difficult and may not be possible from the perspective of a single site. Adding cotton seed to the list of food items, whether domesticated or not, could be an indication of broadening the resources base as climatic conditions became more xeric. Corn came later, perhaps as moisture impacted the availability of wild resources or as the regional population increased and limited mobility.

In sum, the Late Archaic/Early Agricultural role suggested by the material remains and chronometric data recovered from the features at LA 159879 in turn suggests that the site played a role in a seasonal subsistence round that changed in response to regional population growth, mobility, and climatic variability. Toward the end of the period, it is apparent that agriculture assumed a greater role within the subsistence system. LA 159879 probably functioned as a base camp for the exploitation of the area's natural resources along with the limited use of cultigens. Sites such as LA 159879 illustrate the acceptance of cultigens into a basically hunter-gatherer economy and set the stage for the development of the Formative-period settlements that appear around 350 BC. These villages emerged from an initial regional hunting and gathering culture evolving into the ancestral Mogollon pit-house communities along the Mimbres River, the Mogollon highlands, and elsewhere between AD 300 and AD 1150.

References Cited

Adams, Jenny L.
1988 Use-Wear Analyses on Manos and Hide-Processing Stones. *Journal of Field Archaeology* 15(3): 307–315.
1993 Towards Understanding the Technological Development of Manos and Metates. *The Kiva* 58(3):331–344.
1999 Refocusing the Role of Food-Grinding Tools as Correlates for Subsistence Strategies in the U.S. Southwest. *American Antiquity* 64(3):475–498.
2002 *Ground Stone Analysis: A Technological Approach.* The University of Utah Press, Salt Lake City.
2010 Understanding Grinding Technology through Experimentation. In *Designing Experimental Research in Archaeology: Examining Technology through Production and Use*, ed. Jeffrey R. Ferguson, pp. 129-151. University Press of Colorado, Boulder.

Akins, Nancy J.
2003 *Salt Creek; Data Recovery at Seven Prehistoric Sites along US 285 in Chaves and De Baca Counties, New Mexico*. Archaeology Notes 298. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.
2004 Changing Patterns of Animal Use at Fallen Pine Shelter. In *Fallen Pine Shelter: 3,000 years of Prehistoric Occupation on the Mescalero Apache Reservation,* by Yvonne R. Oakes, pp. 99–136. New Mexico Department of Transportation Cultural Resource Technical Series 2004–2 and Archaeology Notes 325. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.
2006 Archaic Animal Subsistence in Fresnel Canyon. In *High Rolls Cave: Insectos, Burrito, y Frajos: Archaic Subsistence in Southern New Mexico*, by Stephen C. Lentz, pp. 85–144. New Mexico Department of Transportation Cultural Resource Technical Series 2005–1 Archaeology Notes 345, Office of Archaeological Studies, Museum of New Mexico Santa Fe.
2014 Large Roasting Features and Brush Shelters. In *10,000 Years of Transient Occupation in the Jornada del Muerto: Excavations at Eight Sites at the Spaceport America Facility, Sierra County, New Mexico*, by James L. Moore and Nancy J. Akins, pp. 701–724. Archaeology Notes 453. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.

Allen, B. D.
1994 *Ancient Lakes: A Tool for Understanding Climatic Change*. Lite Geology, Summer 1994. New Mexico Bureau of Mines and Mineral Resources.

Allen, B. D., and R. Y. Anderson
2000 A Continuous, High-Resolution Record of Late Pleistocene Climate Variability from the Estancia Basin, New Mexico. *Geological Society of America Bulletin* 112:1444–1458.

Allen, B. D., D. W. Love, and R. G. Myers
2005 *Hydrologic and Wetland-Habitat Response to Late Quaternary Climatic Change, Northern Tularosa Basin, New Mexico, Determined by Sedimentology and Geomorphology*. 1 New Mexico Water Research Symposium, Socorro, August 16, 2005.
2009 Evidence for Late Pleistocene Hydrologic and Climatic Change from Lake Otero, Tularosa Basin, South-Central New Mexico. *New Mexico Geology* 31(1):9–14.

Allen, Craig D., Julio L. Betancourt, and Thomas W. Swetnam
2003 *Landscape Changes in the Southwestern United States: Techniques, Long-Term Data Sets, and Trends*. In *Land-Use History of North America*. http://www.biology.usgs.gov/luhna/chap9.html (accessed May 10, 2011).

Anderson, R.Y., B.D. Allen, and K.M. Menking,
2002 Geomorphic Expression of Abrupt Climate

Change in Southwestern North America at the Glacial Trmination. *Quaternary Research* 57:371–381.

Andrefsky, William, Jr.
1998 *Lithics: Macroscopic Approaches to Analysis*. Cambridge Manuals in Archaeology, Cambridge University Press, Cambridge.
2001 Emerging Directions in Debitage Analysis. In *Lithic Debitage: Context, Form, Meaning*, ed. W. Andrefsky Jr., pp. 2–14. University of Utah Press, Salt Lake City.

Antevs, E.
1948 The Great Basin with Emphasis on Glacial and Postglacial Times. *University of Utah Bulletin* 38:168–191.
1952 Arroyo-Cutting and Filling. *Journal of Geology* 60(4):375–385.

Asmerom, Yemane, Victor Polyak, Stephen Burns, and Jessica Rassmussen
2007 Solar Forcing of Holocene Climate: New Insights from a Speleothem Record. Southwestern United States. *Geology* 35(1):1–4.

Bailey, Vernon
1971 *Mammals of the Southwestern United States: With Special Reference to New Mexico*. Dover Publications, New York. Originally published 1931, *North American Fauna* 53.

Baillie, M. G. L.
1994 Dendrochronology Raises Questions about the Nature of the AD 536 Dust-Veil Event. *The Holocene* 4(2):212–217.

Barbour, Matthew J., and Stephen C. Lentz
2011 *Preliminary Results of an Archaeological Data Recovery at LA 159879 along US 180, North Of Deming, between Milepost 163 and 164, Luna County, New Mexico.* Preliminary Report 45, Office of Archaeological Studies, Museum of New Mexico, Santa Fe.

Basehart, Harry W.
1973 Mescalero Apache Subsistence Patterns. In *Technical Manual–1973 Survey of the Tularosa Basin*, pp. 145–181. Human Systems Research, Tularosa.

Bell, Willis H., and Edward F. Castetter
1937 Ethnobiological Studies in the American Southwest V: The Utilization of Mesquite and Screwbean by the Aborigines in the American Southwest. *University of New Mexico Bulletin 314, Biological Series* 5(2). University of New Mexico Press, Albuquerque.

Bemis, W. P., M. Moran, J. W. Berry, and A. J. Deutschman
1967 Composition of *Apodanthera undulata* Oil. *Canadian Journal of Chemistry* 45:2637

Betancourt, J. L., T. R. Van Devender, and P. S. Martin
1990 *Packrat Middens: The Last 40,000 Years of Biotic Change*. University of Arizona Press, Tucson.

Binford, Lewis
1980 Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity* 45(1):4-20.
1994 Systematic Integration of "Fragmentary Oddments": The Challenge of Settlement Pattern Approaches. In *Contributions in Anthropology*, ed. Bradley J. Vierra 13(1):527–566. Eastern New Mexico University, Portales.
2001 *Constructing Frames of Reference: An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets*. University of California Press, Berkeley.

BISON M
2011 Biota Information System of New Mexico. http://www.bison-m.org/reports.aspx?rtype=13&county='029' (accessed May 13, 2011, and October 12, 2011).

Blake, Michael
2006 Dating the Initial Spread of *Zea mays*. In *Histories of Maize: Multidisciplinary Approaches to Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize,* ed. John E. Staller, Robert H. Tykot, and Bruce F. Benz, pp. 55–72. Academic Press, Burlington.

Blake, William P., T. A. Conrad, J. Schiel, and Thomas Antisell
1856 *Geological Report: Chapter XVI, Bituminous Effusions, pp. 107–114, map and 3Plates*. In *Reports of Explorations and Surveys, to Ascertain the Most Practicable and Economical Route for a Railroad from the Mississippi River to the Pacific Ocean, Made Under the Direction of the Secretary of War, in 1853–6, According to Acts of Congress of March 3, 1853, May 31, 1854, and August 5, 1854: Vol. VII, 1857: House of Representatives Executive Document 91, 33d Congress, 2d Session, A.O.P. Nicholson.* U.S. War Department, Washington, DC.

Bohrer, Vorsila L., and Karen R. Adams
1977 Ethnobotanical Techniques and Approaches at the Salmon Ruin, New Mexico. *San Juan Valley Archeological Project, Technical Series* 2; *Eastern New Mexico University Contributions in Anthropology* 8(1).

Bordes, François
1961 *Typologie du Paleolithique Ancien et Moyen*. Delmas, Bordeaux.

Bowers, J. E., and Brian Wignall
1993 *Shrubs and Trees of the Southwest Deserts*. Southwest Parks and Monuments Association, Tucson.

Brackenridge, G.R.
1978 Evidence for a Cold, Dry, Full Glacial Climate in the American Southwest. *Quaternary Research* 9:22–40.

Breternitz, C. D., and D. E. Doyel
1983 A Cultural Resource Overview and Management Plan for White Sands Missile Range. Ms. on file, U.S. Department of Interior, National Park Service, Contract Number CX-800-8-0038. Soils System, Inc., Phoenix.

Briggs, J. M., H. Schaafsma, and D. Trenkov
2006 Woody Vegetation Expansion in a Desert Grassland: Prehistoric Human Impact? *Journal of Arid Environments* 69:458–472.

Brook, George A.
1999 Arid Zone Palaeoenvironmental Records from Cave Speleothems. In *Paleoenvironmental Reconstruction in Arid Lands*; ed. Singhvi, A. K., and E. Derbyshire. A. A. Balkema, Rotterdam/Brookfield.

Brown, David E. (editor)
1994 *Biotic Communities Southwestern United States and Northwestern Mexico.* University of Utah Press, Salt Lake City.

Brown, G.A.,
1983 Florida Mountains Section of Southwest New Mexico: Overthrust Belt-A Evaluation. *New Mexico Geology* May 1983.

Buck, Brenda J., John Kipp, Jr., and Curtis Monger
2002 Inverted Clast Stratigraphy in an Eolian Archaeological Environment. *Geoarchaeology: An International Journal* 17(7):665–687.

Buck, Brenda J., and H. Curtis Monger
1999 Stable Isotopes and Soil-Geomorphology as Indicators of Holocene Climate Change, Northern Chihuahuan Desert. *Journal of Arid Environments* 43:357–373.

Buck, Brenda J., Robert L. Steiner, Galen Burgett, and H. Curtis Monger
1999 Artifact Distribution and Its Relationship to Microtopographic Geomorphic Features in an Eolian Environment, Chihuahuan Desert. *Geoarchaeology: An International Journal* 14(8):735–754.

Buck, Brenda J., and J. G. Van Hoesen
2005 Assessing the Applicability of Isotopic Analysis of Pedogenic Gypsum as a Paleoclimate Indicator, Southern New Mexico. *Journal of Arid Environments* 60:99–114.

Bury, Benjamin G., Peter C. Condon, Linda Perry, Seth Sampson, Adriana Romero, Ken Humphrey, and Paul Lukowski
2009 *A Data Recovery of Nine Prehistoric Sites, Training Area 9, McGregor Guided Missile Range, Fort Bliss Military Installation, Otero County, New Mexico.* Fort Bliss Cultural Resources Report No. 0754, El Paso.

Callahan, Errett
1990 *The Basics of Biface Knapping in the Eastern Fluted Point Tradition: A Manual for Flintknappers and Lithic Analysts*. Eastern States Archeological Federation. Originally published in 1974, Archaeology of Eastern North America 7.

Calvin, Ross
1934 *Sky Determines*. Macmillan Co., New York.

Cane, Scott
1989 Australian Aboriginal Seed Grinding and Its Archaeological Record: a Case-Study from the Western Desert. In *Foraging and Farming: The Evolution of Plant Exploitation,* ed. D. R. Harris and G. C. Hillman, pp. 99–118. Unwin Hyman Publishers, London.

Carmichael, David L.
1984 *Archaeological Excavations at Two Prehistoric Campsites near Keystone Dam, El Paso, Texas.* Cultural Resource Management Division, Sociology and Anthropology Department of New Mexico State University, Report 9. USDI Bureau of Land Management, Santa Fe.

Castetter, E. F.
1935 *Ethnobiological Studies in the American Southwest, 1: Uncultivated Native Plants Used as Sources of Food*. University of New Mexico Bulletin, Biological Series 4(1).

Castetter, Edward F., and Willis H. Bell
1942 *Pima and Papago Indian Agriculture*. University of New Mexico Press, Albuquerque.
1951 *Yuman Indian Agriculture: Primitive Subsistence on the Lower Colorado and Gila Rivers*. University of New Mexico Press, Albuquerque.

Castiglia, Peter J., and Peter J. Fawcett
2006 Large Holocene Lakes and Climate Change in the Chihuahuan Desert. *Geology* 34(2):113–116.

Chapman, Joseph A., J. Gregory Hockman, and William R. Edwards
1982 Cottontails. In *Wild Mammals of North America: Biology, Management, Economics,* ed. Joseph A. Chapman and George A. Feldhamer, pp. 83–122. Johns Hopkins University Press, Baltimore.

Charnov, Eric L.
1976 Optimal Foraging: The Marginal Value Theorem. *Theoretical Population Biology* 9:129–136.

Chrisman, Donald, Richard S. MacNeish, Jamshed Mavalwala, and Howard Savage
1996 Late Pleistocene Human Friction Skin Prints from Pendejo Cave, New Mexico. *American Antiquity* 61(2):357–376.

Chronic, Halka
1991 *Roadside Geology of New Mexico.* Mountain Press Publishing Company, Missoula.

Church, Tim, and Mark Sale
2003 *Uncertain Futures: Mesilla Phase Archaeology in the Tularosa Basin: Data Recovery at FB 16697 (LA 126396) and FB 16698 (LA 126395).* Lone Mountain Report 523, El Paso.

Cleaveland, M. K.
2006 Extended Chronology of Drought in the San Antonio Area. *Tree-Ring Laboratory, Geosciences Department, University of Arkansas, Fayetteville.*

Clemons, R. E.
1998 *Geology of the Florida Mountains*. New Mexico Bureau of Mines and Mineral Resources Memoir 43, Socorro.

Collier, Michael, and Robert H. Web
2002 *Floods, Droughts, and Climate Change*. University of Arizona Press, Tucson.

Collins, Michael B.
1999 *Clovis Blade Technology.* University of Texas Press, Austin.

Condon, Peter C., Willi Hermann, Grant Smith, Lillian M. Ponce, and Howard Higgins
2007 *A Data Recovery of Five Prehistoric Sites in the Hueco Mountain Area, Maneuver Area 2C and 2D, Fort Bliss Military Installation, El Paso County, Texas*. TRC Environmental, Inc., El Paso.

Cordell, Linda
1984 *Prehistory of the Southwest.* Academic Press, Orlando.

Cotterell, Brian, and Johan Kaminga
1987 The Formation of Flakes. *American Antiquity* 52:675–708.
1990 *Mechanics of Pre-Industrial Technology*. Cambridge University Press, Cambridge.

Crabtree, Don E.
1968 Mesoamerican Polyhedral Cores and Prismatic Blades. *American Antiquity* 33:446–478.
1972 *An Invitation to Flintworking*. Occasional Papers of the Idaho State Museum No. 28, Pocatello.

Cutler, H. C., and T. W. Whitaker
1967 Cucurbits from the Tehuacan Caves of Mexico. In *The Prehistory of the Tehuacan Valley,* Vol. 1, Environment and Subsistence, ed. D. S. Byers, pp. 212–219. University of Texas Press, Austin.

Daniel B. Stephens and Associates, Inc.
2005 *Southwest New Mexico Regional Water Plan*. Office of the State Engineer. Albuquerque.

Dean, Jeffrey S., and William J. Robinson
1977 *Dendroclimatic Variability in the American Southwest A.D. 680 to 1970.* Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Dello-Russo, Robert D.
2003 The Responses of Basketmaker II Foragers to Climatic Stress in the Rio Grande Valley of New Mexico. In *Anasazi Archaeology at the Millennium,* ed. P. F. Reed, pp. 23–28. Center for Desert Research, Tucson.
2008 Got Water? Modeling the Early Use of Maize in Regions of the Southwest—Gila Mountains and

Beyond. *The New Mexico Botanist* Special Issue 1—Natural History of the Gila, A Symposium, ed. K. Kindscher and W. Norris, pp. 17–33. Western New Mexico University, Silver City.

2012 Continued Interdisciplinary Research at the Water Canyon Paleoindian Site (LA 134764), Socorro County, New Mexico—Interim Report for the 2010 Field Season and Data Recovery Plan for the 2012 Season. Preliminary Report 42. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.

deMenocal, Peter B.
2001 Cultural Responses to Climate Change During the Late Holocene. *Science* 292(5517):667.

Dick Herbert W.
1965 *Bat Cave*. School of American Research Monograph 27, Santa Fe.

Dick-Peddie, W .A.
1993 *New Mexico Vegetation Past, Present and Future.* University of New Mexico Press, Albuquerque.

Diehl, M. W.
1996 The Intensity of Maize Processing and Production in Upland Mogollon Pithouse Villages A.D. 200–1000. *American Antiquity* 61(1):102–115.

Doebley, John F.
1984 “Seeds” of Wild Grasses: A Major Food of Southwestern Indians. *Economic Botany* 38(1):52–64.

Doleman, William H.
2006 Environmental Constraints on Forager Mobility and the Use of Cultigens in Southeastern Arizona and Southern New Mexico. In *The Late Archaic Across the Borderlands: From Foraging to Farming,* ed. Bradley J. Vierra, pp. 113–140. University of Texas Press, Austin.

Duncan, Gwyneth A.
2000 Faunal Remains from Forest Home, Wood Canyon, and Beargrass. In *A Highway Through Time: Archaeological Investigations Along NM 90*, by Christopher A. Turnbow, J. E. Van Hoose, L. S. Reed, L. W. Huckell, J. A. Railey, R. M. Reycraft, G. A. Duncan, pp. 487–507. Culture Resource Technical Series 2000-3, New Mexico State Highway Department, Albuquerque.

Dunn, John P., Joseph A. Chapman, and Rex E. Marsh
1982 Jackrabbits. In *Wild Mammals of North America: Biology, Management, Economics*, ed. Joseph A. Chapman and George A. Feldhamer, pp. 124–145. Johns Hopkins University Press, Baltimore.

Eggleston, Ted L., and David I. Norman
1986 Summary of the Geology, Geochemistry and Tin Resources in the Black Range, New Mexico. *New Mexico Geological Society Guidebook, 37th Field Conference, Truth or Consequences.* Department of Geoscience, New Mexico Institute of Mining and Technology, Socorro.

Eidenbach, P.L., and M.L. Wimberly
1980 *Archaeological Reconnaissance in White Sands National Monument, New Mexico.* Human Systems Research, Tularosa.

Elias, Scott A.
1987 Paleoenvironmental Significance of Late Quaternary Insect Fossils from Packrat Middens in South-Central New Mexico. *Southwestern Naturalist* 32(3):383–390.

Ellwood, Brooks B., and Wulf A. Gose
2006 Heinrich H1 and 8200 yr. B.P. Climate Events Recorded in Hall’s Cave, Texas. *Geology* 34(9):753–756.

Elmore, Francis H.
1944 Ethnobotany of the Navajo. *Monographs of the School of American Research* No. 8, Santa Fe, New Mexico.

Faught, Michael K., and Andrea K. L. Freeman
1998 Paleoindian Complexes of the Terminal Wisconsin and Early Holocene. In *Paleoindian and Archaic Sites in Arizona,* ed. Jonathan B. Mabry, pp. 33–54. Technical Report No. 97–7, Center for Desert Archaeology, Tuscon.

Fiedel, Stuart J.
1999 Older Than We Thought: Implications of Corrected Dates for Paleoindians. *American Antiquity* 64(1):95–116.

Finch, Jr., Steven T., Annie McCoy and Erwin Melis
2008 *Geologic Controls on Ground-Water Flow in the Mimbres Basin, Southwestern New Mexico. New Mexico Geological Society Guidebook, 59th Field Conference, Geology of the Gila Wilderness-Silver City Area*. New Mexico Institute of Mining and Technology, Socorro.

Findley, James S., Arthur H. Harris, Don E. Wilson, and Clyde Jones
1975 *Mammals of New Mexico*. University of New Mexico Press, Albuquerque.

Firestone, R. B., A. West, J. P. Kennett, L. Becker, T. E. Bunch, Z. S. Revay, P. H. Schultz, T. Belgya, D. J. Kennett, J. M. Erlandson, O. J. Dickenson, A. C. Goodyear, R. S. Harris, G. A. Howard, J. B. Kloosterman, P. Lechler, P. A. Mayewski, J. Montogmery, R. Poreda, T. Darrah, S. S. Que Hee, A. R. Smith, A. Stich, and W. Topping
2007 Evidence for an Extraterrestrial Impact 12,900 Years Ago that Contributed to the Megafaunal Extinctions and the Younger Dryas Cooling. *Proceedings of the National Academy of Sciences* 104(41):16016–16021.

Fitting, James C., and Lyle M. Stone
1969 Distance and Utility in the Distribution of Raw Materials in the Cedar Mountains of New Mexico. *The Kiva* 34(4):207–212.

Fitting, J. E., C. B. Hemphill, and D. R.Abbe
1982a *Cultural Resources of the Upper Gila Water Supply Area*. Hemphill Associates, Springfield, Oregon.
1982b *Cultural Resources of the Upper Gila Water Supply Area, A Class I Cultural Resources Overview*. Hemphill Associates, Springfield, OR.

Foxhall, L., and H. A. Forbes
1982 The Role of Grain as a Staple Food in Classical Antiquity. *Chiron* 12:41–90.

Frechette, Jedediah D., and Grant A. Meyer
2009 Holocene Fire-Related Alluvial-Fan Deposition and Climate in Ponderosa Pine and Mixed-Conifer Forests, Sacramento Mountains, New Mexico, USA. *The Holocene*. 19(4):639–651.

Fredrickson, E. L., R. E. Estell, A. Laliberte, and D. M. Anderson
2006 Mesquite Recruitment in the Chihuahuan Desert: Historic and Prehistoric Patterns with Long-Term Impacts. *Journal of Arid Environments* 65:285–295.

Gabin, Vickie L., and Lee E. Lesperance
1977 *New Mexico Climatological Data: Precipitation, Temperature, Evaporation, and Wind, Monthly and Annual Means 1850–1975*. W. K. Summers and Associates, Socorro, NM.

Gile, L. H.
1987 *Late Holocene Displacement Along the Organ Mountains Fault in Southern New Mexico*. New Mexico Bureau of Geology and Mineral Resources Circular 196, Socorro.
2002 Lake Jornada, an Early-Middle Pleistocene Lake in the Jornada del Muerto Basin, Southern New Mexico. *New Mexico Geology* 24(1):3–14.

Goodfriend, Glenn A., and G. Lain Ellis
2000 Stable Carbon Isotope Record of Middle to Late Holocene Climate Changes from Land Snail Shells at Hinds Cave, Texas. *Quaternary International* 67(1)47–60.

Gorecki, P., M. Grant, S. O'Connor, and P. Veth
1997 The Morphology, Function and Antiquity of Australian Grinding Implements. *Archaeology in Oceania* 32(2):141–150.

Graybill, Donald A.
1983 Mount Goliath, Colorado, 39°N, 105°W, In *Contributions of the International Tree-Ring Data Bank.* IGBP Pages/World Data Center for Paleoclimatology, NOAA/NCDC Paleoclimatology Program, Boulder.
1986 Las Tinajas, Chihuahua, Mexico. In *Contributions of the International Tree-Ring Data Bank.* IGBP Pages/World Data Center for Paleoclimatology, NOAA/NCDC Paleoclimatology Program, Boulder.

Greenwald, David H., Peter L. Eidenbach, Dawn M. Greenwald, and Timothy M. Mills
2009 *Archaeological Data Recovery at Site LA 159879 Along U.S. 180, North of Deming, Between Milepost 163 and Milepost 164, Luna County, New Mexico.* DMG Four Corners Research, Inc., Tularosa.

Gregory, David A.
1999 Data Integration and Synthesis. In *Excavations in the Santa Cruz River Floodplain: the Middle Archaic Component at Los Pozos,* ed. David A. Gregory, pp. 885–124. Center for Desert Archaeology, Anthropological Papers No. 20, Tuscon.
2001 An Evaluation of Early Agricultural Period Chronology in the Tuscon Basin. In *Excavations in the Santa Cruz River Floodplain: The Early Agricultural Period Component at Los Pozos,* ed. David A. Gregory, pp. 237–254. Anthropological Papers No. 21. Center for Desert Archaeology, Tucson.

Grissino-Mayer, Henri D.
1996a *El Malpais Precipitation Reconstruction*. International Tree-Ring Data Bank. IGBP PAGES/World Data Center-A for Paleoclimatology Data

Contribution Series # 96-002. NOAA/NGDC Paleoclimatology Program, Boulder.

1996b A 2129 Year Annual Reconstruction of Precipitation for Northwestern New Mexico, USA. In *Tree Rings, Environment, and Humanity. Radiocarbon 1996*, ed. Dean, J. S., Meko, D. M., and T. W. Swetnam. pp. 191–204. University of Arizona Press, Tucson.

Grissino-Mayer, Henri D, Christopher H. Baisan, and Thomas W. Swetnam

1997 *A 1,373 Year Reconstruction of Annual Precipitation for the Southern Rio Grande Basin*. Report submitted to the Directorate of the Environmental Resources Division, Fort Bliss.

Grissino-Mayer, Henri D., D. Stahle, and M. Therrel

2004 El Malpais, New Mexico update, 34°N, 108°E. In *Contributions of the International Tree-Ring Data Bank.* IGBP PAGES/World Data Center for Paleoclimatology, NOAA/NCDC Paleoclimatology, Boulder.

Grissino-Mayer, Henri D., and Thomas W. Swetnam

1981 Oscura Peak, White Sands Missile Range, Socorro Co. Pied 33°N, 106°W. *Contributions of the International Tree-Ring Data Bank.* IGBP Pages/World Data Center for Paleoclimatology, NOAA/NCDC Paleoclimatology Program, Boulder.

Grissino-Mayer, H. D., T.D. Swetnam, and A. C. Caprio

1990 Salinas Peak, San Andres Mountains, New Mexico, 33°N, 106°W. *Contributions of the International Tree-Ring Data Bank.* IGBP Pages/World Data Center for Paleoclimatology, NOAA/NCDC Paleoclimatology Program, Boulder.

Hall, Stephen A.

2001 Geochronology and Paleoenvironments of the Glacial-Age Tahoka Formation, Texas and New Mexico High Plains. *New Mexico Geology* 23:71–77.

Hall, Stephen A., and William A. Penner

2013 Stable Carbon Isotopes, C3–C4 Vegetation, and 12,800 Years of Climate Change in Central New Mexico, USA. *Palaeogeography, Palaeoclimatology, Palaeoecology* 369:272–281.

Hanson, R. T., J. S. McLean, and R. S. Miller

1994 *Hydrogeologic Framework and Preliminary Simulation of Groundwater Flow in the Mimbres Basin, Southwestern New Mexico.* U.S. Geological Survey Water Resource Investigations Report. Prepared in conjunction with the New Mexico State Engineer Office. Albuquerque.

Hard, Robert J.

1986 *Ecological Relationships Affecting the Rise of Farming Economies: A test for the American Southwest.* Ph.D. dissertation, Department of Anthropology, University of New Mexico, Albuquerque.

Hard, Robert J., A. C. MacWilliams, John R. Roney, Karen R. Adams, and William L. Merrill

2006 Early Agriculture in Chihuahua, Mexico. In *Histories of Maize: Multidisciplinary Approaches to Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize,* ed. John E. Staller, Robert H. Tykot, and Bruce F. Benz, pp. 471–496. Academic Press, Burlington.

Hard, Robert J., Raymond P. Mauldin, and Gerry R. Raymond

1996 Mano Size, Stable Carbon Isotope Ratios, and Macrobotanical Remains as Multiple Lines of Evidence of Maize Dependence in the American Southwest. *Journal of Archaeological Method and Theory* 3:253–318.

Hard, Robert J. and John R. Roney

2005 The Transition to Farming on the Rio Casas Grandes and in the Southern Jornada Mogollon Region. In *The Late Archaic Across the Borderlands: From Foraging to Farming,* ed. Bradley J. Vierra, pp. 141–186. University of Texas Press, Austin.

Harris, Arthur H.

2003 The Pleistocene Vertebrate Fauna from Pendejo Cave. In *Pendejo Cave*, ed. Richard S. MacNeish and Jane G. Libby, pp. 37–65. University of New Mexico Press, Albuquerque.

Harris, Nina M., Thomas Shine, and Kate Wright

2008 *Cultural Resource Survey Report for a 43 Mile Portion of US 180 Between Deming, Luna County, and Bayard, Grant County, New Mexico.* Report Number 724. Ecosystems Management, Inc., Albuquerque.

Haugland, Matt

2010 *The Rain Shadow Effect*. On http://www.weatherpages.com/rainshadow (accessed 2010).

Haury, Emil W.

1936 The Mogollon Culture of Southwestern New

Mexico. *Medallion Papers* No. 20. Gila Pueblo, Globe, AZ.

1950 *The Stratigraphy and Archaeology of Ventana Cave, Arizona.* University of Arizona Press, Tucson.

Havstad, Kris, and Reldon Beck

1996 *Research in the Jornada Basin of Southern New Mexico: A Field Tour*. In *Proceedings: Shrubland Ecosystem Dynamics of a Changing Environment*. Compiled by Jerry R. Barrow, E. Durant McArthur, Ronald E. Sosebee, and Robin J. Tausch. General Technical Report INT-GTR-338, USDA, Forest Service, Intermountain Research Station, Ogden, UT.

Hawley, John W.

1976 *Circular 163 – Guidebook to Rio Grande Rift in New Mexico*. New Mexico Bureau of Mines and Mineral Resources, Socorro.

1993 *Notes on the Geomorphology and Late Cenozoic Geology of Northwestern Chihuahua*. USDA Soil Conservation Service, University Park, NM.

Hawley, John W., G. O. Bachman, and K. Manley

1976 Quarternary Stratigraphy in the Basin and Range and Great Plains Provinces, New Mexico and Western Texas. In *Quaternary Stratigraphy of North America*, ed. W. Mahaney, pp. 235–274. Dowen, Hutchinson, and Ross, Inc., Stroudsburg, PA.

Hawley, J. W., and F. Kottlowski

1969 *Quaternary Geology of the South-Central New Mexico Border Region*. Border Stratigraphy Symposium, ed. F. E. Kottlowski and D. V. LeMone, pp. 89–115. New Mexico Bureau Mines and Mineral Resources Circular 104, Socorro.

Hayden, Brian

1995 A New Overview of Domestication. In *Last Hunters First Farmers*, ed. T. Douglas Price and Anne Birgitte Gebauer, pp. 273–299. School of American Research Press, Santa Fe.

Hayden, Julian D.

1969 Gyratory Crushers of the Sierra Pinacate, Sonora. *American Antiquity* 34 (2): 154–161.

Haynes, C. Vance

1991 Geoarchaeological and Paleohydrological Evidence for a Clovis-Age Drought in North America and Its Bearing on Extinction. *Quaternary Research* 35(3):438–450.

2008 Younger Dryas "Black Mats" and the Rancholabrean Termination in North America. *Proceedings of the National Academy of Sciences* 105(18):6520–6525.

Haynes, Gregory M.

2010 Cross-Cultural Implications for Ancestral Puebloan Agriculture in the Mojave Desert. *Journal of Anthropological Research* 66(3):305–328.

Heywood, Charles E.

2002 *Estimation of Alluvial-Fill Thickness in the Mimbres Ground-Water Basin, New Mexico, from Interpretation of Isostatic Residual Gravity Anomalies*. USGS Water-Resources Investigations Report 02-4007. Prepared in cooperation with the New Mexico Office of the State Engineer. Albuquerque.

Hill, Heather W.

2006 Abrupt Climate Change during the Last Glacial Period: A Gulf of Mexico Perspective. University of South Florida Scholar Commons. Graduate School Theses and Dissertations. USF Graduate School.

Hill, R. T.

1900 Physical Geography of the Texas Region. U.S. Geological Survey Topographic Atlas, Folio No. 3.

Hitchcock, R. K., and J. I. Ebert

1984 Foraging and Food Production among Kalahari Hunter/Gatherers. In *From Hunters to Farmers: The Causes and Consequences of Food Production in Africa,* ed. J. D. Clarke and S. Brandt, pp. 328–348. University of California Press, Berkeley.

Hogan, Patrick

2006 *Southeastern New Mexico Regional Research Design and Cultural Resource Management Strategy*. Office of Contract Archeology, Albuquerque.

Holden, W. C.

1928 West Texas Droughts. *Southwestern Historical Quarterly Online* 32(2):103–123, October 1928, http://www.tshanonline.ort/shqonline/apager.php?vol=32&pag=103 (accessed Sept. 17, 2010).

Holliday, Vance T.

1987 Re-examination of Late-Pleistocene Boreal Forest Reconstructions for the Southern High Plains. *Quaternary Research* 28:238–244.

1989 Middle Holocene Drought on the Southern High Plains. *Quaternary Research* 31:74–82.

2000 Folsom Drought and Episodic Drying on the Southern High Plains from 10,900 to 10,200 ^{14}C yr. B.P. *Quaternary Research* 53:1–12.

Holliday, Vance T., Meyer, James H., and Fredlund, Glen G.
2008 Late Quaternary Sedimentology and Geochronology of Small Playas on the Southern High Plains, Texas and New Mexico, USA. *Quaternary Research* 70(1):11-25.

Holmgren, Camille A., M. Cristina Penalba, Kate Aasen Rylander, and Julio L. Betancourt
2003 A 16,000 ^{14}C yr B.P. Packrat Midden Series from the USA-Mexico Borderlands. *Quaternary Research* 60:319-329.

Hough, Walter
1897 The Hopi in Relation to Their Plant Environment. *American Anthropologist* 10(2):33–44.

Hrdlicka, Ales
1908 Physiological and Medical Observations among the Indians of Southwestern United States and Northern Mexico. *Bureau of American Ethnology Bulletin* 34, Smithsonian Institution, Washington, DC.

Huckell, Bruce B.
1984 *The Archaic Occupation of the Rosemont Area, Northern Santa Rita Mountains, Southeastern Arizona.* Archaeological Series No. 147. Arizona State Museum, Tucson.
1995 *Of Marshes and Maize: Preceramic Agricultural Settlements in the Cienega Valley, Southeastern Arizona.* Anthropological Papers of the University of Arizona No. 59, Tucson.
1996 The Archaic Prehistory of the North American Southwest. *Journal of World Prehistory* 10(3):305–373.

Huckell, Bruce B., Lisa W. Huckell, and Karl K, Benedict
2002 Maize Agriculture and the Rise of Mixed Farming-Foraging Economies in Southwestern Arizona during the Second Millennium B .C. In *Traditions, Transitions, and Technologies: Themes in Southwestern Archaeology*, ed. Sarah H. Schlanger, pp. 137–159. University Press of Colorado, Boulder.

Huckell, Lisa W.
1987 Archaeobotanical Remains. In *The Corona de Tucson Project, Prehistoric Use of a Bajada Environment*, edited by B. B. Huckell, M. D. Tagg, and L. W. Huckell, pp. 221–259. Arizona State Museum Archeological Series No. 174. Vol. 174, Tucson.
1993 Plant Remains from the Pinaleno Cotton Cache, Arizona. *The Kiva* 59(2):147–203.
1994 Paleoethnobotanical Analysis. In *Investigations at Milagro, a Late Preceramic Site in the Eastern Tucson*, ed. B. B. Huckell, L. W. Huckell, and S. K. Fish. Technological Report 94-5:33–40. Center for Desert Archaeology, Tucson.
1998 Macrobotanical Remains. In *Archaeological Investigations of Early Village Sites in the Middle Santa Cruz Valley: Analysis and Synthesis, Part I*, ed. J. B. Mabry, pp. 57–148. Anthropological Papers 19. Center for Desert Archaeology. Tucson.
1995 Farming and Foraging in the Cienega Valley. In *Of Marshes and Maize,* ed. Bruce B. Huckell, pp. 74–97. Anthropological Papers of the University of Arizona No. 59. University of Arizona Press, Tucson.
2000 Paleoethnobotany. In *A Highway Through Time: Archaeological Investigation along NM* 90, by Christopher A. Turnbow, J. E. Van Hoose, L. S. Reed, L. W. Huckell, J. A. Railey, R. M. Reycraft, G .A. Duncan, pp. 509–564. New Mexico State Highway and Transportation Department, Technical Series 2000-3, Albuquerque.
2002 *Additional Plant Remains from AZ EE:1:32 (ASM), the Continental Site, Pima County, Arizona*. Ms. on file, Old Pueblo Archaeology Center, Tucson.

INTERA, Inc.
2009 *Technical Memorandum, Gila Planning Project*. New Mexico Interstate Stream Commission. Albuquerque.

Irwin-Williams, Cynthia
1973 *The Oshara Tradition: Origins of Anasazi Culture*. Eastern New Mexico University Contributions in Anthropology 5(1). Portales.

Jicha, Henry L., Jr.
1954 *Geology and Mineral Deposits of Lake Valley Quadrangle, Grant, Luna, and Sierra Counties, New Mexico*. State Bureau of Mines and Mineral Resources Bulletin 37. Socorro.

Jones, Joshua G., Timothy M. Kearns, and Janet L. McVickar
2010 *Archaeological Investigations for the AT&T NEXGEN/Core Project: New Mexico Segment.* Western Cultural Resource Management, Inc. No. (F)321, Farmington.

Julyan, Robert
1998 *The Place Names of New Mexico.* University of New Mexico Press, Albuquerque.

Justice, Noel D.
2002 *Stone Age Spear and Arrow Points of the Southwestern United States.* Indiana University Press, Bloomington.

Katz, Susana R, and Paul Katz
1985 *The Prehistory of the Carlsbad Basin, Southeastern New Mexico.* Incarnate World College, San Antonio.

Kelly, Robert L.
1988 Three Sides of a Biface. *American Antiquity* 53(4):717–734.
1992 Mobility/Sedentism: Concepts, Archaeological Measures, and Effects. *Annual Review of Anthropology* 21:43–66.

Kelly, W. H.
1977 Cocopa Ethnography. *Anthropological Papers of the University of Arizona* No. 29. Tucson.

Kenmotsu, Nancy A., Tim Graves, and Myles R. Miller
2009 Misconceptions about Hut Signatures and Dating: Protohistoric and Historic Periods in Western Trans-Pecos and Southeastern New Mexico. In *Quince: Papers from the 15th Biennial Jornada Mogollon Conference*, ed. Marc Thompson, pp. 89–119. El Paso Museum of Archaeology, El Paso.

Keenan, D. J.
2012 Calibration of a Radiocarbon Age. *Nonlinear Processes in Geophysics* 19:345–350.

Kitchen, David W., and Bart W. O'Gara
1982 Pronghorn. In *Wild Mammals of North America: Biology, Management, Economics,* ed. Joseph A. Chapman and George A. Feldhamer, pp. 960–971. Johns Hopkins University Press, Baltimore.

Knapp, Brian
1979 *Soil Processes*. George Allen and Unwin, London.

Kroeber, A. L.
1935 Walapai Ethnography. *Memoirs of the American Anthropological Association*, No. 42:7–294.

Kuellmer, Frederick J.
1954 Geologic Section of the Black Range at Kingston, New Mexico: Structure and Stratigraphy of the Black Range, Detailed Petrology of Igneous Rocks, and General Guides to Ore Exploration. *New Mexico Institute of Mining & Technology Bulletin* 3. Socorro.

Kunz, Michael, Michael Bever, and Constance Adkins
2003 *The Mesa Site: Paleoindians above the Arctic Circle.* Open File report 86. USDI, Bureau of Land Management-Alaska, Anchorage.

LaFierreiere, Joseph E. and Charles W. Weber, Edwin A. Kohlhepp
1991 Use and Nutritional Composition of Some Traditional Mountain Pima Plant Foods. *Journal of Ethnobiology* 11(1):93–114.

Lair, Hélene, Donald L. Kramer, and Luc-Alain Girardeau
1994 Effects of Interference on Central Place Foraging in *Behavioral Ecology* 5(3).

LaMarche, V. C., and Harlan, T. P.
1969 Almagre Mountain (1 + 2), Colorado, 39°N, 105°W. *Contributions of the International Tree-Ring Data Bank.* IGBP Pages/World Data Center for Paleoclimatology, NOAA/NCDC Paleoclimatology Program, Boulder.

Lancaster, James W.
1986 Ground Stone. In *Short-Term Sedentism in the American Southwest: The Mimbres Valley Salado,* ed. Ben A Nelson and Steven A. LeBlanc, pp. 177–190. Maxwell Museum of Anthropology Publication Series. University of New Mexico Press, Albuquerque.

Lange, Charles H., Jr.
1944 Tiponi, or Corn Goddess Symbols. *American Antiquity* 9(4):446–448.

Langford, Richard P.
2002 *Eolian Deflation of Holocene Playas and Formation of the White Sands Dune Field.* In *Proceedings of ICAR5/GCTE-SEN Joint Converence,* ed. Jeffrey A. Lee and Ted M. Zobeck, p. 2. *International Center for Arid and Semiarid Lands Studies, Texas Tech University, Lubbock.*

Larsen, L. B., B. M. Vinther, K. R. Briffa, T. M. Melvin, H. B. Clausen, P.D. Jones, M. L. Siggaard-Anderson, C. U. Hammer, M. Eronen, H. Grudd, B. E. Gunnarson, R. M. Hantemirov, M. M. Naurzbaev, and K. Nicolussi
2008 New Ice Core Evidence for a Volcanic Cause of the A.D. 536 Dust Veil. *Geophysical Research Letters* 35(4).

Laumbach, Karl W.
1980 Lithic Artifacts. In *Prehistory and History of the Ojo Amarillo*, Vol. 3, ed. by D. Kirkpatrick, pp. 849–958. New Mexico State University Cultural Resources Management Division Report No. 276, Las Cruces.

Lawton, Harry W., Philip J. Wilke, Mary DeDecker, and William M. Mason
1976 Agriculture among the Paiute of Owens Valley. *The Journal of California Anthropology* 3(1):13–50.

Lentz, Stephen C.
2005 *High Rolls Cave: Insectos, Burritos, y Frajos:* Archaic Subsistence in Southern New Mexico. Archaeology Notes 345. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.

Lira, Rafael, and Javier Caballero
2002 Ethnobotany of the Wild Mexican Cucurbitaceae. *Economic Botany* 56(4)380–398.

Love, David W., and William R. Seager
1996 Fluvial fans and Related Basin Deposits of the Mimbres Drainage. *New Mexico Geology* 18(4):81–92.

Lucas, S. G., B. D. Allen, G. S. Morgan, R. G. Myers, D. W. Love, and D. Bustos
2007 *Mammoth Footprints from the Upper Pleistocene of the Tularosa Basin, Doña Ana County, New Mexico*. In *Cenozoic Vertebrate Tracks and Traces* edited by S. G. Lucas, J. A. Spielmann, and M. G. Lockley, pp. 149–154. New Mexico Museum of Natural History and Science Bulletin 42.

Lucas, S. G., G. S. Morgan, J. W. Hawley, D. W. Love, and R. G. Myers
2002 Mammal footprints from the Upper Pleistocene of the Tularosa Basin, Doña Ana County, New Mexico. In *Geology of White Sands,* ed. V. Lueth, K. A. Giles, S. G. Lucas, B. S. Kues, R. G. Myers, and D. Ulmer-Scholle, pp. 285–288. New Mexico Geological Society Guidebook 53.

Luedtke, Barbara E.
1992 *An Archaeologist's Guide to Chert and Flint*. Archaeological Research Tools 7. Institute of Archaeology, University of California, Los Angeles.

Lupo, Karen D.
2007 Evolutionary Foraging Models in Zooarchaeological Analysis: Recent Applications and Future Challenges. *Journal of Archaeological Research* 15:143–189.

Lyman, R. Lee
1994 *Vertebrate Taphonomy*. Cambridge Manuals in Archaeology, Cambridge University Press, Cambridge.

Mabry, Jonathan B.
1998 Frameworks for Arizona's Early Prehistory. In *Paleoindian and Archaic Sites in Arizona,* ed. Jonathan B. Mabry, pp. 1–18. Technical Report No. 97-7. Center for Desert Archaeology, Tucson.
2006 Changing Knowledge and Ideas about the First Farmers in Southeastern Arizona. In *The Late Archaic Across the Borderlands: From Foraging to Farming,* ed. Bradley J. Vierra, pp. 41–83. University of Texas Press, Austin.

Mackay, William P., and Scott A. Elias
1992 Late Quaternary Ant Fossils from Packrat Middens (Hymenoptera: Formicidae): Implications for Climatic Change in the Chihuahuan Desert. *Psyche* 99:169–184.

Mackie, Richard J., Kenneth L. Hamlin, and David F. Pac
1982 Mule Deer. In *Wild Mammals of North America: Biology, Management, Economics,* ed. Joseph A. Chapman and George A. Feldhamer, pp. 862–877. Johns Hopkins University Press, Baltimore.

MacNeish, Richard S.
1993 *Preliminary Investigations of the Archaic in the Region of Las Cruces, New Mexico*. Andover Foundation for Archaeological Research, Las Cruces.

MacNeish, Richard S., and Patrick H. Beckett
1987 *The Archaic Chihuahua Tradition of South-Central New Mexico and Chihuahua, Mexico.* COAS Monograph No. 7. Las Cruces.
1994 The Archaic Chihuahua Tradition of South-Central New Mexico and Chihuahua, Mexico. In *Archaic Hunter-Gatherer Archaeology in the American Southwest,* ed. B. J. Vierra, pp. 335–372. Eastern New Mexico Contributions in Anthropology 13(1), Portales.

Madsen, David B.
1999 North Asian–North American Connections: The Smithsonian Workshop. Paper presented at the Clovis and Beyond Conference, Santa Fe.

Maker, H. J., O. F. Bailey, and J. U. Anderson
1970 *Soil Associations and Land Classification for Irrigation Luna County*. New Mexico State

University Agricultural Experiment Station Research Report No. 176. New Mexico State University, Las Cruces.

Maker, H. J., H. E. Dregne, V. G. Link, and J. U. Anderson
1978 *Soils of New Mexico*. New Mexico State University Agricultural Experiment Station Research Report No. 285. New Mexico State University, Las Cruces.

Mann, Michael E., Raymond S. Bradley and Malcolm K. Hughes
1999 Northern Hemisphere Temperatures During the Past Millennium: Inferences, Uncertainties, and Limitations. *Geophysical Research Letters* Vol. 25(6):759–762.

Martin, Paul S., and Christine R. Szuter
2004 Revising the "Wild" West: Big Game Meets the Ultimate Keystone Species. In *The Archaeology of Global* Change, ed. Charles L. Redman, Steven R. James, Paul R. Fish, and J. Daniel Rogers, pp. 63–88. Smithsonian Books, Washington, DC.

Martin, William C., and Charles R. Hutchins
1980 *A Flora of New Mexico.* Strauss and Cramer, Germany.

Maslin, Mark, Dan Seidov, and John Lowe
2001 *Synthesis of the Nature and Causes of Rapid Climate Transitions During the Quaternary*. In *The Oceans and Rapid Climate Change: Past, Present, and Future*. Geophysical Monograph 126. American Geophysical Union.

Mauldin, Raymond
1993 The Relationship between Ground Stone and Agricultural Intensification in Western New Mexico. *The Kiva* 58(3):317–330.
2004 Exploring Patterns in Late Archaic and Early Ceramic Residential Occupation in the Northern Chihuahuan Desert. In *The Prehistory of Texas*, ed. T. Perttula, pp. 85–97. Texas A & M University Press, College Station.

Mauldin, Raymond, Tim Graves, and Mark Bentley
1998 *Small Sites in the Central Hueco Bolson: A Final Report on Project 90-11*. Conservation Division, U.S. Army Air Defense Artillery Center, Fort Bliss.

McBride, Pamela J.
2003 *Flotation Sample Plant Remains from Thirty-Nine Sites on Fort Bliss, El Paso County, Texas*. Ms. on file, Lone Mountain Archaeological Services, Inc., Albuquerque.

McFadden, L. D., and J. R. McAuliffe
1997 Lithologically-Influenced Geomorphic Responses to Holocene Climatic Changes in the Southern Colorado Plateau, Arizona: A Soil Geomorphic and Ecologic Perspective. *Geomorphology* 19:303–332.

McLemore, V., and N. Dunbar
2000 Rockhound State Park and Spring Canyon Recreation Area. New Mexico Geology 22(3): 66–71, 86.

McLemore, Virginia T. David M. Sutphin, Daniel R. Hack, and Tim C. Pease
1996 Mining History and Mineral Resources of the Mimbres Resource Area, Dora Ana, Luna, Hidalgo, And Grant Counties. *New Mexico. New Mexico Bureau of Mines and Mineral Resources Openfile Report* 424. http://Geoinfo.Nmt.Edu/Publications/Openfile/Downloads/OFR400-499/451-475/459/LUNA.Pdf.

McNab, H. W., and P. E. Avers (compilers)
1996 *Ecological Subregions of the United States, WO-WSA-5*. Prepared in Cooperation with Regional Compilers and the ECOMAP Team of the USDA Forest Service. USDA, Washington, DC.

Mehringer, P. J., Jr., and C. V. Haynes, Jr.
1965 The Pollen Evidence for the Environment of Early Man and Extinct Mammals at the Lehner Mammoth Site, Southeastern Arizona. *American Antiquity* 31(1):17–23.

Meltzer, D. J.
1991 Altithermal Archaeology and Paleoecology at Mustang Springs, on the Southern High Plains of Texas. *American Antiquity* 56(2):236–267.

Merriam, C. H.
1898 *Life-zones and Crop-zones of the United States*. USDA Division of Biological Survey, Bulletin 10, Washington, DC.

Merrick, L. C.
1991 Systematics, Evolution, and Ethnobotany of a Domesticated Squash, *Cucurbita argyrosperma*. *Ph.D. Thesis*, Cornell University. Ithaca, NY.

Metcalfe, Sarah, Alison Say, Stuart Black, Robert McCulloch, and Sarah O'Hara
2002 Wet Conditions during the Last Glaciation in

the Chihuahuan Desert, Alta Babicora Basin, Mexico. *Quaternary Research* 57:91–101.

Michelini, Antonio Porcayo
2009 Advances in the Study of Prehistoric Yuman Ceramics of the Lower Colorado River Delta Centro Inah Baja California. *SCA Proceedings* 23.

Mick-O'Hara, Linda
1996 Analysis of Faunal Remains from the Picacho Project. In *The Land In Between: Archaic and Formative Occupations Along The Upper Rio Hondo of Southeastern New Mexico*, by Regge N. Wiseman, pp. 157–180. Archaeology Notes 125, Office of Archaeological Studies, Museum of New Mexico, Santa Fe.

Miller, Myles R., and Nancy A. Kenmotsu
2004 Prehistory of the Jornada Mogollon and Eastern Trans-Pecos Regions of West Texas. In *The Prehistory of Texas*, ed. T. Perttula, pp. 205–265. Texas A & M University Press, College Station.

Monger, H. Curtis
1993 *Soil-Geomorphic and Paleoclimatic Characteristics of the Fort Bliss Maneuver Areas, Southern New Mexico and Western Texas* Historic and Natural Resources Report No. 10, Cultural Resources Management Program, Directorate of Environment, U.S. Army Air Defense Artillery Center, Fort Bliss.

Monger, H. Curtis, and B. T. Bestelmeyer
2006 The Soil-Geomorphic Template and Biotic Change in Arid and Semi-arid Ecosystems. *Journal of Arid Environments* 65:207–218.

Monger, H. Curtis, Leland H. Gile, John W. Hawley, and Robert B. Grossman
2009 *The Desert Project – An Analysis of Aridland Soil-Geomorphic Processes*. Bulletin 798. New Mexico State University Agricultural Experiment Station, College of Agricultural, Consumer, and Environmental Sciences, Department of Plant and Environmental Sciences, Las Cruces.

Moore, James L.
1996 *Archaeological Investigations in the Southern Mesilla Bolson: Data Recovery at the Santa Teresa Port-of-Entry Facility*. Archaeology Notes 188. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.
1999 Chipped Stone Reduction: Debitage and Cores. In *Archaeology of the Mogollon Highlands, Settlement Systems and Adaptation: Volume 3. Analysis of Chipped and Ground Stone Artifacts*, ed. Y. Oakes and D. Zamora, pp. 25–82. Archaeology Notes 232. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.
2001 Analysis of the Chipped Stone Assemblages. In *Prehistoric and Historic Occupation of Los Alamos and Guaje Canyons: Data Recovery at Three Sites Near the Pueblo of San Ildefonso*, by J. L. Moore, pp. 77–128. Archaeology Notes 244. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.
2003 *Occupation of the Glorieta Valley in the Seventeenth and Nineteenth Centuries: Excavations at LA 76138, LA 76140, and LA 99029*. Archaeology Notes 262. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.
2014 Chipped Stone Analysis. In *10,000 Years of Transient Occupation in the Jornada del Muerto: Excavations at Eight Sites at the Spaceport America Facility, Sierra County, New Mexico* (vol. 1), by J. L. Moore and N. J. Akins, pp. 321–396. Archaeology Notes 453. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.
n.d. Analysis of the Prehistoric Chipped Stone Assemblages. In *Land Use, Settlement, and Community in the Southern Tewa Basin; Volume 3*, ed. J. L. Boyer and J. L. Moore. Archaeology Notes. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.

Moore, James L., and Nancy J. Akins
2014 *10,000 Years of Transient Occupation in the Jornada del Muerto: Excavations at Eight Sites at the Spaceport America Facility, Sierra County, New Mexico*. Archaeology Notes 453. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.

Morgan, G. S., and S. G. Lucas
2002 Pleistocene Vertebrates from the White Sands Missile Range, Southern New Mexico. In *Geology of White Sands*, ed. V. Lueth, K. A. Giles, S. G. Lucas, B. S. Kues, R. G. Myers, and D. Ulmer-Scholle, pp. 267–276,: New Mexico Geological Society, Guidebook 53.
2005 Pleistocene Vertebrate Faunas in New Mexico from Alluvial, Fluvial, and Lacustrine Deposits. In *New Mexico's Ice Ages*, ed. S. G. Lucas, G. S. Morgan, and K. E. Zeigler, pp. 185–248: New Mexico Museum of Natural History and Science, Bulletin 28.

Morris, D. H.
1990 Changes in Groundstone Following the Intro-

duction of Maize into the Southwest. *Journal of Anthropological Research.* 46(2):177–194.

Morrison, R. B.
1985 *Pliocene/Quaternary Geology, Geomorphology, and Tectonics of Arizona*: Geological Society of America Special Paper 203:123–146.
1991 Quaternary Geology of the Southern Basin and Range Province. In Quaternary Non-glacial Geology; Conterminous U.S., ed. R. B. Morrison, R. B., ed., pp. 353-371. The Geology of North America Vol. K-2 Geological Society of America, Boulder.

Murrell, Jesse B.
2007 *Differential Persistence of Variation in Prehistoric Milling Tools from the Middle Rio Puerco Valley, New Mexico*. British Archaeological Reports International Series 1594. Archaeopress, Oxford, England.

Murry, Harold D.
1985 Appendix 3. Analysis of Molluskan Materials from the Brantley Project Area, Eddy County, New Mexico. In *The Prehistory of the Carlsbad Basin, Southeastern New Mexico,* ed. Susana R. Katz and Paul Katz, pp. A-24-A-32. Incarnate World College, San Antonio.

Native American Ethnobotany
2011 The University of Michigan- Dearborn. http://www.herb.umd.umich.edu (accessed October 16, 2011).

Naylor, Thomas H.
1971 Sierra del Nido Site B, Chihuahua, Mexico, 19°N, 106°W. In *Contributions of the International Tree-Ring Data Bank*. IGBP Pages/World Data Center for Paleoclimatology, NOAA/NCDC Paleoclimatology Program, Boulder.

Neher, Raymond E., and William A. Buchanan
1980 *Soil Survey of Luna County, New Mexico.* USDA, Soil Conservation Service, and New Mexico Agricultural Experiment Station. US Government Printing Office, Washington, DC.

Neilson, Ronald P.
1987 Biotic Regionalization and Climatic Controls in Western North America. *Vegetatio* 70(3):135–147.

Nelson, Margaret C., and Heidi Lippmeier
1993 Grinding-Tool Design as Conditioned by Land-Use Pattern. *American Antiquity* 58(2):286–305.

New Mexico Water Research Institute
2011 http://www.river.nmsu.edu/website/mimbres/index.html (accessed May 9, 2011).

New Mexico Avian Conservation Partner
2011 http://www.nmpartnersinflight.org (accessed May 13, 2011).

Newton, Talon, Stacy Timmons, Geoffrey Rawling, Frederick Partey, Trevor Kludt, Lewis Land, Mike Timmons, and Patrick Walsh
2009 *Sacramento Mountains Hydrogeology Study Open File Report – 518*. New Mexico Bureau of Geology and Mineral Resources, Socorro.

Office of Archaeological Studies Staff (OAS)
1994 *Standardized Ground Stone Artifact Analysis: A Draft Manual for the Office of Archaeological Studies*. Archaeology Notes 24b. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.

Ogburn, Stephanie Paige
2006 *Bred for Success*. *High Country News*, November 13, 2006

O'Laughlin, Thomas C.
1977 Excavations at the Sandy Bone Site, Dona Ana County, New Mexico. *Awanyu*: 5(2):11–42.
1980 *The Keystone Dam Site and Other Archaic and Formative Sites in Northwest El Paso, Texas.* Publication No. 8. El Paso Centennial Museum, El Paso.

Ortega-Ramírez, J., J. M. Maillol, W. Bandy, A. Valiente Banuet, J. Urrutia Fucugauchi, C. A. Mortera Gutíérrez, J. Medina Sánchez, G. J. Chacón-Cruz
2004 Late Quaternary Evolution of Alluvial Fans in the Playa, El Fresnal Region, Northern Chihuahua Desert, Mexico: Palaeoclimatic Implications. *Geofisica Internacional* 43(3):445–466.

O'Shea, John
1989 *The Bridgeport Township Site*. University of Michigan, Ann Arbor.

Parks, James A., Jeffrey S. Dean, and Julio L. Betancourt
2006 Tree Rings, Drought, and the Pueblo Abandonment of South-Central New Mexico in the 1670s. In *Environmental Change and Human Adaptation in the Ancient American Southwest*, ed. David E. Doyel and Jeffrey S. Dean. University of Utah Press, Salt Lake City.

Phillips, Fred M., Leslie A. Peeters, Michael K. Tansey, and Stanley N. Davis
1986 Paleoclimatic Inferences from an Isotopic Investigation of Groundwater in the Central San Juan Basin, New Mexico. *Quaternary Research* 26(2):179–193.

Pielou, E. C.
1991 *After the Ice Age: The Return of Life to Glaciated North America*. University of Chicago Press, Chicago.

Piperno Dolores R, Ehud Weiss, Irene Holst, and Dani Nadel
2004 Processing of Wild Cereal Grains in the Upper Palaeolithic Revealed by Starch Grain Analysis. *Nature* 430(5):670–673.

Polyak, Victor J., and Asmerom, Yemane
2005 Orbital Control of Long-term Moisture in the Southwestern USA. *Geophysical Research Letters*, 32(19).

Polyak, Victor J., James C. Cokendolpher, Roy A. Norton, and Yemane Asmerom
2001 Wetter and Cooler Late Holocene Climate in the Southwestern United States from Mites Preserved in Stalagmites. *Geology* 29(7):643–646.

Poore, R. Z., M. J. Pavich, and H. D. Grissino-Mayer
2005 Record of the North American southwest monsoon from Gulf of Mexico sediment cores. *Geology* 32(1): 5–8.

Presley, Anna Lee, and Brian S. Shaffer
2001 Analysis of Faunal Remains. In *The El Paso Loop 375 Archaeological Project: Phase II Testing and Phase III* Mitigation, ed. Phil Dering, Harry J. Shafer, and Robin P. Lyle pp. 407–427. Report No. 28 ,Texas Department of Transportation Environmental Affairs Division Archaeological Studies Program and Reports of Investigations No. 3, Center for Ecological Archaeology, Texas A & M University, Austin.

Quigg, Mike, Mark Sechrist, and Grant Smith
2002 *Testing and Data Recovery of burned Rock Features in Sites on Otero Mesa, New Mexico*. TRC Mariah Associates, El Paso.

Railey, Jim A., Richrd M. Reycrat, Jonathan E. Van Hoose, and Timothy B. Graves
2002 Pit Features. In *Across the Desert Floor: Cultural Resoures Investigations Along US 54, Otero County, New Mexico* ed. J. Railey, pp. 747–763. TRC Mariah Associates, El Paso.

Rasmussen, J. B. T., V. J. Polyak, and Y. Asmerom
2006 Evidence for Pacific-Modulated Precipitation Variability during the Late Holocene from the Southwestern USA. *Geophysical Research Letters* 33:L08701.

Reagan, A. B.
1929 Plants used by the White Mountain Apache: Indians of Arizona. *Wisconsin Archaeologist* 8:143–161.

Reasoner, Mel A., and Margret A. Jodry
2000 Rapid Response of Alpine Timberline Vegetation to the Younger Dryas Climate Oscillation in the Colorado Rock Mountains, USA. *Geology* 28(1):51–54.

Reed, Stewart, Nathan Bailey, and Oghenekome Onokpise
2000 *Soil Science for Archeologists*. Florida Agricultural and Mechanical University and Southeast Archeological Center, National Park Service.

Reeves, Jr., C. C.
1969 *Pluvial Lake Palomas Northwestern Chihuahua Mexico*. New Mexico Geological Society 20th Field Conference. Guidebook, pp. 142–1534. Lubbock.
1970 Origin, Classification, and Geologic History of Caliche on the Southern High Plains, Texas and Eastern New Mexico. *Journal of Geology* 78(3):352–362.

Reimer, Paula J., Mike G. L. Baillie, Edouard Bard, Alex Bayliss, J. Warren Beck, Paul G. Blackwell, C. Bronk Ramsey, Caitlin E. Buck, George S. Burr, R. Lawrence Edwards, Michael Friedrich, P. M. Grootes, Thomas P. Guilderson, Irka Hajdas, T. J. Heaton, Alan G. Hogg, Konrad A. Hughen, K. F. Kaiser, Bernd Kromer, F. G. McCormac, S. W. Manning, Ron W. Reimer, D. A. Richards, John R. Southon, Sahra Talamo, C. S. M. Turney, Johannes van der Plicht, and Constanze E. Weyhenmeyer
2009 IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP. *Radiocarbon* 51:1111–1150.

Reitz, Elizabeth J., and Elizabeth S. Wing
1999 *Zooarchaeology*. Cambridge University Press, Cambridge.

Reycraft, Richard M.
2000 Beargrass: LA 121158. (USFS No.: AR-03-06-07-00578). In *A Highway Through Time: Archaeological Investigations Along NM 90*, ed. Christopher A. Turnbow, J. E. Van Hoose, L. S. Reed, L. W. Huckell, J. A. Railey, R. M. Reycraft, G. A. Duncan, pp. 175–219. New Mexico State Highway Department, Culture Resource Technical Series 2000-3, Albuquerque.

Robertson, Paul B.
1985 Appendix 2. Analysis of Vertebrate Materials from the Brantley Project Area, Eddy County, New Mexico. In *The Prehistory of the Carlsbad Basin, Southeastern New Mexico,* ed. Susana R. Katz and Paul Katz, pp. A-19-A-23. Incarnate World College, San Antonio.

Robinson, Susan
1985 Letter from Susan Robinson to Marsha F. Jackson, Registrar, Site Survey Records, Laboratory of Anthropology, Santa Fe, regarding Whitney City, Luna County, New Mexico. On file, Archaeological Records Management Section (ARMS), New Mexico Historic Preservation Division, Santa Fe.

Roth, Barbara, and Bruce B. Huckell
1992 Cortaro points and the Archaic of Southern Arizona. *The Kiva* 57:353–370.

Roth, Barbara, and Kevin Wellman
2001 New Insights into the Early Agricultural Period in the Tucson Basin: Excavations at the Valley Farms Site (AZ AA:12:736). *The Kiva* 67(1):59–79.

Roth, Barbara J., and Andrea Freeman
2008 The Middle Archaic Period and the Transition to Agriculture in the Sonoran Desert of Southern Arizona. *The Kiva* 73(3):321–353.

Russell, Frank
1908 The Pima Indians. *26th Annual Report, Bureau of American Ethnology*. Washington, DC.

Sayles, E. B.
1945 *The San Simon Branch: Excavations at Cave Creek and in the San Simon Valley, Volume 1: Material Culture.* Medallion Paper No. 34. Gila Pueblo, Globe, AZ.
1983 *The Cochise Cultural Sequence in Southeastern Arizona.* Anthropological Papers of the University of Arizona, No.42. Tucson.

Sayles, E. B., and Ernst Antevs
1941 *The Cochise Culture.* Medallion Papers No. 29, Globe, AZ.

Schneider, Joan S.
1996 Quarrying and Production of Milling Implements at Antelope Hill, Arizona. *Journal of Field Archaeology* 23(3):299–311.

Schroth, Adella B.
1996 An Ethnographic Review of Grinding, Pounding, Pulverizing, and Smoothing with Stones. *Pacific Coast Archaeological Society Quarterly* 32(4):55–75.

Schutt, Jeanne A.
1980 The Analysis of Wear Patterns Resulting from the Use of Flake Tools in Manufacturing and Processing Activities: A Preliminary Report. In *Human Adaptations in a Marginal Environment: The UII Mitigation Project*, ed. J. L. Moore and J. Winter, pp. 66–93. Office of Contract Archeology, University of New Mexico, Albuquerque.

Scurlock, Dan
1998 *From the Rio to the Sierra: An Environmental History of the Middle Rio Grande Basin*. USDA Forest Service General Technical Report RMRS-GTR-5. Rocky Mountain Research Station, USDA, Fort Collins.

Seager, William R.
1981 *Geology of Organ Mountains and Southern San Andres Mountains, New Mexico*. New Mexico Bureau of Mines & Mineral Resources Memoir 36. Socorro.

Sebastian, Lynne, and Signa Larralde
1989 *Living on the Land: 11,000 Years of Human Adaptation in Southeastern New Mexico, an Overview of Cultural Resources in the Roswell District.* USDI Bureau of Land Management, Cultural Resources Series No. 6. Santa Fe.

Sherwood, Sarah C., Boyce N. Driskell, Asa R. Randall, and Scott C. Meeks
2004 Chronology and Stratigraphy at Dust Cave, Alabama. *American Antiquity* 69(3):533–554.

Smith, G. I., and F. A. Street-Perrott
1983 Pluvial Lakes of the Western United States. In *Late Quaternary Environments of the United States, Volume 1, The Late Pleistocene,* ed. S. C. Porter, pp. 190–212, University of Minnesota Press, Minneapolis.

Smith, M.A.
1986 The Antiquity of Seedgrinding in Arid Australia. *Archaeology in Oceania* 21(1):29–39.

Sollberger, J. B.
1986 Lithic Fracture Analysis: A Better Way. *Lithic Technology* 15:101–105.

Spaulding, W. G., J. L. Betancourt, L K. Croft, and K. L. Cole
1990 Packrat Middens: Their Composition and Methods of Analysis. In *Packrat Middens, the Last 40,000 Years of Biotic Change*, ed. J. L. Betancourt, *Packrat Middens, the Last 40,000 Years of Biotic Change,* pp. 59–84. University of Arizona, Tucson.

Stahl, Ann B.
1989 Plant Food Processing: Implications for Dietary Quality. In *Foraging and Farming: The Evolution of Plant Exploitation,* ed. D. R. Harris and G. C. Hillman pp. 171–194. Unwin Hyman Ltd., London, UK.

Stahle, D. W., M. K. Cleaveland, H. D. Grissino-Mayer, R. D. Griffin, F. K. Fye, M. D. Therrell, D. J. Burnette, D. M. Meko, and Diaz J. Villanueva.
2009 Cool- and Warm-Season Precipitation Reconstructions over Western New Mexico. *Journal of Climate*, 22:3729–3750.

Stevenson, Matilda Cox
1993 *The Zuñi Indians and Their Uses of Plants*. Reprint. Dover Publications, Mineola, New York. Originally published 1915, in the Thirtieth Annual Report of the Bureau of American Ethnology to the Secretary of the Smithsonian Institution, 1908–1909, U.S. Government Printing Office, Washington, DC.

Stiner, Mary C., Steven L. Kuhn, Stephen Weiner, and Ofer Bar-Yosef
1995 Differential Burning, Recrystallization, and Fragmentation of Archaeological Bone. *Journal of Archaeological Science* 22:223–237.

Stockton, C. W.
1981 Gallinas Mountains, New Mexico, 34°N, 105°W. *Contributions of the International Tree-Ring Data Bank.* IGBP Pages/World Data Center for Paleoclimatology, NOAA/NCDC Paleoclimatology Program, Boulder.

Stokes, M. A., T. H. Naylor, and T. P. Harlan
1971 Organ Mountains, New Mexico, 32°N, 106°W. *Contributions of the International Tree-Ring Data Bank.* IGBP Pages/World Data Center for Paleoclimatology, NOAA/NCDC Paleoclimatology Program, Boulder.

Stuart, David E., and Rory Gauthier
1984 *Prehistoric New Mexico: Background for Survey.* Historic Preservation Bureau, Santa Fe.

Stuckey, Ronald L., and Theodore M. Barkley
2000 Weeds in North America. In *Flora of North America*. *Flora of North America* Association, vol. 1, Chapter 8. http://foranorthamerica.org/volume/V01/Chapter08 (accessed May 2011).

Stuiver, M., P. M. Grootes, and T. F. Braziunas
1995 The GISP2 18O Climate Record of the Past 16,500 Years and the Role of the Sun, Ocean, and Volcanoes. *Quaternary Research* 44:341–354.

Szuter, Christine R.
2000 Gender and Animals. In *Women and Men in the Prehispanic Southwest: Labor, Power, and Prestige*, ed. Patricia L. Crown, pp. 197—220. School of American Research Press, Santa Fe.

Tagg, M. D.
1996 Early Cultigens from Fresnal Shelter, Southeastern New Mexico. *American Antiquity* 61(2):311–324.

Taylor, K. C., P. A. Mayewski, R. B. Alley, E. J. Brook, A. J. Gow, P. M. Grootes, D. A. Meese, E. S. Saltzman, J. P. Severinghaus, M. S. Twickler, J. W. C. White, S. Whitlow, and G. A. Zielinski
1997 The Holocene-Younger Dryas Transition Recorded at Summit, Greenland. *Science* 278:825–827.

Telford, R. J., E. Heergaard, and H. J. B. Birks
2004 The Intercept Is a Poor Estimate of a Calibrated Radiocarbon Age. *The Holocene* 14(2):296-298.

Thein, S. J.
1979 A Flow Diagram for Teaching Texture-by-Feel Analysis. *Journal of Agronomic Education* 8:54–55.

Thiel, J. Homer
2002 Rio Nuevo Project. In *Arizona Archaeological Council Newsletter: Current Research* 26(3):14–15.

Thoms, Alston V.
2008 The Fire Stones Carry: Ethnographic Records and Archaeological Expectations for Ho-Rock

Cookery in Western North America. *Journal of Anthropological Archaeology* 27:443–460.

Thornbury, William D.
1954 *Principles of Geomorphology*. John Wiley & Sons, Inc., New York.

Tuan, Yi-Fu, Cyril E. Everard, Jerold G. Widdison, and Iven Bennett
1973 *The Climate of New Mexico*. State Planning Office, Santa Fe.

Turnbow, Christopher A
2000a The Wood Canyon Site (LA 99631) (USFS No.: AR-03-06-07-00589). In *A Highway Through Time: Archaeological Investigations Along NM 90*, by Christopher A. Turnbow, J. E. Van Hoose, L. S. Reed, L. W. Huckell, J. A. Railey, R. M. Reycraft, G. A. Duncan, pp. 91–173. New Mexico State Highway Department, Culture Resource Technical Series :2000-3. Albuquerque.
2000b Summary and Conclusions. In *A Highway Through Time: Archaeological Investigations Along NM 90*, by Christopher A. Turnbow, J. E. Van Hoose, L. S. Reed, L. W. Huckell, J. A. Railey, R. M. Reycraft, G. A. Duncan, pp. 625–649. New Mexico State Highway Department, Culture Resource Technical Series: 2000-3. Albuquerque.

Turnbow, C. A., J. E. Van Hoose, L. S. Reed, L. W. Huckell, J. A. Railey, R. M. Reycraft, G. A. Duncan
2000 *A Highway through Time: Archaeological investigations along NM 90, in Grant and Hidalgo Counties, New Mexico.* U.S. Forest Service Report 03-06-98-005b. New Mexico State Highway and Transportation Department, Technical Series 2000-3, TRC, Albuquerque.

Turnbow, Christopher A., and Alexander Kuroto
2008 *The Scorpion Site (LA 119530): Changing Land Use Patterns on an Alluvial Fan in Alamogordo, New Mexico*, Office of Contract Archeology Report No. OCA-185-828. University of New Mexico, Albuquerque.

Turnbow, Christopher A., and Richard M. Reycraft
2000 The Forest Home Site (LA 78089) (USFS No.: AR-03-06-07-00308). In *A Highway Through Time: Archaeological Investigations Along NM 90*, by Christopher A. Turnbow, J. E. Van Hoose, L. S. Reed, L. W. Huckell, J. A. Railey, R. M. Reycraft, G. A. Duncan, pp. 45–90. New Mexico State Highway Department, Culture Resource Technical Series:2000-3. Albuquerque.

Turner, Ellen Sue, Thomas R. Hester, and Richard L. McReynolds
2011 *Stone Artifacts of Texas*. Taylor Trade Publishing, Lanham, MD.

U.S. Department of Agriculture/Natural Resource Conservation Service
2011 Plants Database. http://www.plants.usda.gov/java (accessed October 16, 2011).

U.S. Department of Agriculture/Natural Resource Conservation Service
2011 U.S. Department of Agriculture/Natural Resource Conservation Service Web Soil Survey. http://www.websoilsurvey.nrcs.usda.gov/app/HomePage.htm (accessed April 28, 2011).

Van Devender, Thomas R.
1990 Late Quaternary Vegetation and Climate of the Chihuahuan Desert, United States and Mexico. In *Packrat Middens – the Last 40,000 Years of Biotic Change,* ed. J. L. Betancourt, T. R. Van Devender, and P. S. Martin, pp. 105–133. University of Arizona Press, Tucson.

Van Devender, Thomas R., Betancourt, Julio L., and Mark Wimberley
1984 Biogeographic Implications of a Packrat Midden Sequence from the Sacramento Mountains, South-Central New Mexico. *Quaternary Research* 22(3):344–360.

Van Devender, T. R., and W .G. Spaulding
1979 Development of Vegetation and Climate in the Southwestern United States. *Science* 204:701–710.

Van Hoose, Jonathan E.
2000 Ground Stone and Miscellaneous Stone Artifacts. In *A Highway Through Time: Archaeological Investigations Along NM 90*, by Christopher A. Turnbow, J. E. Van Hoose, L. S. Reed, L. W. Huckell, J. A. Railey, R. M. Reycraft, G. A. Duncan, pp. 419–479. New Mexico State Highway Department, Culture Resource Technical Series:2000-3. Albuquerque.

Vaughan, Patrick C.
1985 *Use-Wear Analysis of Flaked Stone Tools*. University of Arizona Press, Tucson.

Villanueva-Diaz, José D., Julian Ceraño, Dave W. Stahle, Brian H. Luckman, and Matthew D. Therrell
2006 *Historical Droughts in North-Central Mexico.*

North American Drought Monitor Workshop. Mexico City, Mexico, October 18–19, 2006.

Wallace, Henry
1983 Mortars, Petroglyphs and Trincheras on Rillito Peak. *The Kiva* 48(3):1–246.

Wandsnider, LuAnn
1997 The Roasted and the Boiled: Food Consumption and Heat Treatment with Special Emphasis on Pit-Hearth Cooking. *Journal of Anthropological Archaeology* 16:1–48.

Waters, Michael R.
1992 *Principles of Geoarchaeology A North American Perspective*. University of Arizona Press, Tucson.

Weaver, Andrew J., Oleg A. Saenko, Peter U. Clark, and Jerry X. Mitrovica
2003 Meltwater Pulse 1A from Antarctica as a Trigger of the Bolling-Allerod Warm Interval. *Science* 299(5613):1709–1713.

Welsh, Michael
1995 *Mockingbird Gap Paleoindian Site: Excavations in 1967.* Paper presented at the 33rd Annual Meeting, Society for American Archaeology, Santa Fe.

Wendorf, Fred, and Alex D. Krieger
1959 New Light on the Midland Discovery. *American Antiquity* 25(1):66–78.

Wendorf, F., and J. J. Hester, (editors.)
1975 *Late Pleistocene environments of the southern High Plains*. Fort Burgwin Research Publication 9, Ranchos de Taos, New Mexico.

Western Regional Climate Center
2011 http://www.wrcc.dri.edu (accessed May 12, 2011).

Whalen, Michael S.
1994 Moving Out of the Archaic on the Edge of the Southwest. *American Antiquity* 59(4):622–638.

Whiting, A. F.
1939 *The Ethnobotany of the Hopi*. Museum of Northern Arizona Bulletin No. 15. Flagstaff.

Whittaker, John C.
1994 *Flintknapping: Making and Understanding Stone Tools*. University of Texas Press, Austin.

Wills, W. H.
1988 *Early Prehistoric Agriculture in the American Southwest.* School of American Research Press, Santa Fe.

Wimberly, Mark L., and Peter L. Eidenbach
1981 Preliminary Analysis of Faunal Remains from Fresnal Shelter, New Mexico: Evidence of Different Butchering Practices during the Archaic Period. In Archaeological Essays in Honor of Mark Wimberly, ed. M. S. Foster. *The Artifact* 19(3–4):20–68.

Wiseman, Regge N.
1996 *The Land In Between: Archaic and Formative Occupations Along The Upper Rio Hondo of Southeastern New Mexico*. Archaeology Notes 125, Office of Archaeological Studies, Museum of New Mexico, Santa Fe.
2015 *The Lower Nash Draw Project: Excavation of Seven Prehistoric Sites and Documentation of One Recent Historic Site along NM 128 from Jct. NM 31 to the WIPP Turnoff, East-Central Eddy County, New Mexico*. Archaeology Notes 438. Office of Archaeological Studies, Museum of New Mexico, Santa Fe.

Witter, Dan C.
1972 Faunal Remains from Fresnal Shelter, an Interim Report. In *Training Bulletin, Tularosa Valley Project, 1972 Excavations at Fresnal Shelter*, Appendix 3. Human Systems Research, Albuquerque.

Wood, Chris, and Dan Smith
2004 Dendroglaciological Evidence for a Neoglacial Advance of the Saskatchewan Glacier, Banff National Park, Canadian Rocky Mountain. *Tree Ring Research* 60(1):59–65.

Worcester, Donald E.
1992 *The Apaches: Eagles of the Southwest.* University of Oklahoma Press, Norman.

Wright, Katharine I.
1994 Ground-Stone Tools and Hunter-Gatherer Subsistence in Southwest Asia: Implications for the Transition to Farming. *American Antiquity* 52(2): 238–263.

Appendix 1: OSL Dating

Ronald J. Goble

Department of Earth & Atmospheric Sciences

April 24, 2012

OSL Analysis and Sample Preparation

Sample Preparation/Dose-Rate Determination:

Sample preparation was carried out under amber-light conditions. Samples were wet sieved to extract the 90 – 150 µm fraction, and then treated with HCl to remove carbonates. Quartz and feldspar grains were extracted by flotation using a 2.7 gm cm^{-3} sodium polytungstate solution, then treated for 75 minutes in 48% HF, followed by 30 minutes in 47% HCl. The sample was then resieved and the <90 µm fraction discarded to remove residual feldspar grains. The etched quartz grains were mounted on the innermost 2 mm or 5mm of 1 cm aluminum disks using Silkospray.

Chemical analyses were carried out by using ICP/MS by Activation Laboratories, Ancaster, Ontario, Canada. Dose-rates were calculated using the method of Aitken (1998) and Adamiec and Aitken (1998). The cosmic contribution to the dose-rate was determined using the techniques of Prescott and Hutton (1994).

Optical Measurements:

Optically stimulated luminescence analyses were carried out on Riso Automated OSL Dating System Models TL/OSL-DA-15B/C and TL-OSL-DA-20, equipped with blue and infrared diodes, using the Single Aliquot Regenerative Dose (SAR) technique (Murray and Wintle 2000). Early background subtraction (Ballarini et al. 2007) as used. All D_e values were determined using the Central Age Model (Galbraith et al. 1999), unless data analysis indicates partial bleaching, in which case the Minimum Age Model (Galbraith et al. 1999) was used. Preheat and cutheat temperatures were based upon preheat plateau tests between 180º and 280ºC. Dose-recovery and thermal transfer tests were conducted (Murray and Wintle 2003). Growth curves were examined to determine whether the samples were below saturation ($D/D_o < 2$; Wintle and Murray 2006). Optical ages are based upon a minimum of 50 aliquots (Rodnight 2008), except for UNL3414 for which only a minimum age could be calculated because most aliquots had signals which were saturated. Individual aliquots were monitored for insufficient count-rate, poor quality fits (i.e. large error in the equivalent dose, D_e), poor recycling ratio, strong medium vs fast component (Durcan and Duller 2011), and detectable feldspar. Aliquots deemed unacceptable based upon these criteria were discarded from the data set prior to averaging. Averaging was carried out using the Central Age Model (Galbraith et al. 1999) unless the D_e distribution (asymmetric distribution; decision table of Bailey and Arnold 2006), indicated that the Minimum Age Model (Galbraith et al. 1999) was more appropriate.

214 Bessey Hall / P.O. 880340 / Lincoln, NE 68588-0340 / (402) 472-2663 / FAX (402) 472-4917

Results (see attached tables):

Samples range in age from 0.10±0.01 ka (UNL3407) to 35.2±2.7 ka (minimum age, UNL3414), with a cluster of five ages in the 1.8 to 2.5 ka range and two in the 10.4 to 11.8 ka range. Samples UNL3407 (0.10±0.01 ka) and UNL3409 (2.53±0.15 ka) showed evidence of partial bleaching (decision table of Bailey and Arnold 2006). Therefore, the Minimum Age Model (Galbraith et al. 1999) was used to calculate an age for these two samples. The signal for UNL3414 was saturated ($D_e > 2\ D_o$; Wintle and Murray 2006). A minimum age was calculated based on the observed D_e for a small number of aliquots for which the signals were not saturated, and the value $2D_o$ for the large number of aliquots which for which the signals were saturated.

Ronald J. Goble

Professor & Director, Luminescence Geochronology Laboratory
Dept. of Earth & Atmospheric Sciences
University of Nebraska-Lincoln
214 Bessey Hall
Lincoln, NE 68588-0340

References:

Adamiec, G. & Aitken, M. (1998): Dose-rate conversion factors: update. Ancient TL, **16**, 37-50.Aitken, M. J. (1998). Introduction to Optical Dating. Oxford, Oxford University Press.

Bailey, R.M. & Arnold, L.J. (2006): Statistical modeling of single grain quartz D_e distributions and an assessment of procedures for estimating burial dose. Quaternary Science Reviews, **25**, 2475-2502.

Ballarini, M., Wallinga, J., Wintle, A.G. & Bos, A.J.J. (2007): A modified SAR protocol for optical dating of individual grains from young quartz samples. Radiation Measurements, **42**, 360-369.

Durcan, J.A. and Duller, G.A.T. (2011): The fast ratio: A rapid measure for testing the dominance of the fast component in the initial OSL signal from quartz. Radiation Measurments, **46**, 1065-1072.

Galbraith, R.F., Roberts, R.G., Laslett, G.M., Yoshida, H. and Olley, J.M. (1999): Optical dating of single and multiple grains of quartz from Jinmium Rock Shelter, Northern Australia: Part I, experimental design and statistical models. Archaeometry **41**, 339-364.

Murray, A.S. & Wintle, A.G. (2000): Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. Radiation Measurements, **32**, 57-73.

Murray, A.S. & Wintle, A.G. (2003): The single aliquot regenerative dose protocol: potential for improvements in reliability. Radiation Measurements, **37**, 377-381.

Prescott, J.R. & Hutton, J.T. (1994): Cosmic ray contributions to dose rates for luminescence and ESR dating: large depths and long-term time variations. Radiation Measurements, **23**, 497-500.

Rodnight, H. (2008): How many equivalent dose values are needed to obtain a reproducible distribution? Ancient TL, **26**, 3-9.

Wintle, A.G. and Murray, A.S. (2006): A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regeneration dating protocols. Radiation Measurements **41**, 369-391.

UNL #	Field #	Burial	H_2O	K_2O	±	U	±	Th	±	Cosmic	Dose Rate	D_e	No. of	Age
		Depth (m)	(%)[a]	(%)		(ppm)		(ppm)		(Gy)	(Gy/ka)	(Gy)	Aliquots	(ka)
UNL3405	307	0.60	2.98	2.99	0.08	2.83	0.07	13.6	0.40	0.25	4.22±0.14	9.04±0.36	52	2.14±0.13
UNL3406	308	0.35	2.04	3.40	0.09	2.92	0.07	13.6	0.40	0.26	4.63±0.15	9.71±0.30	60	2.10±0.12
UNL3407	309	0.19	0.87	3.71	0.10	2.78	0.07	12.3	0.37	0.27	4.83±0.16	0.74±0.06	63	0.15±0.01
								Minimum Age Model (Galbraith et al. 1999) =				050±0.03		0.10±0.01
UNL3408	310	0.90	1.41	3.48	0.09	2.61	0.06	11.2	0.33	0.24	4.47±0.15	17.43±0.52	60	3.90±0.21
UNL3409	312	0.88	2.21	3.37	0.09	2.49	0.06	10.5	0.33	0.24	4.26±0.14	21.36±1.01	84	5.01±0.33
								Minimum Age Model (Galbraith et al. 1999) =				10.79±0.43		2.53±0.15
UNL3410	313	0.66	1.20	3.78	0.10	2.55	0.06	12.3	0.37	0.25	4.80±0.16	8.68±0.43	52	1.81±0.12
UNL3411	314	0.16	1.12	3.76	0.10	2.54	0.06	12.3	0.37	0.27	4.80±0.16	12.05±0.31	57	2.51±0.13
UNL3412	315	0.53	1.27	3.81	0.10	2.59	0.06	11.9	0.35	0.25	4.81±0.16	56.52±2.14	57	11.8±0.7
UNL3413	503	1.12	1.55	3.49	0.09	2.59	0.06	9.85	0.29	0.25	4.40±0.15	45.82±1.62	63	10.4±0.6
UNL3414	504	1.45	2.80	3.42	0.09	2.89	0.07	11.6	0.34	0.22	4.43±0.15	155.6±7.4[b]	30	35.2±2.7[b]

[a] In-situ Moisture Content

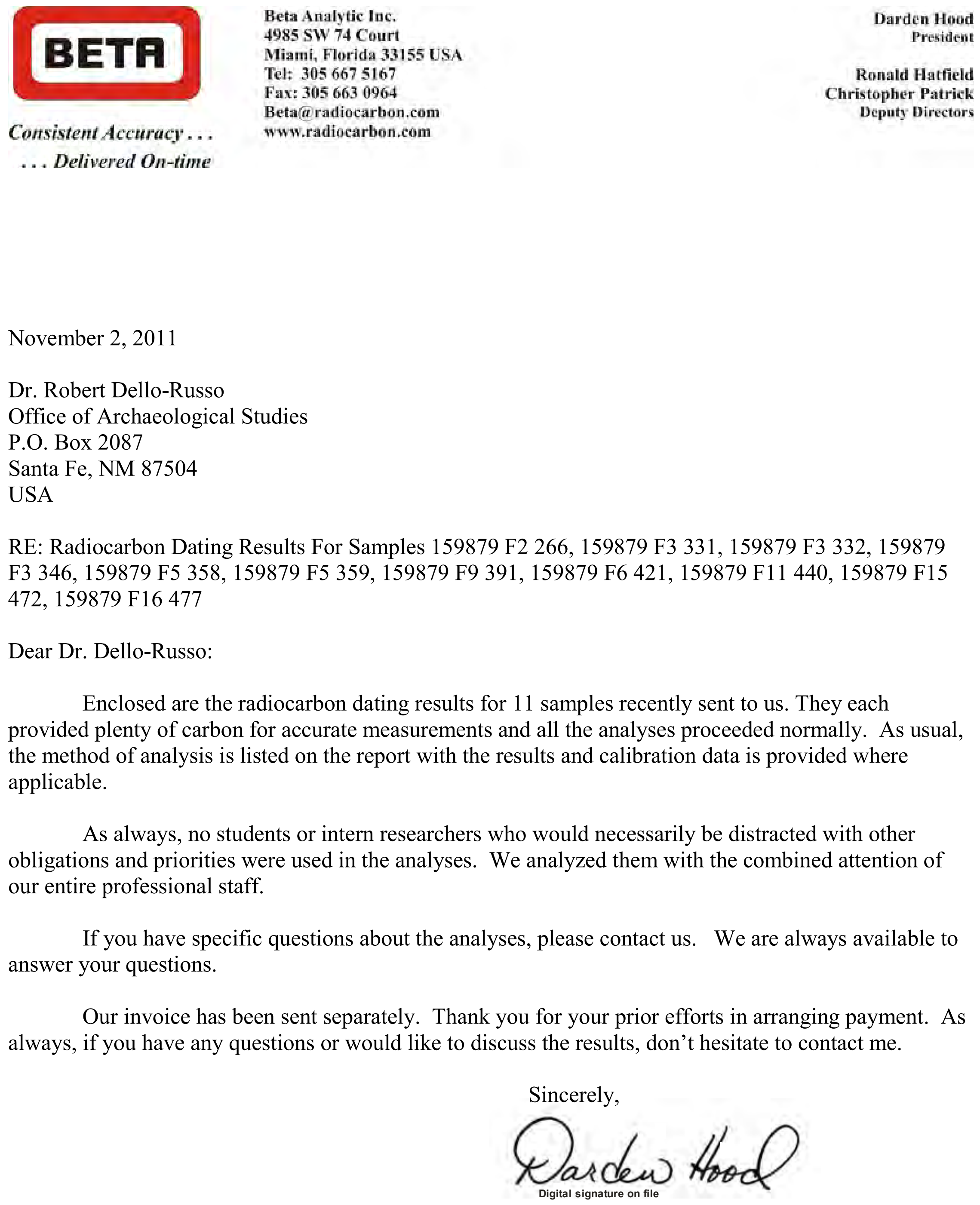
[b] De and age calculated using minimum of the observed D_e and $2D_o$ (Wintle and Murray 2006).

Error on De is 1 standard error

Error on age includes random and systematic errors calculated in quadrature

Appendix 2: Radiocarbon Analysis

Beta Analytic, Inc.



BETA
Consistent Accuracy . . .
. . . Delivered On-time

Beta Analytic Inc.
4985 SW 74 Court
Miami, Florida 33155 USA
Tel: 305 667 5167
Fax: 305 663 0964
Beta@radiocarbon.com
www.radiocarbon.com

Darden Hood
President

Ronald Hatfield
Christopher Patrick
Deputy Directors

November 2, 2011

Dr. Robert Dello-Russo
Office of Archaeological Studies
P.O. Box 2087
Santa Fe, NM 87504
USA

RE: Radiocarbon Dating Results For Samples 159879 F2 266, 159879 F3 331, 159879 F3 332, 159879 F3 346, 159879 F5 358, 159879 F5 359, 159879 F9 391, 159879 F6 421, 159879 F11 440, 159879 F15 472, 159879 F16 477

Dear Dr. Dello-Russo:

Enclosed are the radiocarbon dating results for 11 samples recently sent to us. They each provided plenty of carbon for accurate measurements and all the analyses proceeded normally. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable.

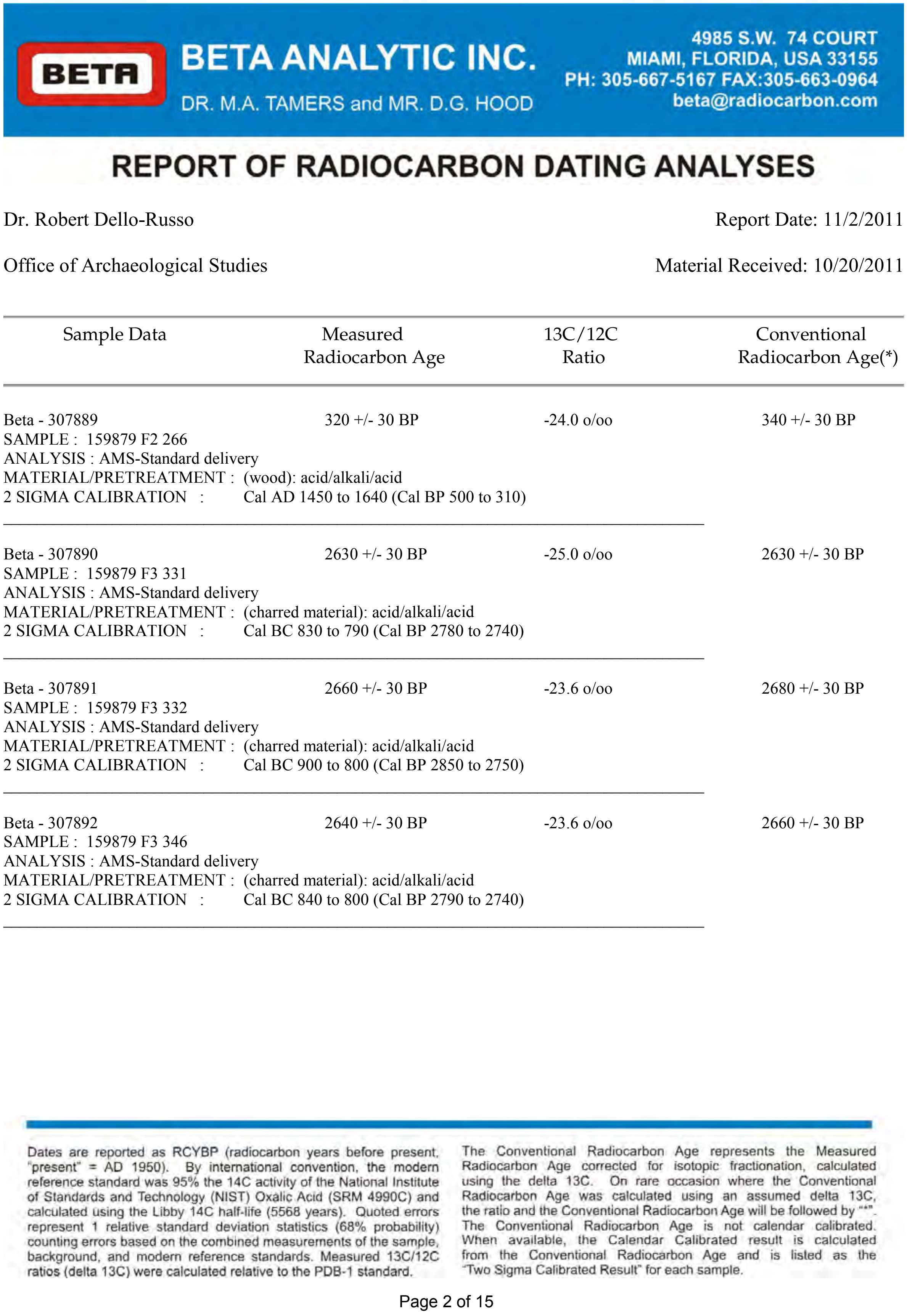
As always, no students or intern researchers who would necessarily be distracted with other obligations and priorities were used in the analyses. We analyzed them with the combined attention of our entire professional staff.

If you have specific questions about the analyses, please contact us. We are always available to answer your questions.

Our invoice has been sent separately. Thank you for your prior efforts in arranging payment. As always, if you have any questions or would like to discuss the results, don't hesitate to contact me.

Sincerely,

Darden Hood
Digital signature on file



BETA ANALYTIC INC.
DR. M.A. TAMERS and MR. D.G. HOOD
4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305-667-5167 FAX:305-663-0964
beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

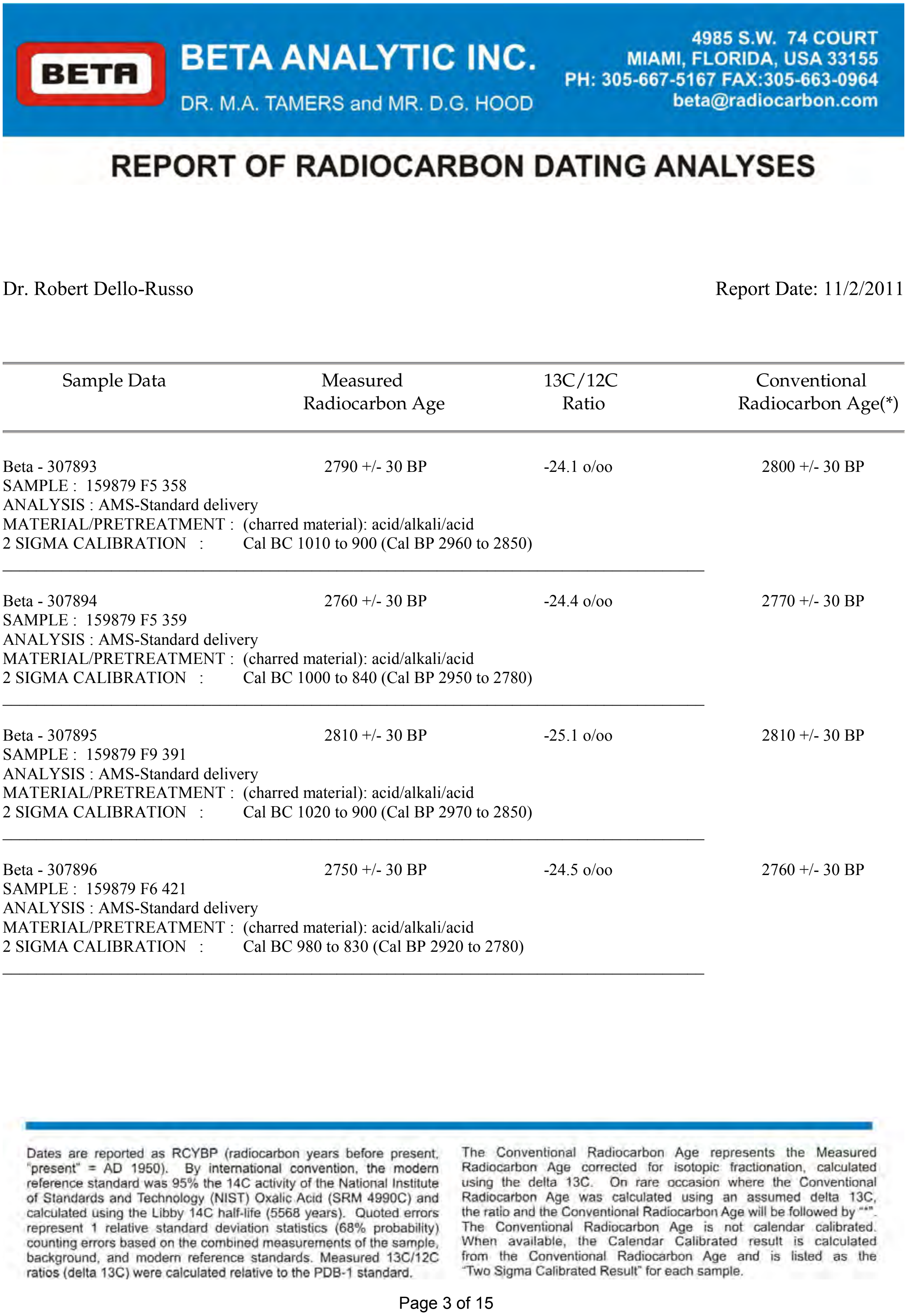
Dr. Robert Dello-Russo — Report Date: 11/2/2011

Office of Archaeological Studies — Material Received: 10/20/2011

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 307889 SAMPLE : 159879 F2 266 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (wood): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 1450 to 1640 (Cal BP 500 to 310)	320 +/- 30 BP	-24.0 o/oo	340 +/- 30 BP
Beta - 307890 SAMPLE : 159879 F3 331 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 830 to 790 (Cal BP 2780 to 2740)	2630 +/- 30 BP	-25.0 o/oo	2630 +/- 30 BP
Beta - 307891 SAMPLE : 159879 F3 332 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 900 to 800 (Cal BP 2850 to 2750)	2660 +/- 30 BP	-23.6 o/oo	2680 +/- 30 BP
Beta - 307892 SAMPLE : 159879 F3 346 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 840 to 800 (Cal BP 2790 to 2740)	2640 +/- 30 BP	-23.6 o/oo	2660 +/- 30 BP

Dates are reported as RCYBP (radiocarbon years before present, "present" = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (SRM 4990C) and calculated using the Libby 14C half-life (5568 years). Quoted errors represent 1 relative standard deviation statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (delta 13C) were calculated relative to the PDB-1 standard.

The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotopic fractionation, calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by "*". The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.



BETA

BETA ANALYTIC INC.

DR. M.A. TAMERS and MR. D.G. HOOD

4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305-667-5167 FAX:305-663-0964
beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Dr. Robert Dello-Russo

Report Date: 11/2/2011

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 307893 SAMPLE : 159879 F5 358 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 1010 to 900 (Cal BP 2960 to 2850)	2790 +/- 30 BP	-24.1 o/oo	2800 +/- 30 BP
Beta - 307894 SAMPLE : 159879 F5 359 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 1000 to 840 (Cal BP 2950 to 2780)	2760 +/- 30 BP	-24.4 o/oo	2770 +/- 30 BP
Beta - 307895 SAMPLE : 159879 F9 391 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 1020 to 900 (Cal BP 2970 to 2850)	2810 +/- 30 BP	-25.1 o/oo	2810 +/- 30 BP
Beta - 307896 SAMPLE : 159879 F6 421 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 980 to 830 (Cal BP 2920 to 2780)	2750 +/- 30 BP	-24.5 o/oo	2760 +/- 30 BP

Dates are reported as RCYBP (radiocarbon years before present, "present" = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (SRM 4990C) and calculated using the Libby 14C half-life (5568 years). Quoted errors represent 1 relative standard deviation statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (delta 13C) were calculated relative to the PDB-1 standard.

The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotopic fractionation, calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by "*". The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.

BETA
BETA ANALYTIC INC.
DR. M.A. TAMERS and MR. D.G. HOOD
4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305-667-5167 FAX:305-663-0964
beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Dr. Robert Dello-Russo

Report Date: 11/2/2011

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 307897 SAMPLE : 159879 F11 440 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 920 to 810 (Cal BP 2870 to 2760)	2710 +/- 30 BP	-23.9 o/oo	2730 +/- 30 BP
Beta - 307898 SAMPLE : 159879 F15 472 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (wood): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 1520 to 1560 (Cal BP 420 to 390) AND Cal AD 1630 to 1670 (Cal BP 320 to 280) Cal AD 1780 to 1800 (Cal BP 170 to 150) AND Cal AD 1950 to 1950 (Cal BP 0 to 0)	230 +/- 30 BP	-23.3 o/oo	260 +/- 30 BP
Beta - 307899 SAMPLE : 159879 F16 477 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 1010 to 900 (Cal BP 2960 to 2850)	2790 +/- 30 BP	-24.4 o/oo	2800 +/- 30 BP

Dates are reported as RCYBP (radiocarbon years before present, "present" = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (SRM 4990C) and calculated using the Libby 14C half-life (5568 years). Quoted errors represent 1 relative standard deviation statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (delta 13C) were calculated relative to the PDB-1 standard.

The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotopic fractionation, calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by "*". The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-24:lab. mult=1)

Laboratory number: **Beta-307889**

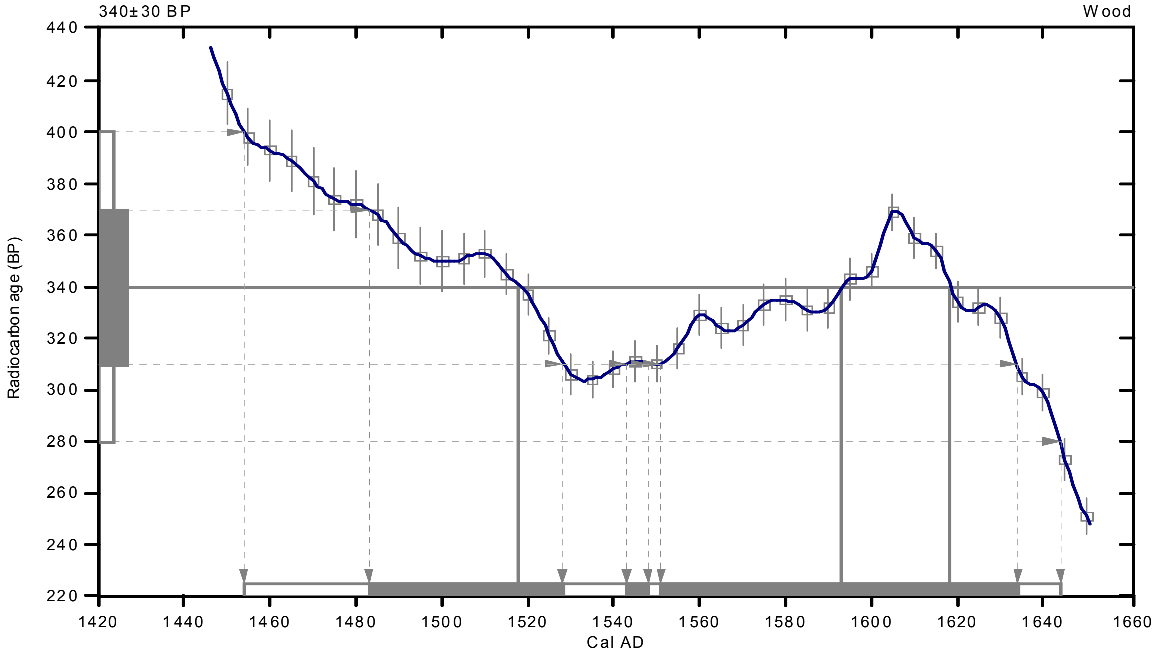
Conventional radiocarbon age: **340±30 BP**

2 Sigma calibrated result: **Cal AD 1450 to 1640 (Cal BP 500 to 310)**
(95% probability)

Intercept data

Intercepts of radiocarbon age
with calibration curve: Cal AD 1520 (Cal BP 430) and
Cal AD 1590 (Cal BP 360) and
Cal AD 1620 (Cal BP 330)

1 Sigma calibrated results: Cal AD 1480 to 1530 (Cal BP 470 to 420) and
(68% probability) Cal AD 1540 to 1550 (Cal BP 410 to 400) and
Cal AD 1550 to 1630 (Cal BP 400 to 320)



References:

Database used
INTCAL09
References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

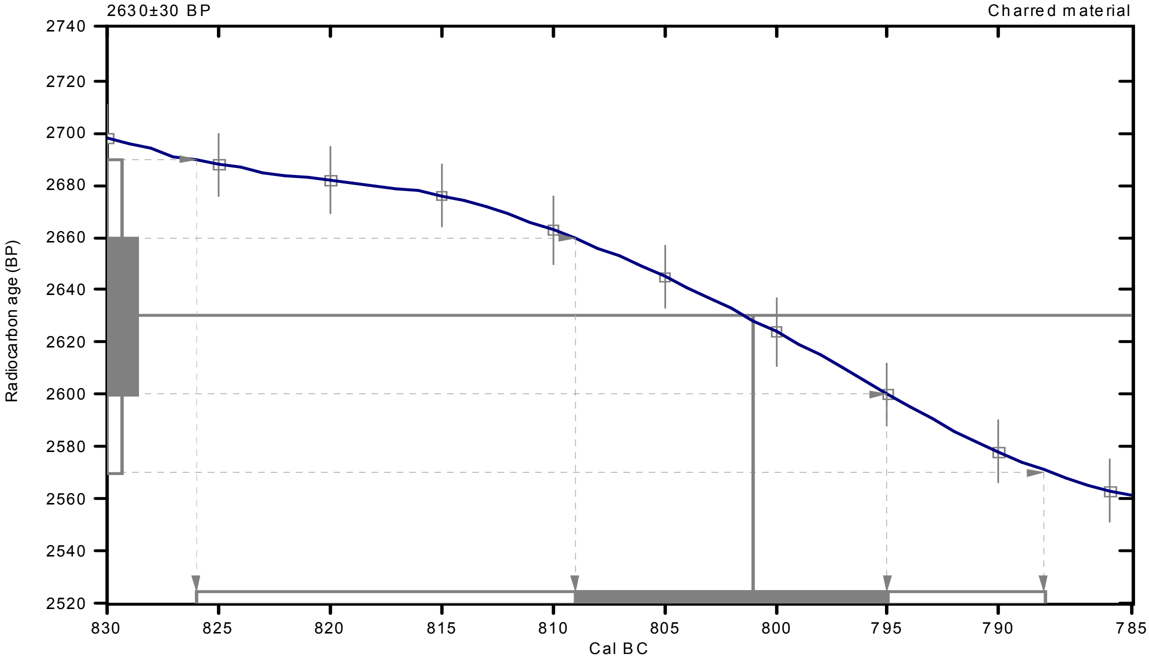
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25:lab. mult=1)

Laboratory number:	**Beta-307890**
Conventional radiocarbon age:	**2630±30 BP**
2 Sigma calibrated result: **(95% probability)**	**Cal BC 830 to 790 (Cal BP 2780 to 2740)**

Intercept data

Intercept of radiocarbon age with calibration curve:	Cal BC 800 (Cal BP 2750)
1 Sigma calibrated result: (68% probability)	Cal BC 810 to 800 (Cal BP 2760 to 2740)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

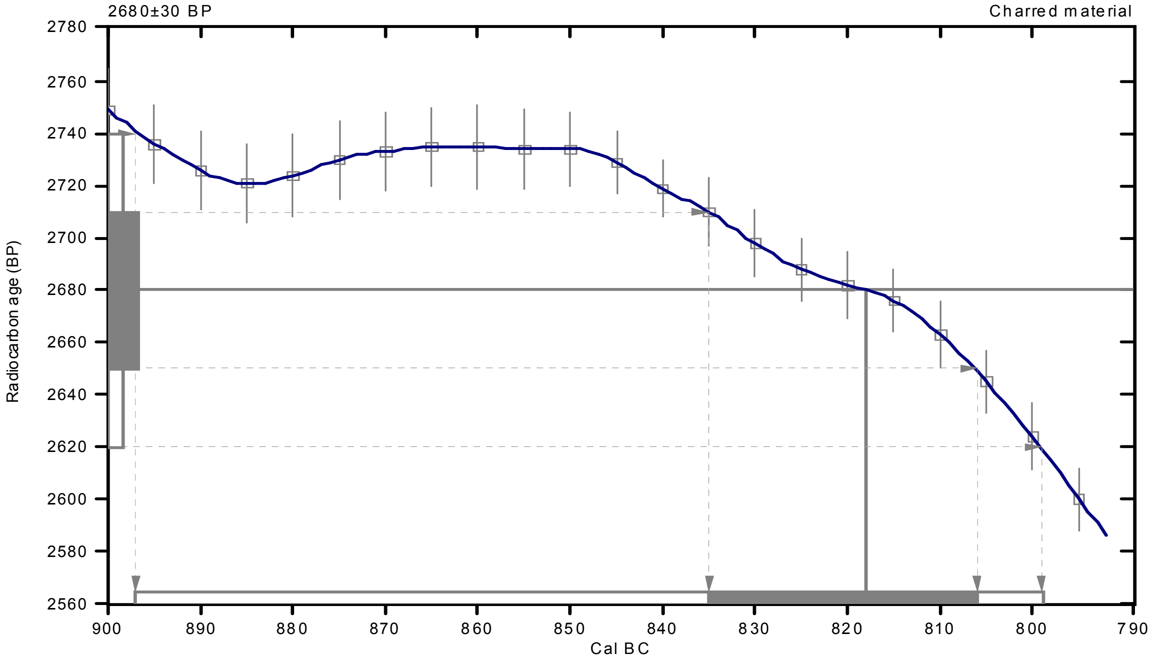
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-23.6:lab. mult=1)

Laboratory number:	**Beta-307891**
Conventional radiocarbon age:	**2680±30 BP**
2 Sigma calibrated result: **(95% probability)**	**Cal BC 900 to 800 (Cal BP 2850 to 2750)**

Intercept data

Intercept of radiocarbon age with calibration curve:	Cal BC 820 (Cal BP 2770)
1 Sigma calibrated result: (68% probability)	Cal BC 840 to 810 (Cal BP 2780 to 2760)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-23.6:lab. mult=1)

Laboratory number: **Beta-307892**

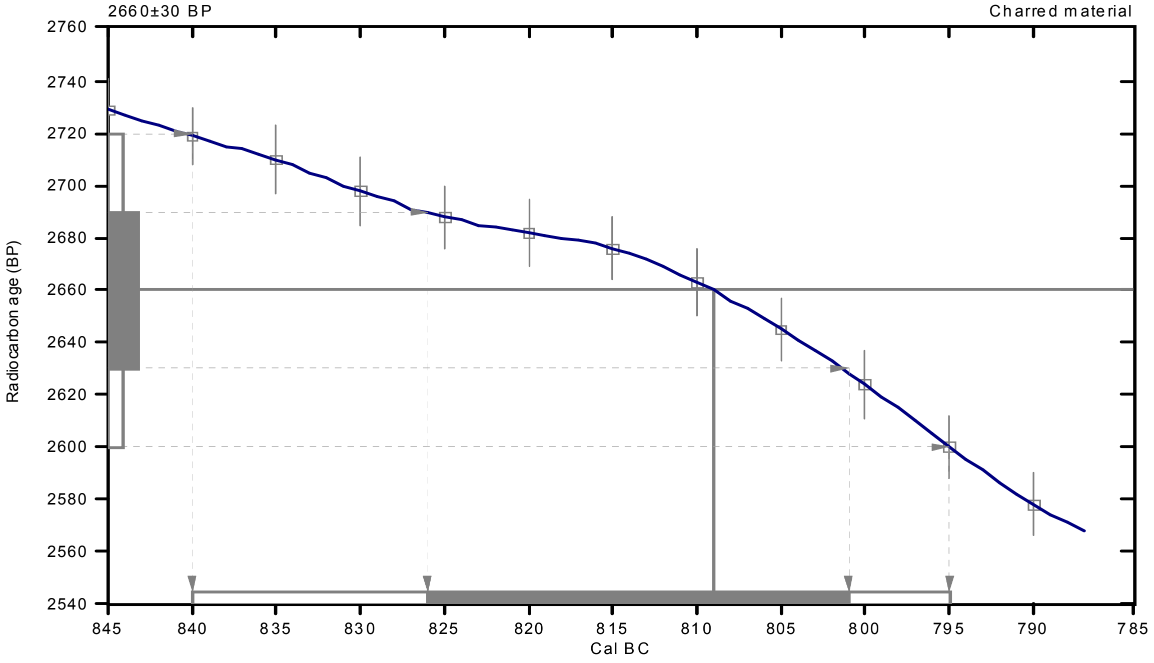
Conventional radiocarbon age: **2660±30 BP**

2 Sigma calibrated result: **Cal BC 840 to 800 (Cal BP 2790 to 2740)**
(95% probability)

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal BC 810 (Cal BP 2760)

1 Sigma calibrated result: Cal BC 830 to 800 (Cal BP 2780 to 2750)
(68% probability)



References:

Database used
INTCAL09
References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

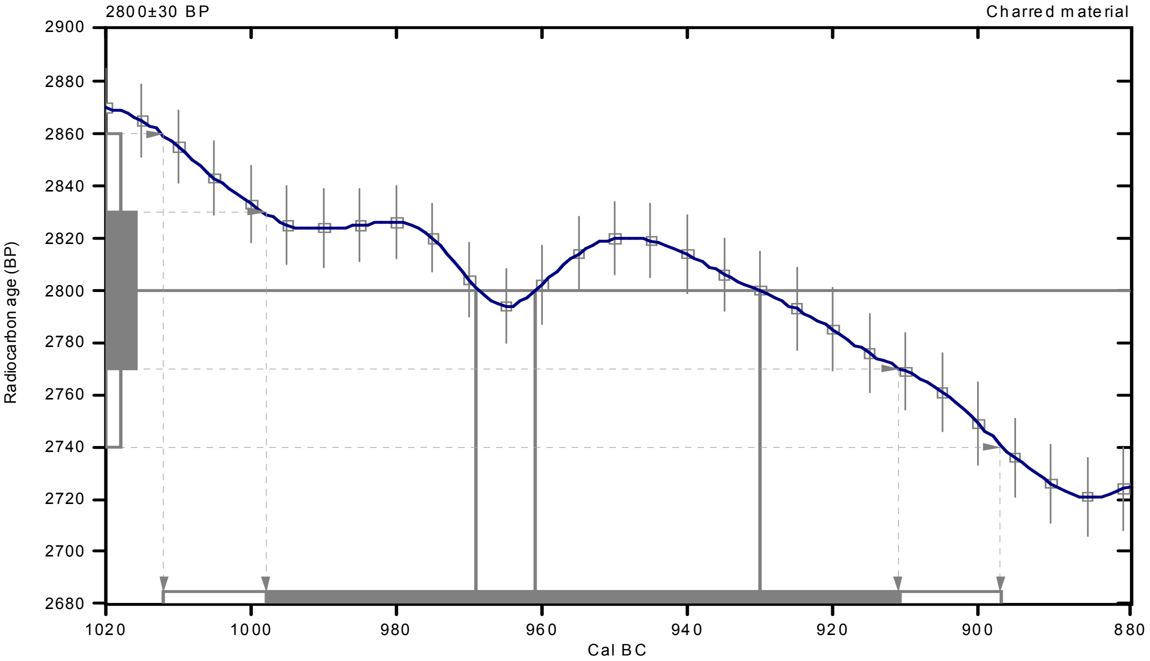
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-24.1:lab. mult=1)

Laboratory number:	**Beta-307893**
Conventional radiocarbon age:	**2800±30 BP**
2 Sigma calibrated result: (95% probability)	**Cal BC 1010 to 900 (Cal BP 2960 to 2850)**

Intercept data

Intercepts of radiocarbon age with calibration curve:	Cal BC 970 (Cal BP 2920) and Cal BC 960 (Cal BP 2910) and Cal BC 930 (Cal BP 2880)
1 Sigma calibrated result: (68% probability)	Cal BC 1000 to 910 (Cal BP 2950 to 2860)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

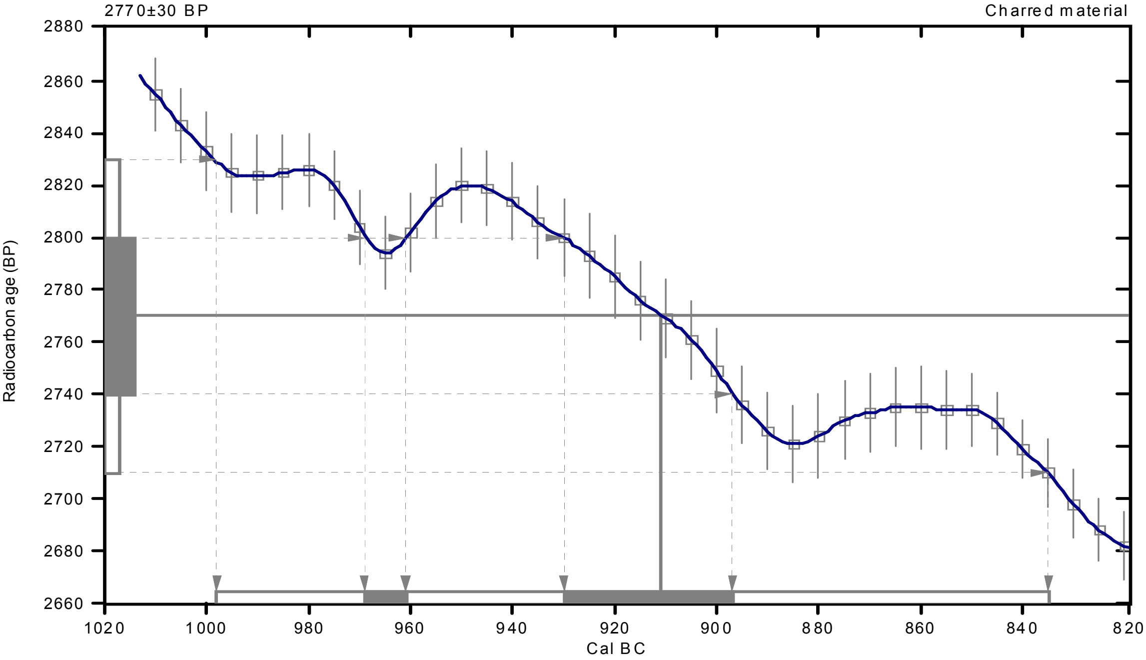
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-24.4:lab. mult=1)

Laboratory number:	**Beta-307894**
Conventional radiocarbon age:	**2770±30 BP**
2 Sigma calibrated result: **(95% probability)**	**Cal BC 1000 to 840 (Cal BP 2950 to 2780)**

Intercept data

Intercept of radiocarbon age with calibration curve:	Cal BC 910 (Cal BP 2860)
1 Sigma calibrated results: (68% probability)	Cal BC 970 to 960 (Cal BP 2920 to 2910) and Cal BC 930 to 900 (Cal BP 2880 to 2850)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

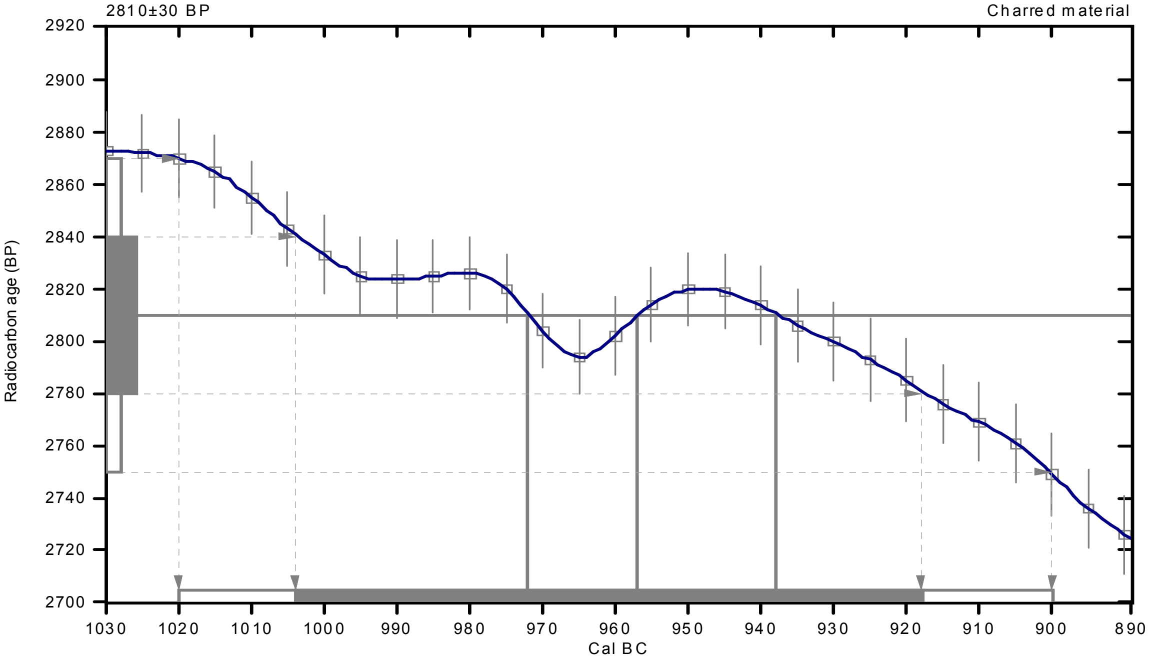
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25.1:lab. mult=1)

Laboratory number:	**Beta-307895**
Conventional radiocarbon age:	**2810±30 BP**
2 Sigma calibrated result: (95% probability)	**Cal BC 1020 to 900 (Cal BP 2970 to 2850)**

Intercept data

Intercepts of radiocarbon age with calibration curve:	Cal BC 970 (Cal BP 2920) and Cal BC 960 (Cal BP 2910) and Cal BC 940 (Cal BP 2890)
1 Sigma calibrated result: (68% probability)	Cal BC 1000 to 920 (Cal BP 2950 to 2870)



References:

Database used
INTCAL09
References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

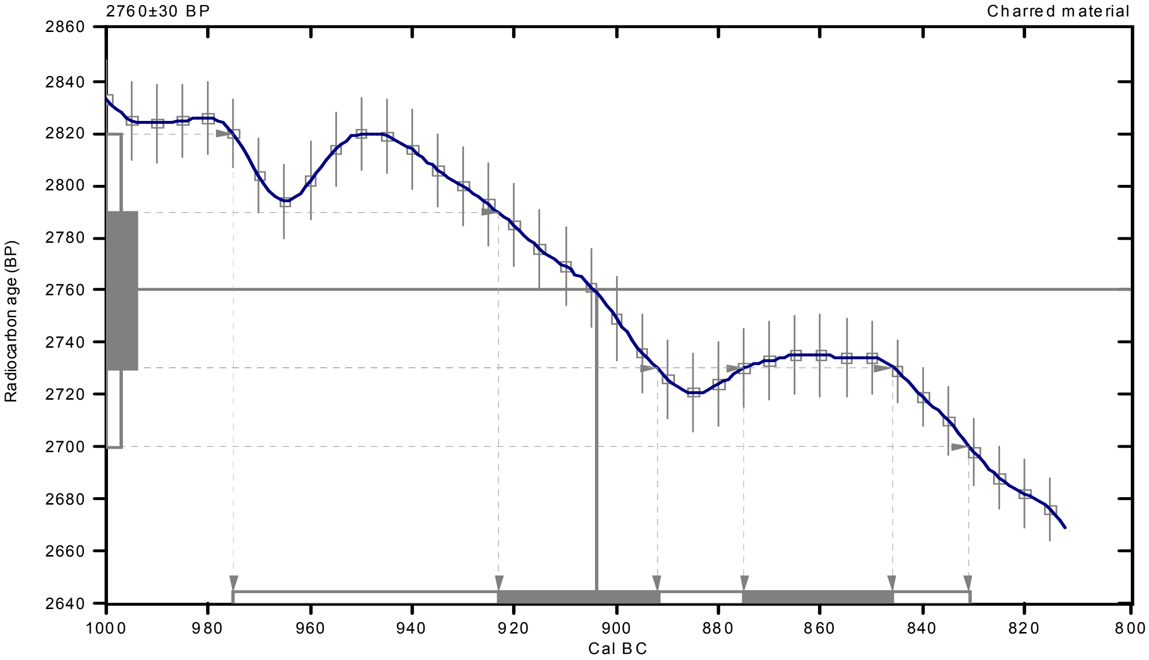
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-24.5:lab. mult=1)

Laboratory number:	**Beta-307896**
Conventional radiocarbon age:	**2760±30 BP**
2 Sigma calibrated result: **(95% probability)**	**Cal BC 980 to 830 (Cal BP 2920 to 2780)**

Intercept data

Intercept of radiocarbon age with calibration curve:	Cal BC 900 (Cal BP 2850)
1 Sigma calibrated results: (68% probability)	Cal BC 920 to 890 (Cal BP 2870 to 2840) and Cal BC 880 to 850 (Cal BP 2820 to 2800)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

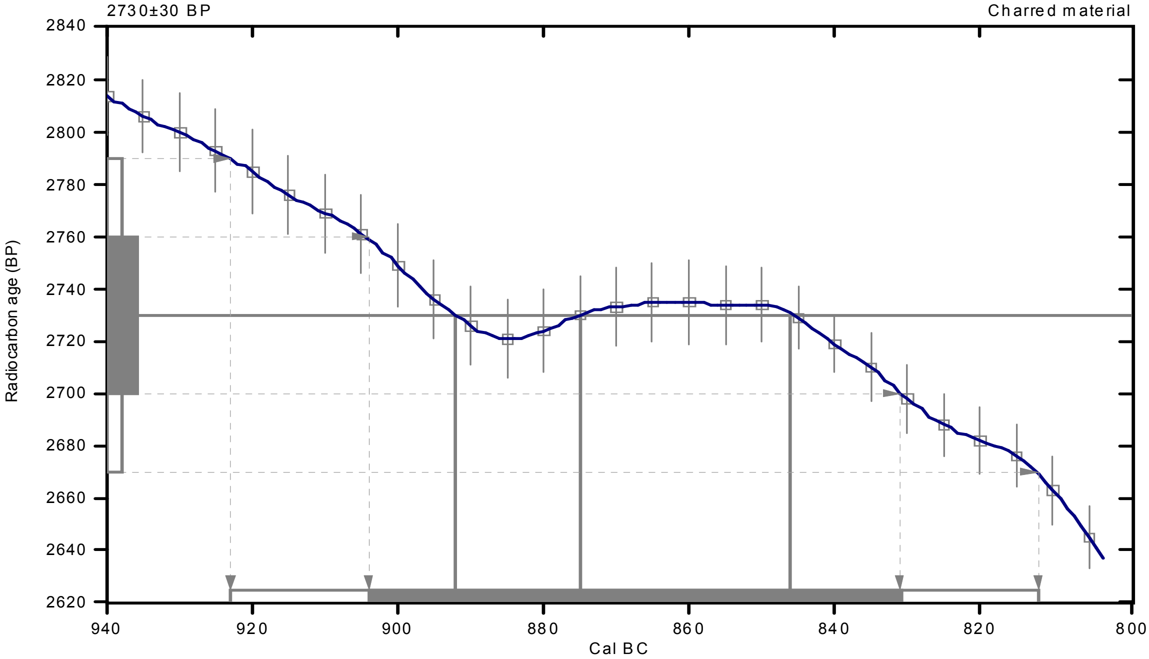
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-23.9:lab. mult=1)

Laboratory number:	**Beta-307897**
Conventional radiocarbon age:	**2730±30 BP**
2 Sigma calibrated result: (95% probability)	**Cal BC 920 to 810 (Cal BP 2870 to 2760)**

Intercept data

Intercepts of radiocarbon age with calibration curve:	Cal BC 890 (Cal BP 2840) and Cal BC 880 (Cal BP 2820) and Cal BC 850 (Cal BP 2800)
1 Sigma calibrated result: (68% probability)	Cal BC 900 to 830 (Cal BP 2850 to 2780)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-23.3:lab. mult=1)

Laboratory number: **Beta-307898**

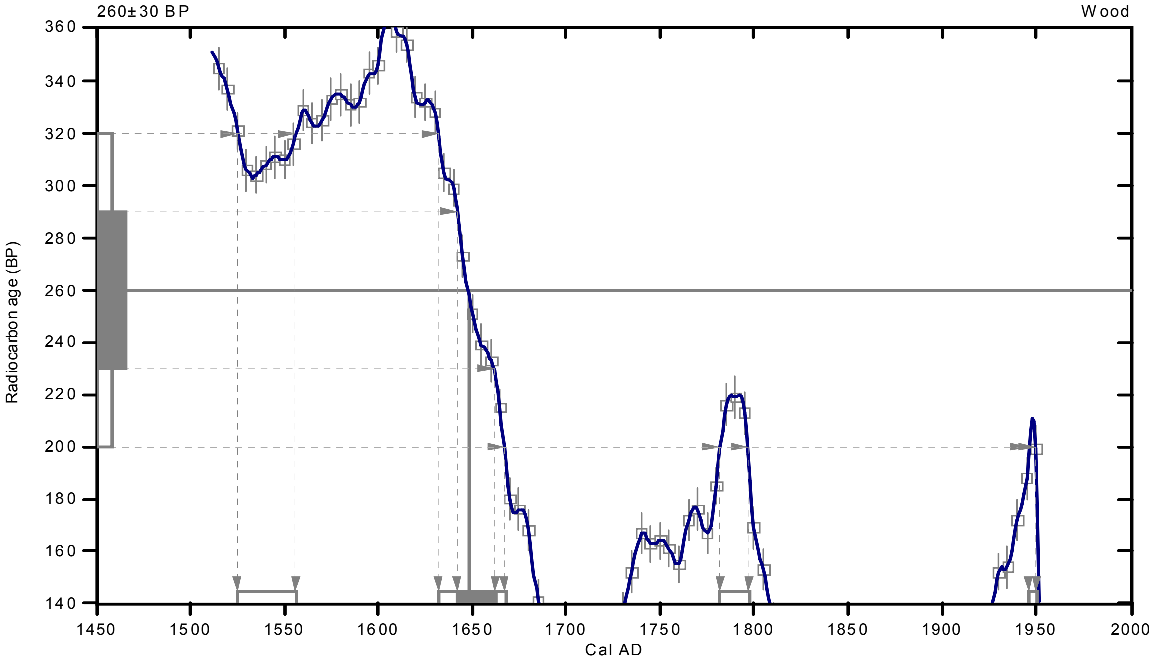
Conventional radiocarbon age: **260±30 BP**

2 Sigma calibrated results: **Cal AD 1520 to 1560 (Cal BP 420 to 390) and**
(95% probability) **Cal AD 1630 to 1670 (Cal BP 320 to 280) and**
Cal AD 1780 to 1800 (Cal BP 170 to 150) and
Cal AD 1950 to 1950 (Cal BP 0 to 0)

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal AD 1650 (Cal BP 300)

1 Sigma calibrated result: Cal AD 1640 to 1660 (Cal BP 310 to 290)
(68% probability)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-24.4:lab. mult=1)

Laboratory number: **Beta-307899**

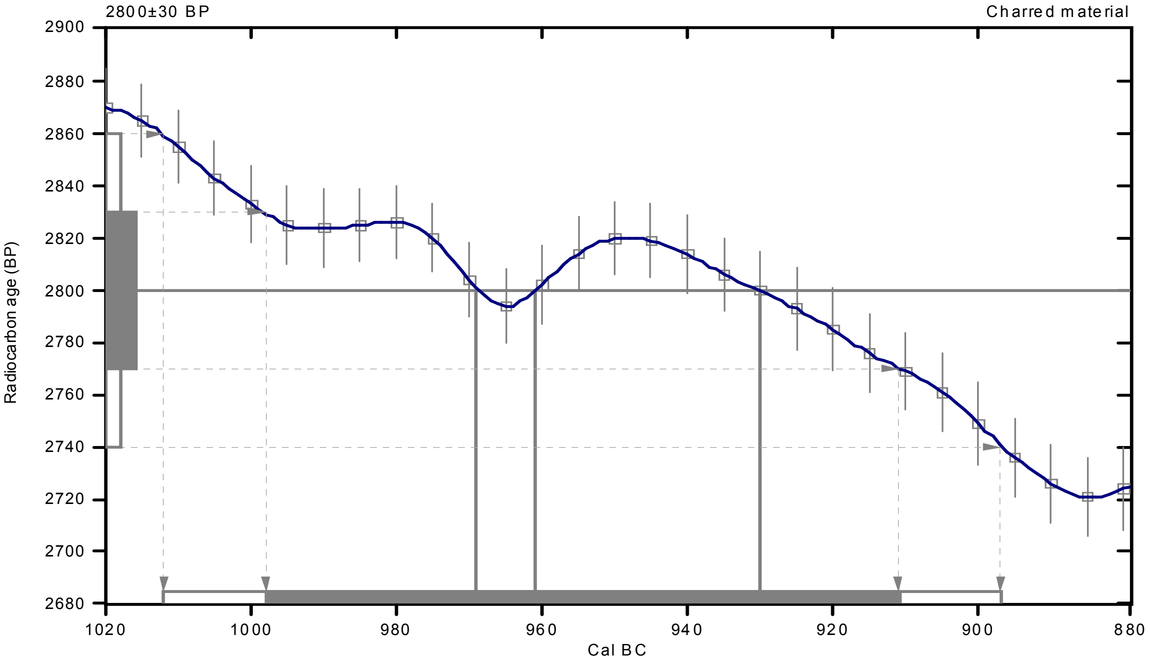
Conventional radiocarbon age: **2800±30 BP**

2 Sigma calibrated result: (95% probability) **Cal BC 1010 to 900 (Cal BP 2960 to 2850)**

Intercept data

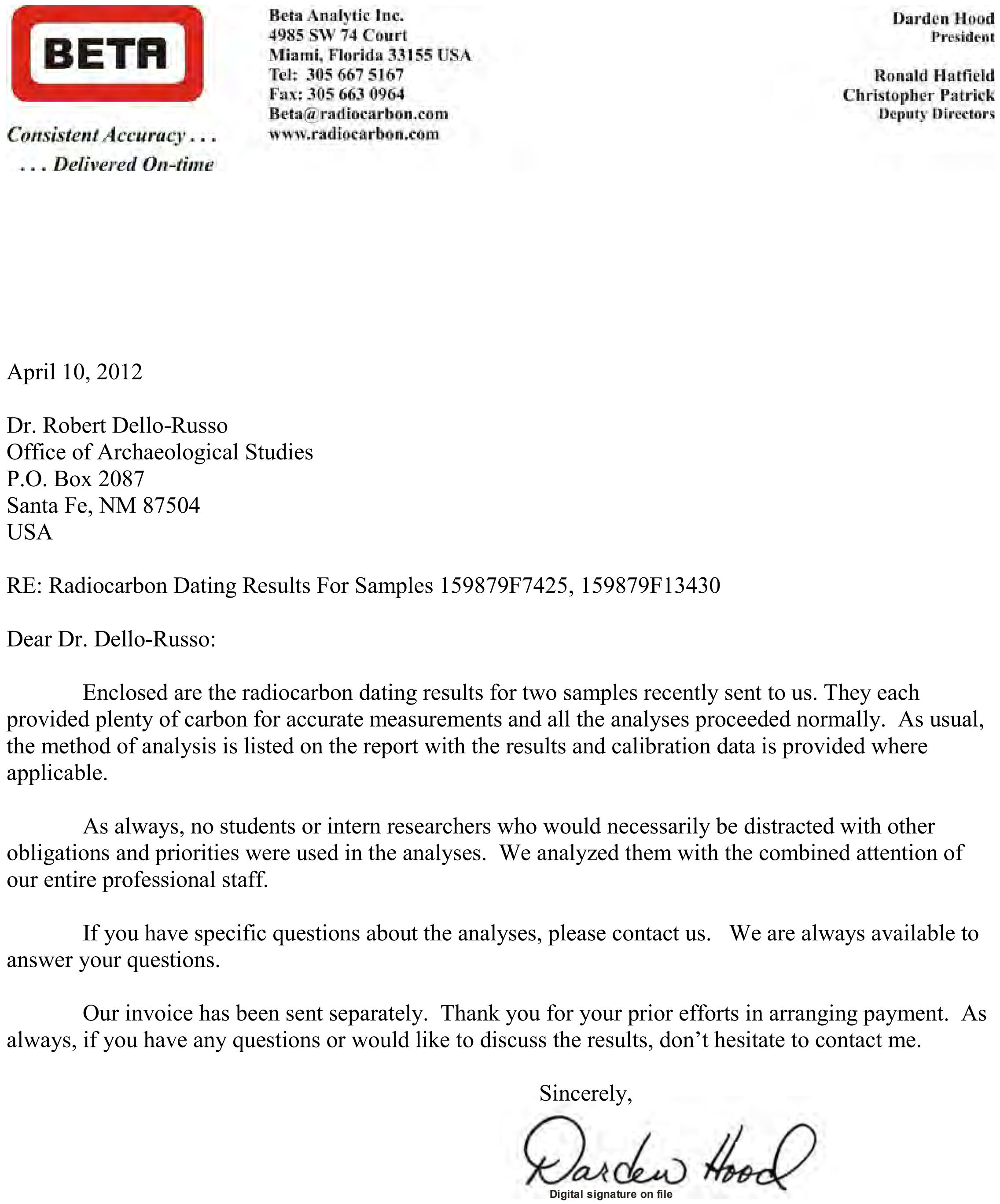
Intercepts of radiocarbon age with calibration curve:
Cal BC 970 (Cal BP 2920) and
Cal BC 960 (Cal BP 2910) and
Cal BC 930 (Cal BP 2880)

1 Sigma calibrated result: (68% probability) Cal BC 1000 to 910 (Cal BP 2950 to 2860)



References:

Database used
INTCAL09
References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322



BETA
Consistent Accuracy . . .
. . . Delivered On-time

Beta Analytic Inc.
4985 SW 74 Court
Miami, Florida 33155 USA
Tel: 305 667 5167
Fax: 305 663 0964
Beta@radiocarbon.com
www.radiocarbon.com

Darden Hood
President

Ronald Hatfield
Christopher Patrick
Deputy Directors

April 10, 2012

Dr. Robert Dello-Russo
Office of Archaeological Studies
P.O. Box 2087
Santa Fe, NM 87504
USA

RE: Radiocarbon Dating Results For Samples 159879F7425, 159879F13430

Dear Dr. Dello-Russo:

Enclosed are the radiocarbon dating results for two samples recently sent to us. They each provided plenty of carbon for accurate measurements and all the analyses proceeded normally. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable.

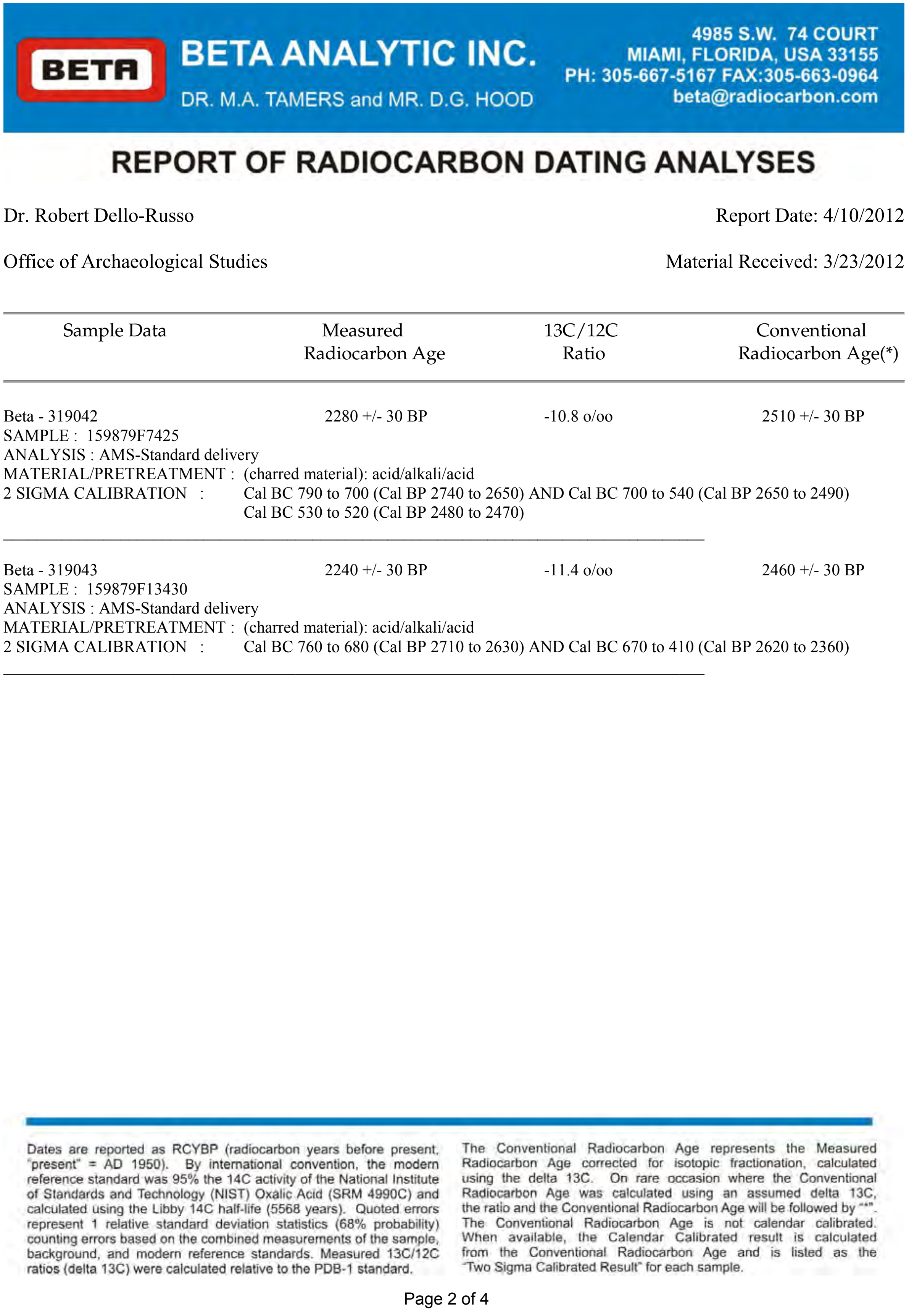
As always, no students or intern researchers who would necessarily be distracted with other obligations and priorities were used in the analyses. We analyzed them with the combined attention of our entire professional staff.

If you have specific questions about the analyses, please contact us. We are always available to answer your questions.

Our invoice has been sent separately. Thank you for your prior efforts in arranging payment. As always, if you have any questions or would like to discuss the results, don't hesitate to contact me.

Sincerely,

Darden Hood
Digital signature on file



BETA
BETA ANALYTIC INC.
DR. M.A. TAMERS and MR. D.G. HOOD
4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305-667-5167 FAX:305-663-0964
beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Dr. Robert Dello-Russo — Report Date: 4/10/2012

Office of Archaeological Studies — Material Received: 3/23/2012

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 319042	2280 +/- 30 BP	-10.8 o/oo	2510 +/- 30 BP

SAMPLE : 159879F7425
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal BC 790 to 700 (Cal BP 2740 to 2650) AND Cal BC 700 to 540 (Cal BP 2650 to 2490)
Cal BC 530 to 520 (Cal BP 2480 to 2470)

Beta - 319043	2240 +/- 30 BP	-11.4 o/oo	2460 +/- 30 BP

SAMPLE : 159879F13430
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal BC 760 to 680 (Cal BP 2710 to 2630) AND Cal BC 670 to 410 (Cal BP 2620 to 2360)

Dates are reported as RCYBP (radiocarbon years before present, "present" = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (SRM 4990C) and calculated using the Libby 14C half-life (5568 years). Quoted errors represent 1 relative standard deviation statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (delta 13C) were calculated relative to the PDB-1 standard.

The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotopic fractionation, calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by "*". The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-10.8:lab. mult=1)

Laboratory number: **Beta-319042**

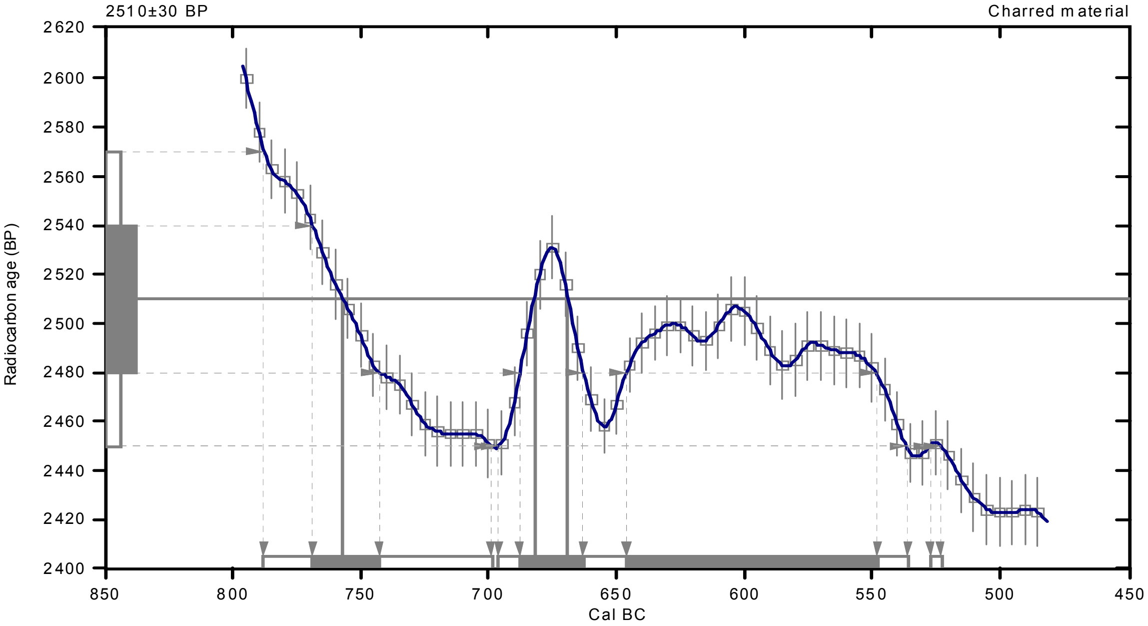
Conventional radiocarbon age: **2510±30 BP**

2 Sigma calibrated results: **Cal BC 790 to 700 (Cal BP 2740 to 2650) and**
(95% probability) **Cal BC 700 to 540 (Cal BP 2650 to 2490) and**
Cal BC 530 to 520 (Cal BP 2480 to 2470)

Intercept data

Intercepts of radiocarbon age
with calibration curve: Cal BC 760 (Cal BP 2710) and
Cal BC 680 (Cal BP 2630) and
Cal BC 670 (Cal BP 2620)

1 Sigma calibrated results: Cal BC 770 to 740 (Cal BP 2720 to 2690) and
(68% probability) Cal BC 690 to 660 (Cal BP 2640 to 2610) and
Cal BC 650 to 550 (Cal BP 2600 to 2500)



References:
Database used
INTCAL09
References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-11.4:lab. mult=1)

Laboratory number: **Beta-319043**

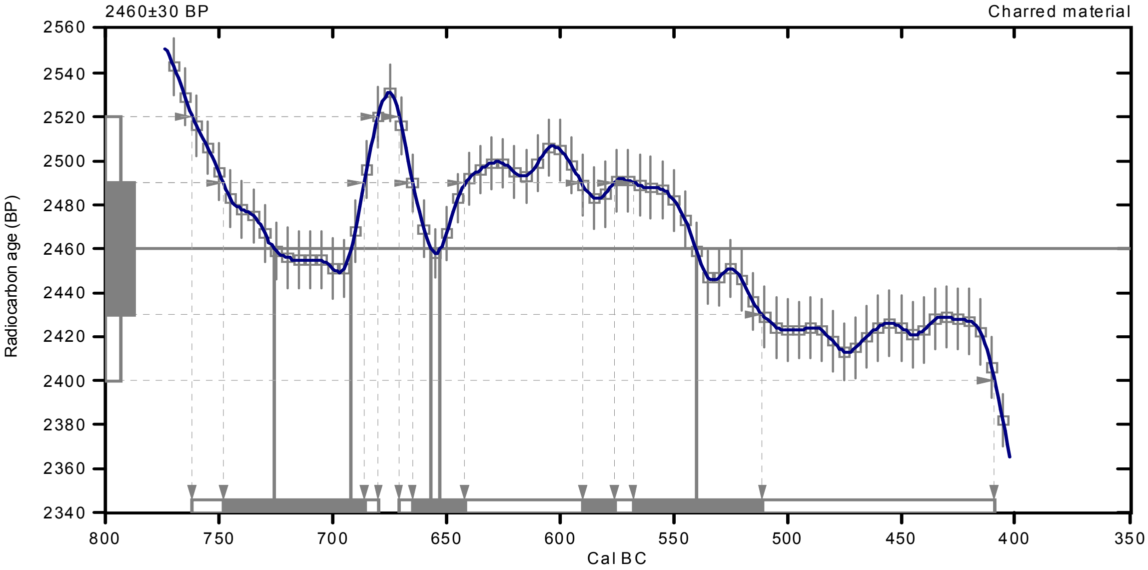
Conventional radiocarbon age: **2460±30 BP**

2 Sigma calibrated results: **Cal BC 760 to 680 (Cal BP 2710 to 2630) and**
(95% probability) **Cal BC 670 to 410 (Cal BP 2620 to 2360)**

Intercept data

Intercepts of radiocarbon age
with calibration curve: Cal BC 730 (Cal BP 2680) and
Cal BC 690 (Cal BP 2640) and
Cal BC 660 (Cal BP 2610) and
Cal BC 650 (Cal BP 2600) and
Cal BC 540 (Cal BP 2490)

1 Sigma calibrated results: Cal BC 750 to 690 (Cal BP 2700 to 2640) and
(68% probability) Cal BC 660 to 640 (Cal BP 2620 to 2590) and
Cal BC 590 to 580 (Cal BP 2540 to 2530) and
Cal BC 570 to 510 (Cal BP 2520 to 2460)



References:
Database used
INTCAL09
References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150,
Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

Appendix 3: Pollen, Phytolith, and Starch Grain Analysis

Linda Scott Cummings and Chad Yost

Appendix 3

Pollen, Phytolith, and Starch Grain Analysis of Feature Fill and Ground Stone Tools from Site LA 159879, Luna County, New Mexico

by
Linda Scott Cummings and Chad Yost

with assistance from
R. A. Varney

PaleoResearch Institute
Golden, Colorado

PaleoResearch Institute Technical Report 11-149

Prepared for
Museum of New Mexico
Office of Archaeological Studies
Santa Fe, New Mexico

February 2012

INTRODUCTION

Feature fill sediment samples and groundstone tools from site LA 159879, Luna County, New Mexico, were submitted for various combinations of pollen, phytolith, and starch grain analysis. Archaeological field investigations at LA 159879 suggest that the site represents the remains of a Late Archaic/Early Agricultural period base camp. The camp is located on the Deming Flood Plain inside the greater Mimbres Bolson. This analysis was undertaken to recover and identify microbotanical remains of plants associated with site LA 159879 feature and tool use.

METHODS

Pollen

A chemical extraction technique based on flotation is the standard preparation technique used in this laboratory for removing pollen grains from the large volume of sand, silt, and clay with which they are mixed. This particular process was developed for extracting pollen from soils where preservation has been less than ideal and pollen density is lower than in peat.

Hydrochloric acid (10%) was used to remove calcium carbonates present in the soil, after which the samples were screened through 250-micron mesh. The samples were rinsed until neutral by adding water, letting the samples stand for 2 hours, then pouring off the supernatant. A small quantity of sodium hexametaphosphate was added to each sample once it reached neutrality, then the samples were allowed to settle according to Stoke's Law in settling columns. This process was repeated with ethylenediaminetetraacetic acid (EDTA). These steps remove clay prior to heavy liquid separation. The samples were then freeze dried. Sodium polytungstate (SPT), with a density of 1.8 g/ml, was used for the flotation process. The samples were mixed with SPT and centrifuged at 1500 rpm for 10 minutes to separate organic from inorganic remains. The supernatant containing pollen and organic remains was decanted. Sodium polytungstate was added a second time to the inorganic fraction to repeat the separation process. The supernatant was decanted into the same tube as the supernatant from the first separation. This supernatant then was centrifuged at 1500 rpm for 10 minutes to allow any silica recovered during the process to be separated from the organics. Following this, the supernatant was decanted into a 50-ml conical tube and diluted with reverse osmosis de-ionized (RODI) water. These samples were centrifuged at 3000 rpm to concentrate the organic fraction in the bottom of the tube. This pollen-rich organic fraction was rinsed, then all samples received a short (20–30 minute) treatment in hot hydrofluoric acid (HF) to remove any remaining inorganic particles. The samples were acetylated for 3–5 minutes to remove any extraneous organic matter.

A light microscope was used to count the pollen at a magnification of 500x. The pollen preservation in these samples varied from good to poor, although most of the pollen was well-preserved. Comparative reference material collected at the Intermountain Herbarium at Utah State University and the University of Colorado Herbarium was used to identify the pollen to the family, genus, and species level, where possible.

Pollen aggregates were recorded during identification of the pollen. Aggregates are clumps of a single type of pollen, and may be interpreted to represent either pollen dispersal over short distances, or the introduction of portions of the plant represented into an archaeological setting. The aggregates were included in the pollen counts as single grains, as is customary. The presence of aggregates is noted by an "A" next to the pollen frequency on the pollen diagram. For most of the samples a plus sign (+) on the pollen diagram indicates that the pollen type was observed outside the regular count while scanning the remainder of the microscope slide. Pollen diagrams were produced using Tilia 2.0 and TGView 2.0.2. Total pollen concentrations were calculated in Tilia using the quantity of sample processed in cubic centimeters (cc), the quantity of exotics (spores) added to the sample, the quantity of exotics counted, and the total pollen counted and expressed as pollen per cc of sediment.

"Indeterminate" pollen includes pollen grains that are folded, mutilated, or otherwise distorted beyond recognition. These grains are included in the total pollen count, as they are part of the pollen record. The microscopic charcoal frequency registers the relationship between pollen and charcoal. The total number of microscopic charcoal fragments was divided by the pollen sum, resulting in a charcoal frequency that reflects the quantity of microscopic charcoal fragments observed, normalized per 100 pollen grains.

The use of ground stone in processing plants and animals can leave evidence on the artifact surface. Concentrations of pollen, starches, and/or phytoliths from the artifact surfaces may represent plants that were processed using the tools.

All visible dirt was removed, then the surfaces were cleaned using pressurized air to remove any modern contaminants. The ground surfaces were washed with a 0.5% Triton X-100 solution to recover any pollen and starches. The surface was scrubbed with an ultrasonic toothbrush and rinsed thoroughly with distilled water. The resulting liquid was saved and processed in a manner similar to the soil samples. For the groundstone sampled (425) a plus sign (+) on the pollen diagram indicates that pollen was observed, in spite of the fact that pollen was not present in a sufficient concentration to obtain a full count.

Pollen analysis also included examination for starch granules and, if they were present, their assignment to general categories. Starch granules are a plant's mechanism for storing carbohydrates. Starches are found in numerous seeds, as well as in starchy roots and tubers. The primary categories of starches include the following: with or without visible hila, hilum centric or eccentric, hila patterns (dot, cracked, elongated), and shape of starch (angular, ellipse, circular, eccentric). Some of these starch categories are typical of specific plants, while others are more common and tend to occur in many different types of plants.

Phytolith and Starch Extraction from Sediment

Extraction of phytolith and starch grains from these sediments was based on heavy liquid floatation. Hydrochloric acid (HCl) was first used to remove calcium carbonates and iron oxides from 30 ml of sediment for each sample. Next, 70% nitric acid was added to each sample and heated to near boiling for 1 hour to destroy much of the organic fraction. Once this reaction was complete, the samples were rinsed to neutral with water. Next, a 10% solution of ethylenediaminetetraacetic acid (EDTA) was added to each sample and throughly mixed. EDTA aids in the removal of organic humic substances and microscopic charcoal particles not removed by the nitric acid step. Next, a 5% solution of sodium hexametaphosphate was added to each sample to suspend the clay fraction. The clays were removed by decanting the supernatant after a two hour gravity settling period. This step was repeated every two hours until the supernatant was clear. Once most of the clays were removed, the silt and sand size fraction was dried under vacuum. The dried silts and sands were then mixed with sodium polytungstate (SPT, density 2.3 g/ml) and centrifuged to separate the phytoliths, which will float, from most of the inorganic silica fraction, which will not. Because a lot of silt-sized inorganic silica was floated with SPT, each sample was again dried under vacuum and then mixed with potassium cadmium iodide (density 2.3 g/ml) to repeat the flotation process. The addition of potassium cadmium iodide greatly improved the recovery and concentration of the phytolith fraction, without which, many of the samples would not have been countable. However, at this point there were still a lot of platy mineral particles (50 to 250 µm in size) that floated in the heavy liquid, severely obscuring the phytolith record. Therefore, the samples were sieved with a 50 µm screen, greatly improving the countability of these samples. Lastly, the samples were rinsed with alcohol to remove any remaining water, and then mounted in optical immersion oil for counting with a light microscope at a magnification of 500x. An initial phytolith count of 100 was conducted, then the entirety of the slide was scanned for starch grains, as well as phytoliths of economic significance. A phytolith diagram was produced using Tilia 2.0 and TGView 2.0.2.

Phytolith and Starch Extraction from Ground Stone

The extraction of phytoliths and starch grains from the surfaces of the ground stone artifacts was based primarily on a phytolith extraction method, with alterations that minimized exposure to oxidizing chemicals to preserve the starch. First, a sonicating toothbrush and a mild detergent (5% Triton X-100) were used to facilitate release of microscopic residue particles adhering to the ground stone surface. Each sample was rinsed thoroughly and centrifuged using short-duration spins (10 seconds at 3000 rpm) to remove clay particles. Next, the samples were frozen and dried under vacuum. The dried samples were then mixed with potassium cadmium iodide (density 2.3 g/ml) and centrifuged to separate the microfossils, which will float, from most of the inorganic silica fraction, which will not. Because a significant portion of microscopic organic matter was recovered that hindered microfossil observation, nitric acid was added to each sample. After one hour, the samples were rinsed to neutral with water and then a final alcohol rinse. Next, the samples were mounted in optical immersion oil for counting with a light microscope at a magnification of 500x. An initial phytolith count of 100 was conducted, then the entirety of the slide was scanned for starch grains, as well as phytoliths of economic significance. Diatoms and sponge spicules, organisms with silica shells, were also noted. A phytolith/starch diagram was produced using Tilia 2.0 and TGView 2.0.2.

ETHNOBOTANIC REVIEW

It is a commonly accepted practice in archaeological studies to reference ethnographically documented plant uses as indicators of possible or even probable plant uses in prehistoric times. The ethnobotanic literature provides evidence for the exploitation of numerous plants in historic times, both by broad categories and by specific example. The presence of numerous sources of evidence for exploitation of a given resource can suggest widespread utilization and strengthens the possibility that the same or similar resources were used in prehistoric times. Ethnographic sources both inside and outside the study area have been consulted to permit a more exhaustive review of potential uses for each plant. Ethnographic sources document that the historic use of some plants was a carryover from the past. A plant with medicinal qualities is likely to have been discovered in prehistoric times, with its use persisting into historic times. There is, however, likely to have been a loss of knowledge concerning the utilization of plant resources as cultures moved from subsistence to agricultural economies and/or were introduced to European foods during the historic period. The ethnobotanic literature serves only as a guide indicating that the potential for use existed in prehistoric times, not as conclusive evidence that the resources were if fact used. Pollen, phytoliths, starch, and macrofloral remains, when compared with the material culture (artifacts and features) recovered by the archaeologists, can become indicators of use. Plants represented by pollen, phytoliths, and/or starches will be discussed in the following paragraphs to provide an ethnobotanic background for discussing the remains.

Native Plants

Acer negundo (Box Elder)

Acer negundo (box elder) is one of the maples. There are several varieties of Western box elder that range in size from shrubs to small trees. It is a quick-growing tree with soft, white wood. The trifoliate leaves often resemble those of poison ivy or poison oak. Box elder produces a sweet sap that was sometimes tapped by native groups to make a sweet syrup. *Acer negundo* can be found in the pinyon/juniper belt of the Southwestern United States in valleys, canyons, the foothills of the Rocky Mountains, along streams, and in moist places (Elmore 1976:46; Peattie 1953:613–615; Petrides and Petrides 1992:87).

Brassicaceae (Mustard Family)

Several members of the Brassicaceae (mustard) family, such as *Arabis* (rockcress), *Descurainia* (Tansy-mustard), *Dithyrea* (spectacle-pod), *Draba* (whitlowgrass), *Erysimum* (Western-wallflower), *Lepidium* (pepperweed), *Rorippa* (cress), and *Thlaspi fendleri* (wild-candytuft) are noted to have been exploited for food, medicinal resources, and for ceremonial purposes. Fresh greens were used as potherbs, and the parched and ground seeds were used to make a flour, thicken soup, and to make pinole. Brassicaceae seeds ripen in early summer (Fernald 1950; Harrington 1967; Kearney and Peebles 1960; Kirk 1975; Vestal 1952:28–29).

Cheno-ams (Goosefoot Family and Amaranth)

Cheno-ams refer to a group representing the Chenopodiaceae (goosefoot) family and the genus *Amaranthus* (pigweed). These plants are weedy annuals or perennials, often growing in disturbed areas such as cultivated fields and site vicinities. Cheno-ams, including a variety of plants such as *Amaranthus, Atriplex, Chenopodium, Monolepsis,* and *Suaeda*, are noted to have been used as food and for processing other foods. These plants were exploited for both their greens (cooked as potherbs) and seeds. The seeds were eaten raw or ground and used to make pinole and/or sometimes mixed with cornmeal to make a variety of mushes and cakes. The seeds usually are noted to have been parched prior to grinding. The greens are most tender when young, in the spring, but can be used at any time. The greens can be harvested and cooked either alone or with other foods. Various parts of the Cheno-am plants are noted to have been gathered from early spring through the fall (Castetter and Bell 1942:61; Curtin 1984:47–71; Kearney and Peebles 1960; Kirk 1975).

Amaranthus (Amaranth, Pigweed)

Amaranthus (amaranrth, pigweed) leaves were an important source of iron. The greens are most tender when young, in the spring, but can be used at any time. The greens can be harvested and cooked either alone or with other foods. The leaves are noted to have been fried sometimes after being boiled. The plant also was used medicinally. *Amaranthus* poultices were used to reduce swellings and to soothe aching teeth. A leaf tea was used to stop bleeding, and to treat dysentery, ulcers, diarrhea, mouth sores, sore throats, and hoarseness (Angier 1978:33–35; Foster and Duke 1990:216; Harris 1972:58; Kirk 1975:63; Krochmal and Krochmal 1973:34–35; Moore 1990:12; Muenscher 1987:192–195; Robbins, et al. 1916:53).

Atriplex (Saltbush)

Atriplex (saltbush) leaves and young shoots have a salty taste and were cooked as greens or added to meat and other vegetables for its salty flavor. The leaves also were boiled in water, then strained and fried in grease. Leaves were rubbed in water to produce a lather for washing clothes and baskets. The dried tops of *A.*

canescens (four-wing saltbush) were used to make a tea for treating nausea and vomiting from the flu. A hot tea was taken for breaking fevers, while a cold tea is used to treat stomachs (Moore 1990:29). The Hopi used ashes of *A. canescens* as a substitute for baking powder. The Tewa at Hano are noted to have used saltbush ashes to color cornmeal (Robbins, et al. 1916:54). *Atriplex* ashes also were used to make hominy. *Atriplex* leaves, twigs, and blossoms yielded a bright yellow dye (Bryan and Young 1978:32). The wood was a source of firewood (Curtin 1984:66–69; Kearney and Peebles 1960:225; Whiting 1939:18, 22, 73). *Atriplex* are annual or perennial, herbaceous or shrubby plants found in arid, alkaline, or saline soil (Kirk 1975:59).

Chenopodium (Goosefoot, Lamb's Quarters)

The tiny flowers of *Chenopodium* (goosefoot) grow in clusters and can produce tens of thousands of seeds per plant. *Chenopodium* "seeds are about equal to corn in the number of calories they contain, but have significantly more protein and fat (Asch 1978:307). The cooked greens contain more than three times as much calcium as cooked spinach and also have more vitamin A and C (Watt and Merrill 1963:37, 59)" (Kindscher 1987:82). *Chenopodium* was used to season beans. *Chenopodium* also was used medicinally. Leaves were eaten to treat stomachaches and to prevent scurvy. Leaf poultices were applied to burns and swellings, and a tea made from the whole plant was used to treat diarrhea. A leaf decoction was used as a bath for rheumatism. Oil of *Chenopodium* is obtained from *C. ambrosioides* (wormseed goosefoot), which is a good cure for intestinal worms *Chenopodium* is a weedy annual commonly found in ecologically disturbed habitats. It is an opportunistic weed, often establishing itself rapidly in disturbed areas (Angier 1978:33–35; Burlage 1968:29–31; Foster and Duke 1990:216; Harris 1972:58; Kindscher 1987:79–83; Kirk 1975:56, 63; Krochmal and Krochmal 1973:66–67; Moore 1990:42; Sweet 1976:48).

Cyperaceae (Sedge Family)

The Cyperaceae (sedge family) are grasslike or rushlike herbaceous plants commonly found in riparian habitats. Several members are noted to have been important resources for Native Americans. Many species of *Cyperus* (flatsedge, nutgrass) have a tuber-like thickening at the base of the plant or possess tubers at the end of slender rootstalks. These tubers were eaten raw, boiled, dried and ground into a flour, or baked in a fire. The nut-like roots also can be roasted until dark brown and ground to make coffee. The seeds of *Cyperus odoratus*, as reported by E. Palmer, are reported to have been eaten by the Cocopah Indians, while the Apache are noted to have eaten the underground parts of *Cyperus fendlerianus*. The Pima are reported to have eaten the small tubers of *Cyperus ferax. Cyperus esculentus* is noted to have been a famous plant food since ancient Egyptian times. Fresh or dried tubers were chewed by the Pima to treat coughs of *Cyperus esculentus* for coughs. *Cyperus* is a grass-like perennial found in moist ground, especially in damp sandy soil and waste places, and can be common weeds in cultivated fields and pastures (Harrington 1967:174; Kearney and Peebles 1960:98–99, 149–150; Kirk 1975:176; Peterson 1977:230). *Eleocharis* (spikerush) is an annual with round, grooved, and spiked sheathing and a bulb-like base. *Eleocharis* bulbs can be eaten raw or cooked. Medicinal uses of *Eleocharis* include as an analgesic, anti-diarrheal, urinary aid, and a ceremonial emetic. Stems and leaves were used for making beads, pillows and bedding, baskets and woven dishes, cooking tools, toys, and games (Hickman 1993:1140; Moerman 1998:208). *Scirpus*-type (bulrush, tule) plants are mostly perennial herbs with triangular or circular stems. Recent studies by taxonomists have resulted in the creation of several new genera, such as *Amphiscirpus*, *Bolboshoenus*, *Isolepis*, *Shoenoplectus*, and others. At one point, the *Scirpus* genus held almost 300 species, but many of the species once assigned to this genus have now been reassigned to the new genera, and it now holds an estimated 120 species. In general, bulrushes have cylindrical, bullwhip-like stems, while threesquares have triangular stalks. These plants were used extensively by native groups. Young shoots were gathered in the spring and eaten raw or cooked. Old stems were woven into mats and baskets. Pollen was collected and mixed with other meal to make breads, mush, and cakes. Seeds also were parched and ground into a flour. The starchy roots are edible and were eaten raw, roasted, or dried and ground into a flour for cooking. Young rootstocks were crushed and boiled to make a sweet syrup. Plants also were used as a ceremonial emetic. *Scirpus*-type plants can be found in woods, thickets, meadows, pastures, ricefields, ditches, swamps, bogs, marshes, and in other low, wet places (Britton and Brown 1970:326; Duke 1986:141; Kearney and Peebles 1960:151; Kirk 1975:175–176; Martin 1972:31; Moerman 1986:446; Muenscher 1987:151; Peterson 1977:230).

Juglans (Walnut)

Walnuts were used less intensively than either hickory nuts or acorns (Reidhead 1981:186), although if they were processed at this site some macrofloral evidence of their presence would be expected. Walnuts may be collected quickly and efficiently, as the entire crop stays on the ground for some time. Animals provide little competition for this resource (Reidhead 1981:186). Current distribution for *Juglans* includes Texas walnut (*Juglans microcarpa*) grows in Texas and into Mexico. It grows in limestone-derived sediments (or sediments overlying limestone) along streams, in valleys, and in dry, rocky ravines. Arizona walnut (*Juglans major*) grows in Nevada, Arizona, New Mexico, Texas, and Oklahoma. In New Mexico it is documented in modern times to grow in the southwestern portion of the state. In Texas, it may be found growing along the Rio Grande.

Poaceae (Grass Family)

Members of the Poaceae (grass) family, such as *Oryzopsis* (Indian rice grass) and *Sporobolus* (dropseed), have been widely used as a food resource. Seeds could be eaten raw, but were usually parched and ground into a flour that could be combined with other flours and ground meal to make breads and mushes. Young shoots and leaves might have been cooked as greens. Grass also is reported to have been used as a floor covering and to make hairbrushes and brooms. Various grasses also were used in the manufacture or decoration of pahos (prayer sticks) and for various ceremonial purposes. Grass seeds ripen from spring to fall, depending on the species, providing a long-term available resource (Chamberlin 1964:372; Colton 1974:338, 365; Cushing 1920:219, 253–254; Elmore 1944:24–27; Robbins, et al. 1916; Rogers 1980:32–40; Vestal 1952:15–18; Whiting 1939:65).

Oryzopsis (Ricegrass)

Oryzopsis (ricegrass) produces an abundant quantity of seeds, which could be eaten raw, but were usually parched and ground into a flour that could be combined with other flours and ground meal to make breads and mushes. Ground seeds also were sometimes used to thicken meat gravy. *Oryzopsis* is a cool season grass available in the spring, and is found in dry, open woods, prairies, deserts, and dry hillsides throughout the western United States (Elmore 1944:26; Gasser 1982:225–226; Kirk 1975:182; Medsger 1966:128; Niethammer 1974:37).

Sporobolus (Dropseed Grass)

Sporobolus can be an annual or perennial grass. The seeds of certain species can be eaten raw or parched and ground into a flour that was used to make mush, cakes, dumplings, and bread. *Sporobolus* is found in a variety of habitats, including dry prairies, sandy or muddy shores and marshes, saline flats, along roadsides, wasteplaces, and in dry, sandy, sterile, or rocky soils (Elmore 1944:27; Fernald 1950; Kirk 1975:181–182; Vestal 1952:17).

Portulaca (Purslane)

Portulaca (purslane) is a weedy annual with fleshy leaves and small black seeds. The greens were boiled and eaten, frequently with gravy. As with many greens, these can be available throughout the growing season but are more succulent in the spring. The greens sometimes were boiled with meat. Purslane leaves and stems are rich in iron and contain vitamins A and C, calcium, phosphorous, and riboflavin. They also are good sources of omega-3 fatty acids. The leaves also have a high water content and can be eaten raw to quench thirst. The plant also was eaten to treat a stomachache. The starchy seeds were parched and ground into a meal or flour that was used in a variety of mushes, breads, and cakes. This plant typically grows on dry soil in full sunlight, and seeds can be harvested in the late summer and fall (Brill and Dean 1994:29; Elmore 1944:47; Kearney and Peebles 1960:290; Kirk 1975:46; Laferierre 1988; Niethammer 1974:121; Peterson 1977:72; Vestal 1952:26).

Prosopis (Mesquite)

Prosopis (mesquite) is a xerophytic shrub or small tree. The pods of both *P. juliflora* (honey mesquite) and *P. pubescens* (screwpod mesquite) were utilized for food. The pods are sweet (*P. juliflora* pods are noted to contain about 25% sugar), and they were eaten fresh, boiled, or fermented to make a mild alcoholic drink. The pods also were dried and ground into flour. Pods boiled in water yield molasses. The sweet pods are a good source of calcium, manganese, iron and zinc. Mesquite seeds also can be eaten and are 40% protein. Pottery paddles and cradleboards also were made from mesquite wood. The gum was applied to sores and wounds or boiled in water to make an eyewash, candy, pottery paint, or hair dye. The bark was used for tanning and dying. Mesquite wood burns slowly, with an intense heat, and burns down to a long-lasting bed of coals (Burlage 1968:105; Kearney and Peebles 1960:402; Loughmiller and Loughmiller 1994:135; Peattie 1953:561–563; Sweet 1976:24).

Cultigens

Gossypium (Cotton)

Gossypium (cotton) is a shrubby plant that needs a long growing season with long, hot days, rich soil, and a sufficient amount of water. Although cotton seeds are not usually thought of as a food, they are noted to have been a good snack after they were roasted. It is possible that the pollen clings to the seeds and is, thus, incorporated into the economic record. Cotton was used by Anasazi, Hopi, and Zuni groups for mats, blankets, ropes, string, and ceremonial clothes. These ceremonies include burial rituals, birth ceremonies, and rain ceremonies associated with rainmakers. In the Anasazi culture, the Pueblo I period (700–900 A.D.) was, in part, marked by the cultivation of cotton. As cotton became more useable, products made of plant fiber became rare. Cotton was used by the Hopi for blankets, dresses, and many woven articles; at times replacing wool. Cotton goods were traded by the Hopi to other pueblos and for *Agave* products from the Apache. When the Spanish arrived cotton was being cultivated by a number of pueblos in both Arizona and New Mexico (Acatos and Bruggmann1990:84; Ambler 1977:27; Moerman 1998:251; Rea 1997:309; Sauer 1993:104).

Zea mays (Maize, Corn)

Zea mays (maize, corn) has been an important New World cultigen, originating from a wild grass called teosinte. Maize has long been a staple of the Southwest inhabitants, and charred maize is found in almost every cliffhouse in the Southwest (Stevenson 1915:73). Maize is by far the most common remain in Anasazi coprolitic material from Basketmaker III to Pueblo times (Clary 1983; Minnis n.d.; Moore 1978; Scott 1979; Stiger 1977; Williams-Dean 1986; Williams-Dean and Vaughn M. Bryant 1975). Innumerable ways of preparing maize exist. Green corn was widely used, and ears were collected from the regular fields. Mature ears were eaten roasted or wrapped in corn husks and boiled. The kernels may be parched, soaked in water with juniper ash, and boiled to make hominy. Dried kernels may be ground into meal, which is used as a staple. Cornmeal may be colored with *Atriplex* ashes. Black corn is used as a dye for basketry and textiles and as a body paint. Maize may be husked immediately upon harvesting. Clean husks are saved for smoking and other uses, such as wrapping food. The Pima (Akimel O'odham) and Papago (Tohono O'odham) harvested corn by pulling up the entire stalk after it was dry and piling them at the edges of the fields. Women and children removed unhusked ears from the stalks and then threw them into piles, which were ultimately carried to the dwelling in burden baskets. Unhusked ears of corn were frequently roasted by piling up corn and mesquite brush and setting this pile on fire. The fire burned much of the husk away and the ears were pulled from the fire and dried on top of the house. The roasted, unhusked corn then was stored for later use. Corn also was sometimes shelled prior to storage. Ears also may be allowed to dry on the roof, and ristras of maize may be hung inside from the roof (Castetter and Bell 1942:180–189; Cushing 1920:564–267; Robbins, et al. 1916:83–93; Stevenson 1915:73–76; Whiting 1939:67–70). “Corn appears in virtually every Hopi ceremony either as corn meal, as an actual ear of corn or as a symbolic painting” (Whiting 1939:67).

PARASITE REVIEW

Trichuris trichiura (Whipworm)

Trichuris trichiura (whipworm) resembles a buggy whip and may average 40 millimeters (nearly 16 inches) in length for the female. They have a thinner wall than do *Ascaris* eggs. Unlike *Ascaris* (roundworm), which lives free and unattached in the small intestine, whipworm lives primarily in the cecum, where it attaches itself to the intestinal wall. In heavy infestations, however, they may be found along the entire colon including the rectum. Whipworms are longer lived than roundworms, living for several years and producing eggs for discharge in the feces. The eggs develop into an infective larval stage within the eggshell in three to six weeks. Adverse conditions may delay development for several months or even years. Once the embryos are ingested, the larvae hatch in the jejunum, penetrating the intestinal villus, where it will develop for three to ten days. The adolescent worm moves into the cecum, where it develops into an adult. Ninety days are required between ingestion and production of a gravid female (Beck and Davies 1976:84–86).

Infections are common in areas of high humidity and hard clay soils, which hold moisture. Dense shade and warm climate are both necessities. Infection is usually heaviest among children, since hand to mouth contact in areas of soil pollution is a common vector in spreading these parasites. Whipworm eggs are less resistant to environmental changes, so infection may be more spotty than *Ascaris* (roundworm), with which it often co-occurs (Beck and Davies 1976:84–86).

Light infestations with whipworm may produce no symptoms. Abdominal pain sometimes mimicking appendicitis, vomiting, constipation, fever, distension and flatulence, headache, backache, anorexia, and weight loss have all been associated with infestation by this parasite. If the infection is heavy bloody diarrhea and emaciation may result. Prolapse of the rectum may also occur with heavy worm burdens. Fatalities are rare even in malnourished and neglected children. Whipworm is more difficult to treat than roundworm, since the worms are embedded in the intestine (Beck and Davies 1976:84–86).

DISCUSSION

The site LA 159879 is located in the southwestern part of New Mexico, in Luna County. Archaeological field investigations at LA 159879 suggest that the site represents the remains of a Late Archaic/Early Agricultural period base camp measuring 324.6 m northwest-southeast by 102 m northeast-southwest and encompassing 23,069 square meters of area. The camp is located on the Deming Flood Plain, along the low-relief crest of a linear, southeast-trending lobate alluvial terrace. The finger terrace forms the southwestern border of one of an extensive network of alluvial distributary channels descending to the Mimbres River drainage from the Cooke's Peak massif to the north of the site. Although the Mimbres River is an intermittent wash on this very dry landscape, the channel network provides avenues for runoff from the upland areas to reach the Mimbres Basin about 30 km (18.6 mi) to the east. Local vegetation in this portion of the Chihuahuan Desert includes mesquite (*Prosopis*), yucca (*Yucca*), saltbush (*Atriplex*—a Cheno-am), and dropseed grasses (*Sporobolus*—Poaceae). A bimodal precipitation pattern includes winter rains and occasional snowfall, as well as summer thunderstorms. The more intense summer storms and heavy rains can fill shallow playas and transform the Mimbres River into a raging torrent. Diagnostic projectile points and dated features indicate that this site was occupied between 900 BC and 200 AD. A total of 21 features were identified at LA 159879, with 9 determined to be prehistoric. It appears that inhabitants of the camp focused on the procurement of wild, and perhaps domestic, plant species and cultigens. Cultigens were not identified during previous botanical investigations, but cotton and maize were present in several of the features at LA 159879 (Stephen Lentz, personal communication 2012).

A total of 24 feature fill sediment samples and ground stone tools from this site were submitted for various combinations of pollen, phytolith, and starch grain analysis (Table 1). Six of the seven ground stone tools are associated with specific features. This study was undertaken to recover and identify microbotanical remains of plants associated with site LA 159879 feature and tool use. The results are organized and discussed below by feature number.

Feature 3

Feature 3 is a large oval pit or possible structure in the central portion of the site, measuring 194 cm long, 164 cm wide, and 14 cm deep. The feature was dated, yielding an age of 2740-2850 years BP. The base of the feature showed evidence of oxidization. Feature fill was a semi-consolidated, fine-grained, silty sandy loam with inclusions of charcoal, <1% pea-sized gravels, and fire-cracked rock. Associated artifacts include flaked stone, bone, and ground stone. Based on the recovery of fire-cracked rock in proximity to this pit, Feature 3 was originally interpreted as a large hearth or roasting pit. Alternatively, it could have been a structure and the fire-cracked rock could have been deposited extramurally. Three feature-fill sediment samples (293, 294, and 295) were collected from the adjacent activity area and submitted for pollen analysis. One ground stone tool (sample 299, an abrader fragment) was submitted for phytolith and starch analysis.

Pollen analysis of three of the Feature 3 sediment samples yielded a record dominated by Cheno-am pollen (Fig. 1, Table 2) that probably represents local vegetation dominated by salt bush. Pollen representing other plants growing locally includes *Artemisia*, Low-spine Asteraceae, High-spine Asteraceae, Brassicaceae, *Ephedra torreyana*-type, and Poaceae representing sagebrush, various members of the sunflower family, members of the mustard family, ephedra, and grasses. The type of *Ephedra* pollen noted in this and other samples from this site reflect the influence of summer precipitation on the local vegetation. Recovery of small quantities of *Ephedra nevadensis*-type, *Eriogonujm*, Nyctaginaceae, and *Rosaceae* pollen in one or more of these samples suggests that ephedra that require winter dominant precipitation, wild buckwheat, and members of the four o'clock and rose families also grew in the area. Recovery of small quantities of *Juniperus* and/or *Pinus* pollen in these samples reflects growth of juniper and pine in the surrounding uplands. One sample also contained a small quantity of *Alnus*, indicating that water was sufficiently regular in the greater Mimbres River drainage to support alder trees. Quantities of *Prosopis* pollen varied greatly, with the largest amount in the sample recovered beneath a complete crusher/pestle, suggesting the possibility that mesquite was processed in this activity area with this tool, particularly since no other samples contained large quantities of *Prosopis* pollen. This suggests that large quantities of *Prosopis* pollen would not be introduced through wind transport of the pollen from local vegetation. Scanning these three samples produced a single grain of *Gossypium* pollen (Fig. 2), documenting growth of cotton by occupants of this site. This is the only evidence of cultigens associated with this feature. Total pollen concentration was relatively high in this sample (over 22,000 pollen per cubic centimeter [cc] of sediment), suggesting the possibility that this area was open and relatively stable for a period of time. The other two samples examined from this feature yielded lower total pollen concentrations of more than 5,000 and less than 4,000 pollen per cc of sediment. Neither of the other two samples examined from this activity area yielded pollen representing cultigens. No starches were observed in these three samples.

Phytolith and starch grain analysis of ground stone abrader fragment sample 299 recovered from the activity area adjacent to Feature 3 yielded no starch grains. The phytolith record appears to be mostly derived from the surrounding vegetation; however, a part of the record may be derived from the use of the tool (Fig. 3). An initial count of 100 taxonomically significant phytoliths was first completed, then the rest of the slide was scanned for starch grains and rare phytolith types of economic significance. During the 100 count, a total of three dendriform phytoliths were observed (see Fig. 4 A for one of these dendriforms). Dendriforms originate in the bract material (lemmas, paleas and glumes) that surrounds the seed (caryopsis) of some wild and domesticated grasses. Dendriforms are very common in the bract material of C3 metabolism Pooideae grasses, some of which are domesticated cereals (originating on other continents). Many of the C3 metabolism native grasses in North America were exploited for their seeds. In grass-dominated landscapes, a small amount of dendriform phytoliths, usually 1 per 100 phytoliths, can be part of the sediment-derived phytolith record. With 3 dendriforms per 100 observed from a ground stone use surface sample, it appears that this tool was, in part, used to process native grass seeds. This is because the dendriform-bearing plant material that encapsulates the grass seed is never entirely removed from all of the grains during parching, winnowing and grinding steps. Generally speaking, disarticulated dendriforms such as the ones observed here, cannot be reliably ascribed to a particular grass.

Feature 4

Feature 4 is a small stain noted in the wall of a backhoe trench located in the northern portion of the site. It contained a small amount of charcoal flecking and some evidence of rodent disturbance inside. This feature is oblong in plan view, basin-shaped in profile, and measures 54 cm long, 28 cm wide, and 6 cm in depth. Its base showed no evidence of oxidization, suggesting a low-fire burn over a short duration. The fill of the feature was a loose, sandy loam with inclusions of charcoal staining, <1% pea-sized gravels, and fire-cracked rock (n<5). In addition, 16 pieces of flaked stone debitage were recovered from the fill. Feature 4 appears to have been a single use fire pit. However, this interpretation is not conclusive because of a significant amount of rodent disturbance. A radiocarbon sample was not taken from this feature.

One feature fill sediment sample (434) was submitted for pollen analysis. Pollen analysis yielded a record dominated by Cheno-am pollen, again probably representing local salt bush-dominated vegetation. Recovery of smaller quantities of *Pinus*, *Prosopis*, *Artemisia*, Low-spine Asteraceae, High-spine Asteraceae, Brassicaceae, *Ephedra torreyana*-type, and Poaceae pollen reflect regional and local plants that included at least pine, mesquite, sagebrush, various members of the sunflower family, members of the mustard family, ephedra, and grasses. No starches were observed and none of the pollen appears to represent economic activity associated with this feature. Total pollen concentration was moderate at more than 2000 pollen per cc of sediment. A much larger quantity of microscopic charcoal was observed in this feature than was noted in Feature 3, which is typical of features identified as fire pits.

Feature 6

Feature 6 is an oval fire pit located in the central portion of the site. This feature is basin-shaped in profile, and measures 120 cm long, 66 cm wide, and 17 cm deep. The base of the feature is lightly oxidized and the fill is semi-consolidated fine-grained sand with inclusions of charcoal. Associated artifacts include flaked stone, bone, and ground stone. Based upon its dimensions and the oxidation, Feature 6 appears to have been an informal hearth. The feature was dated, yielding an age range of 2780–2920 years BP.

One feature fill sediment sample (422) was submitted for pollen analysis. Pollen analysis yielded a record very similar to that noted in Feature 4. Differences include recovery of small quantities of *Quercus* and *Erodium* pollen in this feature, as well as the absence of *Prosopis* pollen. This signature also appears to represent regional and local vegetation. Although the quantity of microscopic charcoal was less in this sample, it is still typical of features identified as hearths. Total pollen concentration was more than 3000 pollen per cc of sediment.

Feature 7

Feature 7 is a small fire pit located in the central portion of the site. The pit is circular in plan view and basin-shaped in profile. It measures 70 cm long, 60 cm wide, and 15 cm deep. Feature fill is a 10YR 5/3, brown, loose sand with inclusions of < 1% gravel and charcoal. A single ground stone abrader fragment was recovered from the fill. Feature 7 appears to have been a small informal fire pit. No radiocarbon date was reported for this feature. A feature fill sediment sample (424) was submitted for pollen, phytolith and starch analysis. The ground stone tool (425) was also submitted for pollen, phytolith and starch analysis.

Feature 7 Fill

Pollen analysis of the Feature 7 fill sample 424 yielded another record dominated by Cheno-am pollen, reflecting local vegetation dominated by salt bush. Other pollen observed in this sample appears to represent primarily plants growing locally. Recovery of a small quantity of Salix pollen indicates that willow grew in a nearby drainage. The most significant pollen observation in this sample was a small quantity of Zea mays that included an aggregate (Fig. 2), indicating that maize was processed in this feature. No starch was observed in the pollen sample. Total pollen concentration was nearly 3500 pollen per cc of sediment. Microscopic charcoal was not as dense in this feature fill as it was in Features 4 and 6, although it was still sufficiently abundant to represent a fire pit.

Phytolith and starch grain analysis of the Feature 7 fill sample yielded no starch. The phytolith record appears to be mostly an environmental signature; however, some phytolith evidence of subsistence was observed. The most significant finding was the recovery of a maize IRP (irregular with projections) phytolith (Fig. 4 B). IRP phytoliths are the product of epidermal silicification in the fruitcase, cupule, glume, and other inflorescence tissues of maize, teosinte, and some non-Zea (wild) grasses (Piperno and Pearsall 1993). The wide (> 7.5 µm), rectangular IRP phytolith observed here is found primarily in Zea species (maize and teosinte), but has been observed in the panicoid grass Oplismenus setarius and two bamboo species (Olmeca and Rhipidocladum), taxa that do not occur in New Mexico. These large IRP-types are very common in Zea inflorescences, often occurring in large sheets (Pearsall et al. 2003). Because Zea pollen was recovered in this sample, the Zea-type IRP observed here can be securely ascribed to maize, and provides a second line of evidence for the presence of maize in this sample.

Phytolith analysis also yielded six disarticulated dendriforms and one fragment of a dendritic sheet element. The disarticulated dendriforms are consistent in shape and ornamentation with those found in grass inflorescence material. Lab processing tends to disarticulate sheet elements, so it is possible that the sediments contain more articulated sheet elements than are represented in this count. Thus, grass seeds were processed or cooked using this feature. Zea mays also produces dendriform phytoliths. The dendritic sheet element observed in this sample (Fig. 4 C) has a granulate surface that is similar to that observed in Zea mays inflorescence material; however, is not diagnostic of Zea mays.

Ground Stone from Feature 7

Pollen analysis of the use surface of ground stone abrader fragment sample 425 did not yield sufficient pollen for analysis. Only five pollen grains representing three taxa (Pinus, Cheno-am, and Poaceae) were observed while counting this sample. Total pollen concentration is calculated at approximately 15 pollen per square cm of ground surface. In addition, the quantity of microscopic charcoal noted in this sample indicates that either the ground stone had been burned or that it had picked up large quantities of charcoal from discard in the hearth. In either case, the presence of large quantities of microscopic charcoal make finding pollen very difficult. If the ground stone was discarded in the hearth, then heated during subsequent use of the fire pit, it would have burned away all of the pollen that would have been present as a result of use of the ground stone. No starch was observed in this sample.

Phytolith and starch grain analysis of the use surface of ground stone abrader fragment sample 425 yielded no starch grains. The phytolith-based subsistence evidence was similar to that described for the feature fill sample. An epidermal sheet with a granulate surface that is similar to those found in Zea mays inflorescence material was observed in this sample. This particular sheet element has a rondel phytolith in situ that is typical for Zea mays (see the red arrow in Fig. 4 D). Sample 425 also yielded 3 disarticulated dendriforms and a dendritic sheet element (Fig. 4 E) that are derived from grass seed inflorescence material. Although the evidence for maize processing with this tool is extremely tenuous, there is good evidence that grass seed was processed with this tool.

Feature 8

Feature 8 is a large fire pit located in the central portion of the site. The feature is oval in plan view and basin-shaped in profile. It measures 109 cm long, 80 cm wide and 9 cm deep. The fill was a very dark grayish brown, fine- to coarse-grained sandy loam with inclusions of fire-cracked rock. A large amount of rodent activity was noted.

Associated artifacts include flaked stone and ground stone. Based largely on the presence of fire-cracked rock, Feature 8 appears to have been a large informal hearth. No radiocarbon date was reported for this feature.

A single piece of ground stone from feature 8 was submitted for phytolith and starch grain analysis (sample 427). Analysis of the use surface of ground stone sample 427 yielded no starch grains. The phytolith record appears to be derived entirely from the surrounding vegetation. In fact, the phytolith concentration from the use surface of this tool was relatively light, with only 75 phytoliths counted. Two dendriforms were observed, but without additional phytoliths evidence, and interpretation of grass seed processing with this tool is fairly weak.

Feature 9

Feature 9 is a small fire pit located in the central portion of the site. The feature is oval in plan view, basin-shaped in profile, and measures 65 cm long, 60 cm wide and 15 cm deep. The fill of the feature is a 10YR 5/3, brown, sandy loam with small inclusions of gravel and fire-cracked rock. There was no evidence of oxidization. Associated artifacts include flaked stone, ground stone, and bone. Based on the lack of oxidization, the feature appears to have been a small fire pit that possibly had a single firing episode. This feature was dated, yielding an age range of 2850-2870 years BP. Fill from Feature 9 was submitted for pollen analysis (sample 392), and one ground stone tool associated with Feature 9 was submitted for phytolith and starch grain analysis (sample 393A).

Feature 9 Fill

Pollen analysis of feature fill sample 392 yielded a record similar to that from other features examined from this site. No starches and no pollen representing cultigens was observed. The dominance of this sample by Cheno-am pollen probably reflects the abundance of salt bush in the local vegetation. Total pollen concentration of more than 3000 pollen per cc of sediment indicates an abundance of pollen, particularly in light of the very large quantity of microscopic charcoal noted which counting this sample.

Ground Stone from Feature 9

Phytolith and starch grain analysis of the use surface of ground stone tool sample 393A found in the vicinity of Feature 9 yielded no starch grains. The phytolith record was very limited, with only 50 taxonomically significant phytoliths observed for the whole sample. All of these phytoliths appear to be derived from the surrounding vegetation, and not derived from the use of this tool.

Feature 10

Feature 10 is a small rock-filled fire pit located in the central portion of the site that is circular in shape, measuring 50 cm long, 45 cm wide, and 31 cm deep. The fill of the feature is a 5YR 4/4, reddish brown, semi-consolidated sand with 1% gravel. The fill of the feature was found on top of and in between numerous cobbles and fire-cracked rock that lined the feature and was similar in texture and appearance to Stratum 2. Artifacts collected from the feature include flaked stone and ground stone. Feature 10 was interpreted as a small fire pit based on the high quantities of ground stone and fire-cracked rock lining the feature's base. No radiocarbon date was reported for this feature. Three feature fill sediment samples were submitted for pollen analysis (samples 451, 452, and 453). Two ground stone tools were submitted for phytolith and starch analysis (samples 449-1 and 449-2).

Feature 10 Fill

Pollen analysis of the Feature 10 fill samples 451, 452, and 453 yielded records similar to one another. Once again, Cheno-am pollen dominated the record. Small quantities of *Acer negundo* and *Abies* pollen were noted in sample 453, indicating wind transport of pollen from box elder that grew locally in a drainage and fir that grew more remotely at higher elevation. *Prosopis* pollen was noted in two of these samples (451 and 453), probably as a result of wind transport from mesquite trees growing locally. No pollen representing cultigens was observed while counting or scanning these samples. Total pollen concentration was moderately high at between approximately 2500 and 5000 pollen per cc of sediment. Quantities of microscopic charcoal were lower than those observed for Features 4, 6, 7, 9, and 15.

Feature 10 Ground Stone

Two ground stone tools from Feature 10 were submitted for phytolith and starch analysis. Analysis of ground stone sample 449-1 yielded no starch grains; however, diagnostic maize (*Zea mays*) phytoliths were observed. A total of 6 wavy-top maize rondels were documented during the phytolith count and the subsequent scan of the slide (Fig. 4 F–K). Wavy-top rondels can be produced in large numbers in the glume material for many varieties of maize (*Zea mays*). A small amount of these phytoliths can accompany the processing, cooking, and consumption of maize, and can be recovered from artifacts and features that represent these various activities. These particular phytoliths meet all of the requirements, as outlined by Pearsall et al. (2003), to be considered diagnostic of maize (*Zea mays*) cob material. The main characteristics are that maize wavy-top rondels have a circular to oval base in outline (top view) that is flat, not concave in side view; the base must be longer than the body is high or tall; the top (the side opposite the rondel base) is a single, complete wave that is equal to or less than the length of the rondel base; and the peak or sides of this wave are not horns or spikes. Thus, the presence of wavy-top maize rondel phytoliths in this sample, and the *Zea mays* pollen recovered in samples 424, 430, and 431 provide unequivocal and multiple lines of evidence that the site occupants were utilizing maize.

Ground stone sample 449-1 also yielded an achene (seed) cone cell phytolith diagnostic of sedges (Cyperaceae), and possibly derived from a species of *Cyperus* (Fig. 4 L). When recovered from sediment samples, these phytoliths typically remain intact. The sedge phytolith recovered here is broken, most likely from being processed with this tool. Thus, it appears that sedge seeds were also being ground and exploited by the site occupants.

Phytolith and starch analysis of ground stone sample 449-2 yielded no starch grains and no wavy-top rondel phytoliths diagnostic of maize. Maize cob material produces a wide variety of rondels; however, only wavy-top rondels are considered diagnostic of maize. This sample did have numerous pyramidal rondels that are within the shape and size variation produced by maize; however, they are not diagnostic and therefore cannot be reported as being unequivocally derived from maize. This sample also produced only one dendriform phytolith (out of 100 counted) that could be associated with grass seeds. This quantity is too low to be considered evidence of grass seed processing. The remainder of the phytolith record appears to be derived from the surrounding vegetation.

Feature 13

Feature 13 is a medium-sized fire pit located in the northern portion of the site. This feature is ovoid in plan view, basin-shaped in profile, and measures 95 cm long, 70 cm wide and 5 cm deep. The fill is a fine- to coarse-grained sandy loam mottled with very dark gray clay and a very small amount of fire-cracked rock. Artifacts recovered from the feature included flaked stone and ground stone. The feature appears to have been an informal fire pit. No radiocarbon date is associated with this feature. One sample from the north half of the feature was submitted for pollen analysis (sample 430). One sample from the southwest half of the feature was submitted for pollen, phytolith, and starch analysis.

Pollen analysis of samples 430 and 431 were similar to one another and dominated by Cheno-am pollen. A small quantity of Liguliflorae pollen was noted in sample 430, indicating that a member of the chicory tribe of the sunflower family also grew in the vicinity of the site. Although most of the pollen signature represents plants growing as part of the local vegetation community, recovery of *Zea mays* pollen while scanning both samples (Fig. 2) indicates that Feature 13 was used to process maize. Recovery of *Zea mays* pollen from both the north and southwest portions of this feature emphasizes the use of this pit or informal hearth for processing maize. Experimental processing of maize by the senior author has recovered *Zea mays* pollen from the husks and silk of maize, from dehusked ears of maize that retain their kernels, from kernels that have been removed from the cobs, and from ground maize. Therefore, recovery of *Zea mays* pollen might represent processing any form of maize.

Phytolith and starch analysis of sample 431 yielded no starch grains and very few phytoliths. Only 30 phytoliths were observed for the entire use surface wash sample. Of these phytoliths, all but one appear to be derived from the surrounding vegetation and not related to the use of this feature to processes or cook food. One large dendritic or possibly IRP-type phytolith was observed; however, it was too damaged or weathered to be confidently ascribed to maize.

Feature 15

Feature 15 is a small fire pit located in the northern portion of the site. This feature is circular in plan view, basin-shaped in profile, and measures 50 cm in diameter and 20 cm deep. The feature fill is a 2.5YR 3/4, dark reddish brown very compact sand with large amounts of charcoal. There was noticeable oxidation at the base of the pit. Associated artifacts include flaked stone and bone. Heavy oxidization and large amounts of charcoal suggest that Feature 15 functioned as a multiple-use hearth. A radiocarbon sample from this feature dated at 310 to 500 BP. The feature is near Feature 16, a small pit structure located roughly 1 meter to the north.

Two pollen samples (470 and 471) representing fill from Feature 15 were submitted for analysis. Pollen analysis yielded a pollen record different from those of other features examined from this site. Although the pollen record was dominated by Cheno-am pollen, more than 50% of the pollen from each sample was comprised of non-Cheno-am pollen. Poaceae pollen was particularly abundant in sample 470 and less so in sample 471. Low-spine Asteraceae pollen and *Erodium* pollen were both more abundant in sample 471, providing a disturbance signature suggesting the possibility that weedy plants grew in this pit after its last use. Grasses might also have grown in the pot as it was filling. A small quantity of *Sphaeralcea* pollen also was observed in sample 471, suggesting that globe mallow also grew in or near the pit. Total pollen concentration was low in both samples (less than 1000 pollen per cc of sediment) and quantities of microscopic charcoal were high. This is consistent with use of the pit as a fire pit and also rapid filling after abandonment. No evidence of food processing was noted in the pollen record.

Feature 16

Feature 16 is a pit structure located in the northern portion of the site. It is circular in plan view, basin-shaped in profile, and measures 136 cm long, 124 cm wide, and 32 cm deep. The feature fill is a loose, fine-grained sandy loam with inclusions of pea-sized gravel and sparse charcoal flecking. Slight oxidation was noted along the eastern edge of the feature. Six flaked stone artifacts were recovered from the feature. This feature was dated, yielding an age range of 2850 to 2960 years BP. Four sub-features (Features 16.1, 16.2, 16.3, and 16.4) were noted inside Feature 16. These features appear to be post holes used to support a roof over the structure.

One pollen sample (476) from the north half of Feature 16 was submitted for analysis. This sample yielded a record heavily dominated by Cheno-am pollen, as were many others. The pollen record appears to represent only local vegetation. Total pollen concentration was very high at more than 10,000 pollen per cc of sediment, suggesting a relatively stable surface that might have been in use for a considerable length of time. No evidence for cultigens was observed. Only a small quantity of microscopic charcoal was noted in this sample.

Feature 17

Feature 17 is a possible pit or animal burrow located in the northern portion of the site. The feature is circular in plan view, basin-shaped in profile, and measures 148 cm long, 144 cm wide, and 60 cm deep. The feature fill is an unconsolidated sandy loam, and a large animal burrow was noted. Two ground stone artifacts were recovered from the feature. There is no radiocarbon date reported for Feature 17. One sample (490) from the north half of the feature was submitted for pollen analysis. A second sample (491), also from the north half, was submitted for pollen, phytolith, and starch grain analysis.

Pollen analysis of feature fill sample 490 yielded a record dominated by Cheno-am pollen that also contained a small quantity of *Juglans* pollen, representing walnut. This is a surprising find for this location. Recovery of *Juglans* pollen suggests local growth of walnut trees, and hence, availability of walnuts to the occupants of this site. This sample also exhibited an elevated frequency of Poaceae pollen suggesting processing grasses or grass seeds. A small quantity of *Portulaca* pollen was noted while scanning the sample, although no *Zea mays* pollen was observed. Recovery of *Portulaca* pollen suggests processing purslane in the feature. The most unusual discovery from this sample was the recovery of a *Trichuris* parasite egg, indicating the presence of whipworm, which is a roundworm. This genus of parasites includes several species that infest humans, dogs, pigs, and mice. The different species of parasites appear to be host-specific and there does not appear to be literature suggesting that humans may contract *Trichuris* parasite infestations from animals. The eggs or ova of each of these species is not sufficiently different to make a distinction in archaeological samples. Therefore, no interpretation can be made here about the animal infested with the parasite. Total pollen concentration was high at more than 9,000 pollen per cc of sediment and only a small quantity of microscopic charcoal was noted.

Pollen analysis of feature fill sample 491 yielded a record very similar to that in sample 490, but without the *Juglans* and *Portulaca* pollen or the *Trichuris* parasite eggs. This pollen record appears to represent primarily local vegetation, rather than economic activity. Total pollen concentration and quantities of microscopic charcoal are similar between samples 490 and 491.

Phytolith and starch analysis of sample 491 yielded no starch grains. The phytolith record did yield numerous grass seed indicating dendriform phytoliths. A total of five dendriforms were tallied during the 100 phytolith count, suggesting that grass seeds were associated with this feature. Supporting this was the recovery of a dendritic sheet element and an epidermal sheet element with patterning along the margins of the long cells that is similar to that observed for *Hordeum* and *Elymus* inflorescence material.

Ground Stone Sample 226

A single piece of ground stone, sample 226, was submitted for phytolith and starch grain analysis. This artifact is not associated with a particular feature, but was recovered from stratum 3. This is the only sample analyzed as a part of this study that yielded a grass seed starch (Fig. 4 E). This starch grain is spherical in 3D shape, somewhat irregular in outline, but is generally considered centric. These characteristics are consistent with starch grains produced by many types of grass seed. No phytoliths suggestive of maize were observed, and all appear to be derived from the surrounding environment.

SUMMARY AND CONCLUSIONS

Samples were examined for pollen, phytoliths, and/or starch from eleven features at LA 159879. Results may be grouped into those features that yielded only environmental information and those that yielded subsistence information. Further, several of the features yielded evidence of cultigens, which had not yet been discovered at this site.

Features 4 and 6, which were examined only for pollen, yielded only an environmental signal. Feature 8 was represented only by phytolith analysis of a piece of ground stone (sample 427). The phytolith record appears to be derived entirely from the surrounding vegetation and not from the use of the tool. Feature 9 is represented by both pollen and phytolith samples. Both records provide evidence of the local environment, but not of use of the feature or ground stone. Feature 15 yielded no positive evidence of food processing, although the signature from this feature was different from that in others. It is possible that the fill from this feature remained in tact and provides evidence of vegetation succession in the pit after it was abandoned. Feature 16 provided pollen evidence of local vegetation, but no evidence of food processing.

The remaining features all yielded subsistence information. Analysis of samples from the activity area adjacent to Feature 3 yielded evidence of the presence of *Gossypium* (cotton) from the pollen record (sample 295) and grass seed processing from the ground stone abrader fragment phytolith record (sample 299). Cotton seeds are rich in oil and it is possible that they were ground to release oil. This is the only evidence of cotton obtained from this site.

Three features yielded evidence of *Zea mays*. Feature 7 yielded *Zea mays* pollen in the fill and phytolith evidence of maize from an IRP-type phytolith, as well as grass seed processing. The ground stone recovered from this feature, represented by sample 425, yielded phytolith evidence of grass seed processing.

Feature 10, which is represented by both pollen and phytolith samples, yielded an environmental signature in the pollen record. Analysis of ground stone sample 449-1 for phytoliths and starch yielded 6 wavy-top maize rondels diagnostic maize (*Zea mays*) phytoliths, indicating grinding maize with this tool. Ground stone sample 449-1 also yielded an achene (seed) cone cell phytolith diagnostic of sedges (Cyperaceae), and possibly derived from a species of *Cyperus.* Analysis of ground stone sample 449-2 did not yield any starch grains or phytoliths indicative of subsistence activities.

Feature 13 was examined for both pollen and phytoliths. Pollen analysis of feature fill (samples 430 and 431) yielded *Zea mays* pollen in both the north and southwest portions of the feature, providing solid evidence for processing maize. Phytolith analysis of sample 431 yielded a possible IRP-type phytolith which was damaged to the point that a positive identification could not be made. By itself this is not conclusive evidence of maize processing. Instead, the two pollen samples provide indisputable evidence of maize processing in this feature.

Finally, one feature and one unaffiliated piece of ground stone yielded evidence of grass seed processing. Feature 17 yielded pollen evidence of local growth of walnut trees and probable processing of purslane, represented by *Portulaca* pollen. Phytolith analysis of feature fill sample 491 yielded dendrifoms and epidermal sheet element evidence that grass seeds utilized for subsistence were associated with this feature. A piece of ground stone, represented by sample 226, without feature affiliation yielded starch evidence that suggests processing grass seeds from a cool season grass.

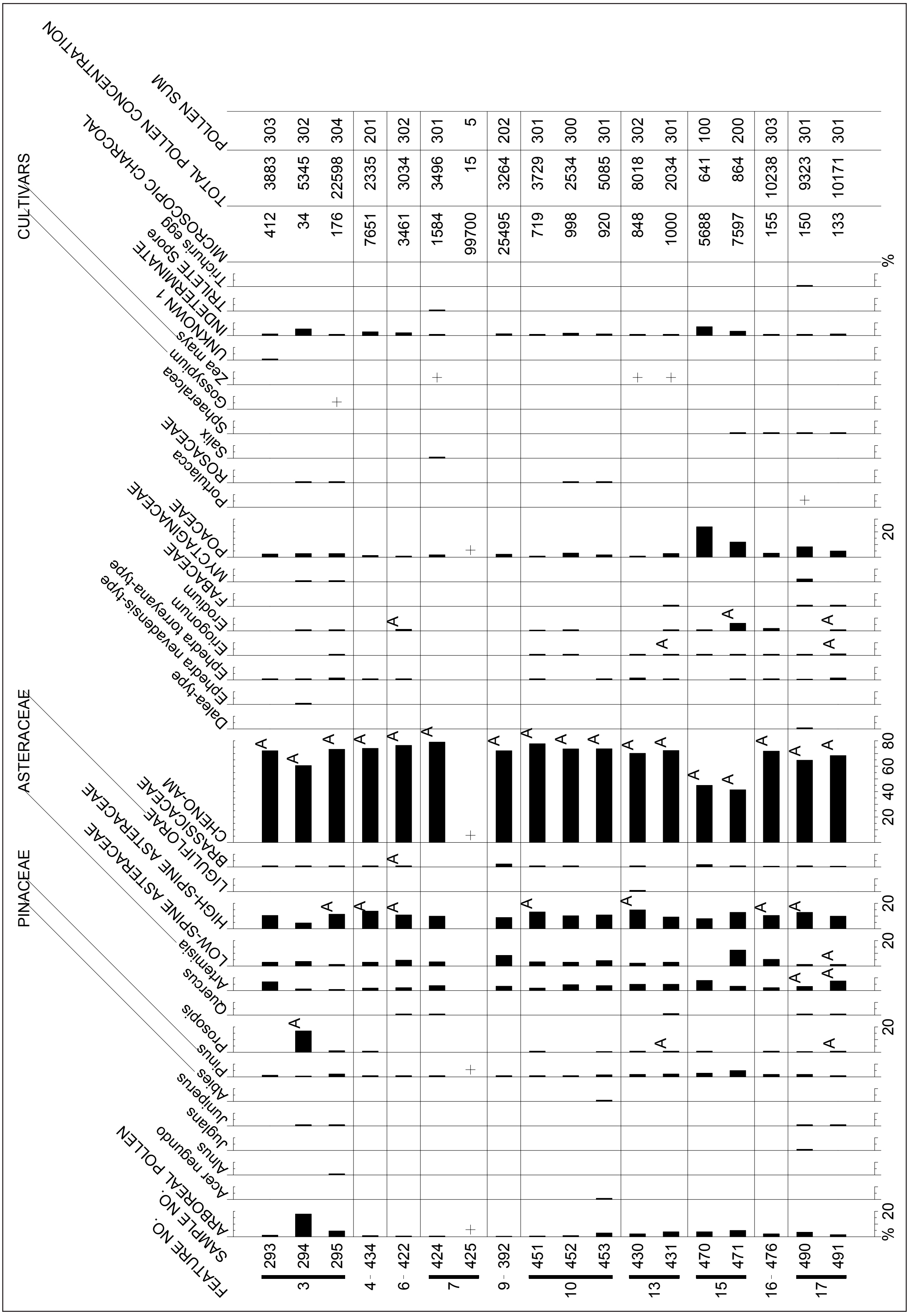
Evidence for cultigens, which had not yet been recovered at this site, was noted in four of the eleven features examined. Radiocarbon dates cluster between approximately 2740 and 2960 BP for those features that were dated. We are not aware of any apparent organization to features that might suggest any organization to the site or identify and single use that included multiple families. Therefore, this record will be considered to represent a series of occupations for these conclusions. Recovery of *Zea mays* pollen and phytoliths in samples representing three features (7, 10, and 13) indicates that maize was processed by people using these three features. In addition, one feature yielded *Gossypium* pollen, suggesting that occupants of this site also processed cotton, possibly cotton seeds for their oil.

Table 1. Provenience Data for Samples from LA 159879, Luna County, New Mexico.

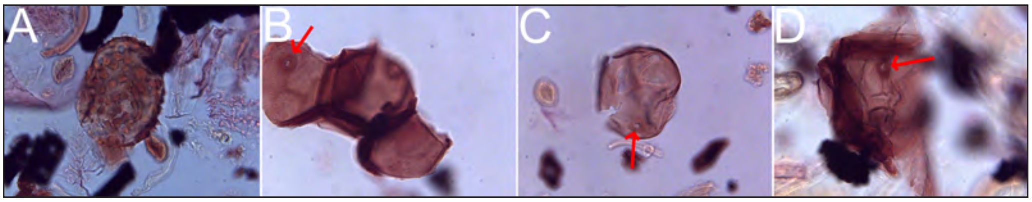
Sample No.	Feature	Area	North/ East	Stratum	Provenience/ Description	Radiocarbon Age BP	Analysis
293	3	2	N275.32 E615.48	3	Activity area adjacent to possible structure in central portion of site. Beneath abrader.	2740–2850	Pollen
294			N275.08 E615.40		Activity area adjacent to possible structure in central portion of site. Beneath crusher/pestle.		Pollen
295					Activity area adjacent to possible structure in central portion of site. Beneath abrader fragment.		Pollen
299			N275.56 E615.60		Abrader fragment from activity area adjacent to possible structure in central portion of site.		Phytolith Starch
434	4	1	N390 E532		Fill from small stain or fire pit in northern portion of site		Pollen
422	6	2	N305.23 E591.57		Fill from N ½ of oval fire pit in central portion of site.	2780–2920	Pollen
424	7	2	N303.54 E592.66		Fill from N ½ of small fire pit in central portion of site.		Pollen Phytolith Starch
425					Ground stone from N ½ of small pit in central portion of site.		Pollen Phytolith Starch
427	8				Ground stone from large pit in central portion of site.		Phytolith Starch
392	9	2	N321.36 E604.57		Fill from small pit in central portion of site.	2850–2870	Pollen
393A					Ground stone from small pit in central portion of site.		Phytolith Starch
451	10	2	N272.20 E629.04		Fill from circular rock-filled fire pit in central portion of site.		Pollen
452			N272.14 E629.10		Fill from circular rock-filled fire pit in central portion of site.		Pollen
453			N272.10 E628.84		Fill from circular rock-filled fire pit in central portion of site.		Pollen
449-1					Ground stone mano from circular roasting pit in central portion of site.		Phytolith Starch
449-2					Ground stone abrader fragment from circular roasting pit in central portion of site.		Phytolith Starch
430	13	1	N352 E552		Fill from N ½ of medium-sized fire pit in northern portion of site.		Pollen
431		1	N352 E552		Fill from SW ½ of medium-sized fire pit in northern portion of site.		Pollen Phytolith Starch
470	15	1	N374.53 E530.38		Fill from small fire pit in northern portion of site	310–500	Pollen
471			N374.64 E530.44		Fill from small fire pit in northern portion of site.		Pollen
476	16	1	N375.58 E531.10		Fill from N ½ of pit structure in northern portion of site.	2850–2960	Pollen
490	17	1	N372.84 E534.46		Fill from N ½ of large burrow or pit in northern portion of site.		Pollen
491		3	N373.34 E534.86		Fill from N ½ of large burrow or pit in northern portion of site.		Pollen Phytolith Starch
226				3	Ground stone.		Phytolith Starch

Table 2. Pollen Types Observed in Samples from LA 159879, Southwestern New Mexico.

Scientific Name	**Common Name**
ARBOREAL POLLEN:	
Acer negundo	Box Elder
Alnus	Alder
Juglans	Walnut
Juniperus	Juniper
Pinaceae:	Pine family
Abies	Fir
Pinus	Pine
Prosopis	Mesquite
Quercus	Oak
NON-ARBOREAL POLLEN:	
Asteraceae:	Sunflower family
Low-spine	Includes ragweed, cocklebur, sumpweed
High-spine	Includes aster, rabbitbrush, snakeweed, sunflower, etc.
Liguliflorae	Chicory tribe, includes dandelion and chicory
Brassicaceae	Mustard or cabbage family
Cheno-am	Includes the goosefoot family and amaranth
Dalea-type	Prairie Clover
Ephedra	Ephedra, Jointfir, Mormon tea
Ephedra nevadensis-type (inc. *E. clokeyi, E. coryi, E. funera, E. viridis, E. californica, E. nevadensis,* and *E. aspera*)	Ephedra, Jointfir, Mormon tea
Ephedra torreyana-type (inc. *E. torreyana*, *E. trifurca*, and *E. antisyphilitica*)	Ephedra, Jointfir, Mormon tea
Eriogonum	Wild buckwheat
Erodium	Storksbill, Heron-bill, Filaree
Fabaceae	Bean or Legume family
Nyctaginaceae	Four o'clock family
Poaceae	Grass family
Portulaca	Purslane
Rosaceae	Rose family
Salix	Willow
Sphaeralcea	Globemallow
CULTIGENS	
EDIBLE/ECONOMIC:	
Gossypium	Cotton
Zea mays	Maize, Corn
Indeterminate	Too badly deteriorated to identify
SPORES:	
Trilete	Fern
PARASITES:	
Trichuris	Whipworm
OTHER:	
Microscopic charcoal	Microscopic charcoal fragments
Total pollen concentration	**Quantity of pollen per cubic centimeter (cc) of sediment**



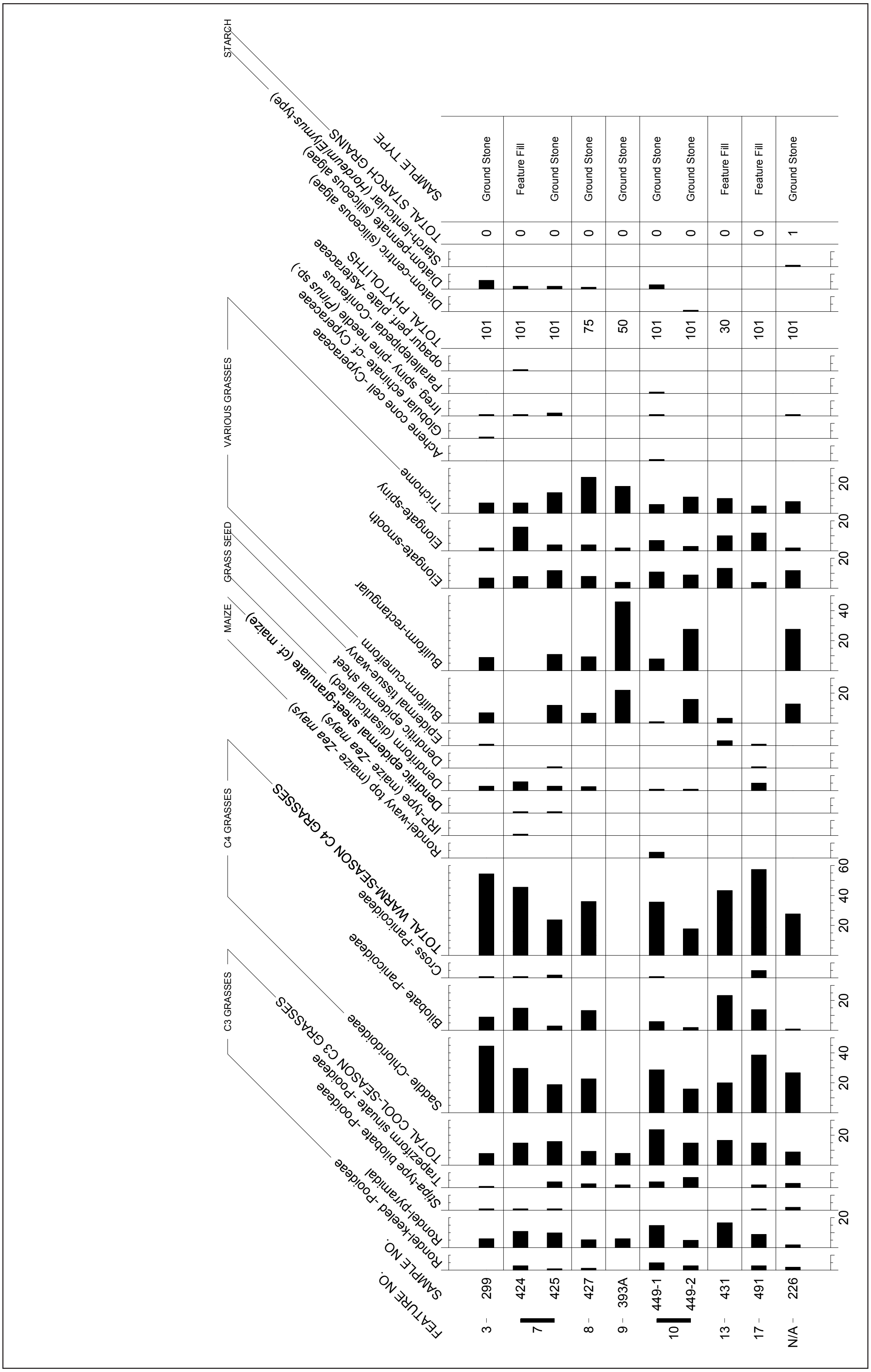
Appendix 3, Figure 1. Pollen diagram for LA 159879.



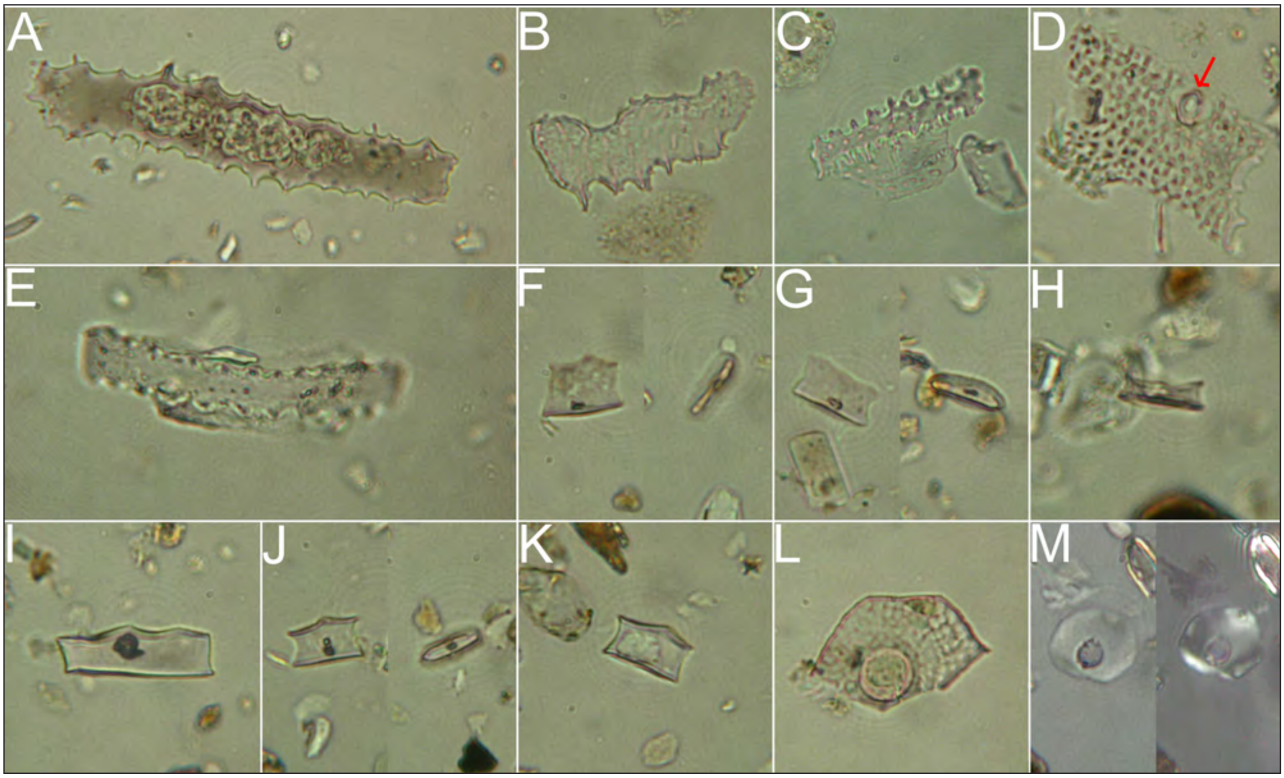
Appendix 3, Figure 2. Photographs of pollen representing cultigens.

All micrographs were taken at 500x magnification. Apparent different in size represents cropping of the individual micrographs to maximize detail.

A: Gossypium pollen.
B: Zea mays pollen cluster, arrow points to the pore on one grain, note the tears in the pollen.
C: Zea mays pollen, note the tears in the pollen, arrow points to the pore.
D: Zea mays pollen, very crumpled, arrow points to the pore.



Appendix 3, Figure 3. Phytolith diagram for feature fill and ground stone from LA 159879, Luna County, NM.



Appendix 3, Figure 4. Selected phytoliths and starch grains recovered from feature fill and ground stone tool samples, LA 159879, Luna County, NM. All micrographs taken at 500x magnification:

A: Dendriform phytolith recovered from ground stone sample 229.

B: IRP-type maize (Zea mays) phytolith recovered from Feature 7 fill, sample 424.

C: Dendritic epidermal sheet element with granulate surface similar to that observed in Zea mays inflorescence material, also from Feature 7 fill.

D: Another dendritic epidermal sheet element with granulate surface with a maize-type rondel in situ (red arrow), recovered from the surface of ground stone tool sample 425.

E: Dendritic sheet element from grass inflorescence material, also recovered from ground stone sample 425.

F–K: Wavy-top rondel phytoliths diagnostic of maize (Zea mays) cob material, recovered from Feature 10, ground stone sample 449-1.

L: Sedge (Cyperaceae) achene cone cell phytolith, also recovered from Feature 10 ground stone sample 449-1.

M: Grass seed starch grain recovered from ground stone tool sample 226.

References Cited

Acatos, S.
1990 *Pueblos: Prehistoric Indian Cultures of the Southwest*. Facts on File, New York.

Ambler, J. R.
1977 *The Anasazi*. Prehistoric People of the Four Corners Region. Museum of Northern Arizona, Flagstaff, Flagstaff, AZ.

Angier, B.
1978 *Field Guide to Medicinal Wild Plants*. Stackpole Books, Harrisburg, PA.

Asch, D. L.
1978 The Economic Potential of Iva annua and Its Prehistoric Importance in the Lower Illinois Valley. In *The Nature and Status of Ethnobotany*, ed. R. I. Ford. Anthropological Paper. vol. 67. University of Michigan, Ann Arbor, MI.

Beck, J. W., and J. E. Davies
1976 *Medical Parasitology*. 2nd ed. C. V. Mosby Company, St. Louis, MO.

Brill, S., and E. Dean
1994 *Identifying and Harvesting Edible and Medicinal Plants in Wild (and Not So Wild) Places*. Hearst Books, New York.

Britton, N. L., and H. A. Brown
1970 *An Illustrated Flora of the Northern United States and Canada, Vol. 1*. 3 vols. Dover Publications, Inc., New York.

Bryan, N. G., and S. Young
1978 *Navajo Native Dyes: Their Preparation and Use*. Chilocco Agricultural School, Chilocco, OK.

Burlage, H. M.
1968 *Index of Plants of Texas with Reputed Medicinal and Poisonous Properties*. Henry M. Burlage, Austin, TX.

Castetter, E. F., and W. H. Bell
1942 *Pima and Papago Indian Agriculture*. University of New Mexico Press, Albuquerque, NM.

Chamberlin, R. V.
1964 The Ethnobotany of the Gosiute Indians of Utah. In *American Anthropological Association Memoirs 2*, pp. 329–405. Kraus Reprint Corp., New York.

Clary, K. H.
1983 *Prehistoric Coprolite Remains from Chaco Canyon, New Mexico: Inferences for Anasazi Diet and Subsistence.* Master's, University of New Mexico.

Colton, H. S.
1974 Hopi History and Ethnobotany. In *Hopi Indians*, pp. 279–424. Garland Publishing, Inc., New York.

Curtin, L. S. M.
1984 *By the Prophet of the Earth*. University of Arizona Press, Tucson, AZ.

Cushing, F. H.
1920 Zuni Breadstuff. In *Indian Notes and Monographs*. vol. VIII. Heye Foundation, New York.

Duke, J. A.
1986 *Handbook of Northeastern Indian Medicinal Plants*. Quarterman Publications, Inc., Lincoln, NE.

Elmore, F. H.
1944 *Ethnobotany of the Navajo*. University of New Mexico with the School of American Research, Santa Fe, NM.
1976 *Shrubs and Trees of the Southwest Uplands*. Southwest Parks and Monuments Association, Globe, AZ.

Fernald, M. L.
1950 *Gray's Manual of Botany*. 8th ed. American Book Company, New York.

Foster, S., and J. A. Duke
1990 *A Field Guide to Medicinal Plants: Eastern and Central North America*. Houghton Mifflin Company, Boston.

Gasser, R. E.
1982 Hohokam Use of Desert Food Plants. *Desert Plants* 2(4):216–234.

Harrington, H. D.
1967 *Edible Native Plants of the Rocky Mountains*. University of New Mexico Press, Albuquerque, NM.

Harris, B. C.
1972 *The Complete Herbal*. Larchmont Books, New York.

Hickman, J. C. (editor)
1993 *The Jepson Manual: Higher Plants of California*. University of California Press, Berkeley.

Kearney, T. H., and R. H. Peebles
1960 *Arizona Flora*. University of California Press, Berkeley.

Kindscher, K.
1987 *Edible Wild Plants of the Prairie*. University Press of Kansas, Lawrence, KS.

Kirk, D. R.
1975 *Wild Edible Plants of Western North America*. Naturegraph Publishers, Happy Camp, CA.

Krochmal, A., and C. Krochmal
1973 *A Guide to the Medicinal Plants of the United States*. Quadrangle, the New York Times Book Co., New York.

Laferierre, J.
1988 Nutricomp (Computer Software).

Loughmiller, C., and L. Loughmiller
1994 *Texas Wildflowers*. University of Texas Press, Austin.

Martin, A. C.
1972 *Weeds*. Golden Press, Western Publishing Company, Inc., New York.

Medsger, O. P.
1966 *Edible Wild Plants*. MacMillan Publishing Company, Inc., Racine, WI.

Minnis, P. E.
n.d. *Prehistoric Diet in the Northern Southwest: Macroplant Remains from Four Corners Feces*. Ms. on file with Department of Anthropology, University of Oklahoma.

Moerman, D. E.
1986 *Medicinal Plants of Native America*. University of Michigan Museum of Anthropology Technical Reports No. 19, 1 and 2. University of Michigan Press, Ann Arbor, MI.
1998 *Native American Ethnobotany*. Timber Press, Portland, OR.

Moore, J. F.
1978 *Human Coprolites from Standing Fall House, Black Mesa, Arizona*. Ms. on file with the University of Michigan, Museum of Anthropology, Ethnobotanical Laboratory.

Moore, M.
1990 *Los Remedios: Traditional Herbal Remedies of the Southwest*. Red Crane Books, Santa Fe, NM.

Muenscher, W. C.
1987 *Weeds*. 2nd ed. Cornell University Press, Ithaca, NY.

Niethammer, C.
1974 *American Indian Food and Lore*. Collier Books, New York.

Pearsall, D. M., K. Chandler-Ezell, and A. Chandler-Ezell
2003 Identifying maize in neotropical sediments and soils using cob phytoliths. *Journal of Archaeological Science* 30:611–627.

Peattie, D. C.

1953 *A Natural History of Western Trees*. University of Nebraska Press, Lincoln, NE.

Peterson, L. A.
1977 *Edible Wild Plants*. Collier Books, New York.

Petrides, G. A., and O. Petrides
1992 *A Field Guide to Western Trees*. The Peterson Field Guide Series. Houghton Mifflin Co., Boston.

Piperno, D. R., and D. M. Pearsall
1993 Phytoliths in the Reproductive Structures of Maize and Teosinte: Implications for the Study of Maize Evolution. *Journal of Archaeological Science* 20:337–362.

Rea, A. M.
1997 *At the Desert's Green Edge: An Ethnobotany of the Gila River Pima*. University of Arizona Press, Tucson.

Reidhead, V. A.
1981 *A Linear Programming Model of Prehistoric Subsistence Optimization: A Southeastern Indiana Example*. Prehistory Research Series VI (1). Indiana Historical Society, Indianapolis, IN.

Robbins, W. W., J. P. Harrington and B. Freire-Marreco
1916 *Ethnobotany of the Tewa Indians*. Bureau of American Ethnology Bulletin 55.

Rogers, D.
1980 *Edible, Medicinal, Useful, and Poisonous Wild Plants of the Northern Great Plains-South Dakota Region*. Biology Department, Augustana College, Sioux Falls.

Sauer, J. D.
1993 *Historical Geography of Crop Plants: A Select Roster*. CRC Press, Boca Raton, FL.

Scott, L. J.
1979 Dietary Inferences from Hoy House Coprolites: A Palynological Interpretation. *The Kiva* 44:257–281.

Stevenson, M. C.
1915 *Ethnobotany of the Zuni Indians*. Thirtieth Annual Report of the Bureau of American Ethnology. Government Printing Office, Washington, D.C.

Stiger, M. A.
1977 *Anasazi Diet: The Coprolite Evidence.* MA, University of Colorado.

Sweet, M.
1976 *Common and Useful Plants of the West*. Naturegraph Company, Healdsburg, CA.

Vestal, P. A.
1952 *The Ethnobotany of the Ramah Navaho*. Papers of the Peabody Museum of American Archaeology and Ethnology 40(4). Harvard University, Cambridge, MA.

Watt, B. K., and A. L. Merrill
1963 *Composition of Foods*. Agricultural Handbook 8. U.S. Department of Agriculture, Washington, D.C.

Whiting, A. F.
1939 *Ethnobotany of the Hopi*. Museum of Northern Arizona Bulletin 15.

Williams-Dean, G.
1986 Pollen Analysis of Human Coprolites. In *Archaeological Investigations at Antelope House*, edited by D. P. Morris, pp. 189–205. National Park Service, Washington, D.C.

Williams-Dean, G., and J. Vaughn M. Bryant
1975 *Pollen Analysis of Human Coprolites from Antelope House.* National Park Service Publication No. 12.

Appendix 4: Soils Analysis

Milwaukee Soils Lab

Appendix 4. Milwaukee Soils Lab Results (depth below ground surface m)

						Sieved		% adjusted for gravel			
Sample ID	Stratum	Source/Depth	Sand %	Silt %	Clay %	(#230) Sand %	sand % diff	Gravel %	Sand %	Silt %	Clay %
3	1	BHT-1/0.19	84	10	6	85.5	-1.5	0	84	10	6
2	2	BHT-1/0.35	52	33	15	53.4	-1.4	0	52	33	15
6	2	BHT-2/0.66	85	9	6	86.2	-1.2	1	84	9	6
7	2	BHT-3/0.155	84	7	9	84.0	0.0	0	84	7	9
4	3	BHT-1/0.90	83	12	5	82.8	0.2	1	82	12	5
5	3	BHT-2/0.88	77	13	10	76.4	0.6	4	74	12	10
8	3	BHT-3/0.53	79	8	13	78.7	0.3	0	79	8	13
9	3	N388/E526/1.12	82	13	5	81.7	0.3	1	81	13	5
1	5	BHT-1/0.60	30	57	13	29.0	1.0	0	30	57	13
10	7	BHT-7/1.45	82	16	2	82.1	-0.1	0	82	16	2
10 dupl	7	BHT 7/1.45	82	16	2	82.4	-0.4	0	82	16	2

			Particle Size (Phi)				
Sample ID	Stratum	Source/Depth	0ø %	1.0ø %	2.0ø %	3.0ø %	4.0ø %
3	1	BHT-1/0.19	1.0	4.9	17.3	41.6	35.2
2	2	BHT-1/0.35	1.3	4.6	14.8	41.6	37.7
6	2	BHT-2/0.66	1.0	8.5	21.5	38.4	30.6
7	2	BHT-3/0.155	1.2	11.9	25.5	33.3	28.1
4	3	BHT-1/0.90	1.8	9.4	23.2	34.4	31.2
5	3	BHT-2/0.88	2.2	11.7	24.5	32.5	29.1
8	3	BHT-3/0.53	2.4	9.9	29.2	36.5	22.0
9	3	N388/E526/1.12	1.2	7.8	24.2	38.9	27.9
1	5	BHT-1/0.60	1.0	5.0	16.0	36.0	42.0
10	7	BHT-7/1.45	1.5	5.4	19.1	40.8	33.2
10 dupl	7	BHT 7/1.45	1.5	5.9	19.8	40.4	32.4

Sample ID	Stratum	Source/Depth	Carbonate %	Organic Carbon % Walkley-Black	Estim. Organic Matter %
3	1	BHT-1/0.19	3.2	0.15	0.26
2	2	BHT-1/0.35	4.4	0.37	0.63
6	2	BHT-2/0.66	2.5	0.15	0.26
7	2	BHT-3/0.155	2.3	0.18	0.30
4	3	BHT-1/0.90	6.7	0.13	0.22
5	3	BHT-2/0.88	9.8	0.23	0.40
8	3	BHT-3/0.53	2.2	0.09	0.15
9	3	N388/E526/1.12	8.2	0.10	0.17
1	5	BHT-1/0.60	6.6	0.61	1.05
10	7	BHT-7/1.45	3.3	0.02	0.04
10 dupl	7	BHT 7/1.45	10.0	0.40	0.69

Appendix 5: Site Location Information

Legal Description: T 23N R 9E, NW¼ of NW¼ of SE¼ of Section 22
Map Source: USGS 7.5′ Deming West, NM Quadrangle (Code: 32107-C7)
UTM Coordinates: NAD 83, Zone 13, E239587, N3576373
Elevation: 4365 ft

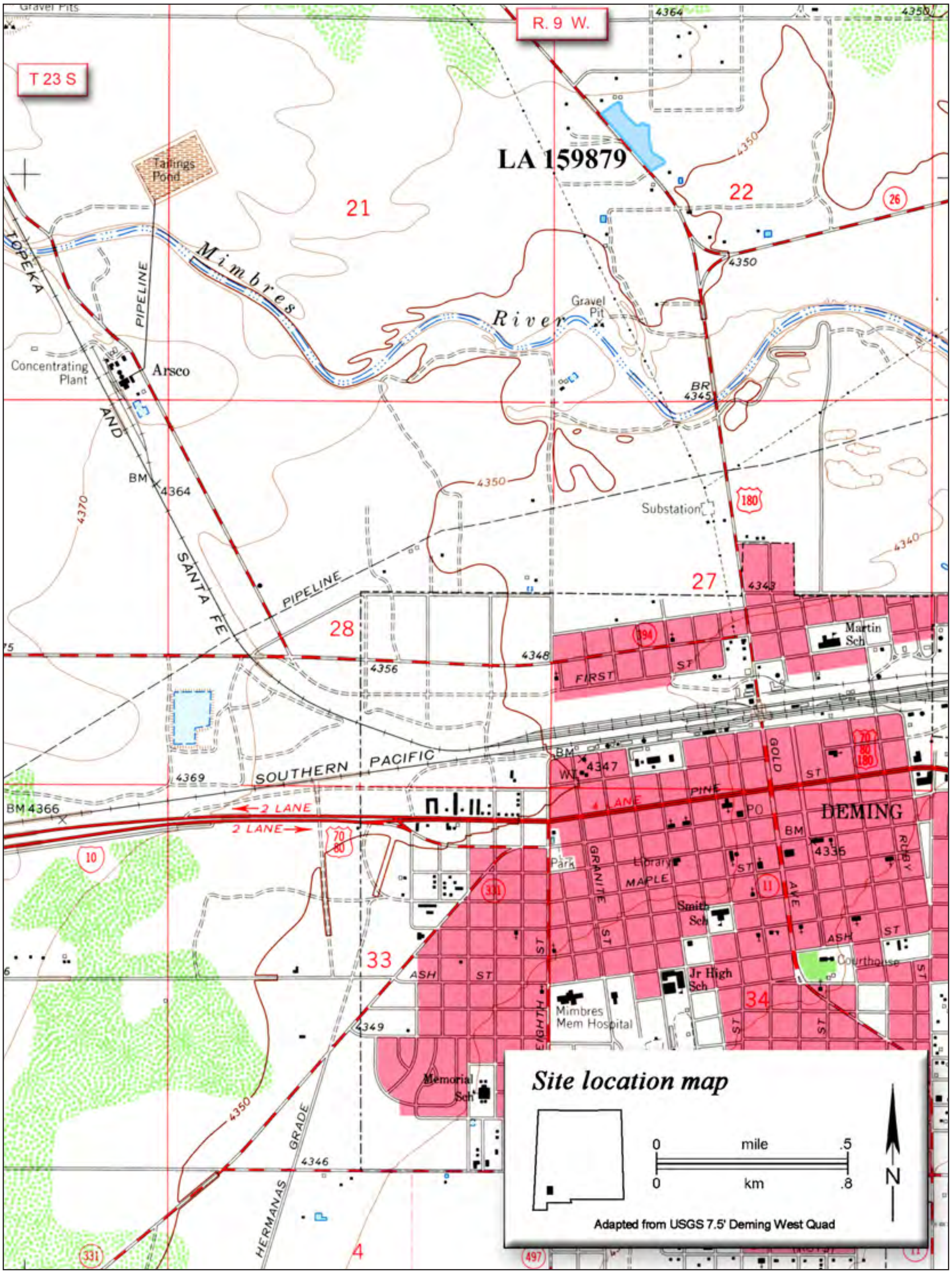


Figure A5.1. Site location map.

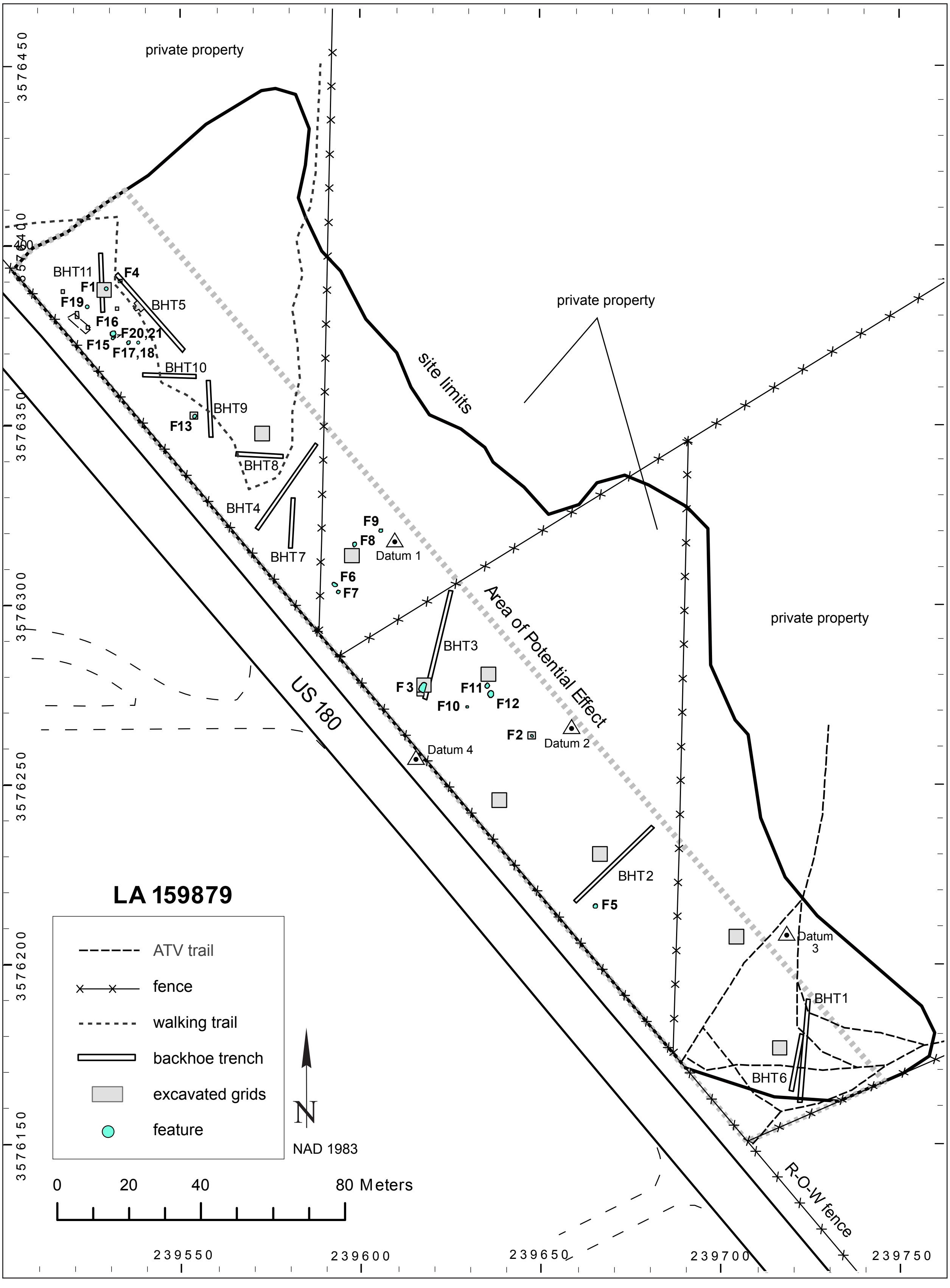


Figure A5.2. LA 159879, site map with property lines.

NMDOT

Office of Archaeological Studies
Museum of New Mexico AN 456

TECHNICAL SERIES 2015-1