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IN THIS ISSUE:

Mission Statement

The Journal of Arizona Archaeology is a peer-reviewed journal that focuses on the presentation of emerging ideas, new methods, and current research in Arizona archaeology. It endeavors to be a forum for the scholarly, yet simple communication of research and management related to Arizona's archaeological record. The journal is published twice a year by the Arizona Archaeological Council (AAC). At least one issue per year is devoted to the theme of the AAC annual fall conference. The conference issue (or issues) is overseen by a guest editor. The remaining issues of the journal are intended for open submissions. The frequency of general submission issues is dependent on the number of appropriate manuscripts received throughout the year and the workload of the editorial staff.

The journal is one benefit of membership in the AAC. Individual membership rates in the AAC are $30 per year. To apply for AAC membership, report a lost/damaged journal, or to learn more about the mission of the AAC, please visit the AAC website: http://arizonaarchaeologicalcouncil.org. Membership must be paid in full in order to receive regular copies of the Journal of Arizona Archaeology. Members and non-members can purchase additional copies of the journal for $15 per issue.

Instructions for Authors

The format of all submitted papers should correspond to the SAA style guide, which can be accessed at this web address: http://www.saa.org/Publications/StyleGuide/styframe.html. All manuscripts must be submitted as a MS Word document. All review (editorial and peer review) will be conducted electronically. Authors should be familiar with the "track changes" and "comments" functions of MS Word. Authors are encouraged to contact the editor with questions regarding the content or formatting of their manuscripts prior to submitting their papers.

Authors should anticipate two to three months for review of their manuscripts. The editor will review each paper prior to peer review to determine if the manuscript meets content and formatting guidelines. If the paper meets these preliminary guidelines, the editor will send the manuscript out for peer review. The editor makes the final decision to accept a manuscript on the basis of his review as well as those of the peer referees. If a manuscript is accepted for publication, authors must submit images in at least 300 dpi. All permissions for photographs and figures are the responsibility of the author and must be obtained prior to publication.

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IN MEMORIAM

This first edition of the Journal of Arizona Archaeology is dedicated to the memory of Jo Anne Medley, long-time liaison to the Arizona Archaeological Council for the Arizona State Historic Preservation Office. Jo Anne was an effective advocate for Arizona archaeology, and a consummate professional whose hard work touched and improved almost every aspect of archaeology in the state. Her vigilance and her friendship will be sorely missed. We hope that this journal lives up to her high standards.

THEMED ISSUE:

ADVANCES IN HOHOKAM ARCHAEOLOGY

PREFACE

One of the missions of the Arizona Archaeological Council (AAC) is to promote and coordinate communication within the archaeological community. Toward this end, the AAC has sponsored more than 50 conferences and published more than 125 quarterly newsletters since its inception in 1977. Now, with the publication of this first issue of the *Journal of Arizona Archaeology*, the AAC has taken their commitment to promote professional communication to a new level.

The papers that follow were originally presented at the AAC's 2008 Conference, *Advances in Hohokam Archaeology*, held at Pueblo Grande Museum on October 23 and 24, 2008. The conference was designed to highlight the results of recent research across the Hohokam region of south-central Arizona. The chief impetus for the conference was the fact that it had been 25 years since the last "big" Hohokam conference, a long time even by archaeological standards. In addition, Phoenix and Tucson are among the fastest growing metropolitan areas in the United States, and new archaeological discoveries are being made all the time. We saw the conference as a good opportunity to bring together the researchers making those discoveries so that they could share ideas and discuss their work. In total, 21 papers and four posters were presented at the conference. A panel discussion was also held to provide perspective on some of the major developments in Hohokam research that have occurred since the 1983 Hohokam conference.

Initially our plan was to publish the proceedings of the conference in a single volume, similar to other AAC-sponsored conferences. Those plans changed, however, when we heard about the decision to launch a new journal. Since we were close to having a completed manuscript and the *JAzArch* editorial staff was looking for papers to publish, we decided to join forces. The only downside is that the conference proceedings will now be published in two issues. This first issue is devoted to papers focusing on the results of recent research in the middle Gila River Valley. The next issue will include papers from other parts of the Hohokam region.

We selected the middle Gila Valley as the focus of this inaugural issue for a number of reasons. First and foremost, it has long been considered the heartland of the Hohokam cultural tradition. Not only does it contain many of the largest and best known sites, including Casa Grande Ruins and Snaketown, but many of the distinctive material traits of Hohokam culture (e.g., buff ware pottery, massive canal systems, ballcourts, platform mounds) either originated from or reached their fullest expression along the middle Gila River. In addition, the middle Gila figures prominently in the history of Hohokam research. Indeed, it was the investigations at Casa Grande in the late 19th and early 20th centuries and at Snaketown in the mid-1930s and mid-1960s that largely defined the Hohokam cultural tradition.

Even though the papers here generally focus on the middle Gila Valley, they cover a range of topics related to Hohokam prehistory—everything from how canals were built and fields were cultivated to how the spiritual world was conceptualized. This diversity, we believe, accurately reflects the dynamic nature of current research. However, it also points to why a journal like this one is so important. A conference is great in terms of meeting people and discussing ideas, but the experience is limited to those on hand. We applaud the AAC's efforts to "get the message out" to a larger audience through the publication of a journal. We hope you enjoy this inaugural issue.

Douglas B. Craig **Todd W. Bostwick**

RE-DRAWING THE MAP OF THE HOHOKAM CANALS IN THE MIDDLE GILA RIVER VALLEY

M. Kyle Woodson

ABSTRACT

Canal irrigation systems were the lifeblood of ancient Hohokam communities in the major river valleys of south-central Arizona. Understanding these systems is pivotal to understanding the social, economic, and political landscapes. A long-term study of irrigation along the middle Gila River has provided much new information on Hohokam canals, including a revised map of the canal systems. Building from early canal maps such as those by Frank Midvale and Emil Haury, this map incorporates the findings of projects from the last 40 years. There is now solid documentation for 13 canal systems, and inferential support for two other systems. In this paper, I present an overview of the revised map and the new insights it has provided for Hohokam prehistory. In addition, the map allows a critical assessment of the irrigable acreage by examining the size of field areas along the canals.

Archaeologists hold the notion that rivers were the lifeblood of ancient Hohokam communities in the valleys of southern Arizona, and that canals were the arteries (Doolittle 1991). Indeed, it could be said that canal irrigation was the key development that allowed the emergence and fluorescence of the Hohokam cultural tradition. Understanding canal systems is therefore pivotal to our understanding of the social, economic, and political landscapes in the Hohokam world. Fortunately, significant advances have been made in these arenas as a result of the increase in Hohokam canal studies over the past 25 years. One benefit of this surge in research is the ability to clarify the map of canal systems along the middle Gila River (Figure 1) (Woodson 2009a). This paper presents an overview of the revised map displaying the canals on the middle Gila, and discusses the new insights it provides for Hohokam prehistory.

Early researchers, like Bandelier (1892) and Fewkes (1913:113–115), noted their observations about canals in the middle Gila River Valley, but they drew no maps. Charles Southworth mapped a few prehistoric canals during his Gila River Survey in 1914–15. However, the first important map of middle Gila canals was drawn by Larson (1926) and published by Cummings in 1926 (Figure 2). Larson's map focuses on the Coolidge and Florence areas. Thereafter, Frank Midvale (1935, 1946, 1963, 1965, 1972) made significant contributions to the mapping of canals and settlements during his survey efforts between 1918 and 1972. His 1963 map of the Casa Grande Ruins area is still used by many archaeologists today as a standard archaeological reference (Figure 3). Downstream of Casa Grande, though, Midvale's canal maps (1935, 1972) are less detailed and have proven to be less accurate. A notable exception is the Snaketown area, where Emil Haury (1937, 1976) excavated numerous segments of the Snaketown Canal in the 1930s and 1960s. More recent maps have filled in details for specific canal systems (e.g., Deaver 2003; Miles et al. 2008; Phillips and Craig 2001; Woodson 2007a), but no previous studies have produced a comprehensive map of all systems along the middle Gila River.

Building from these previous maps and utilizing information from past and current projects, I have worked to update what is known of individual canal systems and to draw a comprehensive map of all the middle Gila systems (see Figure 1). The revised map is based on a study of irrigation conducted as part of the Bureau of Reclamation-funded Pima-Maricopa Irrigation Project (Woodson 2003). It incorporates the findings of projects from the last 40 years, and includes archaeological surveys, surveys of linear features that appear to be relict canals, excavation projects, as well as examination of aerial photographs. The map also benefits from data on more than 200 excavated canal segments from 13 canal systems. All data are plotted

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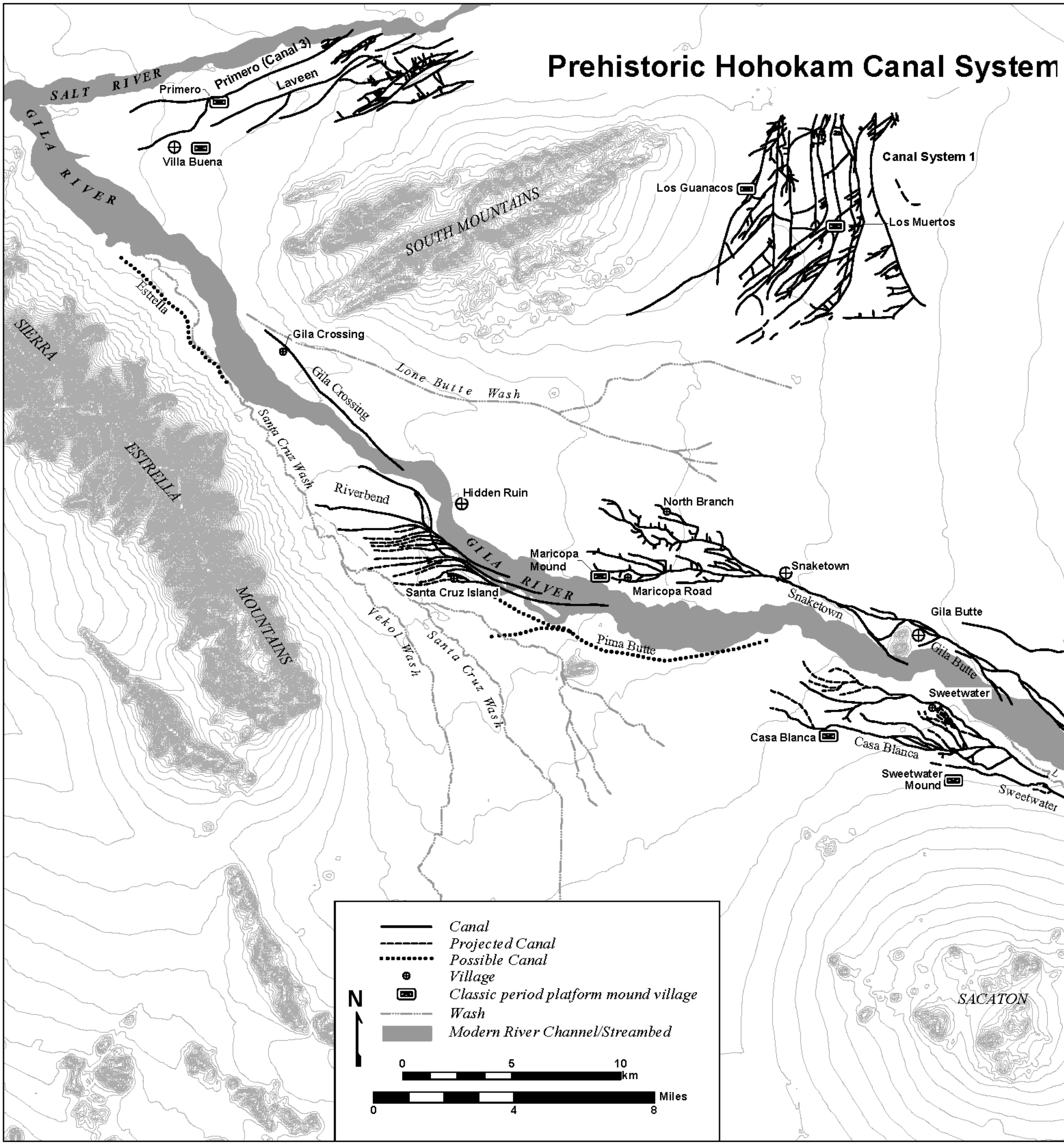
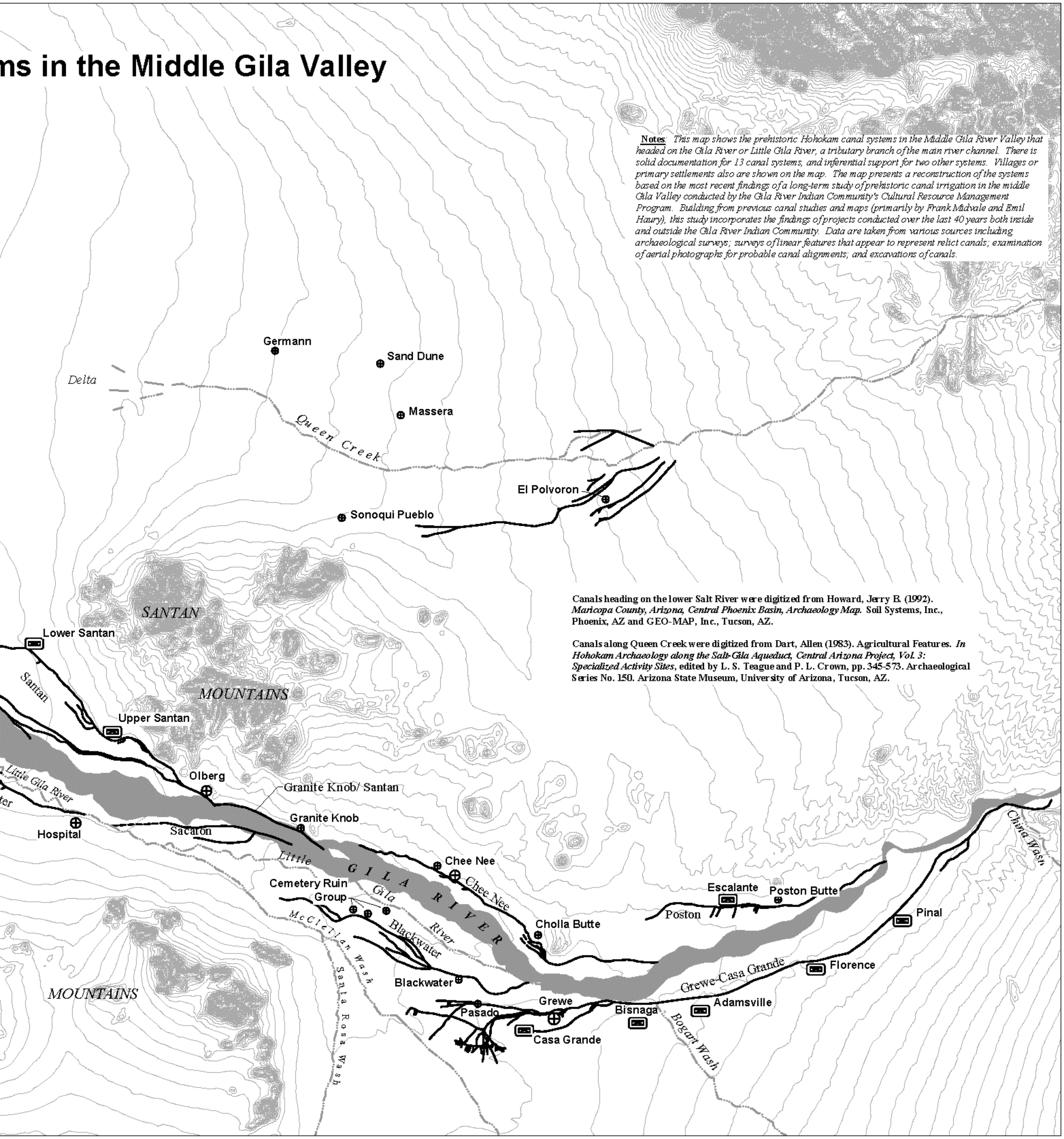


Figure 1. Map of Hohokam canal systems, 3rd edition (Woodson 2009a).


ms in the Middle Gila Valley
Notes: This map shows the prehistoric Hohokam canal systems in the Middle Gila River Valley that headed on the Gila River or Little Gila River, a tributary branch of the main river channel. There is solid documentation for 13 canal systems, and inferential support for two other systems. Villages or primary settlements also are shown on the map. The map presents a reconstruction of the systems based on the most recent findings of a long-term study of prehistoric canal irrigation in the middle Gila Valley conducted by the Gila River Indian Community's Cultural Resource Management Program. Building from previous canal studies and maps (primarily by Frank Midvale and Emil Haury), this study incorporates the findings of projects conducted over the last 40 years both inside and outside the Gila River Indian Community. Data are taken from various sources including archaeological surveys; surveys of linear features that appear to represent relict canals; examination of aerial photographs for probable canal alignments; and excavations of canals.
Germann
Sand Dune
Delta
Massera
Queen Creek
El Polvoron
Sonoqui Pueblo
Canals heading on the lower Salt River were digitized from Howard, Jerry B. (1992). Maricopa County, Arizona, Central Phoenix Basin, Archaeology Map. Soil Systems, Inc., Phoenix, AZ and GEO-MAP, Inc., Tucson, AZ.
Canals along Queen Creek were digitized from Dart, Allen (1983). Agricultural Features. In Hohokam Archaeology along the Salt-Gila Aqueduct, Central Arizona Project, Vol. 3: Specialized Activity Sites, edited by L. S. Teague and P. L. Crown, pp. 345-573. Archaeological Series No. 150. Arizona State Museum, University of Arizona, Tucson, AZ.
SANTAN
Lower Santan
Santan
MOUNTAINS
Upper Santan
Olberg
Little Gila River
Granite Knob/ Santan
Granite Knob
Hospital
Sacaton
Little
GILA RIVER
Chee Nee
Chee Nee
Cemetery Ruin Group
Gila
River
Blackwater
McClellan Wash
Cholla Butte
Escalante
Poston Butte
Poston
Pinal
China Wash
Florence
Grewe-Casa Grande
Blackwater
Santa Rosa Wash
MOUNTAINS
Pasado
Grewe
Bisnaga
Adamsville
Casa Grande
Bogart Wash

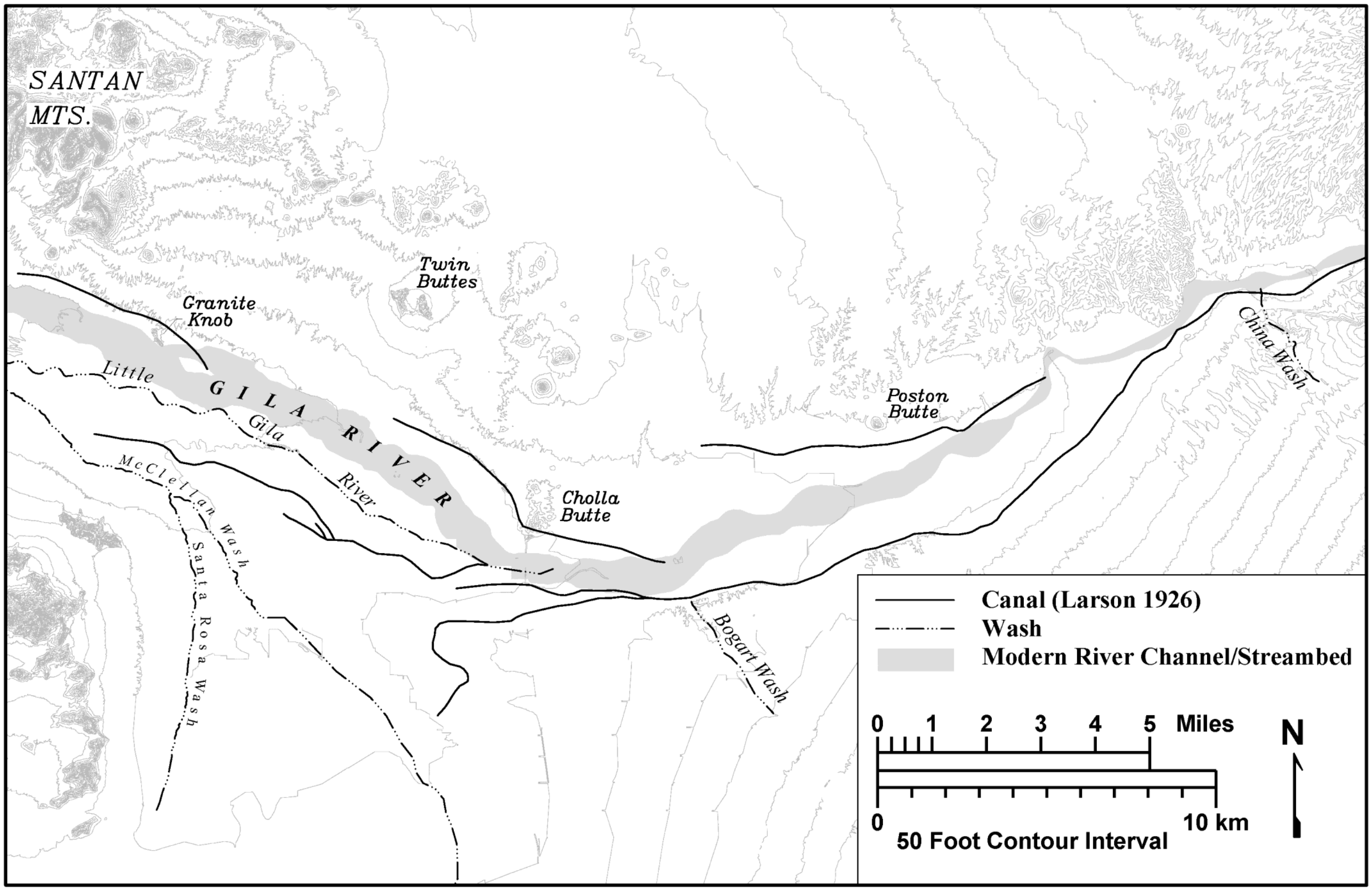


Figure 2. Prehistoric canals mapped by Larson (1926).

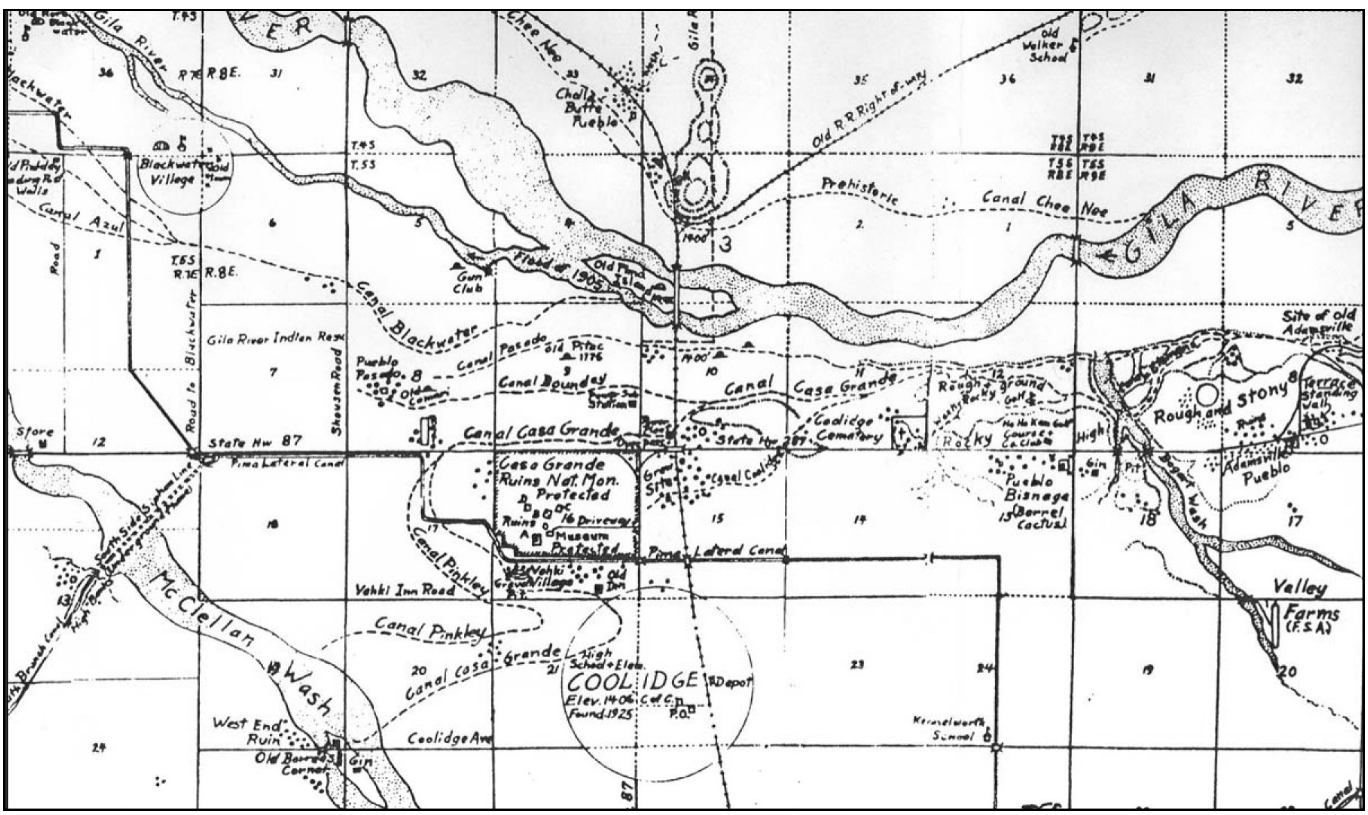


Figure 3. Portion of Frank Midvale’s 1963 map of canals and settlements in the Casa Grande Ruins area.

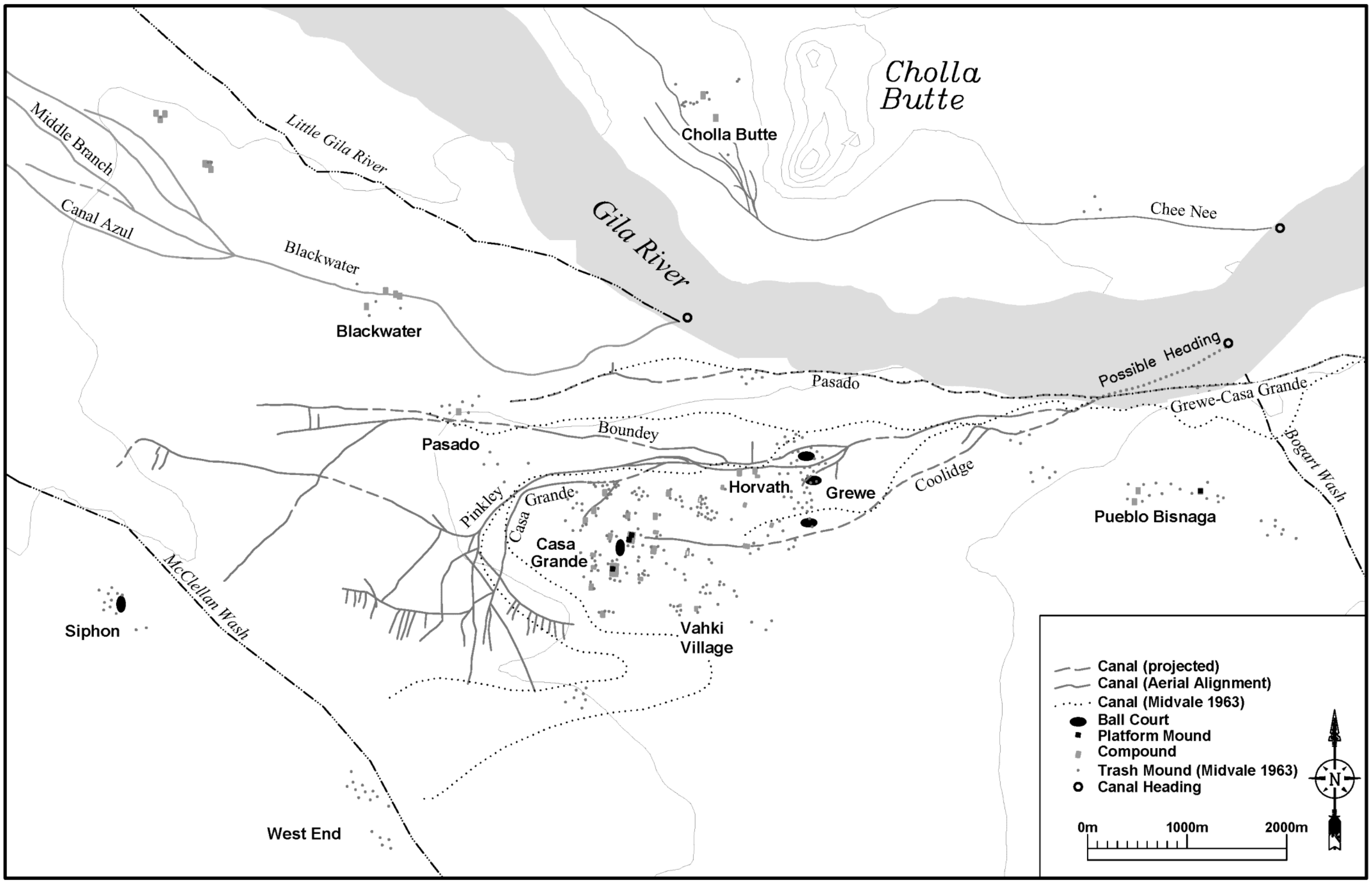


Figure 4. Tail end of Grewe-Casa Grande Canal System.

on topographic quadrangles, which are updated regularly based on the findings of ongoing projects.

As a result of this long-term study, there is now solid documentation for 13 canal systems, and inferential support for two other systems. Table 1 lists these systems in order of the sequence of their headings from upstream to downstream. Information included in this table includes the length of the main canal(s) for each canal system, the main canal gradient (estimated from surface topographic slope), and source data references. The existence of 3 of the 13 systems (Sacaton, Riverbend, and Gila Crossing) was confirmed through excavation only in recent years. Two systems (Sweetwater and Casa Blanca) and possibly a third (Blackwater) actually headed on the Little Gila River. The main canals in the 13 well documented systems have a total length of 221.8 km. The length increases to 242.7 km if the two possible systems are included. The possible systems (Pima Butte, Estrella) are inferred from several of Midvale's (1935, 1972) maps and/or from linear features visible on aerial photographs, but their existence has not been confirmed in the field. Below I highlight some interesting aspects of the revised map, discuss the temporal sequence and general patterns of the systems, and use the map to estimate the size of irrigated field areas.

HIGHLIGHTS OF THE REVISED MAP

Grewe-Casa Grande Canal System

The Grewe-Casa Grande Canal System, in its inferred Classic period configuration, is the longest system at 33.6 km. Its heading is the farthest upstream of all the middle Gila systems. The main canal alignment is similar to what was shown on earlier maps (Larson 1926; Crown 1987), but many details have been added to the tail end of the system (Figure 4). The new details are based on excavated canal segments in the Grewe-Casa Grande area (Deaver 2003; Phillips and Craig 2001; Steinbach and Rice 2006; Woodson 2009b), and linear features visible on aerial photographs from multiple years (Deaver 2003; Woodson 2009a). The canal alignments deviate somewhat from Midvale's (1963, 1965) plots, a result that probably stems from more precise documentation and mapping techniques. The main canal appears to divide into at least two branches (Casa Grande and Pinkley canals) and possibly three branches (Boundey).

Two issues that have yet to be resolved are 1) the length of the main canal, and 2) the possible consolidation of the system into a full 33.6 km. Researchers have assumed that the main canal was shorter during the Pre-Classic period, and that it was consolidated

Table 1. Hohokam canal systems along the middle Gila River (in order of heading, from upstream to downstream).

No.	Canal System Name	Main Canal Length (km)	Grad. (m/m)	Source Data (References)	Comments
1	Grewe-Casa Grande	33.6	0.0015	Crown 1984, 1987; Deaver 2003; Larson 1926; Midvale 1963, 1965; Phillips & Craig 2001; Steinbach & Rice 2005; Southworth 1914; Woodson 1996, 2009b	May have been 2 canals in early stages which later were consolidated into long canal; Midvale (1963, 1965) identifies separate upstream canal as Canal Pinal
2	Poston	12.0	0.0012	Crown 1984, 1987; Foster et al. 1996; Larson 1926; Midvale 1963, 1965, 1972; Yost 1999	Crown (1984, 1987) refers to this as the North Gila canal system
3	Chee Nee	16.0	0.0019	Gregory 1994; Larson 1926; Midvale 1963, 1965; Randolph & Greenspan 2003	Hypothetically this could have been two canals in early stages, with upstream canal serving Cholla Butte site, then they were consolidated by the Sedentary period
4	Blackwater	14.4	0.0011	Fertelmes 2009; Garraty & Woodson 2009; Gregory 1994; Larson 1926; Midvale 1963, 1965; Thompson 2009; Woodson & Randolph 2000; Wright 2009	Closely matches Midvale's (1963) map; system might have headed on Little Gila River near its divergence from Gila River
5	Sweetwater	10.3	0.0016	Eiselt et al. 2002; Miles & Woodson 2008; Wood 1971	Headed on Little Gila River; main canal=AZ U:13:42 (ASM)
6	Casa Blanca	24.2	0.0012	Barz 1998; Eiselt et al. 2002; Midvale 1935; Miles & Woodson 2008; Waters & Ravesloot 2000; Wood 1971; Woodson 2002	Headed on Little Gila River; main canal = AZ U:13:91 (ASM); Main canal + S branch=13.7 km, N branch=10.5 km
7	Granite Knob/Santan	5.5	0.0016	Gregory 1994; Larson 1926; Midvale 1963; Miles 2009	This canal may have been a headward segment of Santan Canal, or a separate canal that was consolidated w/ Santan Canal
8	Santan	26.6	0.0014	Burden & Loendorf 2003; Foster 2000; GRIC-CRMP Site Files (GR-1210); Loendorf et al. 2007; Midvale 1935, 1963; Neily et al. 2000; Woodson 2006	Main canal + N branch=17.3 km; S branch= 9.3 km. S branch links with Gila Butte Canal.
9	Sacaton	8.4	0.0014	Garraty et al. 2009; Midvale 1935; Woodson & Randolph 2000	This recently discovered system correlates roughly w/ a canal mapped by Midvale (1935); it irrigated land between Little Gila and Gila rivers, and may have diverted water into Little Gila R.
10	Gila Butte	11.7	0.0013	Brooks & Vivian 1978; Burt 2007; GRIC-CRMP Site Files (GR-1220); Howard & Rice 1982; Motsinger 1993; Neily et al. 2000; Swarthout & Blank-Roper 1984	Length is from Diversion Point 2 to linking point with Snaketown Canal; south branch of Santan Canal links with Gila Butte Canal
11	Snaketown	25.5	0.0015	Haury 1937, 1976; Midvale 1935, 1972; Motsinger 1993; Southworth 1914; Woodson 2007b	Main canal + N branch=17.4 km; S branch=8.1 km
-	*Pima Butte*	*13.2*	*0.0016*	Midvale 1935, 1972	This inferred canal, based on Midvale maps (1935, 1972), follows early historic ditch (Old Santa Cruz or Old Sranuka)
12	Riverbend	23.6	0.0017	Midvale 1972; Woodson 2007a	Newly discovered system; may have had 2 headings in use at same time
13	Gila Crossing	9.1	0.0016	Webber & Basham 2009	Newly discovered system
-	*Estrella*	*7.7*	***0.0012***	Midvale 1972; aerial photographs	Inferred canal based on Midvale (1972) notes and linear features visible on aerial photo
Total:		**241.7**	-		Includes 15 main canals
w/o possible canals:		**220.8**	-		Total omits Pima Butte & Estrella canals

Italics=possible canal ; Total=13 canal systems with good documentation, 2 possible canals with inferential support with one or more upstream main canals in the Classic period (Crown 1987; Gregory 1994; Midvale 1965; Phillips and Craig 2001). Larson (1926) depicts one long canal that heads at China Wash and ends at McClellan Wash. Midvale (1963, 1965) depicts two canals, with Canal Pinal heading upstream to its farthest point at China Wash and Canal Casa Grande heading about 4.8 km downstream of that point. Midvale (1965:83) states that Canal Casa Grande "was at first only 3 or 4 short canals heading at convenient points along the Gila." On the other hand, Crown (1984:220) contends that Midvale's Canal Pinal actually was part of the Casa Grande Canal (her "South Gila Canal") and was not a separate canal.

An examination of the settlement pattern along the inferred 33-km long canal suggests that initially two separate canals were built in the area (Woodson and Rice 2002). The only settlement with a known Pioneer period component is Grewe. The inferred canal serving Grewe at that time was relatively short, as is assumed for most Pioneer period canals (Gregory 1994:153). The canal may have headed about 5 km upstream near Bogart Wash. During the early Colonial period, the Siphon Ruin and West End Ruin were founded downstream of Grewe along McClellan Wash, and the Grewe Canal probably was extended to the wash (for a total length of around 10.5 km). In the late Colonial period, survey evidence suggests that occupation had begun at Pueblo Bisnaga and Los Canales, located 4 km and 18 km upstream from Grewe, respectively. Pueblo Bisnaga was situated near the possible heading of the Grewe Canal and may have been integrated into the Grewe Canal System.

The wide spacing without habitation sites between Grewe and Los Canales suggests that these two villages were served by separate canal systems. The Pinal/Los Canales Canal probably headed near China Wash, and could have been roughly congruent with Midvale's (1963) Canal Pinal. The longer canal system may have been initiated by the consolidation of these canals prior to the Sedentary period. This assessment is based on the observation that the other major villages upstream of Grewe and Casa Grande (Adamsville Ruin, Clemans Pueblo, Florence Pueblo, and Pinal Pueblo) were built before or in the early part of the Sedentary period. Main canal capacity was doubled with the construction of a new canal in the early Classic period and re-doubled with the building of the Casa Grande Canal in the late Classic (Phillips and Craig 2001).

However, during the Classic period, it is possible that the main canal was not as long as the often cited 33 km. The Casa Grande Canal, according to excavated exposures at the Hovarth site (Phillips and Craig 2001:157), had a discharge that ranged between 4.88 m^3/sec and 6.41 m^3/sec. If the heading for the Casa Grande Canal was 26 km upstream from this point, the canal would have had an estimated maximum discharge of 10.5 m^3/sec at its heading.[1] Although not impossible, a canal of this size would have been over twice as large as any other Classic period main canal along the middle Gila River (Woodson 2004; also see Howard 2006:188–189). Instead, the canal may have been approximately 10.5 km long, with its heading near Bogart Wash. This length would result in a capacity of roughly 8.7 m^3/sec at the heading. If this was the case, then a separate canal system, which would have been roughly congruent with Midvale's (1963) Canal Pinal, would have been in operation upstream of the Casa Grande System. Unfortunately, this issue cannot be resolved until more excavation is conducted in the upper portions of the canal system.

Santan and Gila Butte Canal Systems

The Santan Canal System is now far better delineated than in the past, a benefit of excavating over 50 canal segments and documenting numerous relict canal alignments on the surface (Figure 5). One issue to be resolved is whether this system headed at Olberg Butte or farther upstream at Granite Knob. Historic flooding scoured away most of the terrace where the canal would have existed. However, early maps (Larson 1926; Midvale 1946, 1963) indicate that a canal headed at Granite Knob, and recent work (Gregory 1994; Miles 2009) has documented the only known relict segment of this canal (see "Granite Knob/Santan Canal" on Figure 5). This 5.5-km long canal was either an independent canal or the upstream segment of the Santan Canal. If it was independent, it would be atypically short for a main canal on the middle Gila. Placement of the Santan Canal heading at Granite Knob makes more sense from a settlement pattern perspective, especially given the proximity of Granite Knob and Olberg villages (5 km apart). In addition, placement at Granite Knob provides a heading farther upstream at a bedrock outcrop. A recent investigation of a cutbank exposure of the relict segment of the Granite Knob/Santan Canal suggests it was much larger than necessary for irrigating the area between Granite Knob and Olberg Butte, but it was not large enough to have been the only water supply for the Santan Canal and its fields (Miles 2009). Therefore, the Santan Canal probably headed at Olberg Butte, and the tail end of the Granite Knob Canal was joined to the Santan Canal to provide supplemental water.

The main Santan Canal, including the branches, measures 26.6 km long (32.1 km if it headed at Granite Knob) and is the second longest on the middle Gila. The main canal divides into two branches roughly 2 km from the inferred heading at Olberg Butte, with the north branch coursing by the villages of Upper Santan and Lower Santan and the south branch extending toward Gila Butte. Several distribution and lateral canals,

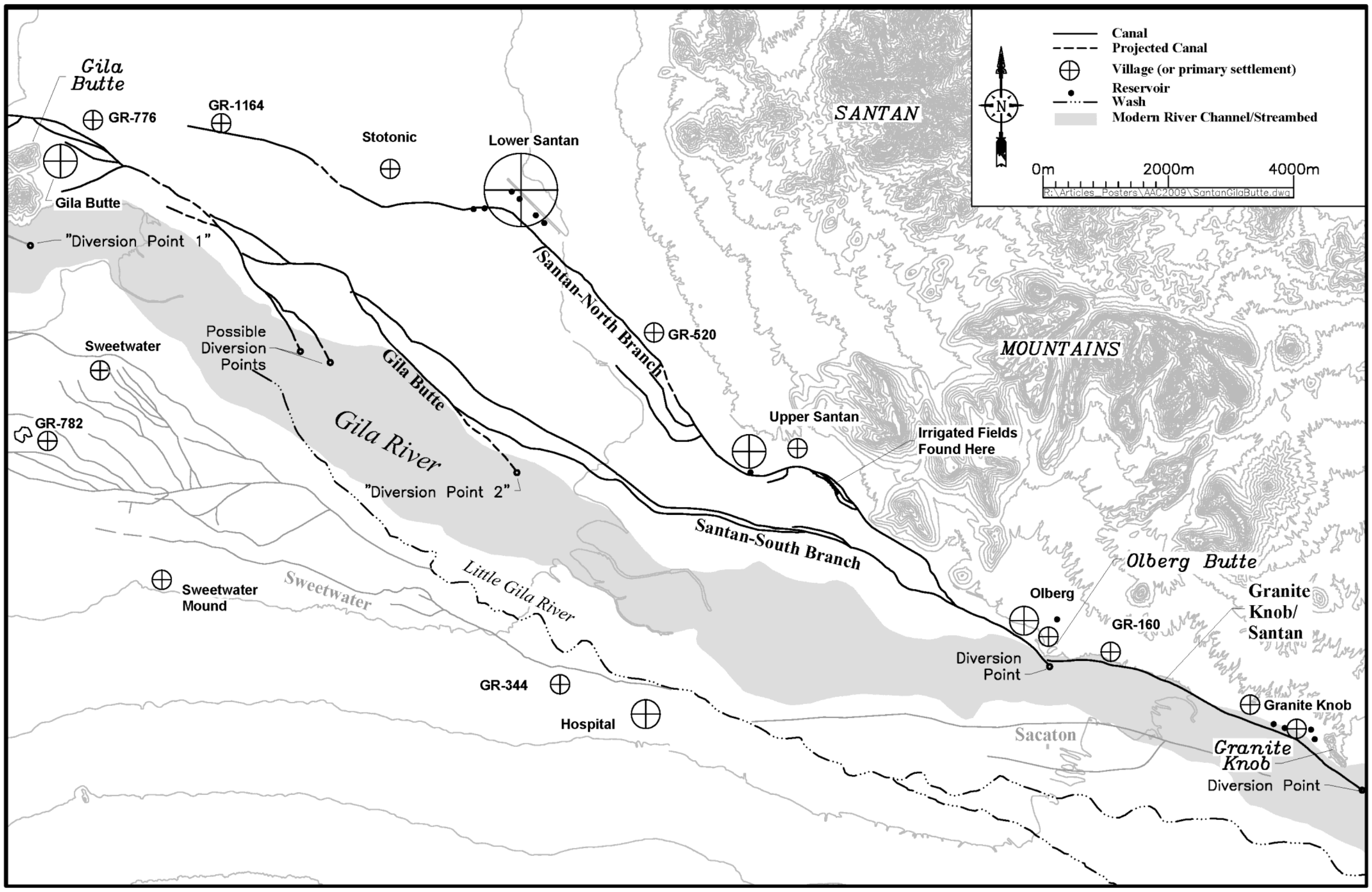


Figure 5. Santan and Gila Butte canal systems.

canal turnouts (or gates), and large reservoirs have been documented along the north branch canal. Reservoirs in Lower Santan Village were filled by water diverted from washes on the bajada (Loendorf et al. 2007), similar to other reservoirs at Olberg and Granite Knob villages (see Gregory 1994). A reservoir at Upper Santan Village appears to have been filled from both washes and the Santan Canal. In one area near Upper Santan Village, a series of irrigated fields have been identified along the north branch canal (see paper by Miles, Wright, and Woodson in this issue). The fields are evident as rectangular areas between distribution and lateral canals and are defined based on the occurrence of anthropogenic sediments, which contrast with the natural soil. The contrast is particularly clear due to the excellent preservation of the fields and the location at the distal end of an alluvial fan. The layout conforms well with the canal-field system model that Howard (2006) has outlined.

The Gila Butte Canal headed at "Diversion Point 2" (see Haury 1976), which is located about 9 km downstream from Olberg Butte. This canal probably was built in the Snaketown phase and initially carried water as far as the Gila Butte site (Swarthout and Blank-Roper 1984). In the Early Colonial period it was extended to a settlement on the northwest side of Gila Butte, and by the Sedentary period it was connected with the Snaketown Canal (Woodson 2007b). The Gila Butte Canal measured 11.6 km long at that time, but it was increased to 12.7 km long in the Classic period when another extension was built to the Snaketown Canal. Excavations near Gila Butte revealed segments of both the Pre-Classic and Classic period main canals in the Gila Butte System (Brooks and Vivian 1978; Motsinger 1993; Swarthout and Blank-Roper 1984). Recent work indicates that the south branch of the Santan Canal connects with the Gila Butte Canal about 3 km below the latter canal's heading (Fertelmes and Loendorf 2010; GRIC-CRMP Site Files). The two canals probably were connected in the Sedentary period, but the timing is unclear. Hence, the Santan (south branch), Gila Butte, and Snaketown canals were joined by the Sedentary period, though each of the three original headings appears to have remained in operation.

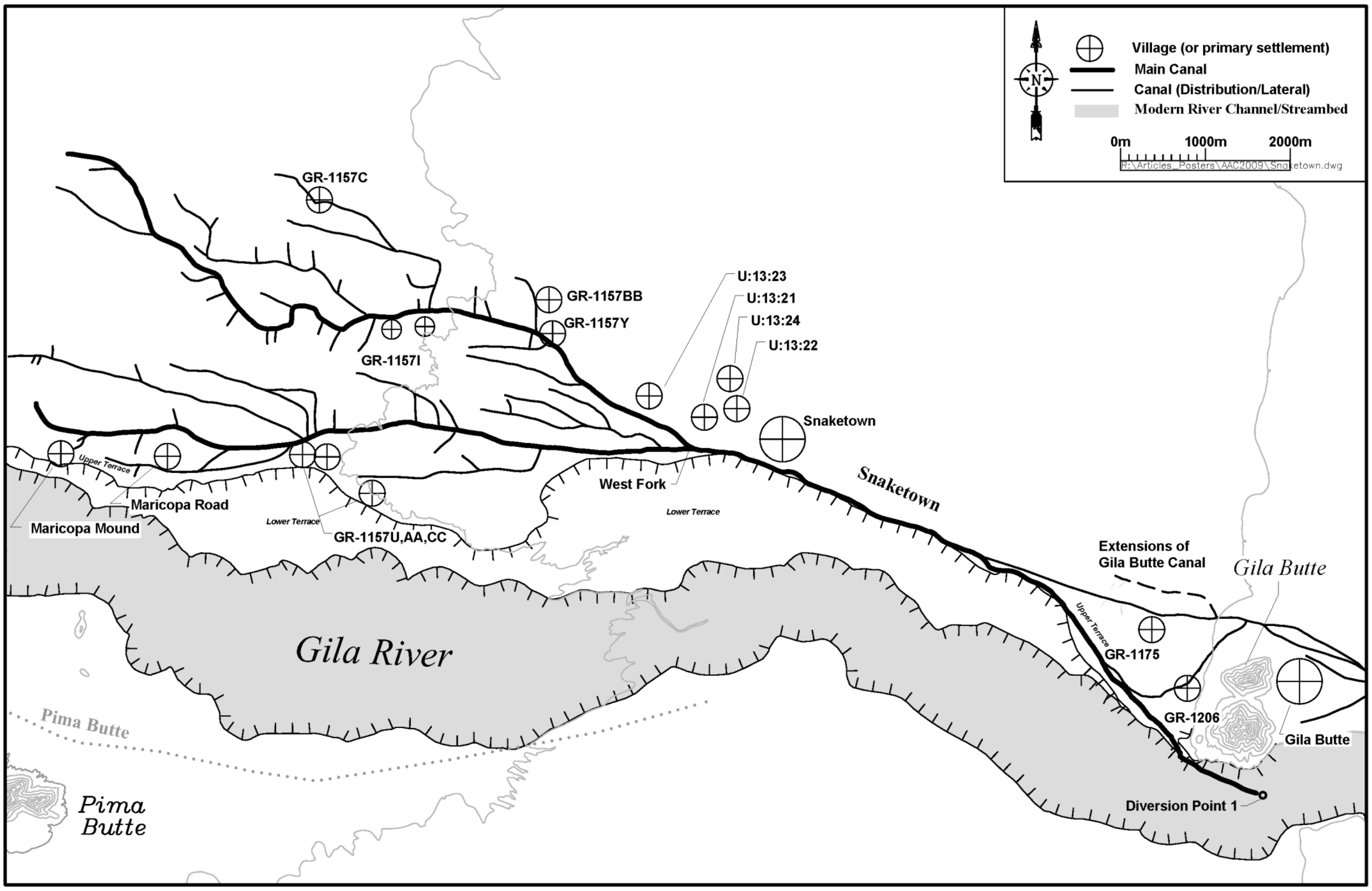


Figure 6. Snaketown Canal System.

Snaketown Canal System

Previously, I presented a revised map of the Snaketown Canal System and discussed the labor requirements for building and cleaning it (Figure 6) (Woodson 2007b). Based on data from surveys, my dissertation research, and Haury's (1937, 1976) excavations, all linear features that are detectable on the ground surface and that are judged to be relict canal alignments in this system have been mapped. The mapping process was greatly facilitated by the undeveloped terrain, and the recognition that the alignments of buried prehistoric canals frequently are marked on the surface by linear earthen mounds or linear artifact scatters, or both (Figure 7).

The layout of the Snaketown System is very different than the spatial arrangement shown on previous maps (i.e., Haury 1937, 1976; Midvale 1935, 1972). In total, more than 64 km of canals have been documented. This figure includes 25.5 km of main canals (the third longest on the middle Gila) as well as 17 distribution canals and 42 lateral canals. The main canal has its primary heading at the foot of Gila Butte (Diversion Point 1), and measure 8.1 km long from its heading to its branch point at the West Fork. Like the Santan Canal, the Snaketown Canal divides into two branches. From there the north branch extends another 9.3 km

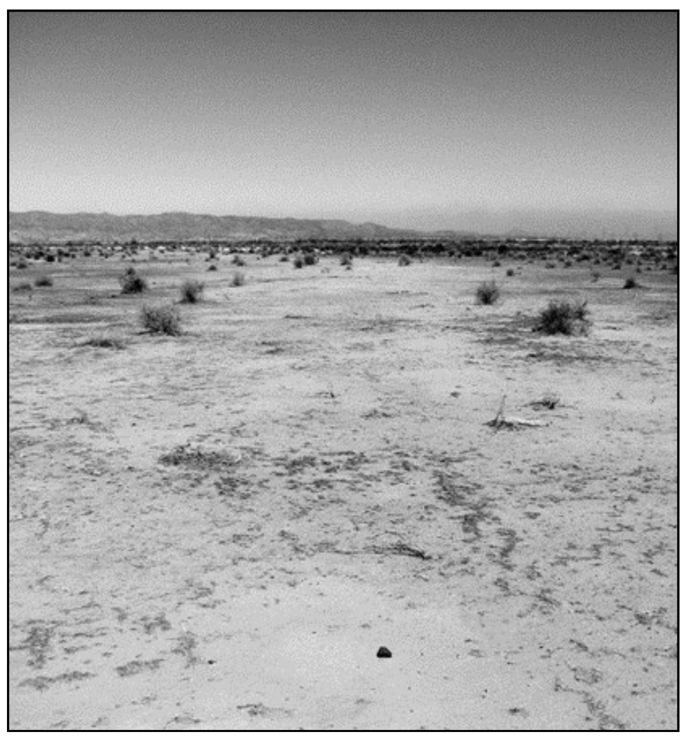


Figure 7. Photograph of the Snaketown Canal, visible here as a linear mound and artifact scatter.

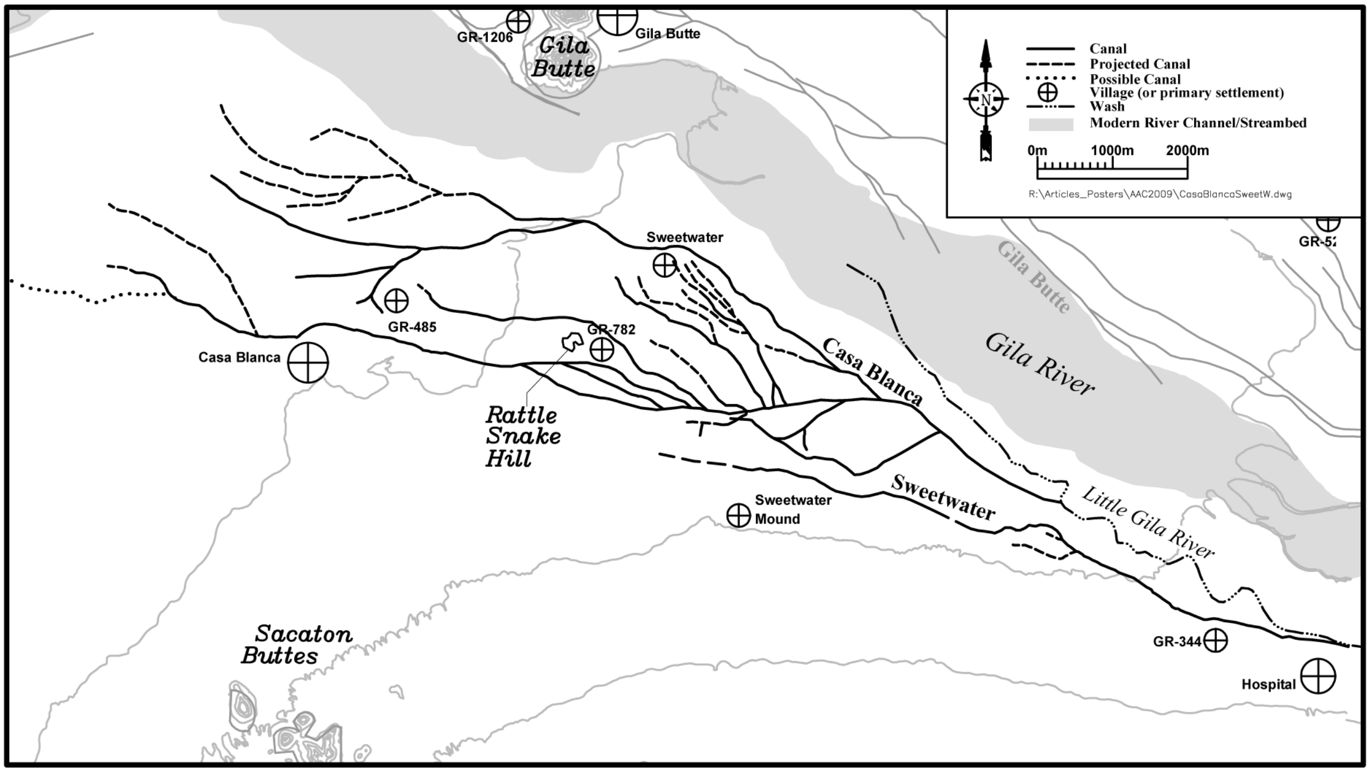


Figure 8. Casa Blanca and Sweetwater canal systems.

and the south branch extends 8.1 km. The new map also defines the interface between the Snaketown and Gila Butte canal systems. The two systems were first connected during the Sedentary period by a short extension of the Gila Butte Canal, and then a second, larger extension was completed in the Classic period.

Casa Blanca and Sweetwater Canal Systems

Since Midvale (1935) completed his initial sketch map of the Casa Blanca area, much has been learned about the Casa Blanca and Sweetwater canal systems (Figure 8). These neighboring systems headed on the Little Gila River. The Casa Blanca System served the Casa Blanca platform mound community, and the Sweetwater System served the Sweetwater platform mound community. The headward portions of the main canals in both systems were recorded previously as sites (Wood 1971). In those portions, the canals are visible on the surface as linear mounds with medium to high density artifact scatters located along them. Excavations have exposed segments of these main canals as well as distribution and lateral canals (Miles et al. 2008; Waters and Ravesloot 2000; Woodson ed. 2002). Recent efforts also were made to map other linear surface features and artifact scatters (Miles et al. 2008), especially in relation to recorded sites in the area (Eiselt et al. 2002). Like the Snaketown and Santan canals, the Casa Blanca Canal divides into two branches. The main canal, including the branches, measures 24.2 km long (fourth longest on the middle Gila). The Sweetwater Canal is 10.3 km long. These systems likely were joined, but this has not been confirmed .

Riverbend Canal System

Work along a gas pipeline in 2005 resulted in the discovery of 40 prehistoric canals at four sites along the left bank of the Gila River (Figure 9) (Woodson 2007a). The canals are located west of Pima Butte on a terrace known as "Santa Cruz Island" between the Santa Cruz and Gila rivers. This canal complex has been named the Riverbend Canal System, as it heads at one of the most pronounced bends in the middle Gila River. Midvale (1972) apparently surmised that prehistoric canals extend onto Santa Cruz Island based on an unpublished map. This project clearly demonstrated the existence of canals on the island. Multiple main canals were documented in the system, and more than one heading was used to supply them. A peak of 23.6 km of main canals was in use during the late Colonial period (fifth longest system on the middle Gila), with 18.5 km used during the Sedentary and Classic periods.

Eighteen canal alignments are visible on the ground surface as linear artifact scatters that extend from the edge of the river terrace to the west. These linear scatters were tracked on foot for distances of up to 1 km, and most of them extend farther. The scatters, varying between 10 and 20 m wide, occur in

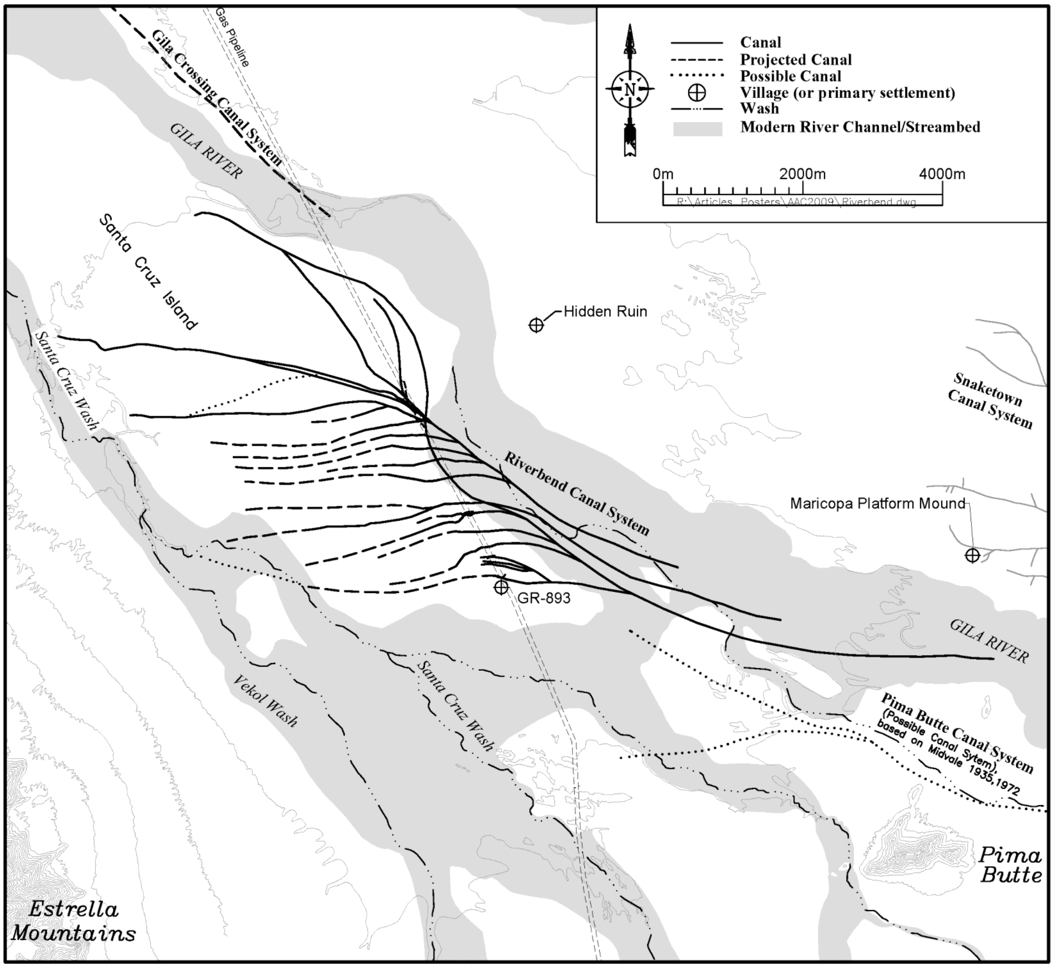


Figure 9. Riverbend canal system.

deflated portions of Santa Cruz Island where the canals and their contents have eroded onto the now flat ground surface. Nine canals at one site were buried under a sand dune. The canals are not evident on the surface as linear artifact scatters because the dune has not deflated significantly. They appear to have been used just prior to and possibly during an environmental change that resulted in the deposition of dunes on Santa Cruz Island. The area may have witnessed intermittent wet and dry periods, with the dunes being deposited during the dry periods. The canals may have been abandoned at the onset of a dry period and subsequently covered by windblown sediments.

TEMPORAL SEQUENCE

The earliest canals along the middle Gila River were built in the Vahki phase of the early Pioneer period. The Snaketown Canal is the only canal that has been confirmed to have been built at that time (Haury 1976). The construction date for the canal is roughly concurrent with the founding of Snaketown. Two other canals (Grewe and Casa Blanca) also may have been built in the Vahki phase. The Grewe Canal is inferred to have been built at the same time as the Grewe site, although none of the known canals in the Grewe System date that early (Phillips and Craig 2001). The possible early age for the Casa Blanca Canal is based on a subsurface feature found during a geomorphological testing project. Waters and Ravesloot (2000:53) documented a probable small canal from which a piece of wood charcoal returned a radiocarbon date of cal A.D. 190–380.

At least one canal system (Gila Butte) was built during the Snaketown phase of the late Pioneer period (Burt 2007; Swarthout and Blank-Roper 1984). Despite the lack of direct evidence for other Snaketown phase canals, I argue that that seven other canals were built at that time: Grewe and Casa Blanca (if they hadn't already been built in the Vahki phase), as well as the Chee Nee, Granite Knob, Santan, Sweetwater, and possibly Blackwater canals. Survey and (non-canal) excavation data from sites along canals support this contention. The Poston Canal also may have been built (based on the presence of Snaketown Red-on-buff sherds at the Poston Butte site), but this is unclear. In the cases of the Chee Nee and Santan canals, it is not clear whether they served the Cholla Butte and Granite Knob settlements, respectively, or if those settlements were served by separate, shorter canals

(Gregory 1994). In sum, it is probable that 9 of the eventual 13 canal systems were in operation by the Snaketown phase (10 systems if the Poston Canal was built by then). These canals had not yet been built to their full extents; that construction was accomplished primarily during the early Colonial period.

The Riverbend System was initiated in the early Colonial period. If some of the canals that are inferred to have been built in the Snaketown phase (see above) were not built at that time, then they almost certainly were in operation by the early Colonial period. So, 11 of the 13 systems had been initiated and largely extended during the early Colonial period. The remaining two canals, the Sacaton and Gila Crossing canals, may not have been built until the Sedentary period, but their construction sequence is currently unclear. All 13 systems were in operation during the Classic period.

OTHER OBSERVATIONS

A few general observations are notable for the middle Gila canal systems. First, the valley topography presented constraints on the layout of the systems (Crown 1987:153; Gregory and Nials 1985). The sharp terraces generally prevented substantial lateral expansion of canals and irrigable lands, and limited intensive settlement and land use to a “ribbon strip” along the river. The systems were strongly linear and closely paralleled the river in most cases, except for a few locations such as the lower parts of the Grewe-Casa Grande, Blackwater, Snaketown systems, which are the only systems that irrigated land on the uppermost, Pleistocene terrace.

Second, some canal systems were consolidated with other systems during their use-life. The timing of consolidation is not well understood, but evidence suggests that the process was underway by the Sedentary period. As noted above it is likely the long Grewe-Casa Grande Canal was originally two separate, shorter canals, which were then joined into the longer canal, perhaps by the Sedentary period. Gregory (1994:153, 169) posits that the Cholla Butte and Granite Knob villages were served initially by their own short canals, which later were consolidated with the Chee Nee and Santan canals by the Sedentary or Classic period. The Santan Canal (south branch) was joined with the Gila Butte Canal, which in turn appears to have been joined to the Snaketown Canal in the Sedentary and Classic periods. The latter cases may not be true “consolidations” because the original headings of each canal probably were still used through the Classic period.

Third, the bifurcation of the main canal into two branches is a notable pattern that has been confirmed in the Grewe-Casa Grande, Blackwater, Santan, Casa Blanca, Snaketown, and Riverbend canal systems and possibly in the Sacaton System. The practice of diverting a large main canal from the river, bringing it up onto higher ground, and then dividing it would have been an efficient way of serving larger field areas without using multiple canal headings. By using one instead of two (or more) headings, irrigators reduced maintenance costs and the risk of damage to canal diversion structures and headgates in the headward portion of the main canals.

Fourth, segments of the main canals in at least eight systems (Poston, Sweetwater, Casa Blanca, Granite Knob, Santan, Gila Butte, Snaketown, and Riverbend) can be traced on the ground surface as linear earthen mounds and/or linear artifact scatters. Midvale (1965:83) also recognized that “[s]ometimes only a path of stone tools and other broken litter marks the course of the canal across the desert.” Even within some historic or modern cultivated fields, linear artifact scatters marking canal alignments can still be discerned by the trained eye (Woodson 2006). Because the middle Gila Valley includes large, undeveloped areas along the river terraces, it is one of the last places in the Phoenix Basin that prehistoric canals can be seen on the surface as artifact “trails.”

Fifth, the hydraulic properties of the main canals tend to be similar. Main canal gradients, velocities, and discharges exhibit unimodal patterns, with a few exceptions (Woodson 2004). The average gradient for all 13 known canals is 1.45 m/km, with a majority (54 percent) of canals having a gradient of 1.4 to 1.6 m/km (see Table 1). For excavated main canals, the mode for canal velocity peaks at 0.8–0.9 m/s. The estimated discharge of these canals at their heading shows a dominant mode of 5–6 m^3/sec (The Classic period Casa Grande Canal is an exceptional outlier).[2] This overall similarity in the hydraulics of main canals suggests that the Hohokam had a shared technological knowledge for canal engineering.

ESTIMATING FIELD AREAS

A benefit of the revised map is that it allows a critical assessment of the size (or command area) of the irrigated field areas. Modeling irrigated area requires a solid understanding of the location of main and distribution canals, but it also depends on the lengths of the lateral canals. Based on my dissertation research on the Snaketown Canal System, I found that lateral canals measured between 94 m and 464 m long and averaged 254 m in length. This range and average length correlates well with the lateral lengths inferred by Howard (2006) in his detailed study of field sizes in the “spider web” area of Canal System 1 along the lower Salt River. He found that field lengths (and, by extension, lateral lengths) varied between 150 m to 380 m and had a mean of 238 m. If correct, both studies sup-

Table 2. Estimated field areas of Hohokam canal systems along the middle Gila River.

No.	Canal System Name	Main Canal Length (km)	Field Area, in ha (Laterals = 500 m long)	Field Area, in ha (Laterals = 254 m long)	Percent of total irrigable area along Gila R.
1	Grewe-Casa Grande	33.6	3,607	2,374	18.6
2	Poston	12.0	544	297	2.3
3	Chee Nee	16.0	839	458	3.6
4	Blackwater	14.4	1,426	830	6.5
5	Sweetwater	10.3	830	457	3.6
6	Casa Blanca	24.2	3,389	2,342	18.3
7	Granite Knob/Santan	5.5	186	133	1.0
8	Santan	26.6	1,457	1,193	9.3
9	Sacaton	8.4	808	469	3.7
10	Gila Butte	12.7	1,048	660	5.2
11	Snaketown	25.5	2,660	1,492	11.7
12	Riverbend	23.6	2,396	1,873	14.7
13	Gila Crossing	9.1	339	203	1.6
	Total:	**221.8**	**19,531**	**12,781**	**100.0**

port the contention that the Hohokam in the lower Salt and middle Gila valleys shared a common irrigation technology that resulted in similar adaptations within separate areas. For comparison, I also examined lateral lengths in two early historic Akimel O'odham canal systems (Bapchil and Stotonick) along the middle Gila River (using the Southworth 1914 maps). Lateral canal lengths ranged between 91 m and 579 m, with average lengths of 213 m and 350 m, respectively. This correlates well with the ranges and average lengths of the laterals in the Snaketown Canal System and Canal System 1.

Table 2 lists the main canal lengths and irrigated field areas (in hectares) for the 13 well defined canal systems on the middle Gila. Two field area estimates are given. One estimate assumes that laterals were 254 m, while the second assumes that they were 500 m long. Field area estimates were calculated by applying a buffer zone of relevant length around the main and distribution canals in each canal system. Adjustments were made where needed to account for topographic constraints and areas where canals could only have irrigated downslope (toward the river). The field area values change significantly depending on the lateral lengths. If the laterals averaged 254 m long, the field areas along the 13 systems would total 12,449 ha. If the laterals were 500 m long, the total irrigated area would be 19,531 ha. If we find that the two possible canals (Pima Butte, Estrella) do exist, then the total irrigated area may have exceeded 20,000 ha. Overall, I think that the actual command area of the 13 systems is somewhere between the two amounts, but probably closer to the lower end. These amounts are much less than previous estimates (e.g., Cummings 1926), but I argue that they are more realistic.

The information on command area can be applied to studies of agricultural potential, as well as to estimates of population size for the middle Gila systems. Although those topics are outside the scope of this paper, a quick calculation of population size can be estimated by assuming a family of five farmed 2 ha per year (Castetter and Bell 1942:54–56). If 12,781 to 19,531 ha were being farmed, then 6,391 to 9,766 households–or 31,953 to 48,830 people–may have been living along the middle Gila River prehistorically.

CONCLUSION

We have made great strides in revising the map of the prehistoric canal systems along the middle Gila River as a result of advances in Hohokam archaeology over the last quarter century. The amount of information accrued in that time represents a quantum leap in our data on canals. The new findings have allowed us to better define the layout, sequence of development, and size of the canal systems. Improvements will continue to be made as work progresses over the coming years. I would suggest, though, that our current understanding of these canal systems has now reached a point that matches the level of importance of canal irrigation to the Hohokam.

Notes

1. The maximum capacity (discharge) of an excavated main canal can be retrodicted at its inferred heading using regression modeling (Howard 1993). The regression formula for the reduction of canal cross-sectional area established by Howard (1993:287) is

$$\hat{y} = z(\log(x+1)) + (y \text{ intercept})$$

where z is the multiplicative constant (slope). The same formula can be applied to discharge reduction. Woodson (2007b) conducted a regression analysis of the areas of excavated segments along four main canals along the right bank of the Gila River (Granite Knob, Santan, Gila Butte, and Snaketown), and found the z value for the Classic period channels was -1.25. This value was used here to retrodict the area of Canal Casa Grande at its heading.

2. See endnote 1.

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HOHOKAM IRRIGATED FIELDS NEAR UPPER SANTAN VILLAGE ON THE GILA RIVER

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ABSTRACT

Recent excavations near Upper Santan Village along the middle Gila River uncovered an extensive section of the prehistoric Santan Canal System that appears to include irrigated agricultural fields. The main canal, two distribution canals, and at least four lateral canals occur in this area. The agricultural fields are situated between the lateral canals and are characterized by blocky silty clay loam sediments resting unconformably atop Bw subsoil. These sediments contrast in both color and texture with the native soil detected elsewhere at the site. The contrast is particularly clear due to the excellent preservation of the fields based on their depth of burial and location at the distal end of an alluvial fan. Paleobotanical, micromorphological, and isotopic analyses of the sediments are underway to confirm the preliminary findings. The Upper Santan fields represent one of the most comprehensive views of Hohokam irrigated fields unearthed to date.

Archaeological investigations have long focused on the vast network of prehistoric Hohokam canal irrigation systems in the middle Gila and lower Salt river valleys (e.g., Haury 1976; Howard 1993; Ingram 2008; Turney 1929; Woodbury 1960). However, documentation of the agricultural fields in which prehistoric farmers irrigated their crops is generally lacking (Howard 1990:14–23). Recent excavations on the Gila River Indian Community (GRIC) near Upper Santan Village uncovered an extensive section of the prehistoric Santan Canal System that includes the main canal, three distribution canal, at least six lateral canals, and a set of associated agricultural fields. The Upper Santan fields represent one of the most comprehensive views of Hohokam irrigated fields unearthed to date within the Phoenix Basin. This paper summarizes ongoing research conducted by the GRIC Cultural Resource Management Program (GRIC-CRMP), as part of mitigation efforts for the Santan (ST) Reach of the Pima-Maricopa Irrigation Project (P-MIP) main-stem canal. The study utilizes particle-size and phenotypic soil data to verify the prehistoric irrigated fields and to refine our understanding of Hohokam irrigation agriculture in the middle Gila Valley.

UPPER SANTAN VILLAGE AND GR-441, LOCUS G

The investigated prehistoric agricultural fields and segments of their associated canal system were identified at site GR-441, Locus G (Figure 1). Site GR-441 is a multi-component Hohokam settlement and associated artifact scatter that encompasses Upper Santan Village, a large habitation site with a platform mound and ballcourt (Loendorf et al. 2007; Neily et al. 1999; Wilcox 1977). Upper Santan Village was described by ethnographer Frank Russell (1975[1908]), whose informants identified the Santan platform mound ruin as *Â–ât ‘kam Va-aki*, or Sandy Ancient House, ruled by *Si' van* (“chief”) *Kĭa'–atak*, or Handle (Russell 1975 [1908]:24). The area of investigation includes a low-density prehistoric and historic surface artifact scatter located 1.3 km southeast of the Upper Santan platform mound. Locus G is overlain by historic Akimel O’odham settlements, consisting of *ki*, *vato*, and other traditional structures dating to the late-nineteenth and early twentieth centuries. The Well Ditch and Santan Flood Canal, which are canals dating to the early twentieth-century, also cut across Locus G. However, records indicate that no historic or modern land disturbing activities occurred at the locus; conditions for preservation of features were ideal.

Overall, the archaeological record present at GR-441 portrays a prehistoric community entrenched in long-standing and diverse agricultural practices (see Loendorf et al. 2007). Temporal evidence suggests the

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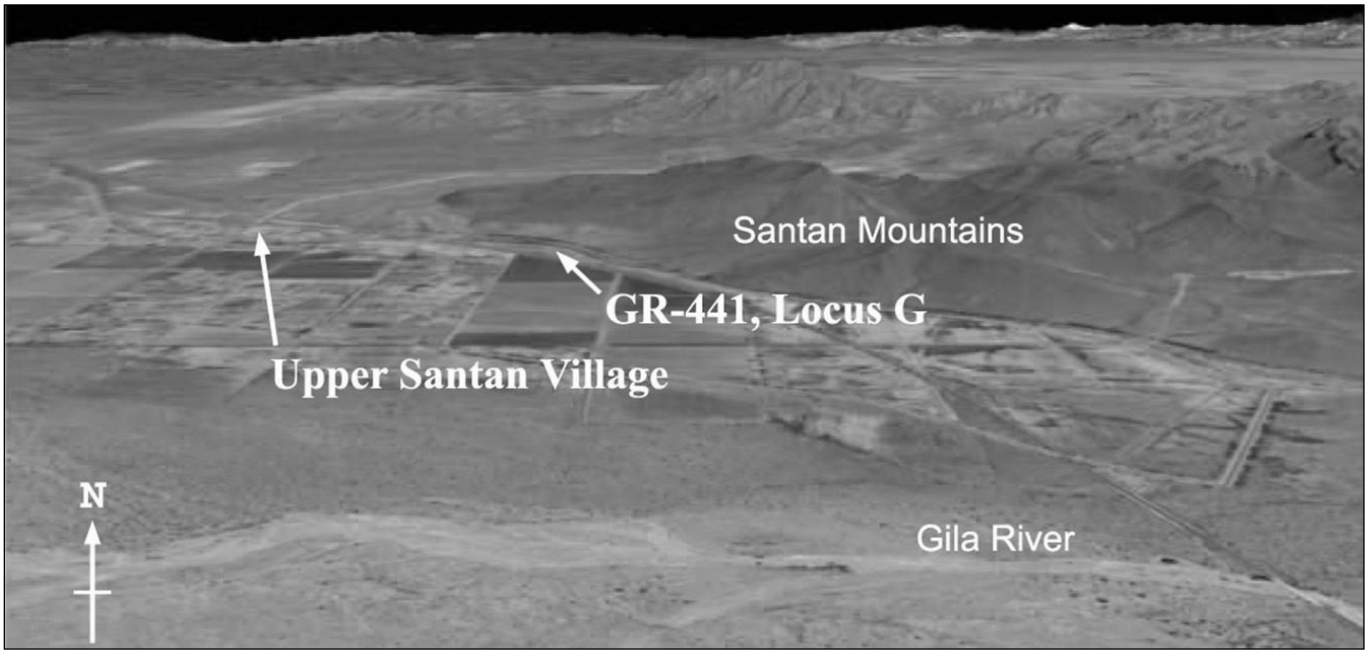

Figure 1. Setting of GR-441, Locus G. Aerial image courtesy of Google Earth.

Upper Santan community developed from the early Colonial to late Classic periods, ca. A.D. 750–1450. Prehistoric cultural remains adjacent to Locus G consist of a series of dry farming agricultural features located to the immediate north, northeast, and northwest. Rock-reinforced compounds dating to the Classic period also occur north and northwest of Locus G

The area investigated is located within the central Basin and Range Province and the bedrock is comprised of Middle Miocene to Oligocene volcanic extrusions (11–38 mya) (Richard et al. 2000). The project area is situated in Quaternary sediments at the interface between the distal end of an alluvial fan of the adjacent Santan Mountains and the margin of the second terrace on the Gila River (T-2, see Waters 1996) (Figure 1). Locus G was well positioned to receive runoff from the Santan Mountains, yet it was far enough away from the river to avoid contact with episodic torrential overbank floodwaters. The native solum is classified within the Shontik-Redun complex (zero to three percent slopes) and is characterized as fine sandy loam stream alluvium with ochric and cambic epipedons. The modern Gila River channel lies ~2.5 km (1.6 miles) to the south.

Excavation of 3,133 linear meters of backhoe trenches and 3,230 m^2 of hand- and backhoe-stripped overburden was conducted as part of phased data testing and data recovery efforts within Locus G. This work resulted in the discovery of 334 cultural features. Specialized samples (e.g., pollen, micro-invertebrate, phytolith, macrobotanical, micromorphological, chemical and particle-size) were collected from a variety of contexts in order to address a number of research topics associated with prehistoric irrigation agriculture (Woodson 2003). Particle-size and phenotypic soil data are the primary analyses used here. The results of other analyses will be presented in the future.

THE CANAL-FIELD SYSTEM

Evidence for prehistoric canal and field systems at GR-441, Locus G was identified largely through a combination of extensive trenching and minimal horizontal exposure. One main canal alignment, three distribution canal alignments (which includes several remodeled canal channels), and six field lateral canal features (Figure 3) were identified at Locus G. A total of five field plots (areas between field lateral canals) were identified, as were several agricultural field areas. The relationships between fields and irrigation features were determined to be a function of slope and water availability.

The main canal alignment consists of a southeast to northwest trending canal located to the northeast of the locus (Figure 2). This canal is the northern-most and largest canal exposure found at GR-441, and represents the north branch of Canal Santan (see paper by Woodson in this issue; see also Mitalsky [Midvale] 1935; Woodson 2004). Ceramics from the main canal, Feature 698, indicate that this canal was in use into the late Classic period, with a realignment episode occurring sometime during the Sedentary period. However, settlement data suggest the alignment was constructed by the early Colonial period (Woodson, this volume). At Locus G, the main canal was characterized by at least three major stratigraphic unconformities,

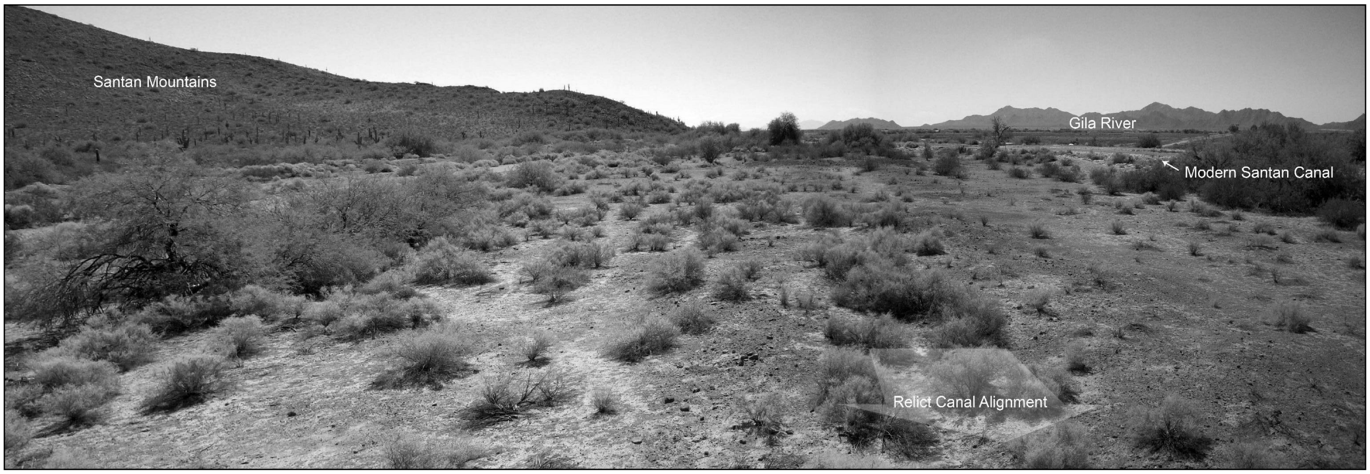

Figure 2. A relict portion of prehistoric Canal Santan near GR-441 Locus G, facing southeast.

indicating major cleanout or scouring events. This canal likely headed on the Gila River approximately 4.6 km to the southeast, near Olberg Butte. Recent investigations, though, indicate that the canal may have had a supplemental heading near Granite Knob, a butte located 4.9 km further upstream (Miles 2009).

Three distribution canal alignments were identified within GR-441, Locus G. Evidence of multiple cleanout episodes, realignment, and complete abandonment were identified within the majority of distribution canals tested. These distribution canals appear to have headed at acute or right angles to the main branch and then turned to parallel the main canal.

Five of six field lateral canals were identified along the downslope side of Feature 696, a distribution canal. These features were characterized by dark brown, blocky silt loam to silty clay loam fill and perpendicular alignment relative to Feature 696. Field lateral spacing on the downslope side varied from 49.3 m to 62.7 m, with a mean spacing of 55.3 m. All identified field laterals flowed downslope (see Figure 3). The length of field lateral canals was not determined, due in large part to their shallow depth and similarities in fill characteristics with that of T-2 Holocene terrace horizons. A single lateral channel (Feature 1084) bifurcated at a common point with Feature 1049 on the upslope side of Feature 696. This channel may have served a small irrigable patch at this location.

Evidence for water-control structures and repaired distribution canal headings were documented at GR-441, Locus G. At the northwestern end of Locus G, the Feature 700 canal complex entailed multiple heading realignments and channel modifications. Evidence at one exposed heading suggests large cobbles transported from the Santan Mountains or obtained on site were used to dam the inlet. This same heading showed signs of uncontrolled erosion and subsequent repair with both cobbles and caliche materials (Figure 3: Stripping Area 2).

Two field laterals (Feature 1049 and Feature 1084) originating from Feature 696 were completely excavated to examine the relationship between the heading and parent canal (see Figure 3). At the junction of the distribution and lateral canals, the distribution canal was widened, and there was a marked increase in quantities of locally-originating cobbles, lithic and ceramic artifacts. Although no posthole patterns were present or preserved, the distribution of cobbles and artifacts suggests a water-control structure was employed at the canal junction (Ackerly et al. 1987; Haury 1976). Channel widening resulted in decreasing water velocity, a trait shared with documented alignments in Canal System 1 (Ackerly and Henderson 1989). The decrease in velocity through widening may have been encouraged by irrigators to facilitate water-flow management at the turnout area. The spatial arrangement of cobbles supports the hypothesis that a main post was anchored across the field lateral with cobbles, while more ephemeral secondary posts and brush were leaned against the main post. These structural elements would have enabled managers to both close the lateral and let water into the lateral as needed. This scenario would explain the apparent lack of posthole arrangements at this canal junction.

Lastly, a backhoe-excavated trench (Trench 546) bisected a field lateral (Feature 1042) nearly completely along the center length of the channel. Here, longitudinal variations in canal sediment were apparent along the course of the profile. A slope analysis of the alignment places the gradient at -.005 from the y-intercept (x = 40 m). A series of possible postholes at the canal junction as well as along its length were exposed in the trench profile. Two postholes that clustered near the canal junction likely served as a footing for a control structure (see Ackerly et al. 1987). Two other isolated postholes at the base of Feature 1042 were situated downstream of the lateral heading. These postholes were spaced at an initial interval of 16.9

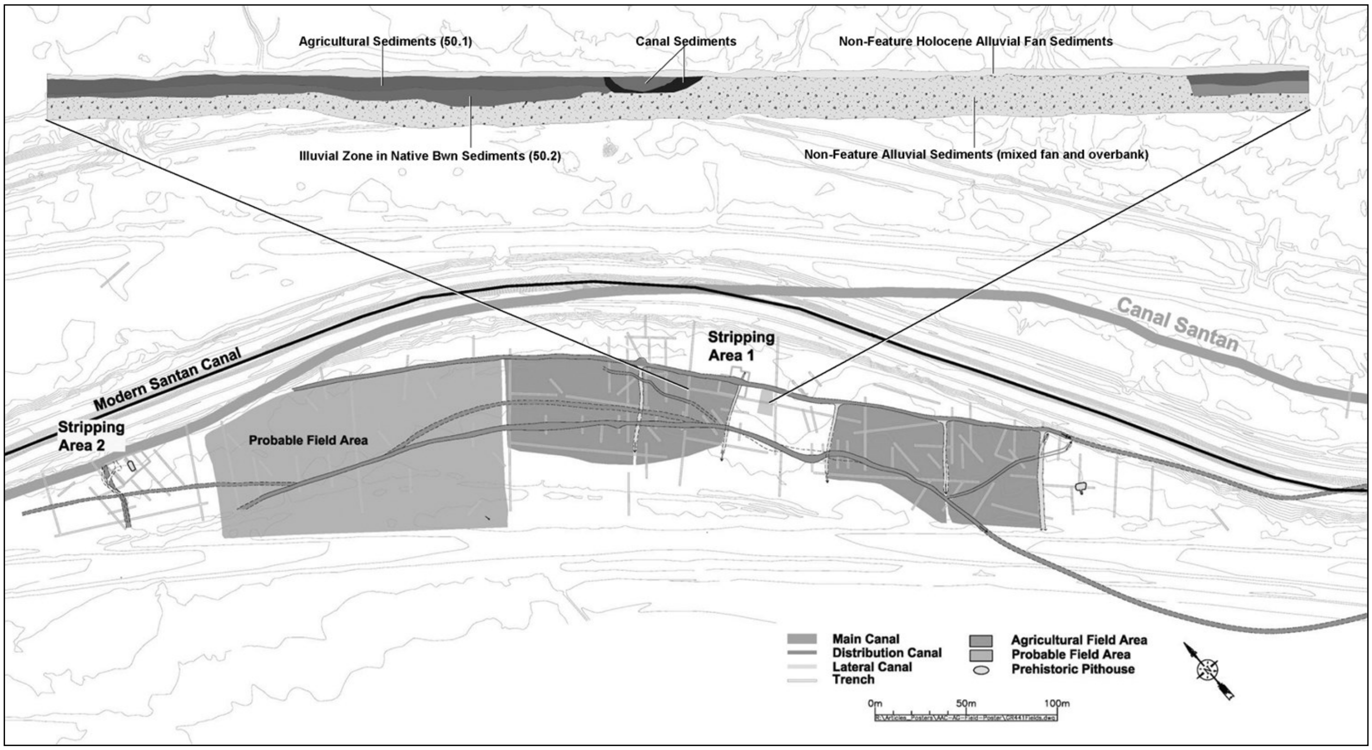

Figure 3. Map of GR-441, Locus G, with abstracted profile of BT-584, showing agricultural field, field lateral, and non-feature sediments.

m, and were followed by a second posthole 9.1 m to the southeast of the heading. These postholes may be indicative of tapon structures placed at regular intervals at field turnout locations. A third posthole was not located; however, this may be due to the meandering of Feature 1042 away from the backhoe trench exposure.

A refined, intra-system view of distribution canals, field laterals, and agricultural fields at GR-441, Locus G was exemplified by those irrigation features associated with Feature 696. As mentioned above, five field laterals along with four agricultural field plots were identified in association with this distribution canal, which was tracked across the locus for over 400 m. These features are hereafter referred to, collectively, as the "Feature 696 sub-system." Three field plots (including Features 1057 and 1066) and two associated field laterals (Features 1042 and 1049) were especially well-preserved and provided focal points for investigations of canal-field systems at GR-441 Locus G. Subsequently, the Feature 696 sub-system provided the subject for specialized biotic, physical, and chemical analyses discussed in part here and in forthcoming publications.

Stratigraphic analyses suggest that the Feature 696 sub-system was functionally contemporaneous. Ceramic evidence suggests that the Feature 696 sub-system may have been in use from the early Colonial period (ca. A.D. 750–850) and abandoned no later than the early Classic period (ca. A.D. 1150–1250). Features 696 and 1049 appear to have been in use during the early Classic period (ca. A.D. 1150–1250). Feature 1042 yielded evidence of use from the Colonial to Sedentary period (ca. A.D. 750–1150); yet stratigraphic articulation within Feature 696 indicates that the two were utilized contemporaneously. Although ceramics from the agricultural fields are rare, they are consistent with the stratigraphic evidence and reflect the likely long-term human utilization of the sub-system area. These activities may not include the use of the study area as agricultural fields. Thus, it is unclear at present time if the Feature 696 sub-system was used continuously from the early Colonial to early Classic period, or used only briefly during the early Classic. The sub-system may have been cultivated intermittently between fallow periods or long-term, multiphase abandonment, and subsequent reuse may have occurred over the suggested time span. Chronometric samples (OSL, AMS ^{14}C) are being analyzed to further refine the canal system chronology.

As a side note, prehistoric habitations appeared to have been strategically placed adjacent to canal junctions (see Figure 3). Three well-built prehistoric pit structures were identified within the investigated area, two of which are superimposed. Two pithouses and a single early Classic period pit room are represented. The distribution of these structures and diagnostic ceramic evidence suggest these houses were associated with management of the canal-field system.

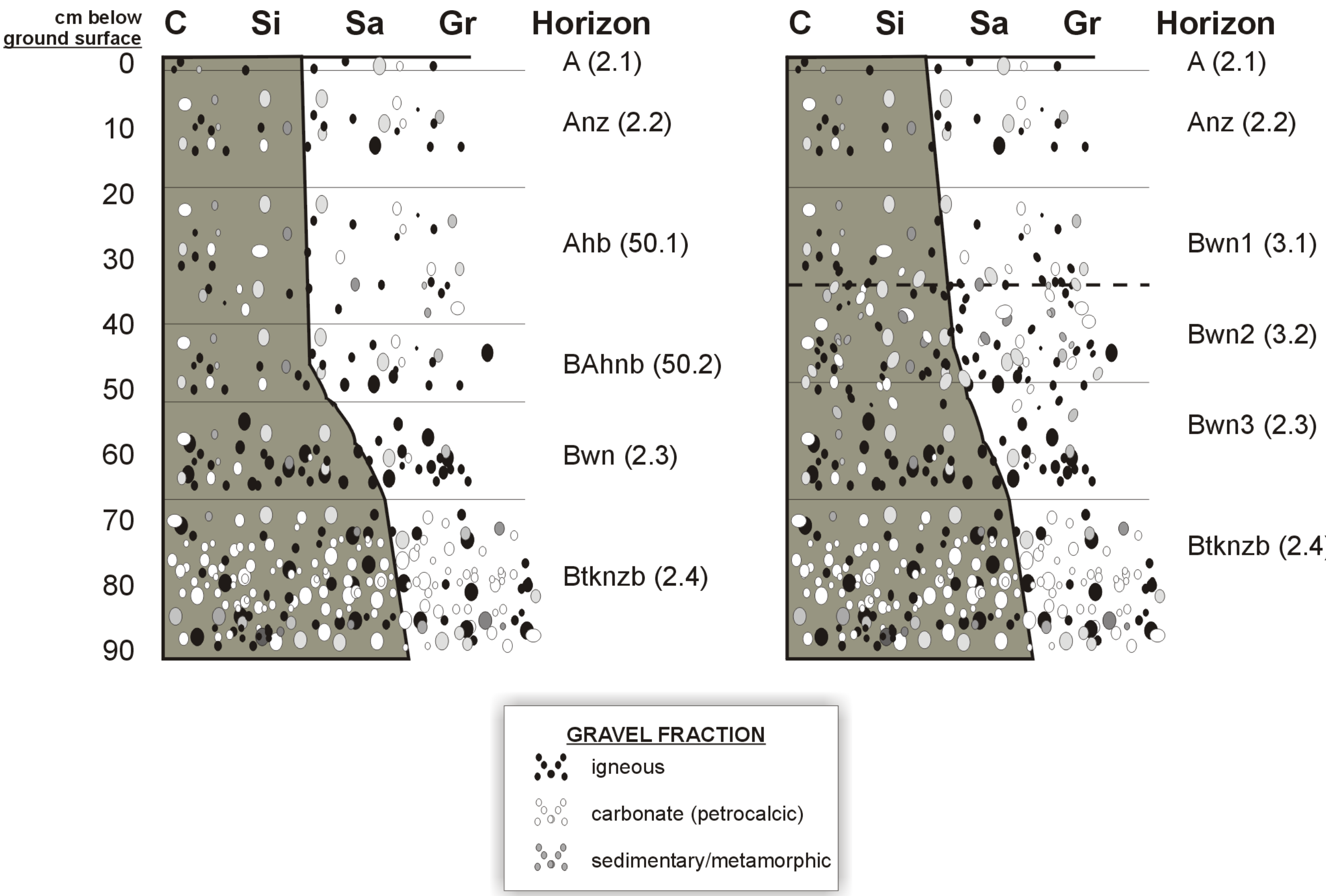

Figure 4. Schematic soil profiles of agricultural field (left) and natural stratigraphy (right) at GR-441, Locus G.

AGRICULTURAL FIELDS

Five field plots were identified at Locus G. These field areas were defined corroboratively through 1) evidence of anthropogenic sediments, and 2) the overall spatial position within the defined canal system. The identification of Hohokam agricultural fields was facilitated by the contrast with the underlying, well-drained alluvial fan beds (Bwn horizons). Areas situated closer to the Holocene river terrace were not conducive to the identification of fields or their associated lateral canals. While similar sedimentary units were present in these topographically lower areas, local sediment conditions complicated the positive identification of these features. Geomorphological, topological, and cultural processes all appear to have contributed to the preservation and thus identification of agricultural sediments at Locus G.

Geomorphological Evidence

Irrigation practices modify soils largely through cumulic sedimentological processes (Huckleberry 1992). Lateral canals located amongst agricultural field features were bounded by areas of increased color intensity and stronger pedological development (Figure 5). At Locus G, culturally modified soil horizons were phenotypically characterized by the presence of blocky peds of silty loam adjacent to irrigation lateral canals. Agricultural field sediments (Ahb) were generally 20–30 cm thick, and were buried under a 10–20 cm mantle of slopewash alluvium (Anz) that was capped by a thin (1–2 cm) desert pavement (Figure 4, see Horizon A). Underlying the agricultural fields was a transitional zone (BAhb) in which organic leaching occurred into the native, weakly-developed Bwn horizon occurred. This sediment unit unconformably overlies a well-developed Btknz characterized by strong carbonate formation and argillic horizonation. Strong color and structural changes associated with agricultural fields were tracked across the length of long backhoe trenches (see Figure 5). Overall, the sediments transitioned to a higher sand sediment fraction as a function of increasing distance from an irrigation feature in locations where agricultural fields were identified.

Horizontally exposed portions of agricultural fields yielded no evidence of secondary field features, such as water-spreaders, bunds, furrows, terraces, or drain-

Figure 5. Excavated backhoe trench exposing agricultural field and lateral sediments at GR-441, Locus G, facing west.

age ditches (after Doolittle 1990). Artifact samples collected within agricultural field sediments yielded low densities of indigenous ceramics and lithic artifacts. Notably, artifacts collected from test excavation units were situated in random orientations. Also of note, agricultural sediments appeared partly beneath field lateral features (Figure 6). Excavation data suggest that clay translocation, field tilling and modification, and bioturbation all likely played a role in the physical character of the field laterals and agricultural fields. Soil signatures were distinct enough in some locations to distinguish spatial areas where agricultural activities were either absent or limited in cumulative use. These contrasts in sediment horizons allowed excavators to identify non-field plots. The spatial area bounded between Feature 1048 and Feature 1049 lacked characteristics of anthropogenic sediments (with the exception of a small, localized patch of possible field area). While in the "correct" position in regards to the canal system layout (i.e. between field lateral canals), pedological evidence suggests these areas were not extensively used for agriculture.

Particle-Size Analysis

Particle-size analysis utilizing the hydrometer method (Jones 2001) was performed on 32 samples from the Feature 696 sub-system (Table 1). Sampled features included two agricultural field plots (Features 1057 and 1066), one non-field plot, two field lateral canals (Features 1042 and 1049), the associated distribution canal (Feature 696), and several non-feature controls. Sampling locations were distributed both in vertical columns and longitudinally along agricultural field and non-field sediments. Additional pollen, phytolith, and chemical composition samples were obtained from the same proveniences. However, microinvertebrate samples were collected exclusively from select canal and agricultural field features and do not directly correspond to the other samples sets.

In general, canal particle-sizes varied texturally from loams to sandy loams (Figure 7). Variations in particle size appear to correspond to periodic episodes of high water velocities, especially within the field lateral features. The upper portion of most canal feature profiles indicated a relatively unvaried sediment texture. These strata were notably shared throughout all sampled canal features, and stratigraphically linked to Features 696, 1042, and 1049. The non- bedded, moderately-well sorted sediment matrix of these deposits suggests that they represent post-abandonment deposition. Feature 696, however, indicated a progressive "fining-upward" sequence, suggesting a decrease in channel velocity as part of the abandonment process.

Samples from agricultural fields were the most homogeneous of any other feature group collected at GR-441 Locus G and were texturally classified as loams (see Table 1). This textural trait was noticed both longitudinally downslope from parent canals, as well as between disparate field plots. A particle-size tri-plot compares sediment textures of non-field plots and environmental controls to agricultural field samples (Figure 8). The analysis demonstrates that field textures remain tightly clustered despite changes in field slope and distance from water source. The control samples, in general, varied more widely between sandy loams, loamy sands, and loams. These fine loams conform to observations in the field, in which agricultural field sediments were found to rest upon well-drained gravelly loamy sands and sandy loams. Average particle-size fractions between all agricultural field samples were 41 percent sand, 46.5 percent silt, and 12.5 percent clay.

While the removal of cobbles from field areas may have been practiced, gravel percentages from the same samples analyzed in Figure 9 showed no correspondence to agricultural fields or non-field areas. Thus, gravel-sized particles do not appear to have been modified in relation to agricultural features. By extension, it is implied that coarse-grained sand fractions within the fields remained unchanged by anthropogenic processes.

DISCUSSION

These findings imply that soil modification by way of canal irrigation occurred in specific areas within GR-441, Locus G. Irrigation alluvium aggradation typically increases the silt and clay content within agricultural fields, and thus creates more loamy textures in naturally sandy soils (King 1919:161-165; UNESCO/FAO 1973:393). Homogeneity of agricultural field deposits

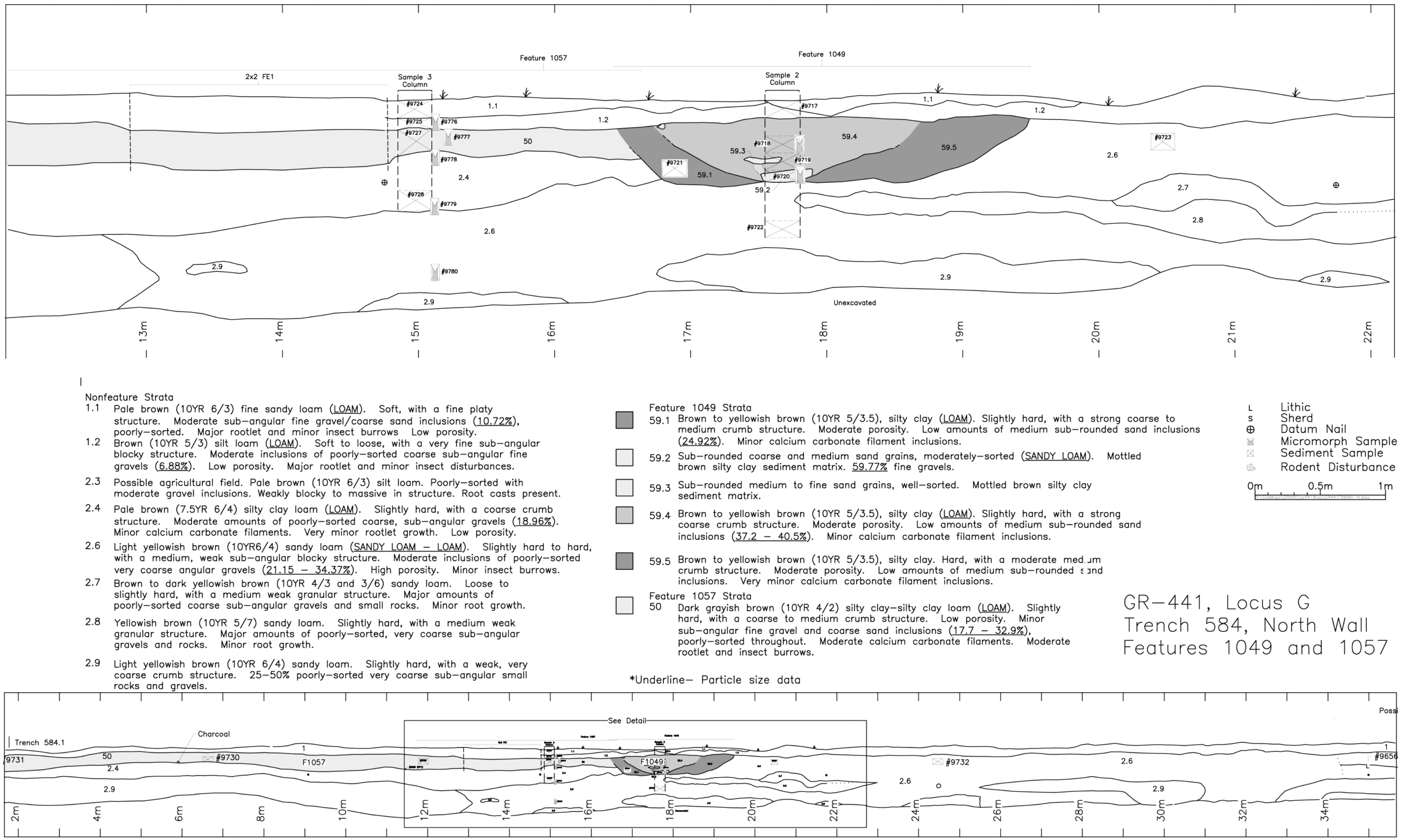

Figure 6. Tri-plot analysis of agricultural field, non-field plot, and natural (non-feature) sediments.

Table 1. Particle-size samples from irrigated field study area, GR-441, Locus G.

Spec. No.	Feature No.	Stratum	Unit	Depth	Feature Type	USDA Textural Class	% Gravel (by weight)	% Sand	% Silt	% Clay
10730	696	59.3	TR-551.01	16.07-16.18	Distribution Canal	LOAM	21.89	41	48	11
10734	696	59.5	TR-551.01	15.93-16.12	Distribution Canal	LOAM	39.46	41	48	11
10738	696	59.5	TR-551.01	15.76-15.87	Distribution Canal	SANDY LOAM	37.49	61	32	7
10742	696	59.5	TR-551.01	15.68-15.54	Distribution Canal	LOAM	32.00	51	42	7
10746	696	59.8	TR-551.01	15.52-15.37	Distribution Canal	LOAM	21.61	41	48	11
9891	1042	59.4	TR-564.2	16.48-16.60	Field Lateral	LOAM	21.28	43	42	15
9892	1042	59.3	TR-564.2	16.59-16.79	Field Lateral	LOAM	30.67	41	48	11
9893	1042	59.2	TR-564.2	16.77-19.95	Field Lateral	LOAM	43.31	51	38	11
9913	1052.01	59.3x	TR-547.3	0.20-0.35	Field Lateral	LOAM	27.94	41	48	11
9914	1052.02	59.1	TR-547.3	0.31-0.56	Field Lateral	LOAM	43.31	51	38	11
9909	1048	59	TR-587.2	0.21-0.36	Field Lateral	LOAM	54.83	51	38	11
9895	1049	59.4	TR-584.1	15.63-15.78	Field Lateral	LOAM	40.54	51	38	11
9896	1049	59.4x	TR-584.1	15.78-15.93	Field Lateral	LOAM	37.22	51	38	11
9897	1049	59.2	TR-584.1	15.93-16.01	Field Lateral	SANDY LOAM	59.77	65	24	11
9898	1049	59.1	TR-584.1	15.83-15.98	Field Lateral	LOAM	24.92	51	38	11
9917	1054	59.2x	TR-595.2	0.30-0.46	Field Lateral	LOAM	31.60	47	42	11
9900	1057	50	TR-584.1	15.63-15.78	Ag. Field	LOAM	25.08	41	45	14
9902	1057	50	TR-584.1	15.63-15.78	Ag. Field	LOAM	17.70	41	46	13
9903	1057	50	TR-584.3	15.63-15.78	Ag. Field	LOAM	32.92	41	46	13
9888	1066	50	TR-598	15.76-15.96	Ag. Field	LOAM	20.87	41	43	16
9906	1066	50	TR-598	15.77-15.90	Ag. Field	LOAM	20.15	41	48	11
9907	1066	50	TR-598	15.76-15.88	Ag. Field	LOAM	24.56	41	48	11
9908	1066	50	TR-598	15.81-15.96	Ag. Field	LOAM	21.26	41	48	11
9910	1066	50	FE-2	15.58-15.68	Ag. Field	LOAM	35.83	41	48	11
9916	-	2.6	TR-584.1	15.63-15.78	non-field plot	SANDY LOAM	34.37	61	31	8
9904	-	2.6	TR-584.2	15.63-15.78	non-field plot	LOAM	21.15	41	48	11
9905	-	1x	TR-598	15.61-15.72	Non-feature Overburden	LOAM	21.61	41	48	11
9918	-	1	TR-584.1	15.40-15.55	Non-feature Overburden	LOAM	10.72	41	48	11
9899	-	1.2	TR-584.1	15.55-15.63	Non-feature Overburden	LOAM	6.88	41	48	11
10250	-	2.2	TR-553.2	0.21-0.35	Non-feature Control	SANDY LOAM	20.96	61	28	11
10726	-	2.3	TR-551.01	16.26-16.31	Non-feature Control	LOAMY SAND	73.54	83	9	8
9901	-	2.4	TR-584.1	16.08-16.23	Non-feature Control	LOAM	18.96	51	38	11

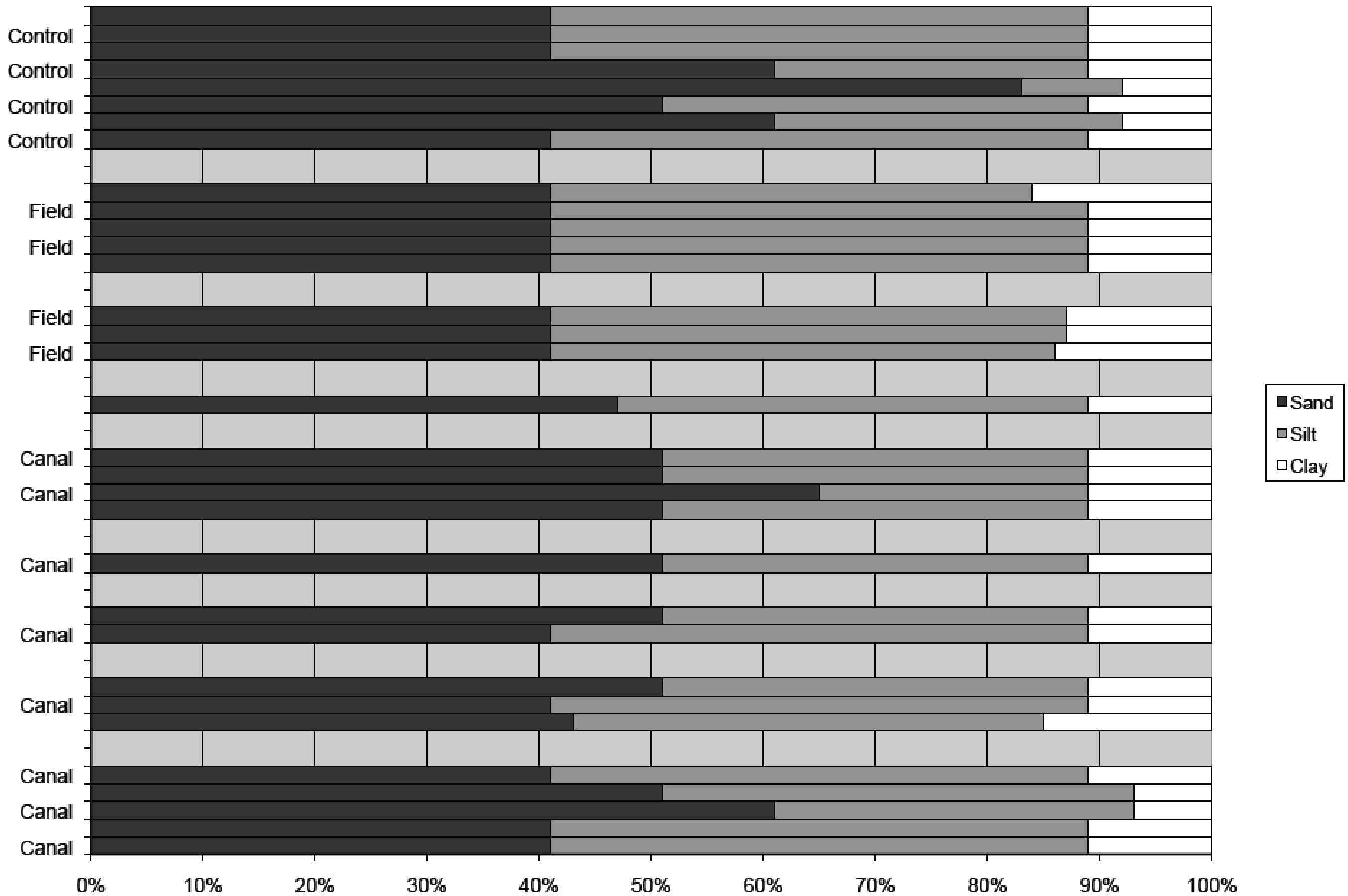

Figure 7. Texture bar chart of sampled canal features at GR-441, Locus G. Analysis performed by Olsens Laboratory using a hydrometer.

may further imply that soil was actively managed by the Hohokam (Schaafsma and Briggs 2007). Furthermore, sampled agricultural field strata correlate well with areas systemically delineated as agricultural field plots. Non-field plots, or areas systemically situated in irrigable areas but otherwise lacking in phenotypic agricultural field signatures, indicated increased particle-size variation and were similar to non-feature control samples taken from across the locus. Thus, selective use of some field plots and not others is substantiated by these results.

Field irrigation methods were likely the primary contribution to analyzed sediment texture patterns within fields at GR-441, Locus G. Nials and Gregory (1989) summarized several field irrigation methods likely employed by the Hohokam. These methods may be tested through particle-size sedimentary patterns. For example, if flood irrigation were practiced, the method would have likely introduced fine silts and clays into field plots through the use of sediment-laden water, a characteristic typical of unlined canals. By these means, canal water would have been dispersed across the field plot as evenly as possible. This process is supported by the relatively even aggradation of silt loam sediments across the field plot. Negative evidence for water-spreaders, bunds, or furrows may further this argument; however, it should be noted the preservation of such structures is dubious. Agriculturalists seasonally (if not more frequently) construct, repair, and reconfigure such features as they see fit, and often make decisions in accordance with selected crop species.

Lastly, the physical reworking of the agricultural field plots with digging sticks may have contributed to the homogeneous texture. Field turnouts entrained increasing sand fractions due to increasing water velocities near the parent canal. In turn, sand particles likely aggraded nearer to the parent canal (Huckleberry 1991). The lack of such structures at Locus G implies they were redeposited laterally during the last use-period of the field. Increasing sand-sized textures deposited near the field lateral canal may have been dispersed by seasonally-reoccurring field tilling and planting activities. These same processes likely masked any vertical variations in sediment particle size. Finally, the homogeneous textures may be the result of the application of dredged canal sediments to the field plot areas. None of these posited causes are

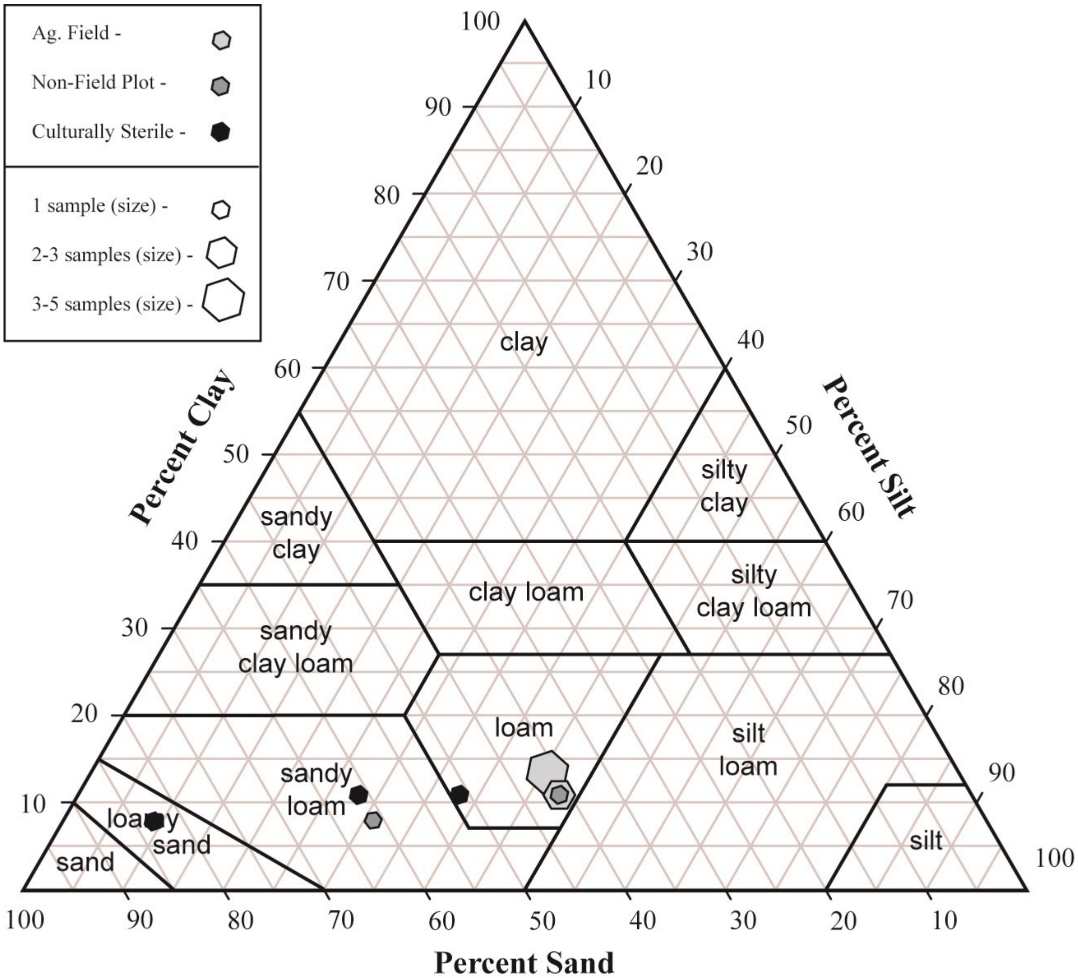

Figure 8. Tri-plot analysis of agricultural field, non-field plot, and natural (non-feature) sediments.

mutually exclusive. Future research, especially in regard to micromorphological studies, may elucidate upon these findings.

SUMMARY AND CONCLUSIONS

The discovery of agricultural fields dating from the early Colonial to early Classic period will significantly augment understandings of settlement-subsistence systems in the Phoenix Basin. Waters (1991, 2008) and Gregory (1991) argue that Hohokam settlement is largely a function of a community's access to water and of landform stability as it relates to drainage and runoff. Southern Arizona landscapes are highly dynamic due to episodic and frequently torrential rainfall interspersed with intense hot and dry cycles. The survival of intensive cultivators such as the Hohokam within this environment required the construction and maintenance of highly managed irrigation networks and fields. Such systems were episodically constructed within floodplains over the course of centuries due to the general regional paucity of water, despite the risk presented by catastrophic flooding (Doolittle 2006).

To this point, numerous water-control features have been documented across the Phoenix Basin, but direct evidence for the presence of agricultural fields has been elusive. The majority of archaeological finds of field features have been classified as check dams and rock piles indicative of non-irrigation or dry farming (*ak chin*) techniques (Crown 1987; Dart 1983; Fish and Fish 1992; Foster et al. 2002; Homburg 1997; Waters and Fields 1986). In these cases, significant changes in the structural and chemical compositions of the sediments were tested and noted.

The discovery of well-preserved, irrigated agricultural fields at GR-441, Locus G provides an opportunity to understand Hohokam subsistence and settlement from the vantage point of the fields in which food was grown. An irrigated floodplain field was identified at AZ T:10:86 (ASM) in the Gila Bend area. Discrete ashy, organic lenses within the gravelly agricultural field were radiocarbon dated to A.D. 550–980 (2-σ, calibrated) (Czarzasty 2008:59-65). Irrigated Hohokam fields adjacent to a small distribution canal are preserved in a surface context within Park of the Canals in Mesa, Arizona (Howard 1987). Schaafsma and Briggs (2007) report extensive areas (>18 ha) of silt fields adjacent to Cave Creek; they use a sediment particle analysis to

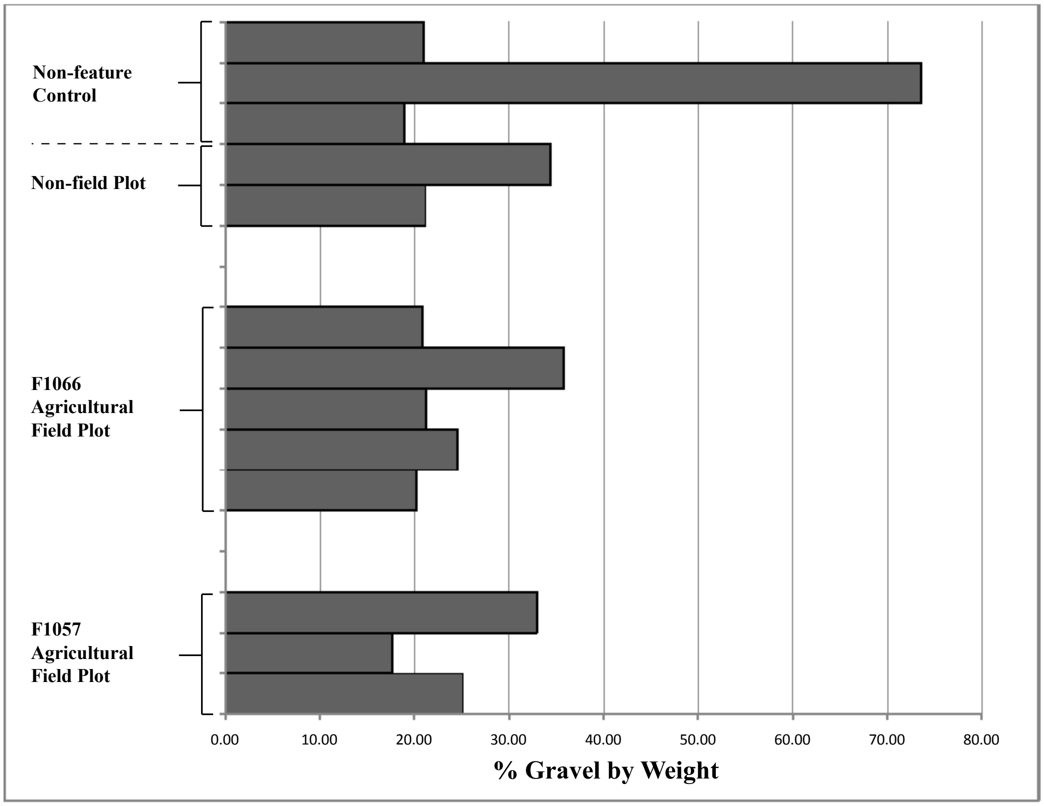

Figure 9. Gravel percentage index of agricultural field, non-field plot, and natural (non-feature) sediments at GR-441, Locus G.

differentiate between field- and non-field areas. In the latter example, overbank sedimentation from the canals and manual dredging are interpreted as the primary silt delivery mechanisms within the native sandy loam sediments.

The small number of actual field features identified in the archaeological record from the American Southwest and Northwest Mexico is a function of the intensity of prehistoric anthropomorphic activity (e.g., canal dredging, fertilization, crop planting) and post-abandonment preservation factors (e. g., soil chemistry, site taphonomy, disturbances) that are required to leave traces of field modification in the sediments. The preservation of agricultural fields in the study area can be attributed to rapid site burial by Late Holocene alluvial slopewash from the Santan Mountains. Soil development (A-Anz) atop the agricultural sediments is indicative of a period of landform stability following alluvial fan deposition. Additionally, the excavation of 5.6 percent of the total locus area illuminated stark contrasts in the sediment matrix between agricultural and non-agricultural contexts. This aggressive testing and stripping strategy afforded broad views of landform evolution and contextualization of anthropomorphic features.

Archaeological investigations at GR-441, Locus G are providing new insight into Hohokam irrigation and cultivation practices. Further analyses are underway to refine the temporal framework and types of crops that were cultivated, but several conclusions can be drawn from the results generated thus far.

(1) Irrigation water carrying substantial suspended load silt loams appears to have been a primary cause of agricultural field aggradation. Additionally, the dredging of canal sediments during clean out maintenance likely contributed to the silt fraction recorded in the sediments at GR-441, Locus G.

(2) The creation of fields was likely a time-intensive and selective process. Longitudinal sediment profiles document field aggradation on one side of the lateral canal but no field construction on the other side. This pattern is best reflected in the areal relationship between Features 1049 and 1057. Intensive investigation of the upslope (east) side of Feature 1049 (lateral canal) failed to elucidate evidence for the presence of improved sediments, even though portions examined were immediately adjacent to the canal.

(3) Intrasite spacing of canals is consistent with archaeological findings elsewhere in the Hohokam region. The mean spacing between lateral canals near Los Hornos on Canal System 1 on the Salt River was determined to be 47.9 m (157 ft) (Howard 2006), while mean lateral spacing at GR-441, Locus G was 55.3 m. Whereas Howard (2006) presumes that agricultural fields encompass entire swaths between the lateral canals, our preliminary results indicate that this may not necessarily be the case.

The detection of agricultural fields at GR-441, Locus G presents a unique opportunity to understand the subsistence component of Hohokam settlements more thoroughly. Risks to settlement in this area would have included cyclic flooding and drought events. Clearly, though, the potential benefits outweighed the detriments. Continuity in settlement models between the inhabitants of GR-441, Locus G and Hohokam elsewhere in the Phoenix Basin are illustrative of the pervasiveness of the cultural template used to overcome the environmental constraints of practicing water-intensive agriculture within a desert ecosystem.

While recent fieldwork has contributed to our understanding of Hohokam irrigated fields, ongoing analyses will refine research on topics such as nutrient enrichment strategies, field irrigation methods, cropping patterns, salinization management, and evidence of land tenure. Phytolith, pollen, microinvertebrate, as well as macrobotanical analyses are currently underway to examine canal and field biotic and environmental conditions. Micromorphological and chemical analyses of the field sediments are also on the horizon. Chronometric data from radiocarbon and luminescence samples will complete our reconstruction of the site. Together, these inter-disciplinary approaches will aid in the temporal and spatial reconstruction of overall environmental context and add to our knowledge of Hohokam subsistence practices in the middle Gila Valley.

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STREAMFLOW AND POPULATION DYNAMICS ALONG THE MIDDLE GILA RIVER

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Douglas B. Craig

ABSTRACT

Floods, droughts, and periods of high streamflow variability continue to influence archaeological interpretations of Hohokam demographic and sociopolitical change. In most instances, extreme streamflow events have been linked to canal system failure and a decline in agricultural productivity. It has been further hypothesized that catastrophic floods and associated geomorphic channel changes contributed to settlement movement and population decline. Contrary to these expectations, a recent study of population change along Canal System 2 in the lower Salt River valley found that as flooding, drought, and streamflow variability increased, population growth rates also increased. We build on the Canal System 2 analysis in this paper by comparing changes in inferred population levels at the Grewe site to annual streamflow patterns along the middle Gila River. Extensive excavation data from Grewe provide a unique opportunity to evaluate the long-term relationship between streamflow and population dynamics at the scale of an individual settlement. Although the Grewe results differ from those observed along Canal System 2, we attribute these differences primarily to scalar factors. We suggest that it is unreasonable to assume that one model or set of expectations regarding the relationship among streamflow, potential agricultural productivity, and human demographic behavior is adequate. Different scales of analysis should yield differences in results.

The purpose of the research presented here is to advance our understanding of the influence of environmental variation on human behavior in the Hohokam region. The specific problem considered is the influence, if any, of annual Gila River streamflow discharge variation on the population dynamics of Grewe, a major Pre-Classic settlement along the Gila River. Prevailing hypotheses regarding the influence of streamflow variation on population dynamics, developed primarily by the pioneering work of Donald Graybill, David Gregory, and Fred Nials[1] (Graybill 1989; Graybill and Gregory 1989; Graybill and Nials 1989; Graybill et al. 2006; Nials and Gregory 1989; Nials et al. 1989), predict that high magnitude annual discharges and pronounced variability may have resulted in changes in river channel position and/or morphology. These studies have linked extreme streamflow events and inferred channel changes to challenges to irrigation systems and declines in irrigated agricultural productivity. They have also hypothesized that catastrophic floods and associated geomorphic channel changes contributed to settlement and population movement and the substantial depopulation of the Phoenix Basin after A.D. 1400.

The general outlines of their model have been effectively applied by a number of researchers (e.g., Ackerly 1989; Craig 2001; Gregory 1991; Kwiatkowski 2003; Masse 1991; Van West and Altschul 1997). For example, Craig (2001) modeled changes in the productive potential of the Grewe irrigation system using the Gila River streamflow retrodictions and found that the population dynamics at Grewe matched well with the model. That is, a dramatic decline in population at Grewe during the late Colonial period (A.D. 875–949) occurred in the context of a concentration of high and low flows when productivity would presumably have been the worst. Likewise, Grewe's population peak during the middle Colonial (A.D. 825–874) is associated with a period of sustained high productivity associated with low streamflow variability and higher than average annual flows.[2]

Similarly, population declines along the nearby lower Salt River have been linked to poor conditions for irrigation agriculture caused by extreme streamflow events. Nials et al. (1989:66) hypothesized that population declines during the Colonial period (ca. A.D. 750–950) were related to destructive streamflow events and patterns during the A.D. 798 to 899 inter-

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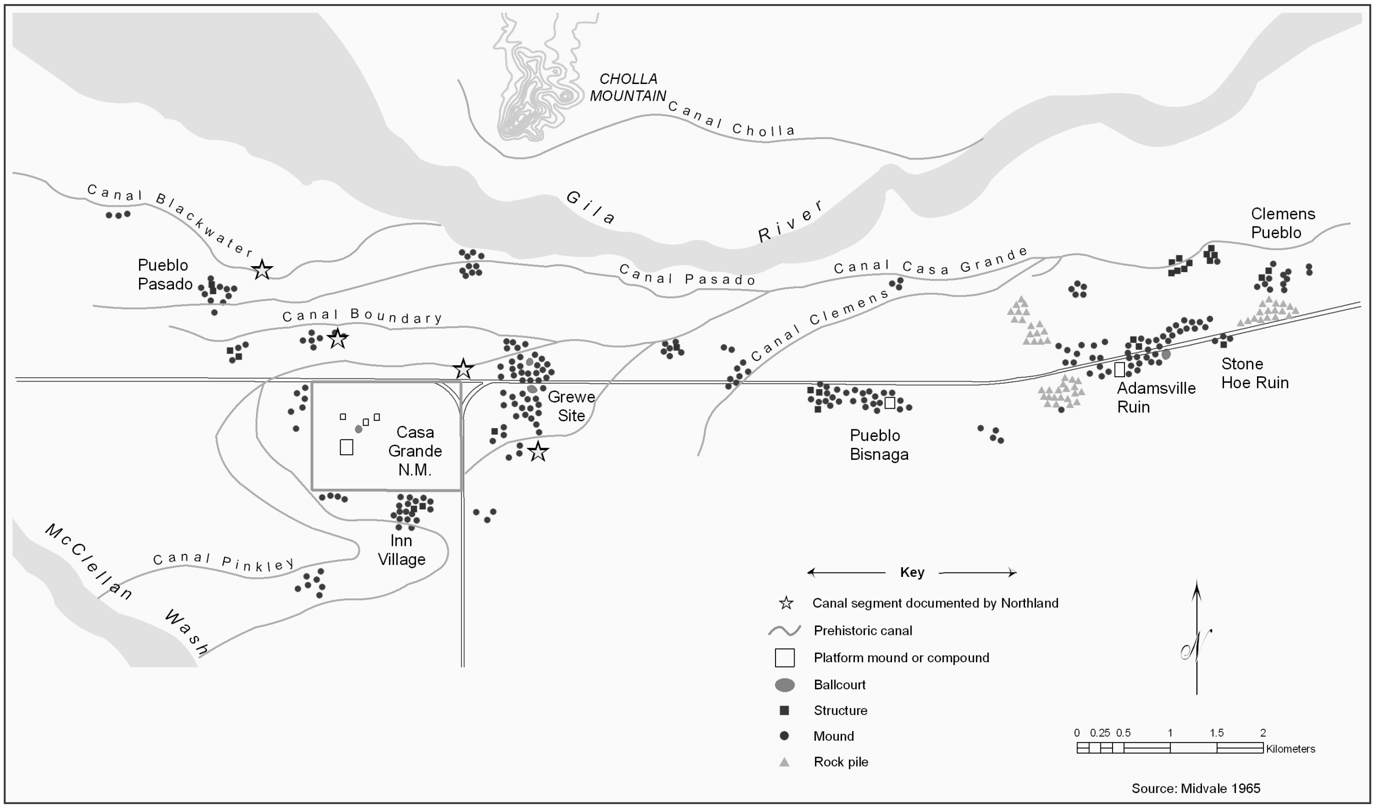

Figure 1. Location of Grewe.

val. Gregory (1991:187) also considers the possibility that floods along the lower Salt River during the Colonial period may explain Hohokam settlement in previously unoccupied areas, some expansion into marginal areas, and the presence of Hohokam populations outside of the Hohokam area and, in some cases, within non-Hohokam settlements. Furthermore, Masse (1991:217) argues that as a result of the presumed disastrous flooding of A.D. 899, settlements on the terminus of irrigation community networks may have been abandoned due to the absence of potable and agricultural water and moved to new settlements in areas favorable to *ak-chin* and dry-farming techniques.

Contrary to expectations derived from the Graybill et al. (2006) model, however, Ingram (2008) recently demonstrated a strong positive relationship between population growth rates within Canal System 2 along the Salt River and extreme streamflow events from A.D. 775 to 1450. In that work, population growth rates increased as the frequency, magnitude, and duration of inferred flooding, drought, and variability increased. Specifically, when the productive potential of irrigation agriculture in Canal System 2 was expected to be the least due to these extreme streamflow events, people moved into the canal system rather than out of it. This pattern of movement challenges commonly held assumptions regarding the negative effects of extreme streamflow events on population growth and out-migration and our understanding of the long-term relationship between annual streamflow discharge volumes and population change in the Phoenix Basin.

The research presented here is intended to further identify and clarify the relationship between streamflow discharge variation and the population dynamics of the Phoenix Basin. Although streamflow and its effect on agricultural productivity is not expected to be the sole influence on the population dynamics of any riverine community practicing irrigated agriculture, we expect it had some effect and seek to identify and describe the extent of its influence. We consider this effort critical for evaluating Graybill and colleagues' (2006) hypotheses and model, which play a prominent role in many cultural-historical interpretations of the Hohokam trajectory in the Phoenix Basin and beyond.

BACKGROUND

This study further explores the relationship between streamflow discharge volumes along the Gila and population dynamics at Grewe, where we have particularly strong and relatively complete data to infer changes in population growth rates (Craig 2001). The Grewe site is a large Pre-Classic period village located along the Gila River near Casa Grande Ruins National Monument (Figure 1). Archaeologists generally consider Grewe and Casa Grande to have been part of the same settlement complex, with Grewe the main locus of occupation during the Pre-Classic period and Casa Grande the main locus of occupation during the Classic period. Grewe is located on the lower terrace of the Gila just outside of the floodplain and towards the end of a main canal.

Between 1995 and 1997, large-scale excavations were carried out at Grewe by archaeologists from Northland Research, Inc. in connection with a road construction project sponsored by the Arizona Department of Transportation. More than 1,300 prehistoric features were uncovered as a result of this work, including 270 houses, close to 900 outdoor pits, segments of 10 canals, and a portion of a large ball court. Most of these features were associated with a residential district situated in the heart of Grewe. This residential district was occupied for virtually the entire Pre-Classic period. Temporal control for this roughly 600-year time span from A.D. 500 to 1100 was established by first assigning individual features to one of nine age groups based on ceramic and stratigraphic evidence. Absolute dates were then assigned to the various age groups based on an analysis of 110 radiocarbon and 52 archaeomagnetic samples. In total, more than 700 features, including 180 houses, were assigned to discrete age groups. The overall distribution of features suggests that Grewe was occupied on a continuous basis for hundreds of years, though not always at the same level of intensity. Grewe was abandoned by about A.D. 1100, corresponding to a shift in settlement over to the Casa Grande Ruins area.

Model

The relationship between streamflow discharge variation and irrigated agriculture productivity employed in this study is informed by the Graybill et al. (2006) model. We have extended their model by linking variation in irrigated agriculture productivity to changes in population growth rates. Variation in agricultural production is also linked to the risk of resource shortfalls. The synthesized model used in this analysis is summarized as follows.

Streamflow events and patterns of these events may induce major changes in stream channel position and/or morphology and negatively impact gravity-fed irrigation systems by changing the location and/or height of the water within the channel relative to the canal infrastructure (Graybill et al. 2006; Nials et al. 1989). Streamflow events and patterns considered in this analysis are floods, wet and dry periods, and periods of high temporal variability. Floods (inferred from high annual discharges) likely damaged and or destroyed canal infrastructure and agricultural land due to erosion or the deposition of impermeable silts. Dry periods reduced water availability to irrigated fields and may have increased the potential for stream channel change during subsequent high magnitude events. Periods of high temporal variability are associated with greater variability in channel morphology due to the effects of both floods and dry periods. Periods of low temporal variability are associated with geomorphic stability and favorable conditions for agricultural production.

Streamflow is not the only variable that likely affected agricultural productivity along the Gila. Temperature affects productivity by increasing or decreasing evapotranspiration and associated plant water needs. In general and within limits, periods of warm temperatures are assumed to have decreased resource productivity by increasing evapotranspiration and plant water requirements, and periods of cool temperatures are assumed to have increased resource productivity by decreasing evapotranspiration and plant water requirements. Higher temperatures also create earlier onsets of springtime snow melt and associated streamflow, higher peak streamflows, and lower summer streamflow (Stewart et al. 2005 and references contained therein). These events may have decreased productivity by decreasing streamflow for irrigation during the growing season and challenged irrigation with flood-related stream channel changes and canal damage. Other factors, such as soil type and quality (e.g., Sandor et al. 2007), affect resource productivity but are beyond the scope of this study.

Negative impacts on irrigation systems due to streamflow and temperature extremes likely decreased agriculture production and may have increased the risk of resource shortfalls. Shortfalls occur where there is not enough food to eat, and starvation became a possibility. To lessen the real or perceived risk of shortfalls, people use a variety of strategies such as storage, trade, exchange, and mobility (Halstead and O'Shea 1989). Population movement, a type of mobility, from areas of lesser to greater productivity is the strategy considered in this model. Population movements affect population growth rates through out-migration (decrease growth rates) and in-migration (increase growth rates). Changes in fertility and mortality also affect growth rates. Increases in productivity are assumed to increase fertility and decrease mortality, thereby increasing growth rates. Decreases in productivity are assumed to decrease fertility and increase mortality, thereby decreasing growth rates.

The real or perceived risk of resource shortfalls can also be affected by the climate-related year-to-year (temporal variability) and place-to-place variation (spatial variability) in resource productivity. Variation in resource productivity is often viewed as riskier if it has greater variance (Cashdan 1990:2-3). Temporal variability has been used either explicitly or implicitly as a proxy for variation in risk in a number of studies in

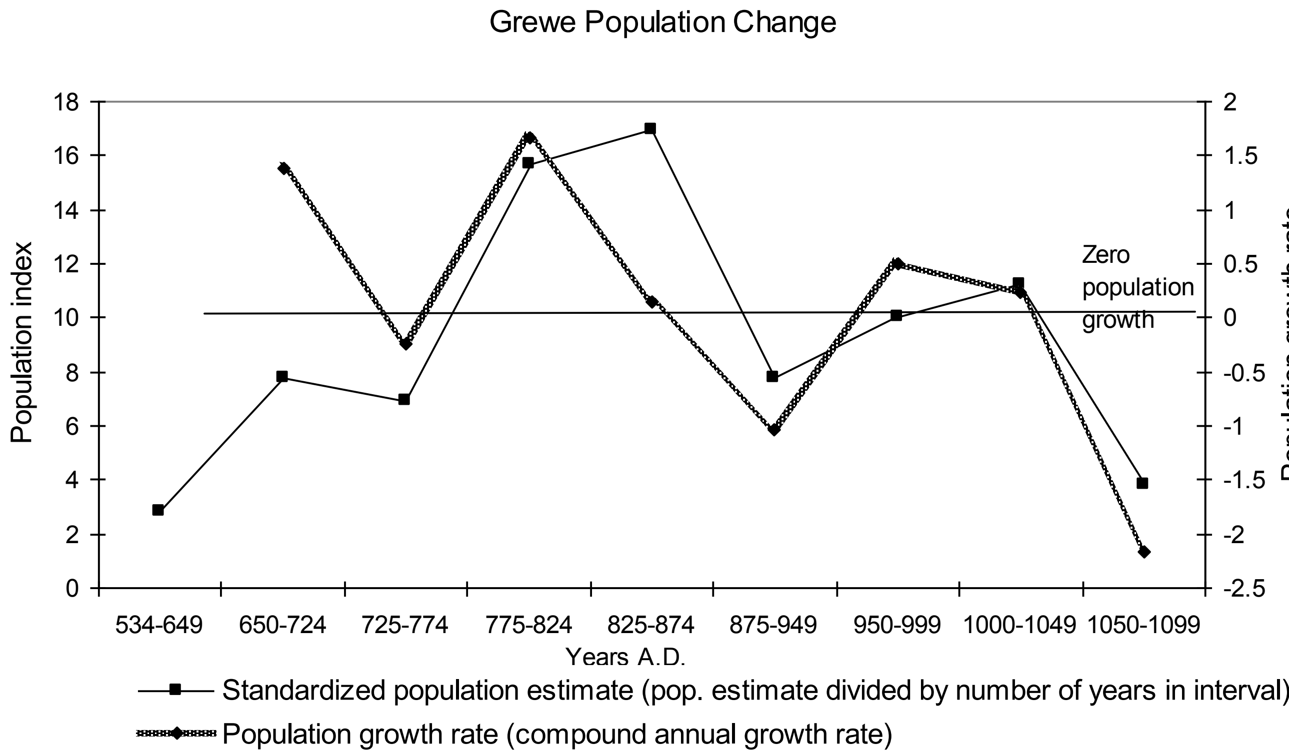

Figure 2. Grewe population change.

the American Southwest to explain buffering strategies, including population movements (e.g., Kohler and Van West 1996; Larson et al. 1996; Nials et al. 1989; Graybill et al. 2006). Periods of low temporal variability are often considered less risky as conditions are considered stable and predictable, while periods of high temporal variability are more risky due to increased uncertainty.

The spatial variability of annual precipitation (Dean et al. 1985:542) is assumed to have influenced the viability of exchange, interaction, and population movements to lessen the negative effects of shortfall (e.g., Braun and Plog 1982; Cordell et al. 2007; Plog et al. 1988). Substantial differences among conditions, during periods of high spatial variability, could have lessened the risk of shortfall if opportunities for exchange, interaction, or movement existed. Periods of low spatial variability, when conditions are the most uniform, that co-occur with dry periods were probably periods when opportunities for movement, exchange, and interaction with others experiencing different conditions were greatly reduced.

Therefore, the expected relationships between streamflow and temperature extremes and population growth rates are as follows: (1) as flooding (inferred), dry and warm periods, and periods of high temporal variability and low spatial variability increased in duration or frequency, population growth rates decreased; (2) and as wet and cool periods, periods of low temporal variability, and periods of high spatial variability increased in duration or frequency, population growth rates increased.

DATA AND METHODS

Population Data

Population estimates were derived for Grewe utilizing architectural evidence and methods that have become fairly standard in Hohokam archaeology (see discussion in Craig 2001). The basic strategy was to apply information learned about the houses in the ADOT right-of-way to other parts of the site. It was further assumed that roughly 10 percent of the houses at the site were investigated by Northland and that the average pithouse was occupied for 25 years. The population figures used for our analysis here represent midpoints of the population ranges previously discussed by Craig (2001).

Using the population estimates derived for Grewe, population growth rates are presented in Figure 2. Population growth rates were calculated using a standard compounded annual growth rate (CAGR) formula:

$$\text{CAGR} = (\text{ending amt}/\text{beginning amt})^{(1/\#\text{of years})} - 1).$$

This formula uses the number of rooms occupied in an earlier interval as the beginning amount and the number of rooms occupied in the next interval as the ending amount and the number of years in the latter interval as the interval duration. We use the average of the high and low population estimates to calculate growth rates. Due to varying durations of the temporal/cultural periods, we standardize the population estimates by dividing the population estimate by the number of years in the temporal interval. The growth rates are calculated from these standardized estimates.

As is evident in Figure 2, there was substantial variation in growth rates at Grewe. Steady increases or decreases in growth rates due to natural increases or decreases in mortality do not explain the range of variation observed. Using the zero population growth line as a reference, negative growth rates are inferred to be periods of out-migration. These periods occurred during the Pioneer to Colonial transition (A.D. 725–774), late Colonial (A.D. 875–949), and middle to late Sedentary (A.D. 1050–1099). Periods of relatively rapid population growth due to in-migration as opposed to accelerated internal demographic changes are difficult to differentiate, but population growth was the greatest during the late Pioneer (A.D 650–724) and the early Colonial period (A.D. 775–824).

Streamflow Data

Gila River streamflow retrodictions were developed by Donald Graybill and others at the University of Arizona's Laboratory of Tree-Ring Research. The lab graciously provided these data for our use. Methods used to develop the streamflow retrodictions are detailed in Graybill (1989) and Graybill et al. (2006). It is beyond the scope of this study to review the strengths and weaknesses of tree-ring retrodicted discharge variation. However, several points are noted that were clearly discussed by Graybill (1989; 2006) but seldom presented by others. First, single flood events are not captured in the tree-ring records. Floods are inferences based on some evidence of the relationship between flooding and high annual discharge years observed in modern streamflow records (Ackerly 1989:61–83; Smith 1981 as cited in Smith and Stockton 1981). Second, the timing of flooding during the agricultural calendar will largely determine the extent of effects on food production. Spring discharge conditions are better detected by the tree-ring records than summer conditions. This implies that we know little about the effects of streamflow conditions on food production during the second half of the annual planting season.

Temperature Data

The San Francisco Peaks temperature reconstruction (Salzer 2000; Salzer and Kipfmueller 2005) can be used to identify warm and cool periods across the region. In that study, the annual mean maximum temperature was reconstructed from 250 B.C. to A.D. 1997. This variable can be considered a general measure of how warm it gets during the daytime of a given year (Salzer and Kipfmueller 2005:470) and, while most accurate locally, is also applicable on a regional scale (Salzer 2000:63 as cited in Bradley 1980).

Identification of Climate Extremes

To identify patterns in the streamflow data, we identify multiple types of climatic extremes. These extreme events capture the range of patterns that are expected to have affected changes in the productive potential of irrigated agriculture along the Gila. Climate extremes are identified using a centered nine-year interval running average throughout the duration of the streamflow retrodiction, A.D. 534–1988. Extreme periods are defined as those intervals in the lowest and highest quartile and decile of the distribution of all nine-year intervals in each reconstruction. Quartile and decile threshold values are arbitrary but are assumed to represent values and periods with sufficient rarity to have substantially influenced resource productivity. A similar approach has been used with standard deviation units by Dean (1988), and percentile approaches to identify thresholds are currently used by the U.S. Drought Monitor (www.cpc.noaa.gov) and others to track drought severity across the U.S. (e.g., Hirshboeck and Meko 2005; Steinemann et al. 2006; Smakhtin 2001). Using several threshold values to identify the extremes acknowledges the uncertainty inherent in projecting a threshold above which shortfalls were unlikely (thus a behavioral response is not expected) and below which they were likely (thus a behavioral response is expected). Use of a single threshold presumes a shortfall threshold is known and introduces the possibility of failing to detect a relationship, if one existed, at a slightly higher or lower threshold.

Climate Extremes Considered and Methods of Identification

1. Inferred flooding is identified by counting the number of discharge years in the seventy-fifth and ninetieth percentiles per temporal/cultural period.

2. Wet periods are defined as those nine-year intervals in the seventy-fifth and ninetieth percentile of the distribution of nine-year interval averages calculated using the streamflow reconstructions.

3. Dry periods are defined as those nine-year intervals in the tenth and twenty-fifth percentile of the distribution of nine-year interval averages calculated using the streamflow reconstructions.

4. Temporal variability is assessed by calculating a nine-year centered moving standard deviation of the streamflow annual values. The nine-year standard deviation intervals are divided by the nine-year interval

averages to produce a coefficient of variation for each interval. Periods of low temporal variability are defined as those nine-year intervals in the lowest decile and first quartile, and periods of high temporal variability are in the third quartile and highest decile of the distribution of interval coefficient of variation values.

5. We combine wet/very wet and dry/very dry periods into a single index. This index differs from the other indices as the pattern of the wet and dry years are not considered; that is, this index identifies the number of wet and dry years in each temporal/cultural period, not the duration of prolonged wet and dry periods. If these extremes in streamflow are assumed to negatively impact productivity, then this measure identifies the proportion of years within each interval in which productivity was relatively low.

6. The spatial variability considered in this analysis is the difference in discharge patterns between the lower Salt River and the middle Gila River. In other words, this variability represents the extent to which discharge patterns were "in-sync" or "out-of-sync" with each other. Spatial variability is assessed by calculating the annual standard deviation of the Salt and Gila discharge volumes for each year of the reconstructions. The annual standard deviations are divided by the associated annual averages to produce an annual coefficient of variation. The coefficients of variation are smoothed by nine-year centered moving averages that are then ranked and assigned percentile values. Periods of low spatial variability are defined as those nine-year coefficient of variation intervals in the lowest decile, and first quartile and periods of high spatial variability are in the third quartile and highest decile of the distribution of coefficient of variation intervals.

7. Cool periods are defined as those nine-year intervals in the tenth and twenty-fifth percentile of the distribution of interval averages calculated using the temperature reconstructions.

8. Warm periods are defined as those nine-year intervals in the seventy-fifth and ninetieth percentile of the distribution of interval averages calculated using the temperature reconstructions.

To allow comparison of the climate extremes with population growth rates, the number of years within each temporal/cultural interval (e.g., late Pioneer period) of each type of climate extreme (e.g., wet, warm, cool, etc.) is calculated. Because the intervals are different lengths, the number of years in which a climate extreme occurred during each interval is divided by the number of years in the interval to create a standardized and interpretable index that allows each interval to be compared and ranked. These indices are the percent of extreme years within each interval.

Summarizing the annual climate data by temporal intervals is appropriate because tree-ring based climate reconstructions are the strongest and most reliable when they are used to represent relative changes in climate conditions rather than absolute (year-to-year) changes. Relative changes are better represented because of the biological characteristics of trees, such as food storage, that create time lags in growth responses to moisture variations and the statistical approaches used in climate reconstruction used to reduce autocorrelation (Fritts 1976; Meko and Graybill 1995; Meko et al. 1995). The statistical correlation between tree growth and climate is also always less than perfect; therefore, an emphasis on individual retrodicted years gives a false sense of precision to an analysis. Numerous climate studies have also documented persistence in climate patterns on decadal scales in both the modern instrumental and proxy records (Cayan et al. 1998; Dettinger et al. 1998; Fritts 1991; Gray et al., 2004; Grissino-Mayer 1995). In sum, analyses and explanations based on year-to-year change are not as reliable and well grounded in the data as investigations of multi-year wet and dry or warm and cool periods (e.g., Salzer and Kipfmueller 2005:472-473).

Relationship Between Climate Extremes and Growth Rates

We conduct correlation analyses and inspection of associated scatterplots to assess the long-term relationship between the climate extremes and population growth rates. A rank order correlation procedure, Spearman's *r*, is used for the correlation analyses. High correlation coefficients (positive or negative) are evidence of a long-term relationship and one wherein the magnitude of change in growth rates is related to the duration of the extreme period. A strong correlation coefficient indicates a long-term pattern of sensitivity and vulnerability to a climatic extreme. Low correlation coefficients do not provide evidence of long-term climatic sensitivity and vulnerability because they imply an uneven relationship, if any, between climatic extremes and population movement. We argue that the 566 years or roughly 22 human generations represented by the population and streamflow data we are considering represent a sufficiently long sample capable of detecting a relationship, if any existed, between discharge variation and human demographic behavior at Grewe.

RESULTS

The correlation coefficients representing the relationships between the population growth rates and climate extremes at several thresholds are presented in Table 1. Some representative scatterplots are presented in Figure 3. Straight lines are fit to the data points in the scatterplots to aid visual identification of

Table 1. Correlations between climate extremes and population growth rates.

Climate extremes	Percentile threshold	Population growth rates
High annual discharge years	75	-0.50
Very high annual discharge years	90	-0.45
Wet periods	75	-0.74
Very wet periods	90	-0.64
Very dry periods	10	-0.26
Dry periods	25	-0.01
Combined very wet and very dry years	10 and 90	-0.90
Combined wet and dry years	25 and 75	-0.74
Years between median and fourth quartile	50 and 75	0.06
Periods of very low temporal variability	10	-0.57
Periods of low temporal variability	25	-0.10
Periods of high temporal variability	75	0.00
Periods of very high temporal variability	90	0.05
Periods of very low spatial variability	10	0.10
Periods of low spatial variability	25	-0.40
Periods of high spatial variability	75	0.31
Periods of very high spatial variability	90	0.17
Very cool periods	10	0.57
Cool periods	25	0.83
Warm periods	75	-0.68
Very warm periods	90	-0.48

the relationship between growth rates and the streamflow and temperature indices.

High Annual Discharge Years

Population growth rates at Grewe decreased as the frequency of high magnitude annual discharge years (inferred floods) increased. That is, periods with frequent inferred floods were periods with generally lower population growth rates. The correlation coefficients are moderately strong at the seventy-fifth (r = -.50) and ninetieth percentiles (r = -.45). This relationship supports the prevailing model (Graybill et al. 2006) wherein flooding threatened agricultural productivity through challenges to the canal infrastructure. These declines in productivity then likely led to out-migration or declining internal growth rates. This finding is inconsistent with the relationship identified within Canal System 2, wherein high magnitude discharge years were associated with increases in growth rates (Ingram 2008).

Wet Periods

The relationship between wet periods and population movement has not been previously considered in the Phoenix Basin. Population growth rates at Grewe decreased as the duration of wet periods increased. Wet periods are prolonged periods of relatively high annual streamflow related to relatively wetter conditions throughout the watershed. These are periods when the productive potential of both irrigated and non-irrigated agriculture should have been the greatest as water availability was the greatest. Wet periods may have encouraged migration out of Grewe if the increased productivity was sufficient to support settlement elsewhere. Or, if the wet periods frequently damaged canals, then out migration fits with the prevailing model that damage to canals and crops influenced movement to more productive locations.

Dry Periods

There is no evidence for a long-term relationship between dry periods and population growth rates at

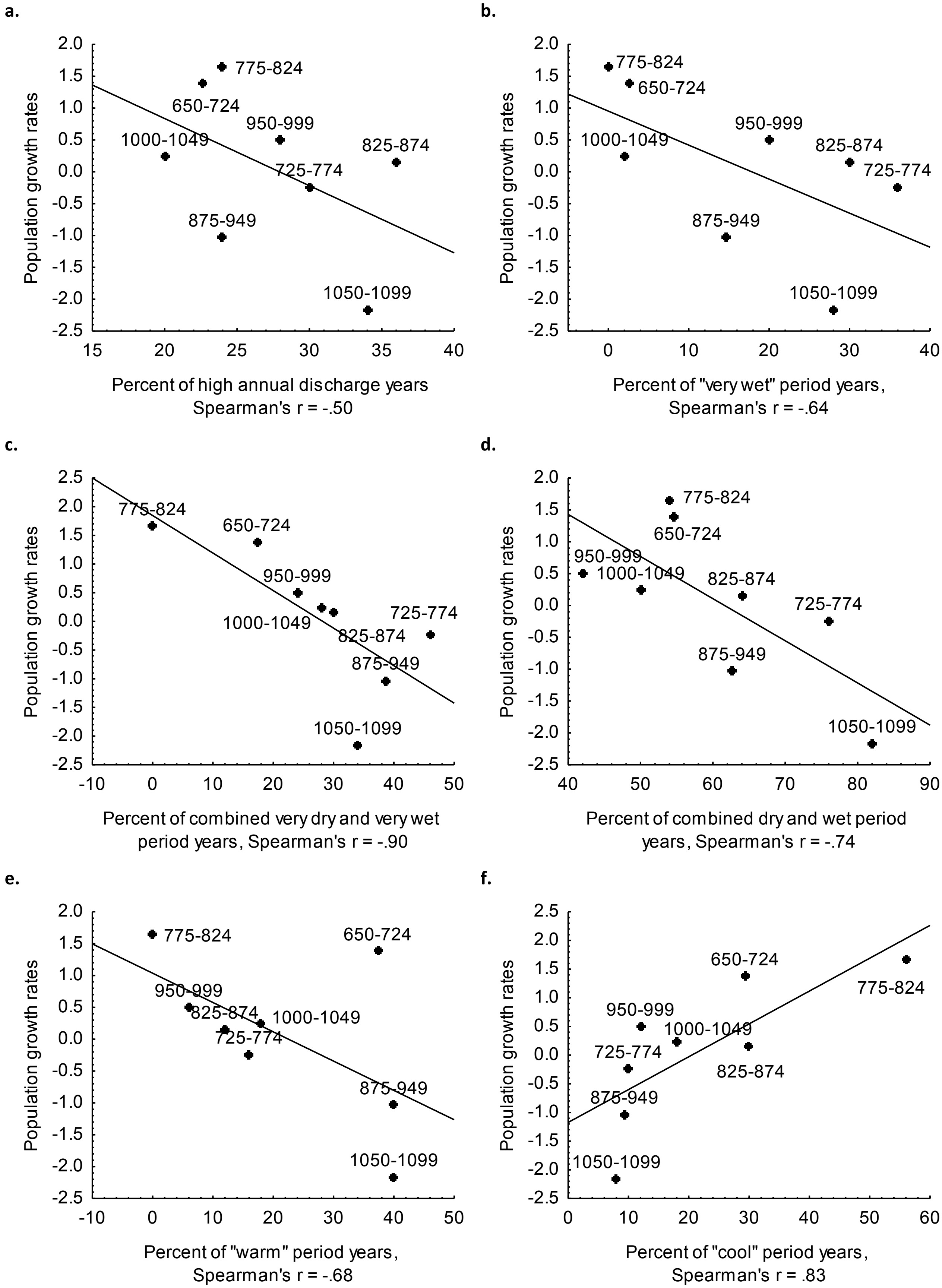

Figure 3. Some climate extreme and growth rate scatterplots.

Grewe. This suggests that Grewe residents were able to maintain or acquire sufficient resources or adequate productivity during dry periods. Alternatively, it may indicate that low streamflow discharge years had a minimal impact on the productive potential of irrigation agriculture in and around Grewe, perhaps due to the favorable upstream position of the canals close to Grewe. If people suffered from dry-period related declines in productivity, they may have just suffered in place where conditions may have been bad but not as bad as elsewhere. Overall, this result implies that dry periods did not affect decisions to move into or away from Grewe. This result is inconsistent with findings in Canal System 2 where dry periods are related to increases in population growth rates.

Low and High Temporal Variability of Streamflow

There is no evidence that periods of high or low temporal variability affected growth rates at Grewe. To further examine this result, the frequency of years with discharge volumes between the median discharge level and the third quartile was calculated. These should have been optimal years for irrigated agriculture, neither especially low nor high. However, no influence on growth rates was detected. These results are inconsistent with expectations that equate high variability with geomorphic instability and greater risk of shortfalls and low variability with stability and lesser risks of shortfall. These findings are also inconsistent with results from Canal System 2 (Ingram 2008). Little influence of temporal variability on growth rates suggests that periods of high temporal variability were anticipated and effectively buffered by existing strategies. And, periods of low variability, if advantageous in any way, were not sufficient to influence decisions to move into or out of Grewe or to affect fertility or mortality substantially.

Combined Wet and Dry Years

Population growth rates decreased and the frequency of wet and dry years increased. With this index, both wet and dry years (not prolonged periods) are assumed to decrease resource productivity. Results indicate that as the frequency of these wet and dry years increased, growth rates decreased. The relationships are strong when extreme years are defined with the upper and lower deciles (r = -.90) and upper and lower quartiles (r = -.74). It may be that this index better represents the type of temporal variability that was most meaningful to irrigation agriculturalists rather than prolonged periods of low or high temporal variability.

Low and High Spatial Variability of Streamflow

Population growth rates at Grewe were not affected by patterns of similarity and difference in discharge volumes between the Gila and Salt rivers. This implies that if population movements occurred between the two riverine settlement areas, Grewe was not involved in this shifting, or that the movements were not related to prolonged variations in discharge volumes and associated changes in resource productivity.

Warm and Cool Temperatures

Population growth rates increased as periods of relatively cool temperatures increased, and growth rates decreased as warm periods increased. Expectations are met for both warm and cool temperatures, thereby strengthening the evidence for a strong relationship between temperature, productivity, and population growth rates. Given the long growing seasons throughout much of central and southern Arizona, it is unlikely that people moving to Grewe were seeking to reduce cool-temperature related risks of shortfalls. Rather, the cool temperatures may have increased productivity at Grewe by either decreasing evapotranspiration and associated plant water stress and/or lessening the potential problems of early snowmelt and streamflow, higher peak streamflow, and lower summer flows possibly associated with warm temperatures. More research needs to be done to understand the impact of the reconstructed temperature variable on the productive potential of irrigated agriculture.

Depopulation of Grewe

Grewe was abandoned by about A.D. 1100, corresponding to a shift in settlement over to the Casa Grande Ruins area. To examine potential climate-related influences on this settlement shift, conditions during the A.D. 1050 to 1099 period (the middle to late Sedentary period) are considered. The most anomalous change in streamflow patterns are the two wet periods (seventy-fifth percentile threshold), totaling 35 years or 70 percent of the years from A.D. 1050 to 1099. This proportion of wet period years was unprecedented throughout the 566 years considered in this analysis. This analysis has previously established a long-term and strong negative relationship (r = -.74) between growth rates and wet periods throughout the history of Grewe. It is possible that Grewe's position near the floodplain of the Gila made residents and the canal infrastructure vulnerable to potentially damaging effects of these frequently occurring and relatively high flows. If so, the shift in settlement to Casa Grande, nearby but further from the floodplain, makes sense as a reasonable remedy and response to the increased risks associated with the high flows.

DISCUSSION AND CONCLUSION

This effort has identified long-term relationships between specific Gila River streamflow discharge patterns and population growth rates. Given the complexity of human demographic behavior and the necessity of a plethora of methodological decisions necessary to assess potential influences of streamflow on this behavior, we find the detection of long-term relationships remarkable and compelling. It is also notable that despite a range of potential buffering mechanisms, such as storage, trade, and abundant seasonally distributed wild foods, patterns of sensitivity and vulnerability to streamflow discharge variation persisted throughout the history of Grewe. In short, we cannot decouple the demographic trajectory of Grewe from the vagaries of Gila River discharge variation.

Relationships identified in this paper demonstrate that human decision-making at Grewe was consistently affected by specific types of climate-related streamflow discharge variation and associated changes in resource productivity. Patterns of movement as reflected in the growth rates indicate that high annual discharge years, wet periods, frequent wet and dry years, and warm periods influenced movements out of Grewe. It is impossible to conclude given the limited spatial scale of this analysis whether these movements were the result of declines in agricultural productivity related to high annual discharge events, geomorphic changes, and associated negative impacts on canal infrastructure; and/or, were the result of relatively better and attractive conditions in the watershed unrelated to streamflow-related threats to irrigated agriculture. During high annual discharge years, precipitation conditions were relatively high throughout the watershed. These precipitation conditions may have expanded settlement opportunities away from Grewe along smaller rivers and streams or in non-riverine locations (see Ingram 2008:157-160). This analysis has also demonstrated that decisions to move into and out of Grewe were not consistently related to dry conditions and periods of low and high temporal and spatial variability.

Three spatial scales of analysis have been considered in this research: 1) a river basin scale as used by Graybill and colleagues (Graybill et al. 2006); 2) a canal system scale as used with the Canal System 2 analysis of population change (Ingram 2008); and, 3) the settlement scale as considered in this analysis. Differing scales undoubtedly contribute to differences in results. There is no reason to expect population dynamics at an individual settlement will mirror dynamics within a canal system or within a river basin. Population dynamics in an individual settlement, if related at all to the productive potential of canal irrigation, are likely strongly influenced by the position of the settlement along a canal as it relates to access to water. Canal system population dynamics are probably strongly related to the up-stream or down-stream position of the canal in relation to other canals. River basin population dynamics are an amalgamation of shifting settlement and canal locations and unique population histories responsive to a variety of local and regional factors through time. At each scale, the demand for water must be reconciled with the supply of water. Thus, adaptations and responses to climatic extremes cannot be expected to have been the same at each spatial scale of analysis.

We suggest that it is implausible that one model or set of expectations regarding the relationship among streamflow, the productive potential of irrigated agriculture, and human demographic behavior is adequate. Different scales of analysis should yield differences in results. Importantly, demographic factors that contribute to the vulnerability of people to climate-related declines in productivity should be considered. There is no basis for expecting everyone in a river basin to have been equally vulnerable to declines in productivity. Some people may have benefitted from changes in discharge patterns, while some likely did not. Demographic factors that affect the demand for resources (such as population levels) and productivity that affects the supply of resources should be considered when streamflow variation is expected or asserted to influence demographic behavior.

It is also important to acknowledge the fundamental assumption inherent in this and many other studies of the influence of environmental variation on human behavior. This is the assumption of productive resource marginality supported by relatively dry and variable conditions in the American Southwest. An assumption of marginality establishes the link between environmental variation (including climate and streamflow) and human behavior through the risk of shortfalls and the necessity of acting to prevent starvation. The assumption requires that shortfalls occurred and that productivity hovered around a threshold above which shortfalls did not occur and below which shortfalls were frequent. If resource shortfalls were rare, unrelated to climatic conditions, and/or effectively accommodated by existing buffering strategies, then there is little reason to expect or assume that climatic variation impacted human demographic behavior. Modeling and simulating irrigated agricultural production and projecting demand for this production through our best population estimates is likely the best way to identify how tightly coupled the people of the Phoenix Basin were to streamflow events that affected agricultural production.

We have more to learn about how people benefitted and coped with climate extremes. "Unpacking" streamflow discharge variation and its effects on human behavior is essential to understanding the cultural-historical trajectory of the Hohokam and evaluating the potential influence of discharge variation on the depopulation of the Phoenix Basin. It is also important that we search for insights into climate and human behavior informed by the long-term archaeological record so that we can contribute to the current search for understanding and to the guidance necessary to meet potential challenges related to projected global-scale climatic change.

Acknowledgements. This analysis would not have been possible without the annual streamflow retrodictions provided by the Laboratory of Tree-ring Research at the University of Arizona. Excavations at Grewe were conducted by Northland Research under contract to the Arizona Department of Transportation.

Notes

1. For convenience, this model will be referred to simply as the "Graybill model" and repetition of the six associated references will be omitted. The model is well summarized in the Graybill et al. (2006) publication and this will be used for subsequent in-text citation of the model.

2. These data are also compelling because the population changes identified occurred before evidence of channel cutting and widening along the nearby Gila River sometime between A.D. 1020 and 1160 (Waters and Ravesloot 2000, 2001). Channel cutting and widening could have altered the relationship between annual streamflow discharge variation and irrigated agricultural productivity.

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REGIONAL AND TEMPORAL VARIATION IN OBSIDIAN USE WITHIN THE HOHOKAM REGION

Chris R. Loendorf

ABSTRACT

During the Classic period in central Arizona, there is considerable variation among adjacent areas in raw material utilization, and direction of the source has a greater effect than distance. This suggests that populations in the Hohokam region maintained different trade relationships. Obsidian data suggest that the strongest socioeconomic ties among communities were between sites located on the same streams. Regional variation in acquisition patterns suggests that the Classic period Hohokam were not a politically centralized or economically integrated entity. Despite these differences, it appears that two trends occur throughout the core area. First, use of the closest source, Superior, decreased over time. Second, Sauceda obsidian became one of the most important supplies by the late Classic. Data from the middle Gila suggest that these trends continued into the Historic period. This continuity of patterns is one example of the link between the Hohokam and the Akimel O'odham.

For a number of reasons, obsidian has properties that are ideally suited for the study of prehistoric exchange and interaction in the Hohokam region of central Arizona (Shackley 2005). First, obsidian is a highly desirable raw material for retouched tool manufacture (e.g., arrow points). As a result, it was commonly transported and exchanged across long distances. Second, obsidian has geochemical properties that allow source areas to be identified with a high degree of precision. Third, obsidian sources are generally localized deposits that in most instances are also abundant. Consequently, obsidian found at archaeological sites can be traced to specific locations. Fourth, because obsidian does not occur within the Phoenix Basin, all of the obsidian found at archaeological sites in the Hohokam core area must have been transported there from other regions. It is therefore possible to examine the nature of interaction between core area populations and populations from surrounding areas, as well as interactions among communities within the core area.

This paper presents the results of geochemical studies of nearly 100 obsidian artifacts from the Lower Santan Platform Mound Village, which is located along the middle Gila River within the Gila River Indian Community (GRIC) (Figure 1). The results of the Lower Santan analysis are then compared to recent sourcing studies from other Hohokam sites. I argue that the distribution of obsidian within the Hohokam core area was more closely tied to directional factors than distance considerations, and that there is considerable regional variation in the obsidian source use. Furthermore, rather than being transported as finished products, obsidian was generally brought to the core area in unreduced form. This suggests that prehistoric populations in the lower Salt and middle Gila River valleys, as well as those in the Tonto Basin, maintained different trade contacts. Regional obsidian acquisition patterns indicate that the strongest socioeconomic ties among communities were those between people who lived on the same waterways.

This regional variability in obsidian use also suggests that the Classic period Hohokam were not a politically centralized or economically integrated entity. In general, over time there is a tendency for increasing reliance on obsidian sources located to the south of the core area, and use of sources to the north, west, and east substantially decreased or ended. This pattern appears to begin during the Classic period (ca. A.D. 1150–1450) when use of some previously heavily exploited obsidian sources dramatically declined or stopped. Data from Historic period sites within the GRIC suggests that this pattern continued and intensified to the extent that Sauceda obsidian, which occurs

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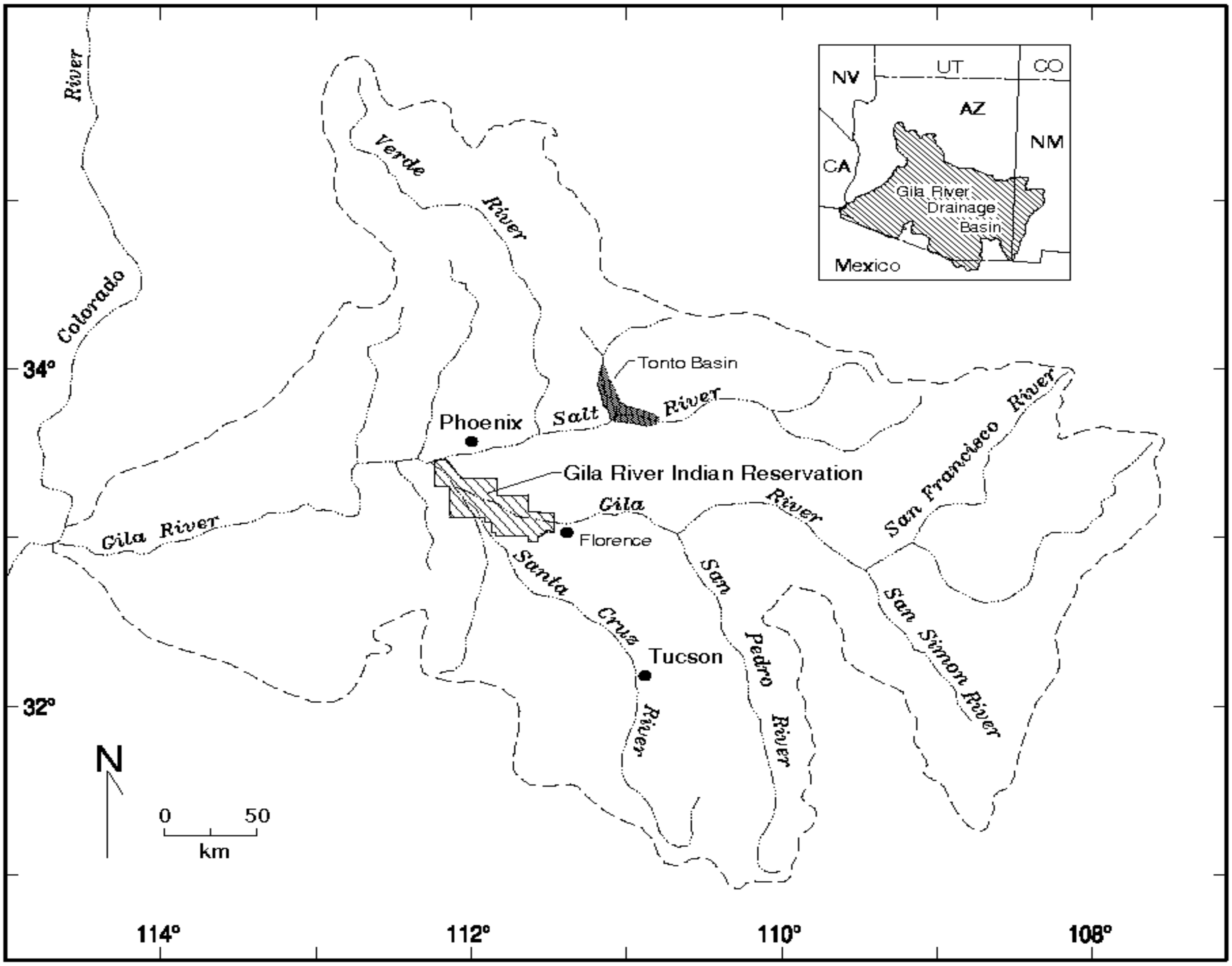

Figure 1. Gila River drainage and the location of the Gila River Indian Community.

to the southwest of the core area, was nearly the exclusive source utilized. This continuity of trends between the Classic and Historic periods is one example of the link between the Hohokam and the Akimel O'odham (Pima), who live in the area today.

SOUTHWESTERN OBSIDIAN STUDIES

Study of the intersocietal movement of goods is one of the primary methods archaeologists employ to study prehistoric interaction systems at different scales from the local to the regional (Schortman and Urban 1992:236). Exchange patterns reflect community and regional economic, ideological, and political interrelationships (Simon and Gosser 2001:220). These socioeconomic relationships involve many factors, including value, the number and type of transactions between the source and the consumer, regional distribution, competition, and cultural beliefs regarding the goods (Kooyman 2000:140).

During the last three decades, geoarchaeological investigations in Arizona have located and chemically characterized more than 50 sources, many in the Sonoran Desert, that were variously utilized by the Hohokam and their descendants (Loendorf et al. 2004; Marshall 2002; Mitchell and Shackley 1995; Rice et al. 1998; Shackley 1988, 1990, 1992, 1995, 2005). Geochemical data from these sources provides the means for identifying the distribution of obsidian raw materials. Trace element analysis of the Gila River samples was performed at the Archaeological XRF Laboratory, Department of Earth and Planetary Sciences, University of California, Berkeley, under the supervision of M. Steven Shackley.

Shackley (2005) has identified sources of both calc-alkaline and per-alkaline obsidian throughout western New Mexico, Arizona, Nevada, California, Baja California, and Sonora (Figure 2). The sources are the result of volcanism that occurred during two periods: the middle to late Tertiary and the Quaternary. Middle to Late Tertiary sources in Arizona include Antelope

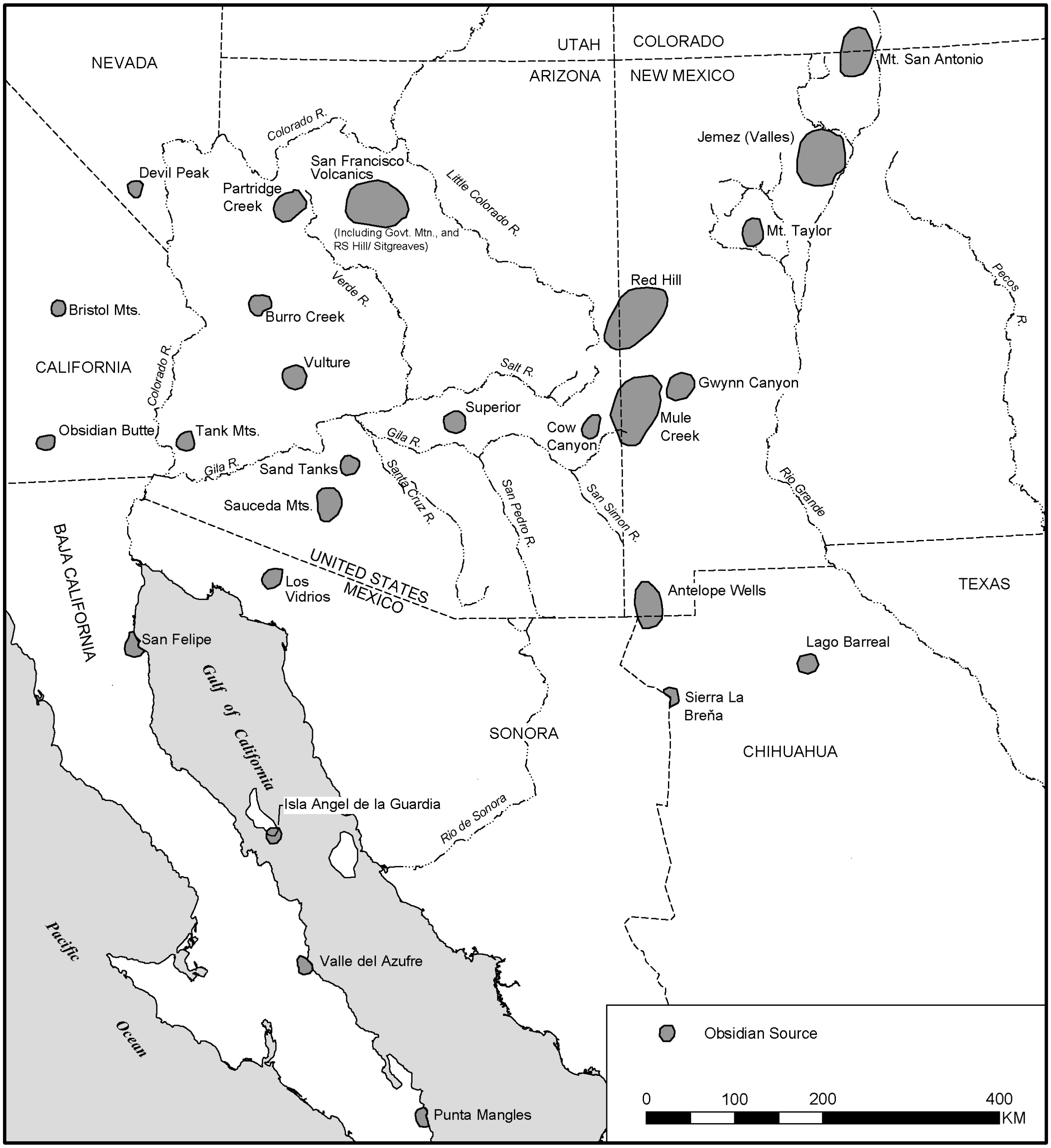

Figure 2. Southwestern obsidian sources (adapted from Shackley 2005).

Wells, Burro Creek, Vulture, Sauceda Mountain, Superior, Los Vidrios, and Tank Mountain. Somewhat more recent marekanite sources farther to the east include Mule Creek and Red Hill in western New Mexico. Quaternary sources produce larger nodules as much as 30 cm in diameter. Obsidian sources of this period include the San Francisco Volcanic Fields in northern Arizona (Government Mountain), Cow Canyon in southeastern Arizona, and the Río Grande Rift zone including Jemez and San Antonio mountains in central and northern New Mexico.

GRIC ARCHAEOLOGICAL RESEARCH

Beginning in 1993, the GRIC Cultural Resource Management Program (GRIC-CRMP) undertook an extensive regional survey encompassing more than 145,000 acres and documenting over 1,000 archaeological sites within the modern community (Ravesloot and Waters 2004). These investigations were funded by the Bureau of Reclamation as part of the Pima-Maricopa Irrigation Project (P-MIP). More than 7,700

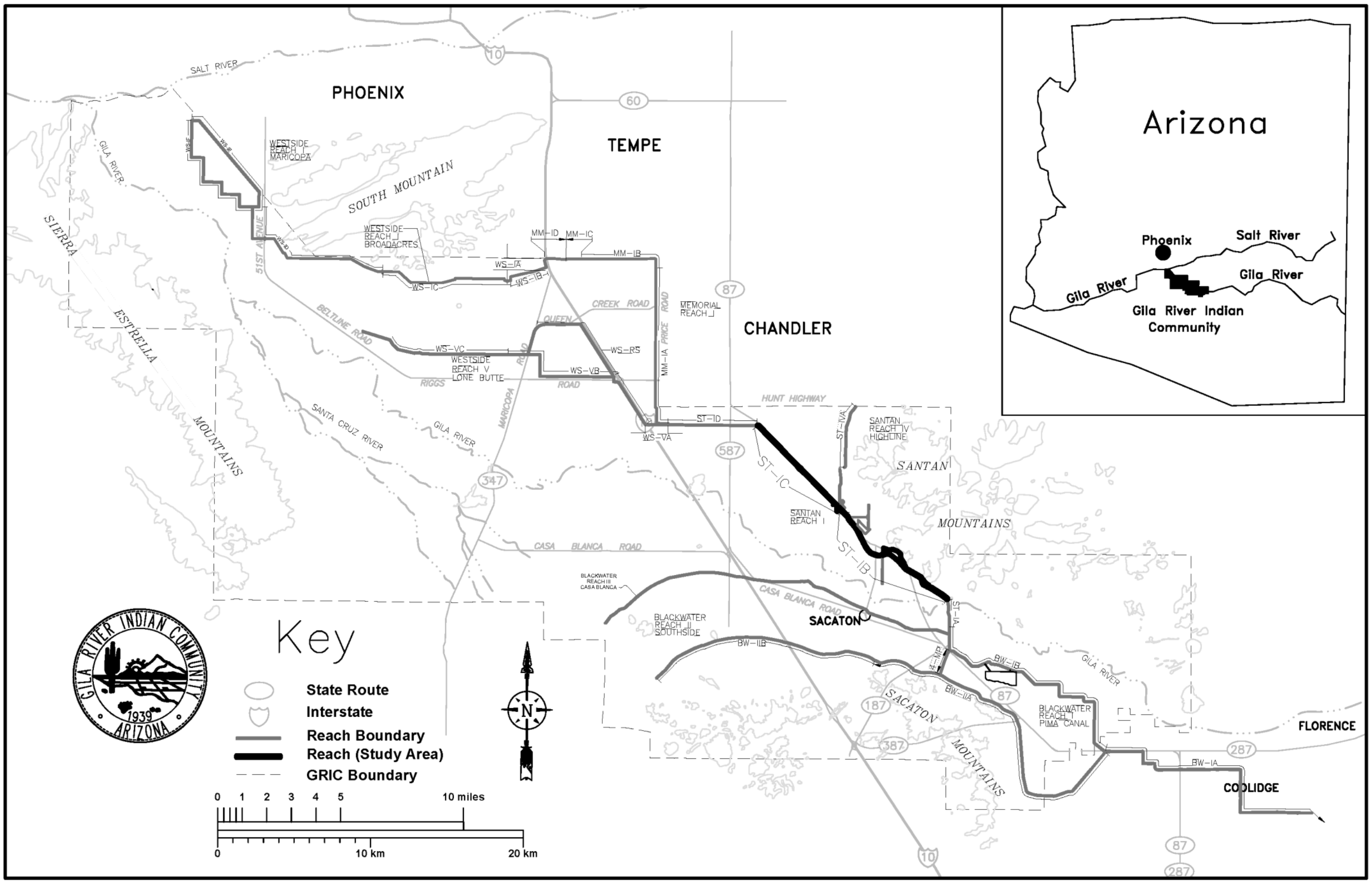

Figure 3. P-MIP mainstem and ST-IC study area, Gila River Indian Community.

pieces of obsidian were collected during the course of this survey. Almost 1,000 projectile points, nearly 30 percent of which were made from obsidian, were recovered (Loendorf and Rice 2004). This collection is one of the largest and most comprehensive available from the region, and these data have substantially improved our understanding of both temporal and spatial variability in archaeological remains from the middle Gila River region. For example, contrary to what some previous researchers have argued the GRIC was not an empty niche during the Archaic period, and nearly 300 points from this time were collected during the survey (Loendorf and Rice 2004).

In contrast to most surrounding areas, Historic period Native American cultural remains are common within the community. Over 200 projectile points from this time were collected during the survey; the points included examples produced from man-made glass. These data were largely not available prior to the P-MIP investigations, and they are particularly important for addressing aspects of the Hohokam continuum debate.

P-MIP DATA RECOVERY

Data recovery investigations for the P-MIP are currently on-going. This paper focuses on recent investigations along Santan Reach ST-1C (Figure 3) (Loendorf et al. 2007). Our work along this reach concentrated on the Lower Santan Platform Mound Village (GR-522). More than 1,200 features, including over 100 structures, were identified within the investigated portion of the site (Figure 4). These remains date from the Hohokam Colonial to the late Classic period, ca. A.D. 750–1450. Excavations were completed in two loci (Loci A and D), which were separated into sub-loci on the basis of feature distributions. Late Classic (A.D. 1300–1450) features within the project area were only identified in the Pear Road 1 sub-locus, whereas the sub-loci within Locus D included predominately Pre-Classic remains (ca. A.D. 500–1150). Consequently, it is possible to consider temporal variation in obsidian usage at the site by comparing the remains from Locus A (obsidian from Pear Road 2 is not included) to those recovered from Locus D.

Table 1. Obsidian source proportions for collections with more than 40 sourced artifacts (source data from Loendorf et al. 2004; Marshall 2002; Mitchell and Shackley 1995; Peterson et al. 1997; Rice et al. 1998; Shackley & Bayman 2006).

					(West)		Obsidian Source				(East)						
Collection	Period	Tank Mtns.	Burro Creek	Partridge Creek	Los Vidri-os	Vulture	Govern-ment Mtn	RS Hill/ Sitgreaves	Sauceda Mts	Sand Tanks	Superior	Cow Can-yon	Mule/ Antelope Creek	Unknown/ Other	Distance From Snaketown in Km	K-Means Cluster	Sample Size
Snaketown	Pre-Classic	0%	0%	0%	0%	5%	2%	2%	22%	1%	60%	2%	1%	0%	0	3	299
GR-522 Locus D	Pre-Classic	0%	0%	0%	0%	3%	13%	0%	15%	0%	51%	0%	0%	18%	14	3	39
GR-522 Locus A	Classic	0%	0%	0%	2%	0%	4%	0%	61%	0%	20%	0%	2%	12%	14	1	51
ELXP	Classic?	0%	1%	0%	7%	5%	3%	4%	63%	5%	8%	0%	0%	1%	15	1	76
Rowley	Classic	0%	0%	0%	0%	47%	0%	0%	30%	0%	23%	0%	0%	0%	29	5	43
Pueblo Grande	Classic	1%	0%	4%	4%	27%	22%	0%	30%	0%	10%	0%	0%	3%	31	5	220
Los Colinas	Pre-Classic	4%	0%	2%	4%	26%	38%	10%	10%	0%	2%	0%	0%	4%	36	2	50
Casa Grande	Classic	0%	0%	0%	0%	1%	29%	0%	46%	0%	7%	0%	14%	2%	42	4	137
Grewe	Pre-Classic	0%	0%	0%	0%	1%	0%	0%	1%	0%	95%	0%	1%	2%	45	3	137
Palo Verde	Pre-Classic	0%	0%	2%	0%	55%	31%	11%	0%	0%	0%	1%	0%	0%	64	2	122
Gatlin	Pre-Classic	0%	3%	0%	1%	4%	0%	0%	85%	0%	0%	0%	0%	7%	73	1	75
Brady Wash	Classic	0%	0%	0%	3%	7%	4%	0%	79%	0%	3%	0%	1%	1%	86	1	67
Tonto Arm Early	Classic	0%	0%	0%	0%	0%	5%	0%	0%	0%	90%	2%	0%	3%	93	3	11
Tonto Arm Late	Classic	0%	0%	0%	0%	0%	38%	0%	20%	0%	6%	4%	32%	0%	93	4	80
Salt Arm Early	Classic	0%	0%	0%	0%	0%	13%	13%	13%	0%	64%	0%	0%	0%	97	3	54
Salt Arm Late	Classic	0%	0%	0%	0%	3%	33%	0%	11%	0%	15%	9%	26%	3%	97	4	45
Marana	Classic	0%	0%	0%	0%	6%	0%	0%	85%	0%	4%	1%	3%	1%	124	1	152
P-MIP Survey Data																	
Pre-Classic GRIC	Pre-Classic	0%	0%	0%	0%	0%	11%	0%	55%	0%	33%	0%	0%	0%	N/A	N/A	9
Classic GRIC	Classic	0%	0%	0%	0%	8%	0%	0%	67%	0%	8%	0%	8%	8%	N/A	N/A	12
Historic GRIC	Historic	0%	0%	0%	5%	9%	0%	0%	76%	0%	9%	0%	0%	0%	N/A	N/A	21
All Data																	
Pre-Classic Avg.	Pre-Classic	0.6%	0.4%	0.6%	0.7%	13.5%	13.5%	3.3%	26.8%	0.2%	34.4%	0.4%	0.2%	4.4%	N/A	N/A	731
Classic Average	Classic	0.1%	0.1%	0.3%	1.3%	8.7%	12.6%	1.4%	42.1%	0.4%	21.5%	1.4%	7.2%	2.8%	N/A	N/A	948
Total Average	Both	0.3%	0.3%	0.5%	1.0%	11.1%	13.0%	2.4%	34.5%	0.3%	28.0%	0.9%	3.7%	3.6%	N/A	N/A	1679

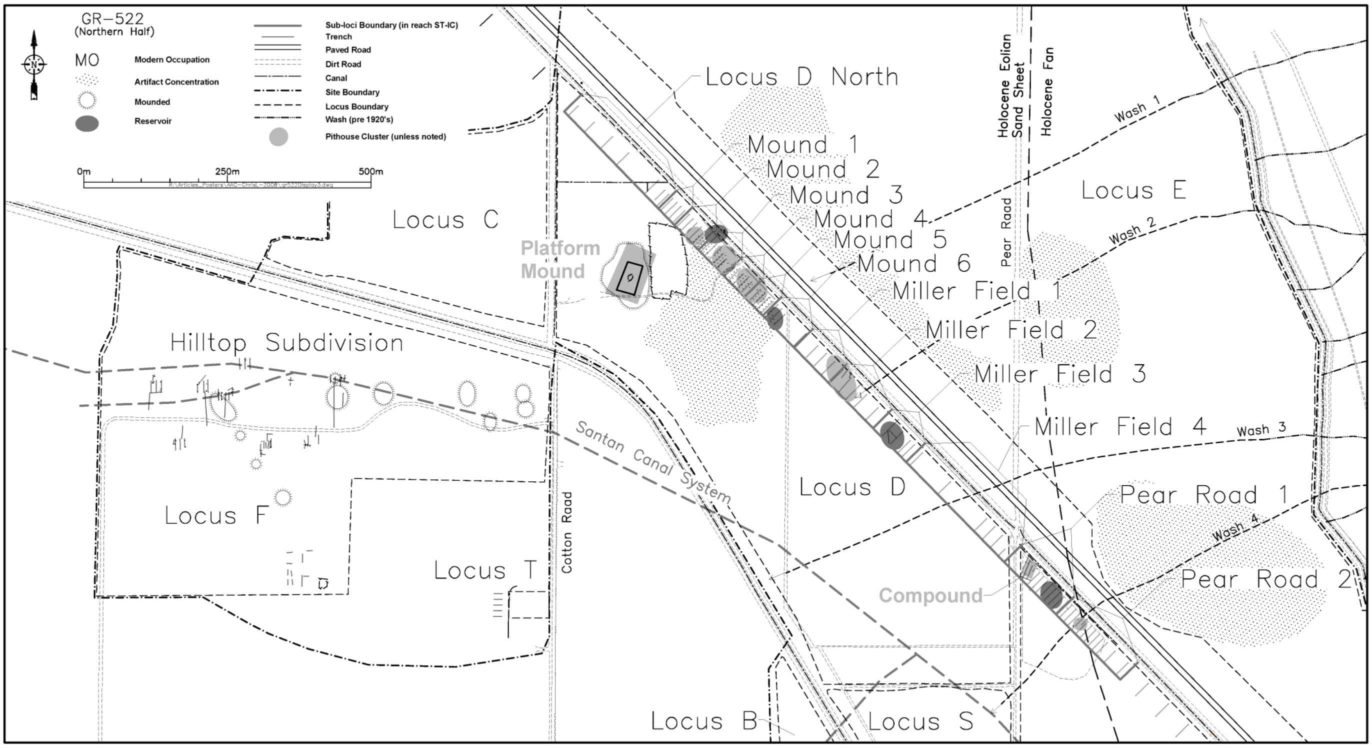

Figure 4. Excavations at Lower Santan, P-MIP Reach ST-IC, Gila River Indian Community.

HOHOKAM OBSIDIAN RESEARCH

Table 1 presents obsidian source proportions for collections with more than 40 sourced artifacts from the Hohokam area in southern Arizona (Figure 5). Sites are organized based on their distance from Snaketown, and the sources are arranged across the top from west to east. The results from a non-hierarchical K-means cluster analysis are also reported. As can be seen in the cluster assignments, site proximity appears to be a surprisingly poor predictor of obsidian assemblages, and considerable temporal and regional variation are present in these data.

Although it is a relatively straightforward process to identify source locations for obsidian found at archaeological sites, understanding how that material came to the sites is more complicated. "Identifying the precise behavioral mechanisms behind Hohokam, indeed any form of obsidian circulation, is extremely difficult given that multiple processes could account for its movement" (Bayman and Shackley 1999:842). Although obsidian acquisition may have been a complicated process that lacks a single universal explanation, it is still possible to evaluate different explanations for obsidian movement. Models that have previously been proposed for Hohokam obsidian acquisition can be grouped into three general categories: 1) "direct access," 2) "elite control," and 3) "social exchange" models (Peterson et al. 1997). In the late 1990s, researchers concluded that elites at platform mounds "did not exercise managerial control over long-distance exchange or the production of craft items" (Peterson et al. 1997; Rice et al. 1998), and this model is now largely rejected. Therefore, this model will not be considered further here. Instead, the following discussion considers if the "direct access" or "social exchange" models most closely match patterning in the archaeological record.

REGIONAL AND TEMPORAL VARIATION IN OBSIDIAN USE

With the exception of Sand Tank, the closest obsidian sources to the core area were the most commonly used by the Hohokam (Shackley 2005). These include the Sauceda, Superior, and Vulture sources. The use of these materials, however, varies substantially over time and space. Although Sand Tank is the closest source to the GRIC, this material rarely occurs there. Sand Tank obsidian does not appear to have been extensively utilized throughout the Hohokam region, but the reasons for this remain unclear (Shackley and Tucker 2001).

Sauceda obsidian was one of the most common types used by the Hohokam, and its proportion in assemblages is very weakly correlated (Pearson correlation = -.03) with distance from the source (Figure 6). These data are not consistent with "direct access"

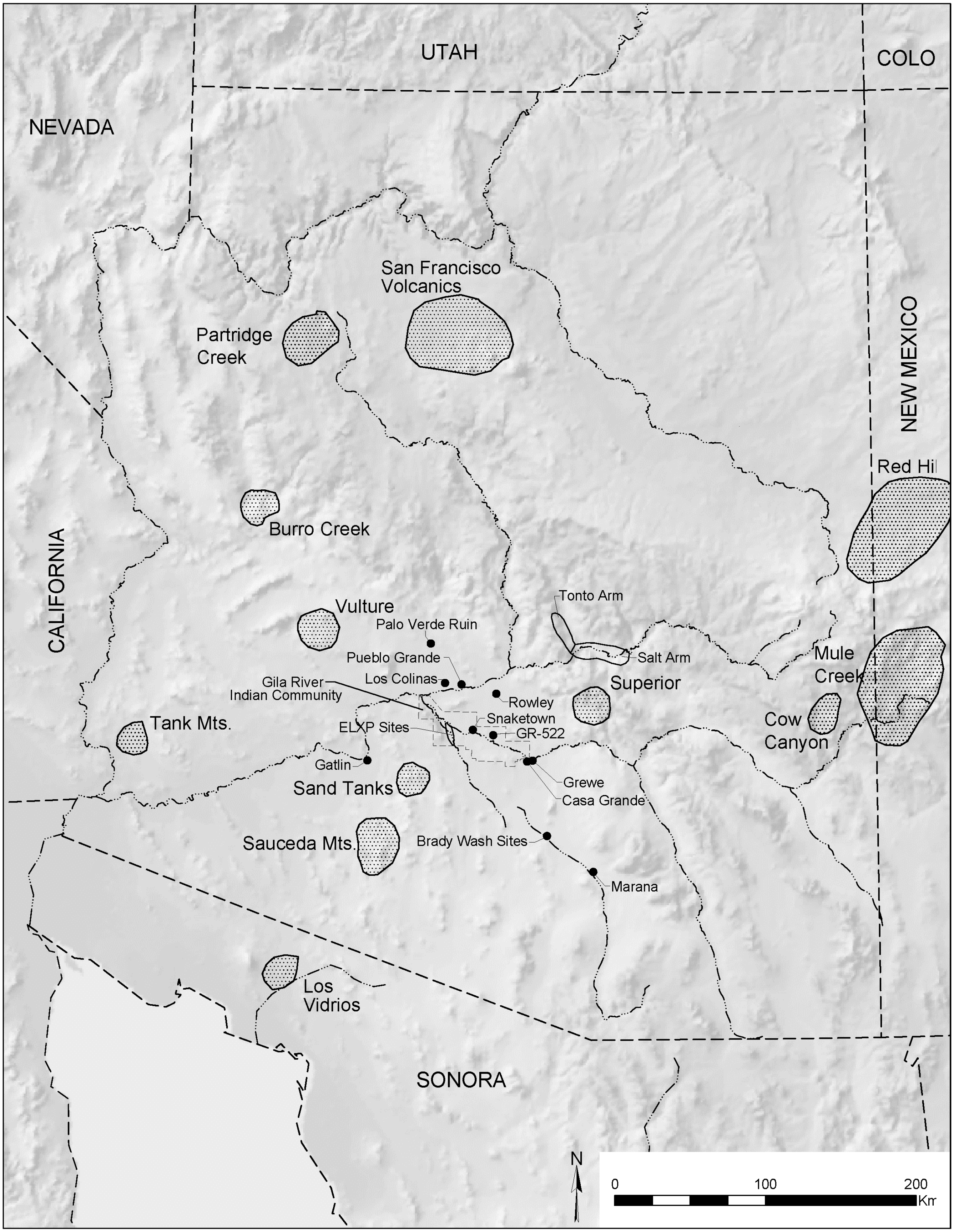

Figure 5. Archaeological site locations and obsidian sources identified at these sites.

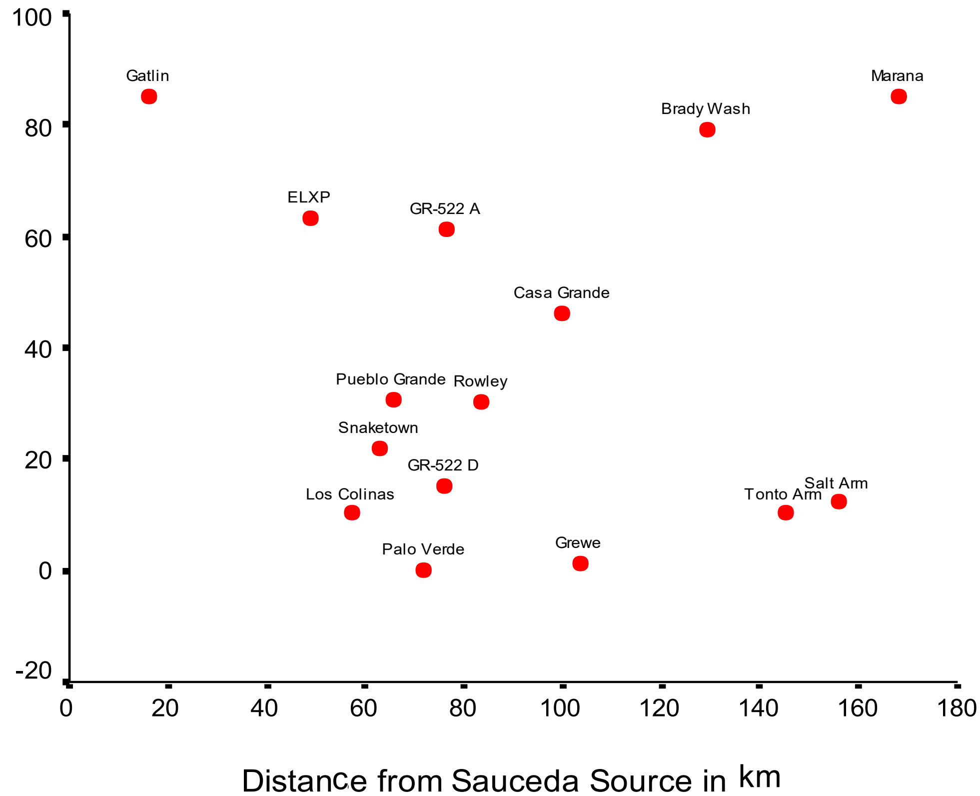

Figure 6. Scatterplot of Sauceda obsidian proportions by straight line distance in kilometers from the source location.

models for obsidian acquisition. Models in this category assume that the end user of the obsidian personally traveled to the source to collect the material. Peterson et al. (1997) referred to this category as the Opportunistic Model, in part, because some researchers argue that obsidian procurement strategies were embedded within the acquisition of other goods. It is assumed that obsidian was a comparatively low value item that was obtained when possible in the context of other activities. This model holds that distance to the source should be a primary factor that determines obsidian frequencies at sites. Temporal variation in obsidian utilization as well as the lack of distance decay relationships for common obsidian types suggests this model is not the most parsimonious explanation for obsidian acquisition in the Hohokam region.

Nonetheless, some distance decay relationships are apparent in the obsidian frequencies for the P-MIP survey data. Figure 7 graphs average distances to the three most common source areas for different portions of the community by distance to the sources. A rapid fall off with distance is apparent for the proportions of Superior and Vulture obsidians; however, the two types have opposite fall off patterns. Proportions of Superior obsidian, which is located to the east, fall off from east to west. In contrast, proportions of Vulture obsidian, which is located to the west, fall off from west to east. Excluding the Sauceda source, a strong negative linear relationship exists between the log transformations of source proportion and distance. The Pearson correlation coefficient for this relationship is -.87, with a probability of .02. Distance to the source appears to be the primary barrier for the movement of these two obsidian types within the GRIC, which is consistent with down-the-line exchange or direct procurement.

P-MIP survey data suggest that the dependence on Sauceda obsidian increased over time, with the highest incidence occurring in the Historic period (Loendorf et al. 2004). This possibility is also supported by the observation that obsidian artifacts in the sample from one of the largest single-component Historic period sites identified within the community (Sacate) are almost exclusively from the Sauceda source. The diagnostic artifact assemblage at Sacate consists largely of Historic period materials, and Pre-Classic or Classic period artifacts are rare (Randolph et al. 2002). Obsidian samples from the site are dominated by material from the Sauceda source: 13 of the 14 submitted samples are Sauceda obsidian, and the remaining artifact is from Los Vidrios, which is located farther to the south in Mexico. The proportion of Sauceda obsidian in the Phoenix Basin also increased during the Classic period, and this trend toward greater reliance on southern

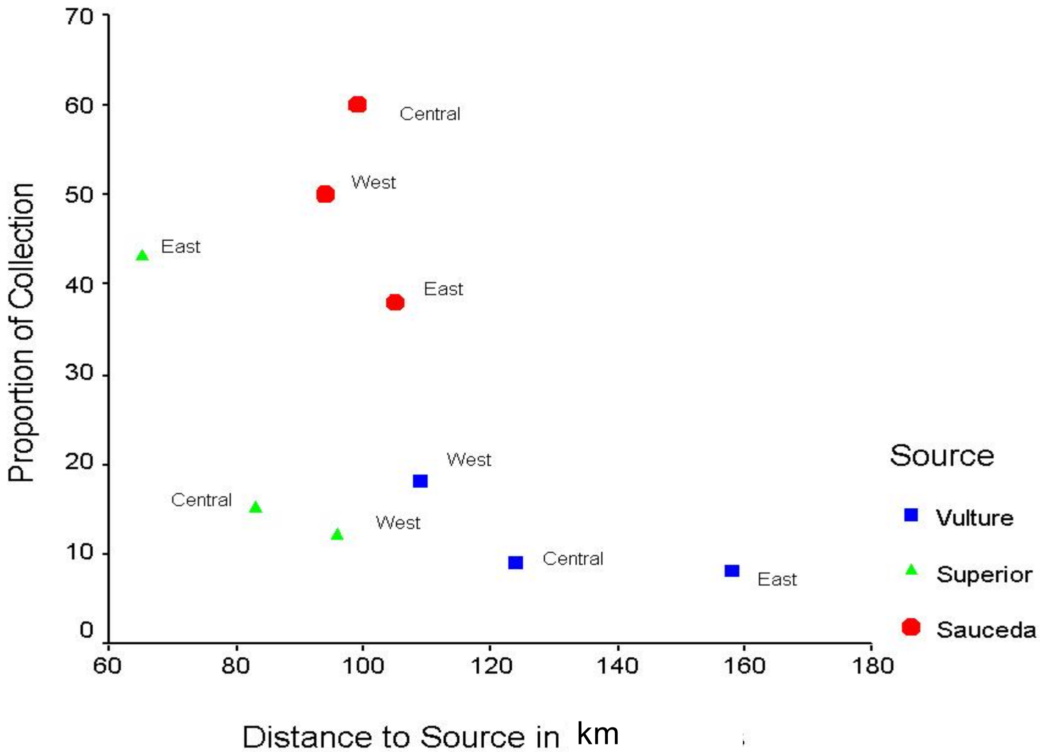

Figure 7. Obsidian proportion by location with in the GRIC and distance to the source, P-MIP survey collection, Gila River Indian Community.

sources appears to have occurred throughout the Hohokam area (Marshall 2002:132–133).

At the same time, use of obsidian from the Superior source appears to have declined after the Pre-Classic period. For example, data from Grewe (a large Pre-Classic period village) and Casa Grande (a nearby Classic period village) show that a dramatic decline occurred in the use of Superior obsidian during the Classic period (Bayman and Shackley 1999). Superior obsidian was also the most common material identified at the Pre-Classic period site of Snaketown (Shackley and Bayman 2006). A similar pattern occurs in the Tonto Basin, where the use of Superior obsidian also declined over time (Rice et al. 1998).

Vulture obsidian utilization may have peaked during the Classic period in the community, when it constitutes 18 percent of the survey sample. Previous examination of sites in the Phoenix Basin shows a slight increase in the use of Vulture obsidian during the Classic period; however, this material is substantially more common during both the Pre-Classic and Classic periods in the Phoenix Basin than it appears to be in the GRIC study area (Marshall 2002; Mitchell and Shackley 1995; Peterson et al. 1997). The western portion of the survey area is closer to the Vulture obsidian source than sites in the core of the Phoenix Basin, but only seven percent of the obsidian from the western-most portion of the community was derived from the Vulture source. However, this material constitutes roughly 30 percent of the overall Phoenix Basin collection (Loendorf et al. 2004). These observations suggest that proximity to the source alone does not fully account for differences in the utilization of Vulture obsidian.

LOWER SANTAN DATA

Similar patterns in obsidian utilization are also apparent in the Lower Santan data. Very little Vulture obsidian is present for either the Pre-Classic or Classic periods, and Sauceda proportions increase during the Classic period, while the proportion of Superior decreases (Figure 8). Shackley argues that access to the source was restricted by the Salado during the Classic period (Shackley 2005). However, a similar temporal pattern of decline in the use of Superior obsidian occurs in the Tonto Basin (Rice et al. 1998), which has traditionally been considered to be the heartland of the Salado. It is possible that access to the source was cut off in the Classic period, but if this was the case, then it occurred for all of the communities of sedentary agriculturalists that have been sampled to date.

Rice et al. (1998) suggested two possibilities for the decline in Superior obsidian use during the late Classic period. First, the source was depleted. Second, a large village appropriated exclusive use of the

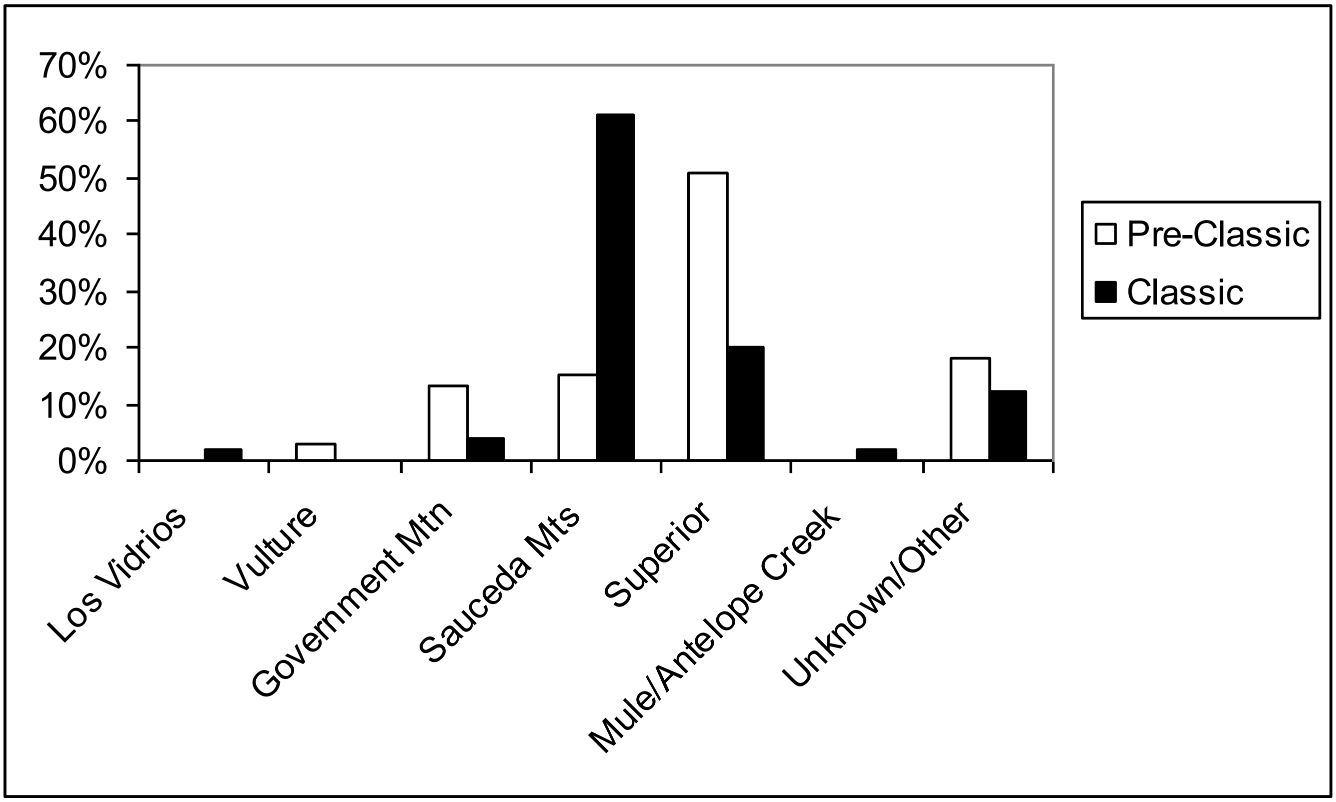

Figure 8. Obsidian proportions by period, Lower Santan Platform Mound Village, Gila River Indian Community.

source. The first possibility appears unlikely because substantial obsidian deposits remain at the source today. The second possibility is more probable; however, the site that cut off access has not as yet been identified. A third possibility is that a group of foragers (e.g., the Apache), who are difficult to otherwise identify in the archaeological record, moved into the area around Superior and cut off access to the source.

Differences in obsidian utilization among sites in different portions of the Hohokam area can be illustrated by comparing individual sites such as Pueblo Grande and Lower Santan (Figure 9). Although these two sites are less than 35 km apart, obsidian acquisition patterns differ substantially between them (see Table 1). For example, in addition to the previously noted differences in Vulture obsidian frequencies, sites in the Phoenix Basin generally have much higher proportions of obsidian from the large nodule sources in northern Arizona than occurs along the Gila River, where northern Arizona sources are comparatively rare throughout the sequence. The northern Arizona sources are approximately 265 km from the Gila River sites, a distance that far exceeds the roughly 35 km that separates the two sites. These data show that direction of the source has a greater effect than absolute distance. This pattern suggests that prehistoric populations in the Phoenix Basin and along the middle Gila River maintained different trade contacts, which is consistent with social exchange models for obsidian transport.

REGIONAL PATTERNS

In order to further consider regional variation in obsidian use, it is necessary to control for the temporal differences that are apparent in these data. One way to do this is to consider only those sites that are from the same time period. Figure 10 is a cluster analysis dendrogram for Classic period obsidian frequencies. The analysis employed a squared Euclidian distance measure and Ward's method. At the two cluster solution level, all lower Salt River sites are in one cluster, whereas all middle Gila River sites are in the second. Although some middle Gila sites such as GR-522 occur in proximity to the lower Salt sites, obsidian proportions differ substantially between sites along the two rivers. At the same time, the Tonto Basin is more than 80 km away from Pueblo Grande, yet it has similar obsidian proportions. These data suggest that the strongest socioeconomic ties were among communities located on the same waterways.

SUMMARY AND CONCLUSIONS

Studying materials that were transported to the Hohokam core area provides a complementary perspective with materials that were produced and dis-

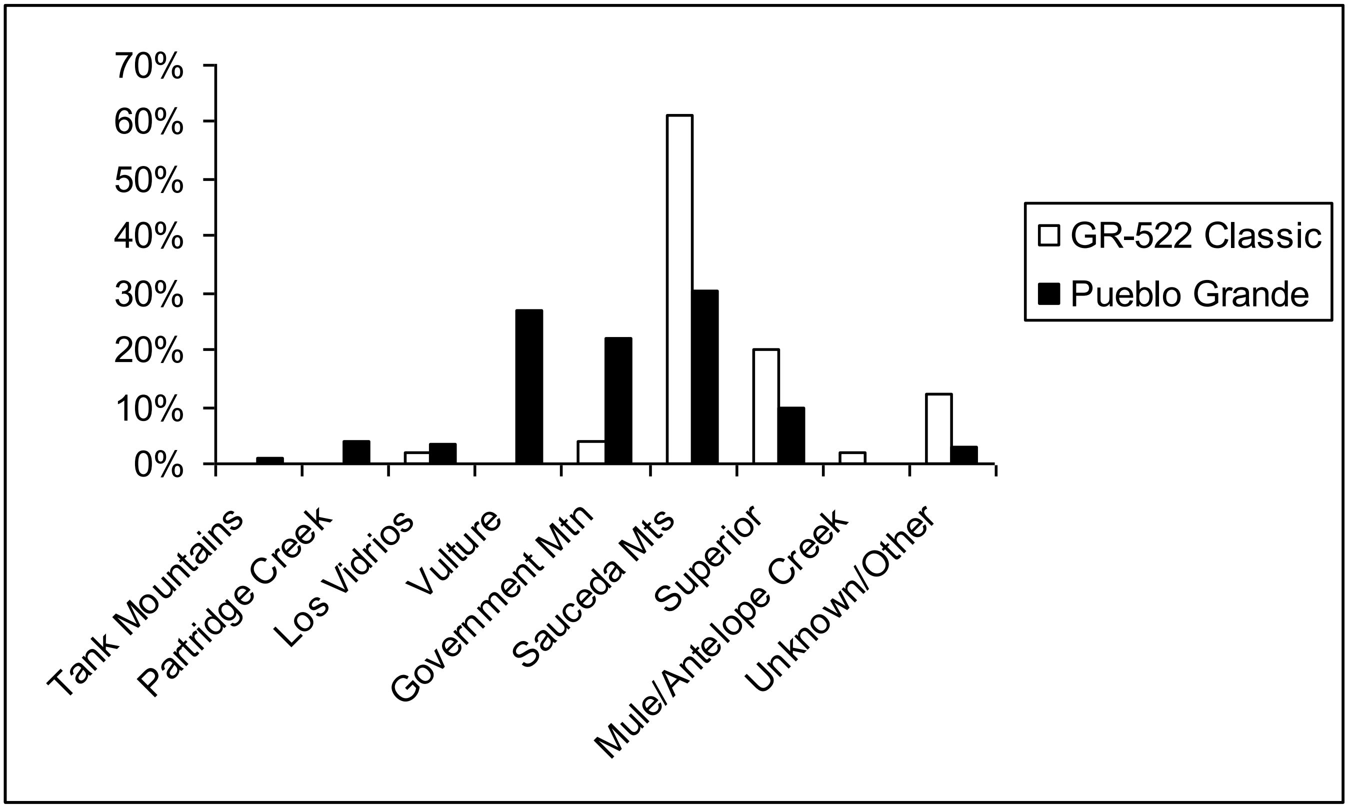

Figure 9. Pueblo Grande and Lower Santan obsidian data.

tributed locally (e.g., ceramics), which may have different patterns of distribution. In the past 30 years, obsidian analyses have become increasingly comprehensive (Shackley 2005), and broad regional and temporal patterns have now become apparent in these data.

The results of my research indicate that the direction of the obsidian source has a substantially greater effect than absolute distance on raw material utilization. Further, obsidian commonly arrived in the core area in unreduced form. If people traveled directly to sources to obtain obsidian, then distance should be the primary barrier to the acquisition of the material. However, obsidian proportions for the most commonly utilized sources are not correlated with distance. These observations suggest that prehistoric people in the lower Salt, middle Gila, Casa Grande, and Tonto Basin maintained different trade contacts. Patterning in obsidian acquisition suggests that the strongest socioeconomic ties among communities were those between sites located on the same waterways.

Variation in acquisition patterns among these areas supports the argument that the Classic period Hohokam were not a politically centralized or economically integrated entity. Data suggest that by the late Classic period, little obsidian was transferred between some adjacent subregions. Instead, communities of sites received most of their obsidian from distant areas in different directions. Use of the closest source, Superior, decreased dramatically over time from the Pre-Classic to the Classic periods. In contrast, Sauceda obsidian, which is located to the southwest of the core area, became the main supply of obsidian by the late Classic period, and this trend appears to have continued into the Historic period. This continuity of trends between the Classic and Historic periods is one example of the link between the Hohokam and the Akimel O'odham, who live in the area today.

The Historic period represents the culmination of this long trend toward greater reliance on obsidian sources located to the southwest of the middle Gila, and during this period Sauceda obsidian may have become nearly the exclusive source. The well-documented relocation of Akimel O'odham populations to the south bank of the Gila River for protection from Apache raiding during the seventeenth century offers a partial explanation. Access to northern, western, and eastern sources including the San Francisco Volcanics, Vulture, and Superior sources was effectively cut-off by intervening Apache and Yavapai populations. Meanwhile, alliances between the Tohono O'Odham (Papago), Cocopah, and the Pee Posh (Maricopa) would have allowed continuing access to raw materials in the direction of the Gulf of California. The observation that the decline in the use of obsidian from northern, western, and eastern sources begins during the Classic period suggests the possibility that foragers such as the Apache and Yavapai may have moved into

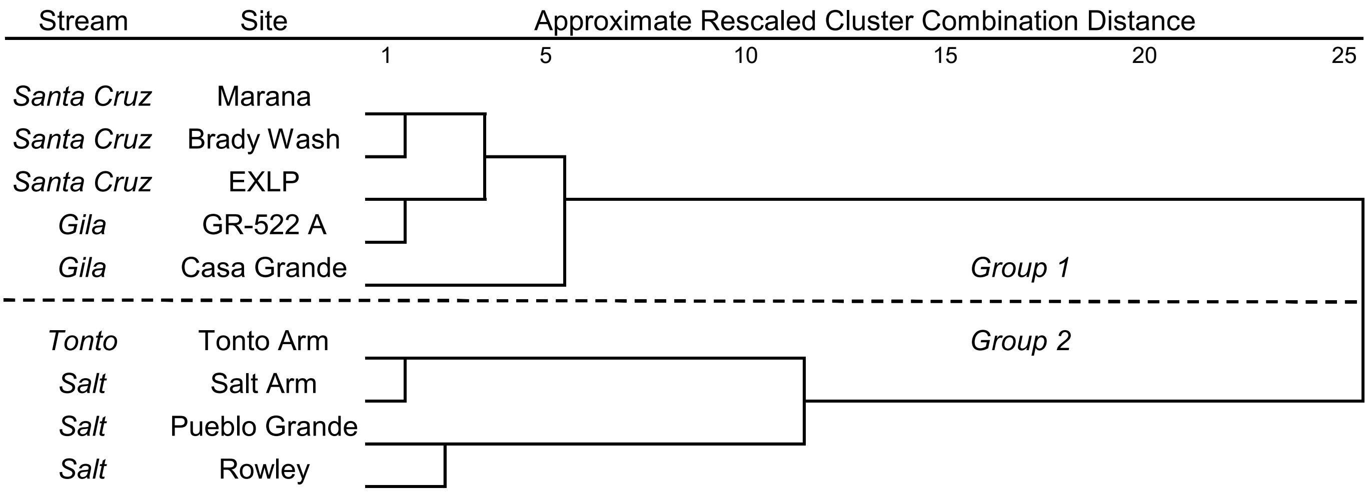

Figure 10. Cluster analysis dendrogram (squared Euclidean distance measure and Ward's method) for Classic period obsidian data.

southern Arizona earlier than has traditionally been assumed.

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ASBESTOS IN THE HOHOKAM WORLD

Sophia E. Kelly
Laurie D. Webster

ABSTRACT

Raw and modified asbestos artifacts have been found on Hohokam sites across the Phoenix and Tucson Basins, as well as on numerous sites in the Tonto Basin. Although these artifacts are rare, their distribution and archaeological contexts suggest that they had important social and/or ritual connotations. We take initial steps towards building a case for the prehistoric value of asbestos in Hohokam communities. First, we evaluate how the material properties of asbestos, such as its capacity to be woven into cloth, make it inherently unusual. Then, we explore the contexts in which asbestos artifacts have been found in the Hohokam culture region, and make a preliminary assessment of the distribution of raw and modified asbestos artifacts during the Sedentary and Classic periods. Examination of asbestos in local contexts can eventually lead to an understanding of the social and ritual value of raw and modified asbestos throughout the Hohokam world.

The unusual material properties of asbestos have contributed to its widespread use in antiquity across the world. In central and southern Arizona during the eleventh and twelfth centuries A.D., chrysotile asbestos was mined from large deposits along the Salt River Canyon and brought to settlements in the Tonto, Phoenix, and Tucson basins, as well as to a few sites in northern Arizona. The use of asbestos in the American Southwest appears to differ dramatically from the use of asbestos in ancient Eurasia, which is the primary model for the use of asbestos in the ancient world. This paper presents preliminary efforts to understand the kinds of value that asbestos had in the American Southwest, and ultimately to illuminate some of the meanings attached to this value.

We begin with a brief outline of asbestos' material properties. These properties form the basis for an innate value that is associated with asbestos minerals. We then review the uses and value of raw and processed asbestos in the Old World to provide a comparative framework for examining the value of asbestos in the American Southwest. Finally, we discuss several asbestos artifacts in their archaeological context in the prehistoric Southwest. This discussion suggests that the values and meanings attached to asbestos in the Southwest may have been quite different from those associated with the mineral in other parts of the world.

DEFINING ASBESTOS

Asbestos is an industry term for a set of six fibrous silicate minerals whose material qualities are suitable for various commercial applications. These include the amphibole minerals actinolite, amosite, anthophyllite, crocidolite, as well as the serpentine mineral chrysotile (Skinner et al. 1988). Although many minerals can appear in fibrous form, asbestos minerals have an extremely large length-to-width ratio of 3:1 or longer and are extremely thin (Ross et al. 1984; USGS 2002; Virta 2002, 2005). The diameters of individual fibers average between 16 to 20 times smaller than a human hair (Harris 2004:2). Asbestos minerals possess the extraordinary combination of flexibility, electrical resistivity, high tensile strength, and resistance to degradation, which have contributed to their widespread use in industrial and commercial products (Virta 2005:1).

The serpentine mineral chrysotile accounts for over 90 percent of the asbestos used in commercial and industrial applications today (Virta 2002). Chrysotile was also the most frequently used asbestos mineral in antiquity. Chrysotile was and still is sought-after because it has soft, flexible fibers that enable it to be twisted, matted, or woven. The unusual material properties of chrysotile asbestos are a product of its crystal

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structure, which consists of sheets of molecules that have curled to produce long, hollow, fibers. In contrast, the fibers in amphibole asbestos are formed by long chains of molecules that tend to be shorter and less pliant (Harris 2004:2).

Asbestos minerals, particularly chrysotile, are relatively rare across the world. In North America, large chrysotile deposits are present in only a few concentrated locations that are associated with tectonic belts. Some of the most extensive deposits are in the Sierra Anchas and Salt River Canyon area of Arizona (Harris 2004; Stewart 1955; Van der Hoeven 1999). Chrysotile deposits in Arizona are a product of contact metamorphism when diabase sills intruded into Mescal limestone deposits. Magnesium-rich fluids reacted with silica inclusions in the limestone and produced veins and masses of chrysotile within the rock (Van der Hoeven 1999). Most asbestos minerals appear in a granular or massive crystalline form (Harris 2004:2).

The prehistoric use of asbestos in North America is even more restricted than the distribution of natural asbestos deposits. In fact, the only documented prehistoric asbestos textiles in North America are from archaeological sites in the Hohokam culture region as well as neighboring culture regions in central and northern Arizona and northwest Mexico. The limited use and modification of asbestos by prehistoric populations in this region suggests that unique values and meanings may have been attached to the mineral throughout the prehistoric Southwest.

To address these issues, we compare the use of asbestos in the American Southwest to the value of asbestos in trade routes that connected Imperial Rome, China, Southeast Asia, and Central Asia during the first millennium B.C. This comparison sheds light on how the unusual material properties of asbestos were valued, manipulated, and conceptualized in antiquity.

THE VALUE OF ASBESTOS IN ANCIENT EUROPE AND ASIA

Asbestos, particularly asbestos cloth, was highly prized in ancient Europe and Asia, where large chrysotile deposits enabled the production of asbestos textiles. All asbestos cloth woven in antiquity was probably produced using chrysotile, which is extremely fibrous and pliant (Stewart 1955:13). During the first millennium B.C., asbestos cloth was an important component of the early textile trade between China and Rome (Cameron 2000). It was also among the most valued commodities circulated in trade routes between China, Central Asia, Southeast Asia, India, and Iran (Chandra 1960; Laufer 1915:327-328; Lombard 1978:115-116; Marco Polo 1996[1958]:89-90; Ray 1917:220; Su and Li 1980; Yates 1843:360). Not surprisingly, its expense contributed to its association with the wealthiest sectors of society in the ancient world. For instance, in Imperial Rome, asbestos cloth was more costly than silk (Cameron 2000:48). In 23 B.C., Pliny the Elder noted that raw asbestos was worth as much as pearls (Pliny 2008).

Textual sources and archaeological evidence also suggest that asbestos and asbestos cloth were material symbols of political and social power in Rome, China, and Southeast Asia (Browne 2003; Zussman 1972). Pliny the Elder notes that royalty were wrapped in asbestos burial shrouds in Rome. Several of these shrouds were excavated from high-status Roman tombs (Yates 1843). In addition, numerous elite burials in important trade capitals in Southeast Asia, such as the site of Khok Phanom Di, contained asbestos burial clothes (Cameron 2000). In China, asbestos textiles were important commodities for royal tribute, and were used in elaborate costumes after 90 B.C. (Laufer 1915; Needham 1959; Su and Li 1980; Wylie 1897).

Asbestos was linked with wealth and power in ancient Europe and Asia during the first millennium B.C. for three principal reasons. First, chrysotile asbestos can be woven into a rare cloth. The value of this cloth stems in large part from the specialized knowledge and skills necessary to produce it. Only particular grades of chrysotile asbestos that are long and flexible can be woven into textiles successfully. Furthermore, spinning and weaving chrysotile fibers is considerably more difficult than weaving organic fibers. No one but a master weaver well acquainted with the skills to weave asbestos can produce a successful asbestos textile (Browne 2003). Second, the cloth produced from chrysotile asbestos is particularly soft and lustrous. Historical documents suggest that the sheen of asbestos cloth was among the primary reasons why its beauty rivaled silk in Old World economies.

Third, asbestos and asbestos cloth is impermeable to fire and has very low thermal conductivity. Numerous textual documents note the miraculous way that asbestos cloth resists burning. In fact, many of these documents report that a person can hold fire in their hands when draped with asbestos cloth. The importance of incombustibility to asbestos' value is reflected in the words people used for the mineral. The ancient Greek word for asbestos, asbestinon, means "inconsumable" (Pliny the Elder 2008[1847]). The Chinese word for asbestos cloth, huo huan pu, means "cloth that can be cleansed by fire" (Laufer 1915:309).

ASBESTOS ARTIFACTS IN THE AMERICAN SOUTHWEST

We suggest that asbestos and asbestos cloth in the American Southwest was valued for different reasons than it was in ancient Eurasia. Based on the small num-

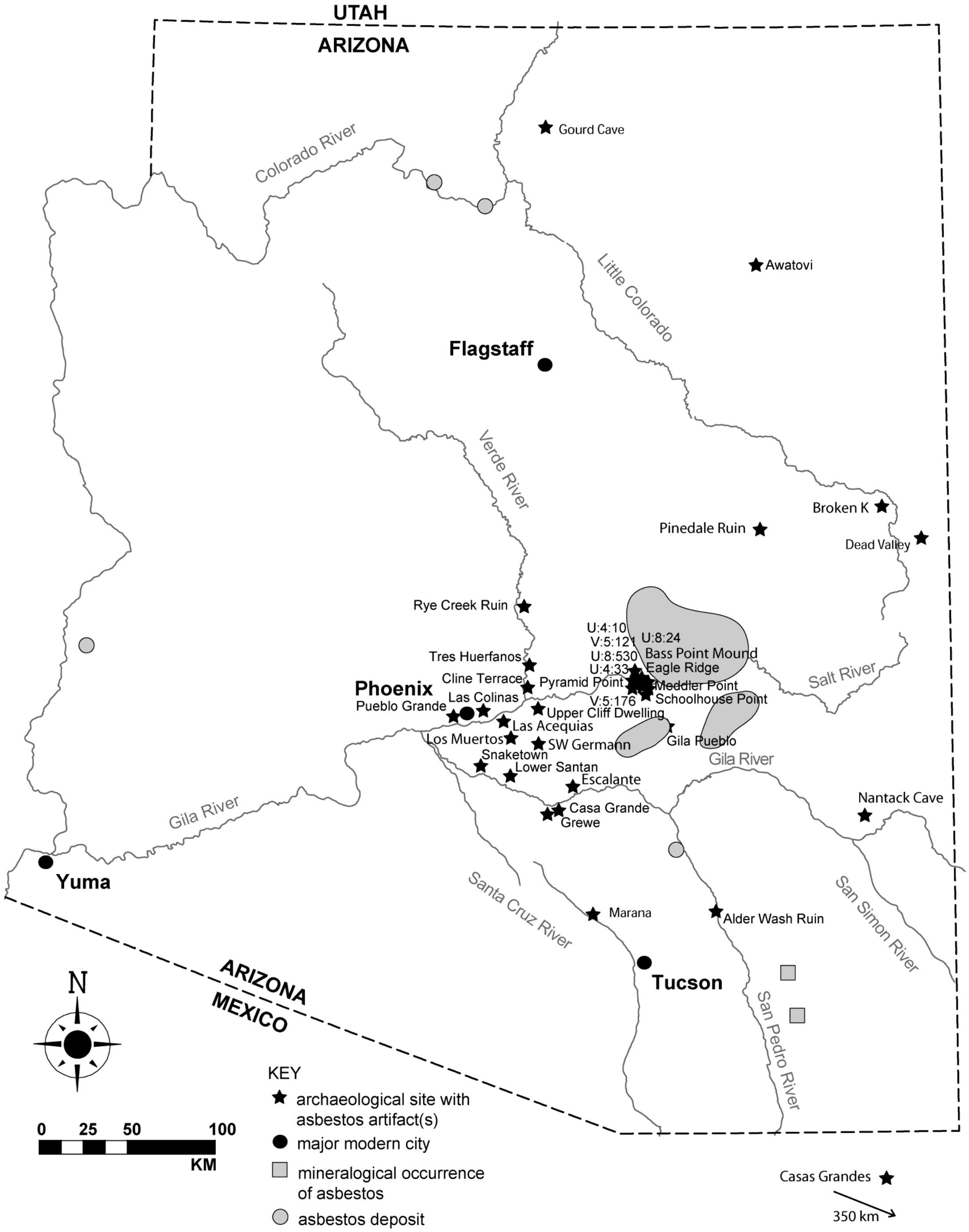


Figure 1. Distribution map of asbestos artifacts and natural asbestos deposits in the American Southwest.

ber of modified asbestos artifacts in the Southwest, we argue that the inherent properties of raw asbestos were emphasized over those of modified asbestos in Southwestern communities. Our preliminary survey of asbestos artifacts across the American Southwest highlights the intrinsic value of raw asbestos. Our review suggests that asbestos textiles were not made with the intention of creating a soft, lustrous cloth, as they were in the Old World. There is little evidence that asbestos textiles were used in the Southwest to highlight the fire resistance and low thermal conductivity of the mineral, as seems to have been the case in Eurasia during the first millennium B.C.

Raw Asbestos Artifacts

In the American Southwest, asbestos artifacts have been recovered from at least 34 sites that date between A.D. 700 and 1450 (Figure 1, Table 1). Raw asbestos was recovered from 31 sites, whereas modified asbestos artifacts were recovered from only four sites. Sites with raw asbestos include a number of communities along the middle Gila River, including Snaketown,

Table 1. Raw and modified asbestos artifacts recovered from archaeological sites in the American Southwest

Site Name	Artifact Type	Artifact Count	Context	Dates A.D.	References
AZ V:5:121(ASM)	Raw	1	Feature 16: burial pit (multiple persons)	1275-1400	Jacobs 1994:490; RPMS database
AZ U:4:33(ASU)	Raw	5	Features 81 and 62	1275-1400	RPMS database
AZ U:8:530(ASM)	Raw	1	Feature 17	1275-1400	RPMS database
AZ U:4:10(ASU)	Raw	15 (4 may not be chrysotile)	Features 10, 37, 54, and 55	1275-1400	RPMS database
AZ V:5176/2029	Raw	2	Context not identified	1275-1400	Adams and Elson 1995:Table 3.2
AZ P:13:10(ASU)	Raw	2+	Feature 3: burial; Feature 5: burial	1100-1300	Nelson 1981:315
Alder Wash Ruin	Raw	1	Feature 19: pithouse (on floor)	950-1300	ASM Artifact No. A-46550
Awatovi	Braided sash (painted with hematite)	1	Burial	1300-1540	Stubbs 1959; Webster 1997:293-294
Bass Point Mound	Raw	1	Feature 25C: elevated floor in plaza	1275-1400	Lindauer 1995:86, 452
Broken K site	Raw	1	Room (on floor)	1150-1280	Martin et al. 1967:115
Casa Grande	Raw	3	Surface collection; Compound A, B, C, D	1150-1350	Ambler 1962; Fewkes 1912:176; Gladwin 1928; Nelson 1981:314, Table 48; Zedeno and Stoffle 1995, ASM Artifact No. GP5207
Casas Grandes (Paquimé)	Raw	75	Medicine man's kit; Cache in room niche; Cache in Plaza 3-13 (on floor A)	1150-1450	Di Peso 1974:451-454, 630
Dead Valley	Raw	8	Feature 6: fire box; Grid E8; Grid E7; Feature 7: roofed area (various locations including hearth and floor); Room 2	1100-1150	ASM Artifact Nos. 77-57-3, 77-57-6, 77-57-8, 77-57-9, 77-57-10, 77-57-11, 77-57-12, 77-57-13
Eagle Ridge	Raw	5	Feature 1: large trash mound	950-1100	Adams and Elson 1995:135, Table 3.2
Escalante Ruin	Raw	16	Rooms (on floor, in hearths and fill)	1300-1350/1375	Doyel 1974:168, 296; Nelson 1981:314, Table 48
Gila Pueblo	Raw	68	Rooms 24, 72, 71, 96, 97; Burial (two inside bowl)	1275/1300-1375	Gladwin 1957:323; Nelson 1981:315; ASM Artifact Nos. GP7243, GP7635, GP10855, GP12858, GP42045, GP42276
Gourd Cave	Raw	1	Surface collection	1100-1300	ASM Artifact No. 1974
Grewe	Raw	1	Context not identified	900-1150	Nelson 1981:314, Table 48; Zofkie (2001:536, Table 13.2
Las Acequias	Raw	1	Context not identified	1300-1350/1375	Nelson 1981:314, Table 48
Las Colinas	Raw (in leather pouch)	1	Burial 14 (adult female)	1150-1450	Bostwick 1992; Crown and Fish 1996:810; Hammack (1969:25); Nelson 1981:314, Table 48, 315, 317; Saul 1981:266

Table 1 (continued). Raw and modified asbestos artifacts recovered from archaeological sites in the American Southwest.

Site Name	Artifact Type	Artifact Count	Context	Dates A.D.	References
Los Muertos	Raw	2	Architecture (non-specific)	1300-1350/1375	Nelson 1981:314, Table 48
Lower Santan	Clump of fibers, may be modified	1	Feature 373: compound room (on floor)	1150-1450	Kelly 2008
Marana	textile composed of asbestos and apocynum	1	Trash mound (associated with Compound 1)	1150-1300	Teague 1998:13; unpublished artifact in the collections of the Marana Mound Project
Marana	Raw	3	Compound 5, Room 2 (house floors)	1150-1300	Unpublished artifact in the collections of the Marana Mound Project
Meddler Point	Raw	2	Feature 77 (in floor fill); Compound 7 (masonry rooms)	1275-1325	Adams and Elson 1995:130, Table 3.2
Nantack Cave	Painted cordage	1	Surface collection	950-1400	ASM Artifact No. 73.1.30
Pinedale Ruin	Fetish?	1+	Context not identified	1290	Haury and Hargrave 1931:156
Pueblo Grande	Raw	2+	Platform Mound, Room JH45	1150-1450	Bostwick 1992:79; Bostwick and Downum 1994:361, Table 8.6; Downum and Bostwick 2003:194; Nelson 1981:314, Table 48
Pyramid Point	Raw	1	Feature 43: masonry room associated with platform mound (in cache with other minerals)	1275-1325	Adams and Elson 1995:123, Table 3.2
Rye Creek Ruin	Raw	1	Burial 182	1150-1450	Elson and Craig 1992; Haury 1930; ASM Artifact No. GP12013
Schoolhouse Point Ruin	Raw	4	Feature 247 and Feature 59: cobble masonry room	1275-1400	Lindauer 1990:255; RPMS database
Snaketown	Raw	6 (1 pc. actinolite asbestos)	Mound 39, 6G: House 8 (on floor, in vessel); Feature 6E: House 2 (on floor); Feature 8E: Pit 4 (midden fill); Feature ED:1: midden fill	850-1070	Gladwin et al. 1937:163; Haury 1976:275-277, Figure 14.5; Nelson 1981:314, Table 48, 316-317; Nelson 1991:83-84
SW Germann Site	Raw	1	Burial (cremation)	1150-1450	Unpublished burial form SSI Inc., (2008)
Tres Huerfanos	Raw	1	Feature 101.02: small pit within informally built structure (in cache)	850-900	Adams 2002:636-640, Table 10.45, Figure 10.24; Vint et al. 2000:353-362, Figure 15.24

Notes:
ASM = Arizona State Museum
ASU = Arizona State University
RPMS = Roosevelt Platform Mound Study

Grewe, Casa Grande, and Escalante Ruin. Raw asbestos artifacts were also excavated from features at Pueblo Grande, Las Acequias and Las Colinas on the Salt River, and from numerous sites in the Tonto Basin by the Roosevelt Platform Mound Study, the Roosevelt Community Development Study, the Tonto Creek Project, and Gila Pueblo projects. Finally, Amerind Foundation excavations at Casas Grandes (Paquimé) in northwest Chihuahua found a large number of asbestos artifacts in various features at the site. The Marana Mound in the Tucson Basin is the only site in the American Southwest where both raw and modified asbestos artifacts have been found.

The majority of asbestos artifacts occur in the Tonto Basin in close proximity to the large chrysotile deposits in the Sierra Anchas and in the Salt River Canyon. It is likely that most asbestos used in the prehistoric Southwest was extracted from these deposits. However, asbestos materials also appear at several Hohokam sites throughout the Phoenix Basin, the Tucson Basin, and at sites in northeastern and eastern Arizona. Asbestos recovered at Casas Grandes (Paquimé) could have been obtained from chrysotile deposits in southwestern New Mexico (Di Peso 1974:630).

Several patterns in the distribution of raw, unprocessed asbestos artifacts in the Hohokam culture region, as well as the rest of the Southwest reveal important information about the use of the mineral in prehistory. First, asbestos is very rare in archaeological contexts across the Southwest. Second, in those areas where asbestos occurs with some frequency, asbestos artifacts or raw asbestos do not appear to be concentrated at particular archaeological sites. Casas Grandes represents a notable exception to this pattern. Third, although the majority of asbestos artifacts are located near the large asbestos deposits in the Sierra Anchas and the Salt River Canyon, some samples were carried long distances from these source areas. All raw, unmodified asbestos samples were carefully extracted from their limestone parent rock. No samples consisted of chunks of limestone with chrysotile veins.

Modified Asbestos Artifacts

Modified asbestos is more rare than raw asbestos in the American Southwest. Of the asbestos artifacts in our current sample, only four have been modified from their raw form. Two of these artifacts were recovered from Hohokam sites. A clump of asbestos fiber was excavated from a large, non-residential room at the Lower Santan site on the middle Gila River during excavations for the Pima-Maricopa Irrigation Project conducted by the Cultural Resource Management Program of the Gila River Indian Community. The Marana Archaeological Project, directed by Paul Fish and Suzanne Fish, recovered a textile with asbestos fibers from an early Classic period trash mound at Marana.

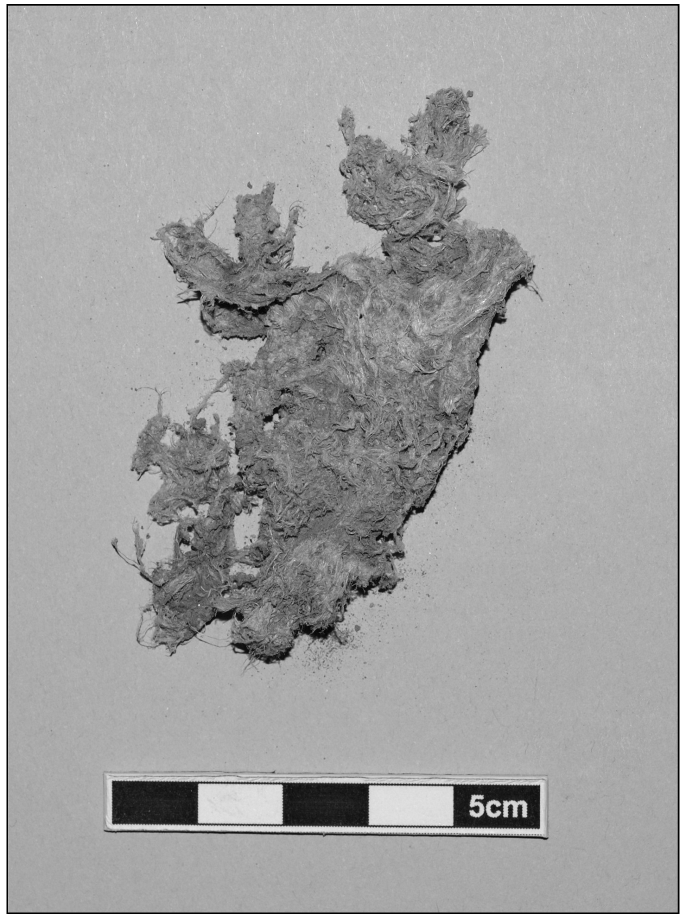


Figure 2. Matted clump of chrysotile fibers from Lower Santan Village. Photograph by Melissa Altamirano, Gila River Indian Community, Cultural Resource Management Program.

The asbestos artifact from the Lower Santan Village consists of a matted clump of chrysotile asbestos fibers (Figure 2). The pale brown fibers are not woven or spun, but could have been teased apart or combed. Although the fibers are not heavily processed, they are a soft, pliant chrysotile and would have been suitable for weaving. The sample was recovered from along the east wall of a large, late Classic period adobe room that appears to have hosted some kinds of non-domestic activities. The size and positioning of the room in the center of a compound courtyard indicate that the structure may have served as a meeting place for communal activities. The entire room and its intact floor assemblage, including shell beads, projectile points, and polishing stones, were intentionally burned just prior to abandonment.

The second modified asbestos artifact from a Hohokam site is the fragmentary remains of a 2/1 twill woven textile of blended asbestos and apocynum (Indian hemp) fibers from an early Classic period trash

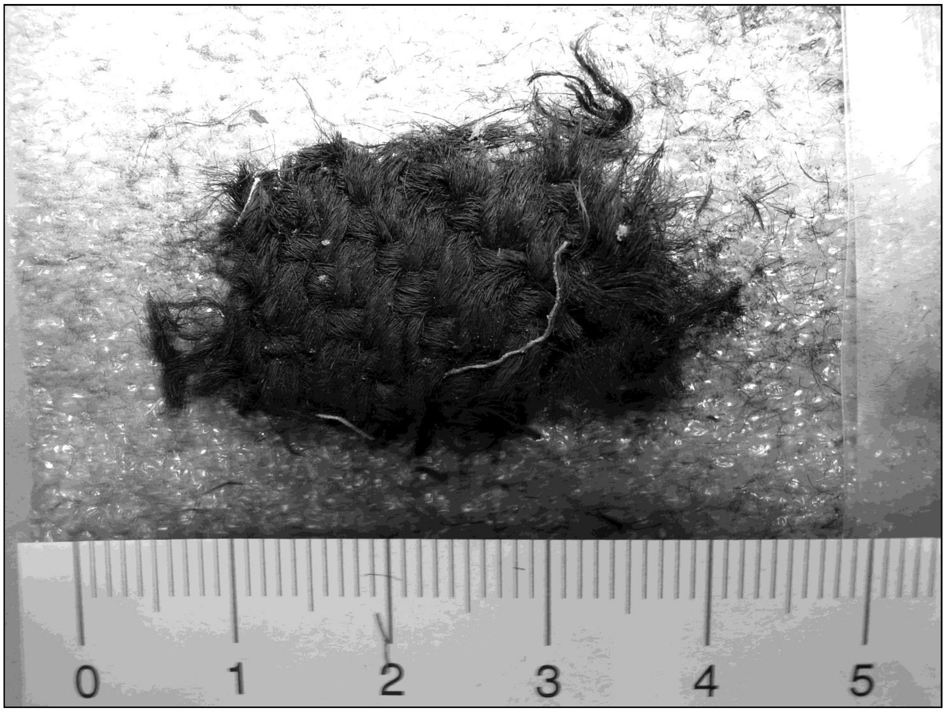
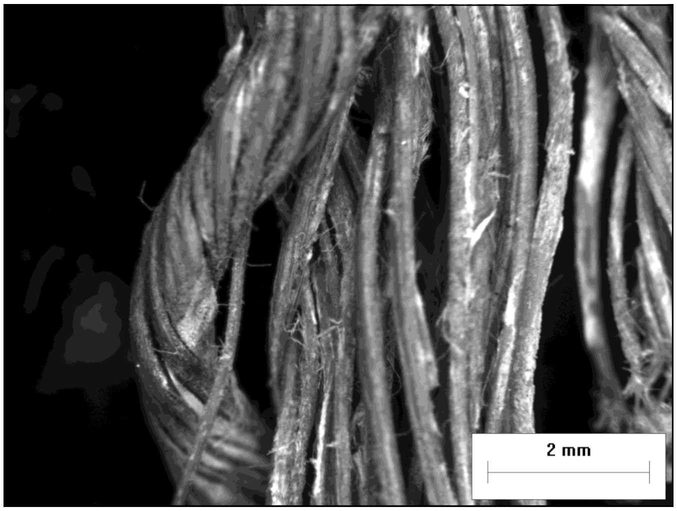


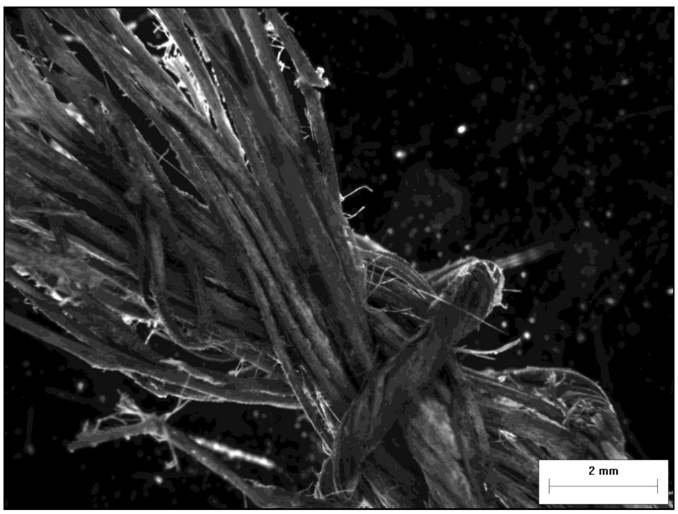
Figure 3. Fragment of 2/1 twill textile composed of asbestos and apocynum fibers from the Marana site.

Figure 4. Braided asbestos sash painted with hematite from Awatovi.

mound at the Marana site (Figure 3). The apocynum fibers compose over 90 percent of the yarns and the asbestos fibers are sparsely interwoven with them. Microprobe analysis under the supervision of Arizona State Museum Conservator Nancy Odegaard confirmed that the asbestos fibers are chrysotile. Charles Miksicek identified the apocynum component of the fiber, and Laurie Webster identified the weave structure of the textile. The textile is carbonized and only a few fragments remain.

In addition to the modified asbestos artifacts from Hohokam sites, two modified asbestos artifacts have been found some distance from the asbestos sources in the southern deserts. A braided sash of woven asbestos fibers was recovered from a Pueblo IV period burial in the Western Mound at Awatovi, an Ancestral Puebloan site near the Hopi Mesas of northern Arizona (Stubbs 1959; Webster 1997:293-294) (Figure 4). Scanning electron microscopy (SEM) and energy dispersive x-ray (EDX) analysis conducted by Laurie Webster confirmed the presence of chrysotile asbestos. The asbestos may have been mixed with other fibers. Unfortunately, the burial was excavated by an amateur archaeologist who did not record precise provenience information. The sash is woven in the technique of 2/2 oblique interlacing or braiding (Webster 1997:293-294), and one face appears to have been painted with hematite pigment (Stubbs 1959).



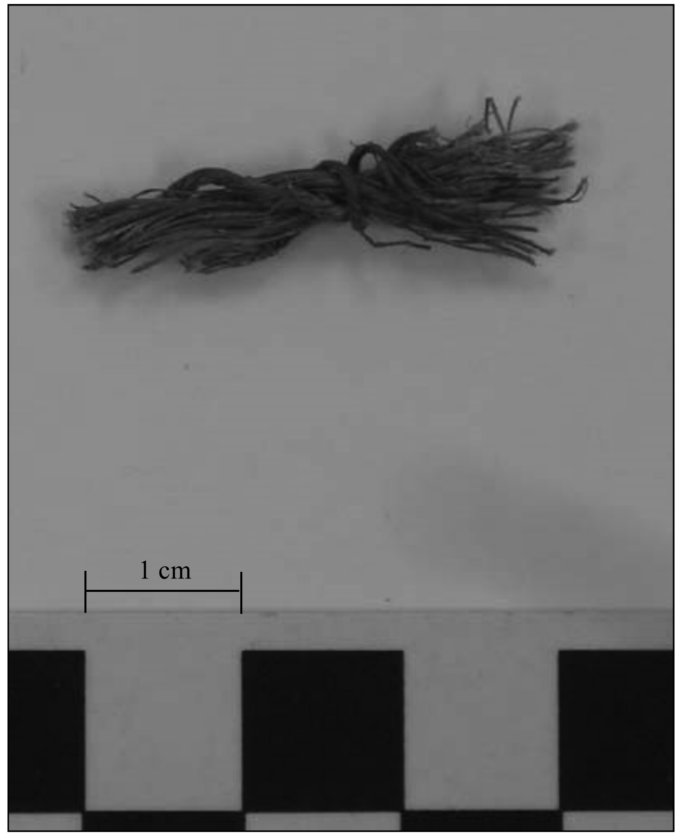


Figures 5 (above) and 6 (below). Micrographs of asbestos cordage with hematite pigment from Nantack Cave. Photographs courtesy of Rachel Freer, Arizona State Museum.

A piece of asbestos z-twist cordage colored with hematite was recovered in a surface collection from Nantack Cave in the Point of Pines area (Figures 5, 6, and 7). Rachel Freer at the Arizona State Museum confirmed that the cordage was chrysotile asbestos through polarized light microscopy. The cordage is approximately 4 cm long. The fibers are not interwoven with other stands of chrysotile, so the length of the artifact represents the width of the chrysotile vein from which it was extracted. The short length of the cord and its hematite coloring suggest that it did not serve a utilitarian purpose.

THE USE OF ASBESTOS IN THE PREHISTORIC AMERICAN SOUTHWEST

The use of asbestos in the American Southwest differs dramatically from the ways in which asbestos was used in Eurasia during the first millennium B.C.



Figures 7. Photograph of asbestos cordage with hematite pigment from Nantack Cave.

First, many more examples of raw asbestos than asbestos cloth have been found in archaeological contexts in the Southwest. There is little to no evidence that these raw samples were associated with textile production. One possible exception is the matted asbestos from the Lower Santan site, which could have been in the midst of preparation for weaving.

Second, the few examples of modified asbestos and asbestos cloth in the Southwest do not suggest that the fiber was used because of its lustrous sheen. The Marana textile was composed of only three percent asbestos and was not soft and lustrous like the asbestos cloth described from Eurasia. Other examples of modified asbestos, such as the cordage from Point of Pines and the asbestos sash from Awatovi, were painted with hematite, which would have obscured the shininess and softness of the asbestos fibers. The application of hematite, however, underscores the probable ceremonial association of these items.

Finally, there is no conclusive evidence that people in the Southwest chose to use asbestos textiles because of the mineral's fire resistant properties. The asbestos sash from Awatovi would have been the best suited of the known artifacts to demonstrate resistance to fire, but there is no indication it was used in this way. The Marana textile was primarily composed of apocynum fibers that burned and carbonized when exposed to heat. The small amount of asbestos in the textile did not make it impervious to flames. The asbestos cordage and the matted asbestos from the Lower Santan site were small objects that would not have produced a visual impact on a large crowd of people. It is conceivable, however, that such objects were used in small demonstrations to highlight asbestos' resistance to fire. The matted asbestos could have been used to hold cinders or flaming material during some type of demonstration while protecting the hand or mouth from exposure.

CONCLUSION

Asbestos was undoubtedly valued by the Hohokam and their neighbors. It was procured from large, concentrated deposits along the Salt River Canyon and transported to the Phoenix and Tucson basins and beyond. Asbestos has been found in caches with other rare minerals in the Phoenix and Tonto basins. Its value may be associated with a sense of place or with other types of materials whose combination created an emergent set of values. In addition, asbestos artifacts were included with several burials in the Phoenix Basin and in other areas of the American Southwest. Several authors have argued that the use of asbestos on Hohokam platform mounds was associated with ceremonialism (Bostwick 1992:79; Bostwick and Downum 1994; Nelson 1981; Teague 1984a:173, 1984b:220).

Modified asbestos may have been used in some cases to showcase the most unique material property of the mineral: its resistance to fire. We can imagine how this characteristic of asbestos might have been incorporated into ritual and shamanic performances. The rarity of asbestos cloth in the archaeological record may reflect the great effort that it takes to spin asbestos fibers, as well as the closely guarded knowledge of how to produce asbestos cloth. Weaving with asbestos is more complex than weaving with plant or animal fibers. The sheer difficulty of weaving with asbestos probably would not justify weaving it for strictly utilitarian purposes.

Our survey of raw and modified asbestos artifacts provides a tantalizing picture of the use of asbestos in the American Southwest. However, the data are far from complete. The asbestos cordage from Point of Pines and the matted asbestos from the Lower Santan site were both misclassified as organic materials until they were closely inspected under a microscope. It is highly probable that more asbestos artifacts have been recovered but are yet to be unidentified. Future research in the American Southwest has the potential to further our understanding of the unique purposes and meanings of asbestos artifacts in prehistory.

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MODELING LEADERSHIP STRATEGIES IN HOHOKAM SOCIETY

Douglas B. Craig

ABSTRACT

Recent discussions of Hohokam sociopolitical organization have focused on how aspiring leaders went about integrating, mobilizing, and coordinating low-level social groups. Most models view these low-level social groups as structurally and functionally equivalent. Contrary to this perspective, I argue that inequality was pervasive and persistent in Hohokam society from the early Pre-Classic period onward. Drawing on the ideas of Claude Lévi-Strauss and others, I argue that wealth and power were concentrated in the hands of a relatively small group of aristocratic houses. These aristocratic houses are believed to have controlled access to large tracts of irrigable land, and their members are thought to have shared an identity closely tied to property and place (i.e., an estate). In turn, securing and maintaining an estate is believed to have been an important organizing principle in Hohokam society during both the Pre-Classic and Classic periods. Two case studies are provided to illustrate these points.

> This is the story of Danny and of Danny's friends and of Danny's house. It is a story of how these three became one thing, so that in Tortilla Flat if you speak of Danny's house you do not mean a structure of wood flaked with old whitewash….No, when you speak of Danny's house you are understood to mean a unit of which the parts are men….For Danny's house was not unlike the Round Table, and Danny's friends were not unlike the knights of it. And this is the story of how that group came into being, of how it flourished and grew to be an organization beautiful and wise.
>
> — John Steinbeck, *Tortilla Flat*

Between A.D. 500 and 1450, members of Hohokam society built a vast network of canals that irrigated tens of thousands of acres along the lower Salt and middle Gila rivers of south-central Arizona (Figure 1). Despite the massive scale of the irrigation works and the apparent need to coordinate large labor forces, the absence of paramount chiefs has been interpreted for many years as evidence that Hohokam society was fundamentally egalitarian, a "benign primitive democracy," in the words of Emil Haury (1976:353). The demands of survival in a harsh desert climate supposedly dictated that everyone who lived along the same canal worked together and shared rights to the means of production.

Although this position has been challenged in recent years, the challenges have come mainly in the form of indirect or circumstantial evidence. The leaders themselves continue to remain elusive. Some researchers have argued that a strong centralized government was required to manage canal systems as large as those built by the Hohokam (Howard 1993; Nicholas and Neitzel 1984). Others view the widespread distribution of ballcourts, platform mounds, and other forms of public architecture as evidence for the emergence of a corporate-based political system that rewarded group interests over individual interests (see papers in Mills 2000). Still others point to iconography on pottery, rock art, and ritual artifacts to argue that Hohokam society was a "ritual suzerainty" governed by religious elite (Wilcox 1999:124). Arguing against these possibilities is the lack of obvious administrative or group meeting facilities. In addition, irrigation managers or heads of corporate hierarchies are not readily apparent in the archaeological record. And even though there is some evidence for ritual specialists at different points in time, particularly during the Colonial and Classic periods, it is unclear how a few rich burials translate into institutionalized positions of leadership that spanned multiple generations.

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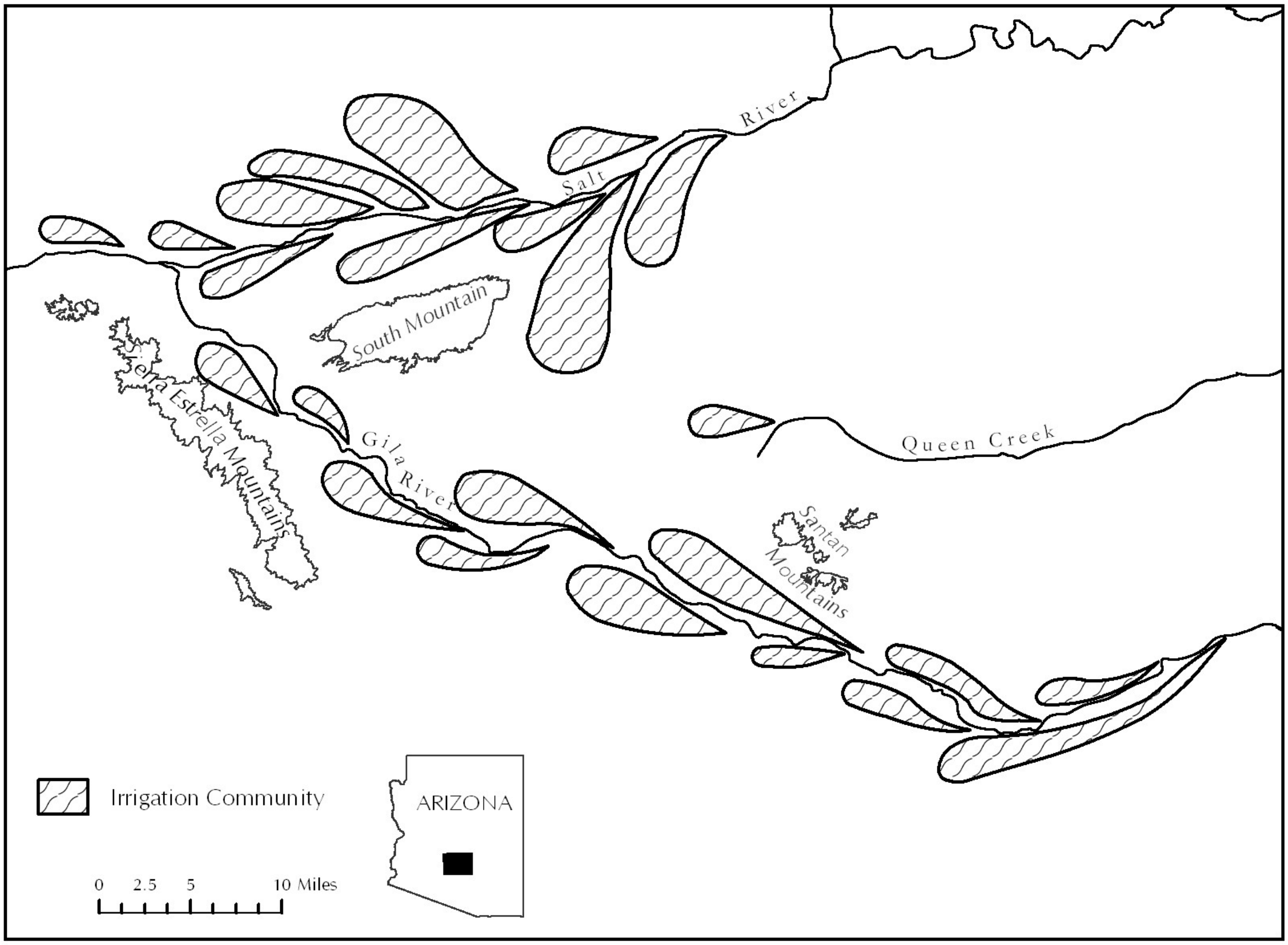


Figure 1. Phoenix Basin Hohokam irrigation communities (after Gregory 1991; also see paper by Woodson in this issue).

ARISTOCRATIC HOUSES AND LEADERSHIP IN HOHOKAM SOCIETY

I take a very different perspective on Hohokam leadership in this paper. Drawing on the ideas of Lévi-Strauss (1982, 1987), Gillespie (2000a, 2000b), Helms (1998), and others (e.g., Beck 2007, Wills 2005), I argue that wealth and power in Hohokam society were concentrated in the hands of a relatively small group of aristocratic "houses" who controlled access to large tracts of irrigable land and whose members shared an identity closely tied to property and place. Although these houses would have been kin-like, in that they were probably made up of related or affiliated households, it is my contention that recruiting labor and maintaining property were more important considerations in determining house membership than adherence to rigid descent or post-marital residence rules. Studies of house societies in other parts of the world further suggest that houses are dynamic institutions that respond to changing historical conditions, especially challenges from competing houses (Gillespie 2000b:33; Lévi-Strauss 1987:184). Consequently, houses typically develop in moderate to highly competitive environments for restricted or highly desired resources (Wills 2005:55).

Successful houses are also durable; that is, they persist over time (Beck 2007; Gillespie 2000b; Helms 1998). Moreover, because persistence is a precondition for existence, houses are typically defined by the actions involved in the maintenance and transfer of an estate. It is common for property claims to be contested when estates are transferred. Conflict over the transfer of property often provides a basis for economic differentiation and social ranking. Within houses there is usually a core set of high-ranking households and a group of affiliated households of lower rank (Gillespie 2000b; Wills 2005). Although these affiliated households provide an important source of labor and domestic capital, they are often cut loose during bad economic times or periods of social unrest.

Consistent with this theme of persistence, ancestor veneration often plays an important role in the ritual life of house societies (Beck 2007; Joyce 2000;

Helms 1998). Ancestor veneration helps establish the legitimacy and status of houses by linking the present with the past. It also provides a visible expression of house membership and unity. In many instances, the dwelling itself serves as the main locus of house-sponsored rituals, but places on the landscape that figure prominently in origin narratives may also be important ritual loci (Beck 2007:6–7). Additionally, because the bones of ancestors provide a tangible link between a house and its past, it is common for there to be a close spatial relationship between the living and the dead; often, shrines or burial areas are located in and around dwellings (Gillespie 2000a:19). Statuary or iconic representations of the dead, such as human figurines, are also common, as are finely crafted heirlooms made of exotic materials. These objects—many of which are made of durable materials such as stone, pottery, or wood—are thought to signify expressions of social memory that link the actions of the past with those of the present (Beck 2007:7–10).

With its emphasis on property, the house society model would seem to be a good fit for a group of people with property holdings as extensive as those of the Hohokam. Access to water and land presumably topped the list of Hohokam property concerns. There can be little doubt that irrigation water was a common-property resource managed at the community level, whereas rights approximating those of private ownership likely developed to manage plots of irrigable land (Mabry 1996; Netting 1993:158). In addition, the fact that many Hohokam irrigation communities were occupied for hundreds of years implies that these property rights were transferred across generations. It further implies that rules were in place to restrict access to property and resolve property disputes. The alternative of open access would have led to resource depletion and could not have been sustained over the long term (Hardin 1968; Ostrom 1992).

Another aspect of the house society model that should appeal to Hohokam researchers is the concept of the "house" as a unit of group association and personal identification. Houses thus operate at an intermediate level between the household and the community, and they provide a means to link microscale and macroscale processes (Gillespie 2000b:43; Helms 1998:14–19). Moreover, unlike current interpretive models, which tend to conceptualize social identity in terms of kinship relations that are difficult to sort out archaeologically (e.g., clans, lineages), the material traces of houses are expressed in forms that lend themselves to archaeological inquiry, such as architecture and burials. In turn, the property holdings that constitute the house estate provide a useful frame of reference for examining the material underpinnings of social inequality.

In the case of the Hohokam, the construction of massive, adobe-walled platform mounds during the Classic period is commonly viewed as a sign of increased social differentiation and political centralization (Bayman 2001). It is also viewed as evidence that key leadership roles in Classic period society were not prescribed by kinship alone (Yoffee et al. 1999:262). Although researchers continue to debate whether platform mounds served as elite residences or ritual facilities (see Bostwick and Downum 1994; Elson and Abbott 2000), there is general consensus that one of their functions was to mark social boundaries and reaffirm property rights (Bayman and Sullivan 2008; Fish and Fish 1994, 2000). The exclusionary nature of platform mounds is further indicated by their restricted access (Howard 1992), the presence of a wide variety of highly prized ritual items (Bostwick and Downum 1994), and the use of mounds and mound precincts for human burials (Brunson-Hadley 1994a, 1994b).

The affiliated households that lived on or near platform mounds are the most obvious candidates for aristocratic houses in Hohokam society. They likely controlled access to the mound and were the primary beneficiaries of mound-related activities. In addition, even though the quantity and value of grave goods from burials found on mounds does not appear to have been significantly greater than those from non-mound areas, being buried in association with a mound may represent a degree of social importance that goes beyond burial accompaniments (Bostwick and Downum 1994:366). Interestingly, the spatial distribution and demographic composition of burials in mound precincts suggests the presence of multiple, interrelated social groups rather than a single paramount lineage. This form of social organization is similar to the organizational structure inferred at some late prehistoric sites in the Southeastern United States (e.g., Etowah), where competition among rival houses is believed to have played a major role in shaping the region's social and political history (Brown 2007).

Multi-household residential compounds have also been documented at many Classic period sites, and some of these should be considered candidates for aristocratic houses, especially the larger and more populous ones (Fish and Fish 2004). Not only do compounds embody many of the characteristics of houses (e.g., residential continuity, intergenerational transfer of valued property, attached craft specialists, burials near residential areas), but they also controlled access to critical resources, including arable land, water rights, and a sizable labor force. This base of power would have provided an opportunity for heads of compounds to advance their political interests by forming strategic alliances with community leaders and/or heads of rival compounds. It also would have provided

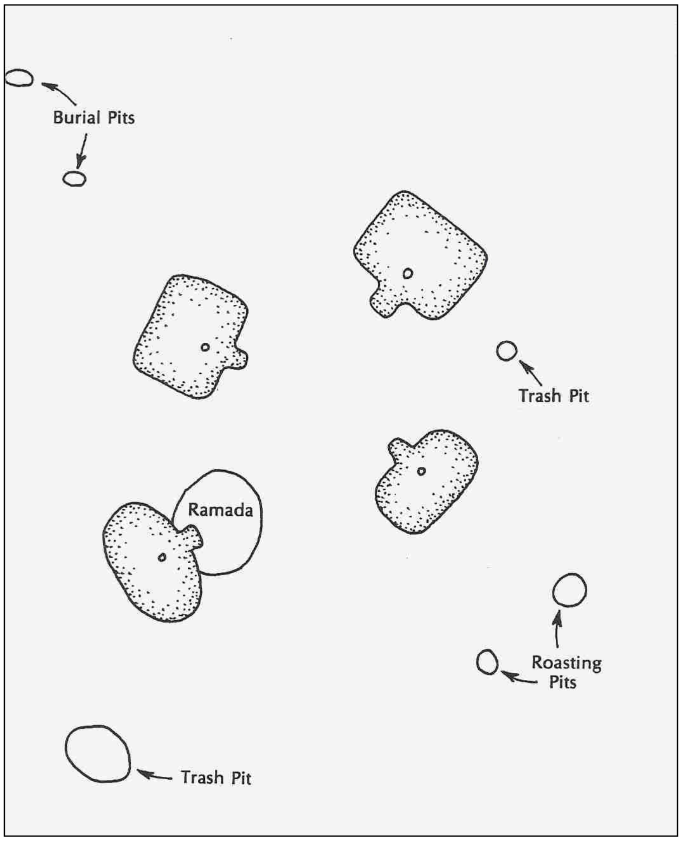


Figure 2. Idealized Hohokam courtyard group (after Craig and Henderson 2007)

a basis for societal competition and evolving inequality, both hallmarks of house societies in which kinship ties are no longer adequate to organize political and economic life, and in which non-kinship relationships (e.g., class, contract, market) have not yet developed fully (Gillespie 2000b:33).

HOUSE FORMATION AND DEVELOPMENT

Given the longevity of most Hohokam irrigation communities, it should come as little surprise that many of the organizational patterns discussed above have considerable time depth. In particular, the presence of extended family or multi-family co-residential groups with a long-term commitment to property and place can now be traced back to the early Pre-Classic period (Henderson 2001b, 2001c; Wallace and Lindeman 2003). These co-residential groups are commonly known as courtyard groups, because they consist of two or more houses arranged around a shared courtyard (Figure 2). Courtyard groups have been identified at both Pre-Classic and Classic period sites across the Sonoran Desert region. This widespread distribution has led many researchers to consider them the basic building blocks of Hohokam society (Clark 2001; Henderson 2001b, 2001c; Wilcox et al. 1981).

Once courtyard groups became established as basic structural elements, the main way that they could have been modified was to manipulate their size rather than their form. In addition, because Hohokam houses are generally single-room dwellings, courtyard size is most often measured in terms of the number of houses that were occupied at a given point in time. Prior to A.D. 800, courtyard groups tended to be small; they consisted of only one to two houses that were occupied simultaneously. After that time, some courtyards, especially in the Phoenix Basin, became much larger, with as many as four to six houses occupied simultaneously. However, smaller courtyards remained the norm (Henderson 2001c; Wilcox et al. 1981). Small courtyards are thought to have been occupied by five to eight people, on average. Perhaps as many as 20 to 25 people may have lived in large courtyards (e.g., Henderson 2001c:97).

The size and appearance of many courtyard groups changed over time as new houses were built and old houses were abandoned. Courtyards also varied in their lengths of occupation, with some occupied for a generation or less and others occupied for hundreds of years (Henderson 2001b). The degree of residential continuity seen in these long-lived courtyard groups is impressive by virtually any standard. It implies a long-term recognition of place and the emergence of property rights that were transferred across generations. Courtyard members presumably pooled labor, shared resources, and acted as a unified body in making decisions about food production and land tenure. In addition, even though new houses were often built on top of or adjacent to old houses, courtyard areas generally remained open (i.e., unroofed) for the entire length of their occupation. The preservation of a common, open area indicates a shared commitment to maintaining the integrity of the courtyard over time (Craig 2004).

Current interpretive models tend to downplay this variability in courtyard size and longevity, and instead focus on how allegedly interchangeable courtyard groups were integrated to form higher-level social formations (Abbott 2000; Nietzel 1999; Rice 1998, 2000). Although disparities in access to resources among courtyards are recognized, they are thought to have been relatively minor, particularly during the Pre-Classic period when the ballcourt system was in place. The fiesta-like atmosphere that many believe characterized ballcourt events is credited with promoting cooperation, consensus, and social stability across the region (Abbott et al. 2007:479). Thus, any disparities that may have existed among courtyards at that time are thought to have been balanced out over the long-term. Social cooperation and wide economic distribution would have suppressed the concentration of resources and accumulation of wealth in the hands of a permanent upper stratum (Wilcox 1999:124).

It is difficult to reconcile this view of Pre-Classic courtyard groups as essentially equivalent social units with the kinds of hierarchical organizational patterns postulated for Classic period society, especially since courtyard groups formed the basic socio-spatial unit during both the Pre-Classic and Classic periods. Moreover, many Classic period courtyard groups were first established during the Pre-Classic period, long before the construction of compound walls (Bostwick and Downum 1994; Gregory 1995; Mitchell 1994; Sires 1987). It thus appears that compound walls merely formalized social arrangements that were already in place. Further anchoring courtyards in place and past, many burial areas associated with Classic period compounds, including platform mound compounds, contain earlier Pre-Classic burials (Brunson-Hadley 1994a; Mitchell 1994).

It is important to recognize that these long-lived courtyards represent the success stories; not everyone was as fortunate. Many settlements that had been occupied for hundreds of years, such as Snaketown and Grewe, were abandoned near the end of the Pre-Classic period, and, as a result, a large number of courtyard groups were either displaced or simply dissolved. Some of these displaced courtyard groups likely moved to nearby sites. For example, Grewe was abandoned at roughly the same time that Casa Grande experienced a sharp increase in population. (Craig 2001; Wilcox and Sternberg 1983). In other instances, new villages were established on the outskirts of existing settlement systems, such as in the northern Tucson Basin at the Marana Platform Mound site (Fish et al. 1992). But even with the "reshuffling" of property holdings that occurred in some areas, Hohokam property rights, which were likely based on the right of prior possession (Bell 1998:36–38), do not appear to have changed in any fundamental way. The degree of courtyard persistence seen at some sites (e.g., Pueblo Grande) further suggests that maintaining an estate remained an important organizing principle in shaping Hohokam social relations.

From my perspective, the house society model captures the dynamic quality of courtyard groups in a way that current interpretive models do not. Perhaps foremost, it places individual patterns of choice and strategic behavior within a historical context, and does not assume that all courtyard groups adhered to a generalized adaptive strategy. Secondly, it recognizes courtyard groups as important agents of historical change. This emphasis on agency seems especially relevant to the large, multi-family courtyard groups that made the transition from the Pre-Classic to Classic period. However, I believe it has relevance for earlier time periods as well. Even if Pre-Classic courtyard groups were not full-fledged houses, they still followed similar organizational principles (i.e., securing and maintaining an estate) and performed many of the same functions. Moreover, the long-term success of courtyard groups, like houses, was dependent on their ability to maintain themselves in the face of competition from other courtyard groups.

CASE STUDIES

To illustrate these points, I turn now to a consideration of two case studies: one based on actual data and one based on virtual data. The actual case is from the Grewe site, where large-scale excavations were conducted by Northland Research in the mid-1990s under contract to the Arizona Department of Transportation (ADOT). More than 250 pithouses and almost two dozen courtyard groups were identified in the portion of the site investigated by Northland. The following discussion focuses on the changing fortunes of these courtyard groups, with special attention paid to the "rise and fall" of the largest and, by all indications, wealthiest courtyards. Drawing on lessons learned from Grewe, I then create a virtual Hohokam village populated by household-level social groups that make decisions about post-marital residence based on property and inheritance considerations. Although the model is still fairly basic at this point in its development, it nonetheless offers insights into some of the conditions that can lead to the emergence of both courtyard groups and house-like social formations. It also provides a graphic and quantitative means of tracking the life histories of these social groups.

Grewe Archaeological Research Project (GARP)

Between 1995 and 1997, archaeologists from Northland Research investigated a large residential district in the heart of the Grewe site. The project resulted in the discovery of hundreds of houses and other domestic features (Figure 3). We also investigated an area directly adjacent to the residential district that contained a communal cooking area with more than two dozen earth ovens (hornos) and a small portion of a central plaza with one of the largest ballcourts ever built by the Hohokam (Craig 2001). The significance of the GARP investigations, in addition to the large sample of materials recovered, is that it represents the first time that modern field methods and analytical techniques were used to study the "downtown" section of a large Pre-Classic settlement in the Hohokam "core" area. This might seem like an odd statement given the level of research that has taken place in the Phoenix Basin in the past 30 years. But it should be kept in mind that current interpretive models are

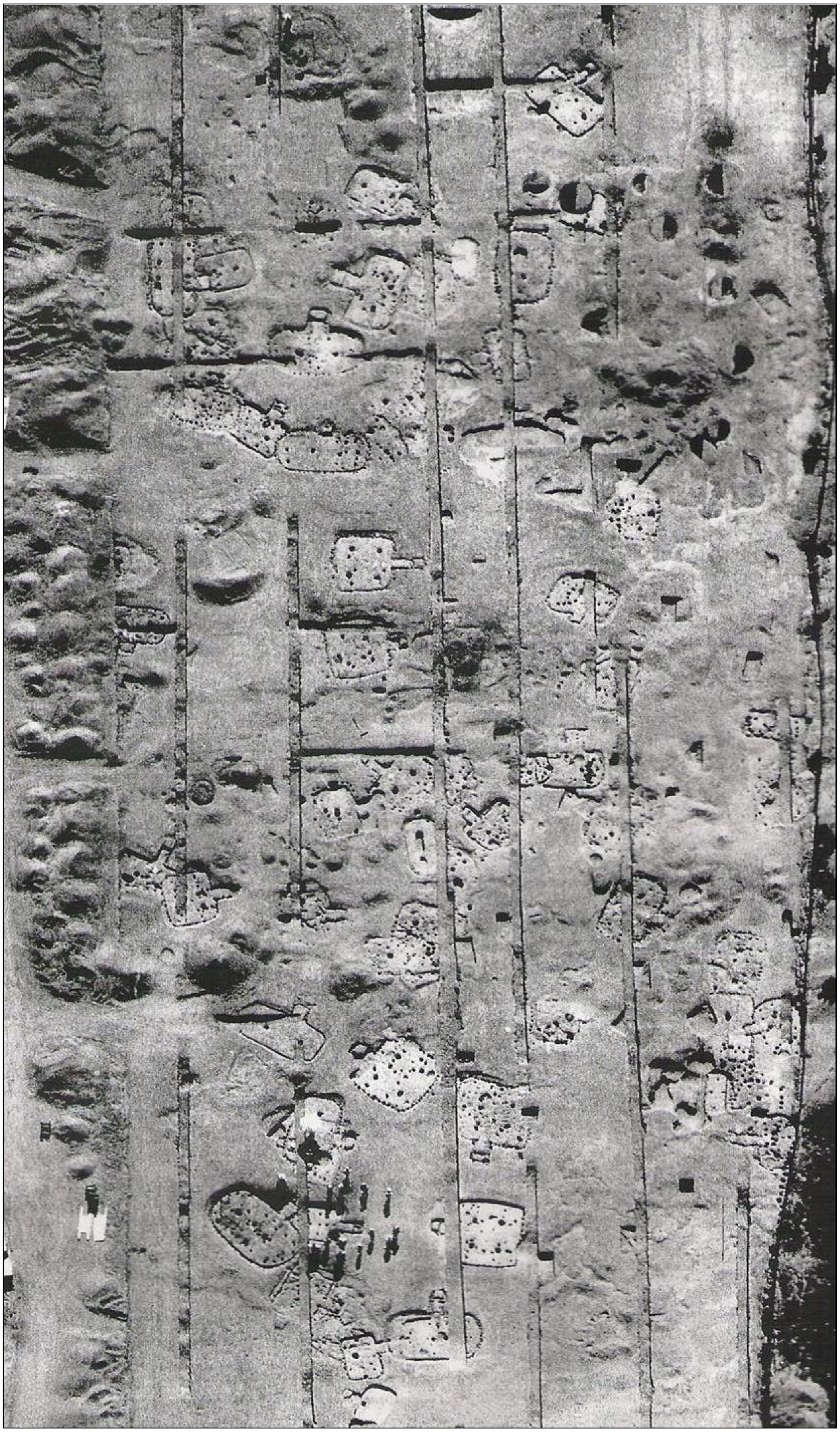


Figure 3. Portion of GARP residential district with pithouses and adjacent communal cooking area (upper right).

Table 1. Grewe age groups.

Grewe Age Group	Dates (A.D.)	Traditional Age Designation
Early Pioneer	500/550-625/650	Vahki
Late Pioneer	625/650-725	Late Vahki/Snaketown
Pioneer/Colonial	725-775	Late Snaketown/Early Gila Butte
Early Colonial	775-825	Gila Butte
Middle Colonial	825-875	Late Gila Butte/Early Santa Cruz
Late Colonial	875-950	Santa Cruz
Early Sedentary	950-1000	Late Santa Cruz/Early Sacaton
Middle Sedentary	1000-1050	Sacaton
Mid-to-Late Sedentary	1050-1100/1150	Mid-to-Late Sacaton

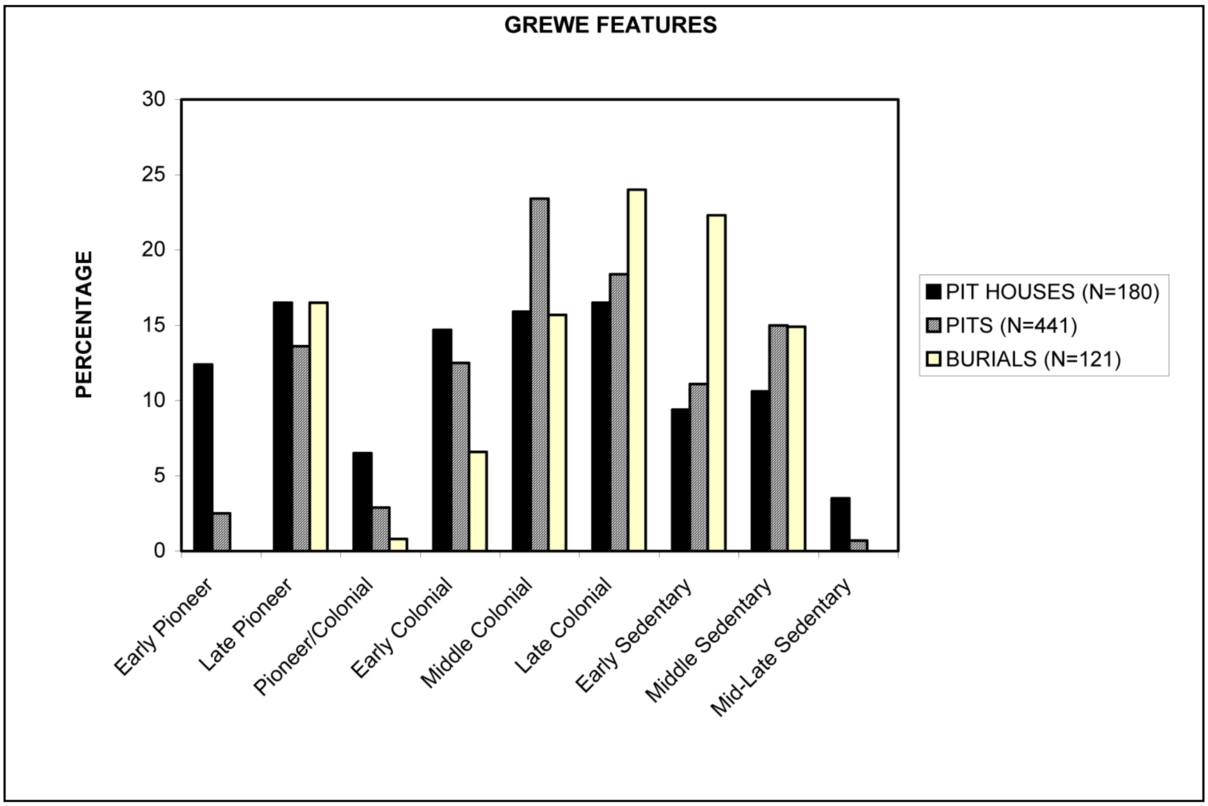


Figure 4. Temporal distribution of feature types recorded in GARP residential district.

based either on data collected many years ago (e.g., Snaketown), or on data collected from outlying habitation areas where house-like social formations are unlikely to be found (see Cable 1994:48-51).

The GARP residential district was occupied for virtually the entire Pre-Classic period, ca. A.D. 500–1100 (Table 1). Temporal control for this time span was established by first assigning individual features to one of nine age groups on the basis of ceramic and stratigraphic evidence. Absolute dates were then assigned to the various age groups based on an analysis of 110 radiocarbon and 52 archaeomagnetic samples (Henderson 2001a). In total, more than 700 features, including 180 houses, were assigned to discrete age groups (Figure 4). The overall distribution of features suggests that Grewe was occupied on a continuous basis for hundreds of years, though not always at the same level of intensity. Roughly 1,000 people are estimated to have lived at Grewe at the peak of its occupation in the middle of the ninth century, and an additional 300–400 people may have been living a short distance away at Casa Grande Ruins (Craig 2004).

The spatial distribution of pithouses in the GARP residential district was similar to patterns reported at many other Pre-Classic sites. Groups of houses were commonly arranged around courtyards, though isolated structures were also present. In total, almost two dozen courtyard groups were identified in the GARP residential district, which we estimate comprised about four percent of the entire site and about 10 percent of the site's residential space (Craig 2004). All indications are that these courtyard spaces provided a stage for the unfolding drama of everyday life. Courtyard residents used pithouses as dwellings and utility rooms; they prepared, cooked, and consumed food in courtyard areas; they manufactured clothing, textiles, pottery, stone tools, and shell jewelry in and around courtyards; and, they disposed of trash in nearby borrow pits, mounds, and abandoned houses

Courtyard groups at Grewe varied considerably in size and composition. The smallest courtyard contained two pithouses and covered a total area of about 100 m2; the largest contained 21 pithouses and covered a total area of more than 600 m2 (Henderson 2001c:Table 4.2). Courtyard groups also varied in their lengths of occupation. Some were occupied for only one or two generations, whereas others were occupied for more than 200 years (Figure 5). The longevity of some Grewe courtyards implies that courtyard members were committed to maintaining their corporate holdings over time. Such commitment suggests that an individual's social identify was closely tied to membership in a specific courtyard group.

In an attempt to model the changing economic fortunes of the Grewe courtyard groups, I have used three lines of evidence to estimate the amount of labor expended in house construction for 132 pithouses (see Craig 2004). First, the raw materials used in house construction were inferred from excavation data and feature maps. Only houses for which relatively complete architectural information was available were included in the analysis. Next, key tasks associated with obtaining and assembling the building materials were identified in light of ethnographic data and general engineering considerations. Finally, labor costs associated with the various construction tasks were calculated based on published experimental data (e.g., Abrams 1994; Erasmus 1965). This information was used to explore the degree to which labor expenditures varied among courtyard groups. One advantage of a labor-based approach to architectural analysis is that it provides a common unit of measure (labor-time expenditures) that can be applied to different generations of house builders (Abrams 1994).

Wealth parameters were estimated for courtyard groups at Grewe by combining the labor figures for all contemporaneous pithouses in a given courtyard, regardless of the presumed function of the structure (Craig 2004). The assumption is that the material wealth of a courtyard group is best reflected in its entire architectural portfolio. It is further assumed that structures were more or less contemporaneous if they were occupied during the same time period (Henderson 2001a).

Labor expenditures for the seven most intensively occupied courtyards are summarized in Figure 6. Two basic levels of labor expenditure are evident in the graph: one in the range of 75 to 150 person days per courtyard per time period, and the other in the range of 200 to 300 person days per courtyard. Prior to the middle of the eighth century, most courtyard groups appear to have been similar in size, composition, and presumably wealth. Beginning in the early ninth century, however, and continuing for the rest of the site's occupation, two distinct wealth strata can be identified based on the amount of labor invested in domestic architecture (Craig 2004). The upper stratum consisted of courtyard groups with well-made, ornate houses, of which there were only one or two examples per time period in the GARP residential district. The lower stratum consisted of the remaining smaller courtyards with less expensive houses. Importantly, once these structural differences became established within the settlement, the percentage of courtyards in the two strata did not change appreciably over time. However, there was considerable movement of individual courtyards up and down the social ladder, a pattern that is similar to what Netting (1993:197) has referred to as a "system of inequality with mobility." Some courtyards were nonetheless able to maintain their position at or near the top of the social hierarchy for many generations.

The rise and fall of individual courtyard groups at Grewe is consistent with the competitive nature of resource control in middle-range societies throughout the world (see papers in Price and Feinman 1995). It is also consistent with the dynamic nature of property arrangements in many house societies. Indeed, as Lévi-Strauss (1987:148) has noted, houses commonly "come into being and fade away" in the face of competition from other houses. He also noted that high-ranking houses were the ones most likely to maintain their property holdings and to perpetuate their estates over time. It follows that the development of an effective strategy for maintaining and perpetuating an estate is an important first step in the emergence of houses and house societies (Gillespie 2000b:50–51). From such a perspective, the type of continuity in courtyard location that is apparent at Grewe can be viewed as a materialization of a strategy for house persistence.

Another way that courtyards materialized and maintained a social identity over time was through mortuary rituals. Bioarchaeologist Lane Beck (2000) has suggested that the Pre-Classic Hohokam practiced a three-stage mortuary program. The first stage con-

Figure 5. Examples of courtyard groups at Grewe.

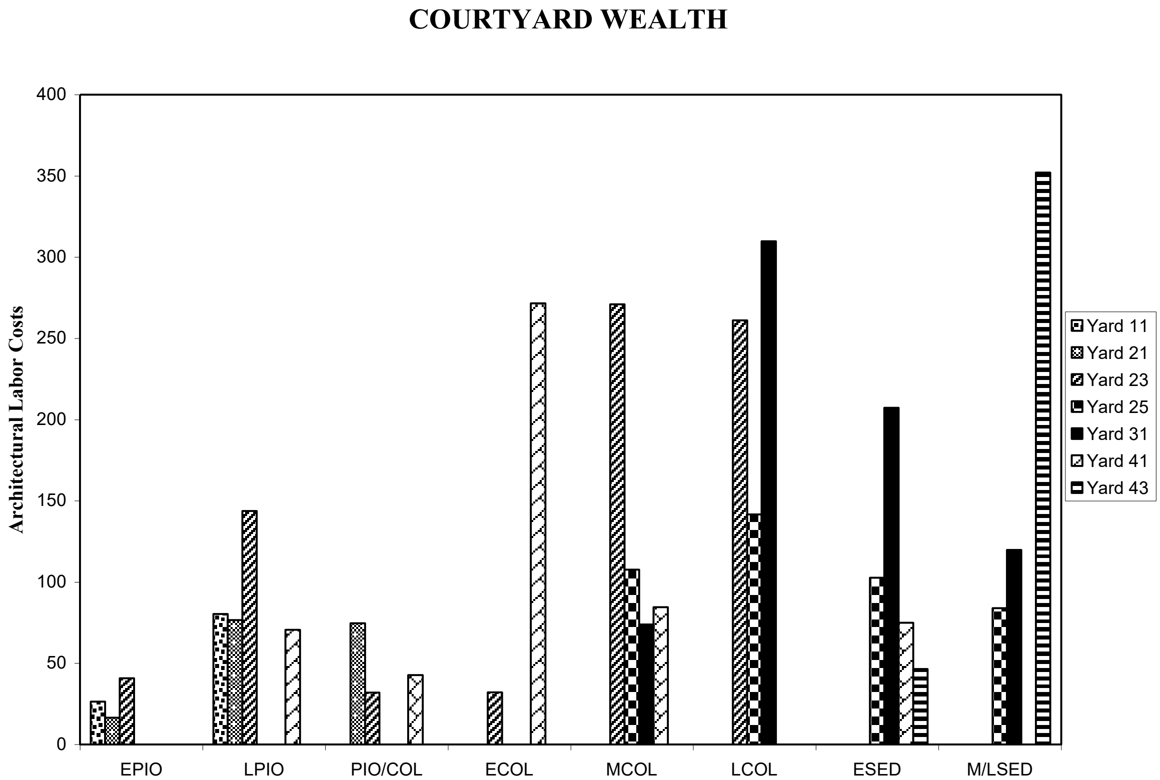


Figure 6. Courtyard labor costs associated with house construction in GARP residential district.

sisted of cremating the body shortly after death, the second stage involved the interment of the the cremated remains, and the final stage entailed a mourning ceremony in which the cremated remains may have been exhumed and reburied. Support for this reconstruction is provided by burial data from Grewe. Excavations conducted in the early 1930s recovered approximately 180 cremations from several cemeteries located near the southern edge of the site's central plaza (Woodward 1931). Many of these cremations contained extremely rich burial assemblages with a variety of exotic artifacts. By way of contrast, 130 cremations, most containing very few artifacts and very little human bone, were found associated with courtyard groups in the GARP residential district (Minturn and Craig 2001). One explanation for these differences is that the plaza cemeteries contained the remains of high-status individuals, whereas the courtyard cemeteries contained the remains of lower status individuals. A more likely alternative is that the two kinds of cemeteries represent different stages in the mortuary ritual. The plaza cemeteries presumably contained mortuary remains associated with the initial interment, while the courtyard cemeteries included the remains that resulted from periodic mourning ceremonies. If this interpretation is correct, it implies that individuals were members of courtyard groups in both life and death. It also reinforces the impression that the corporate identity of courtyard groups extended across multiple generations.

The larger and more persistent courtyard groups at Grewe embody many of the corporate characteristics of aristocratic houses: long-term residential continuity, the intergenerational transfer of material and immaterial property, and the use of ritual to sanctify and legitimize property holdings. Moreover, as noted previously, the long-term success of courtyard groups, like houses, was dependent on their ability to maintain themselves in the face of competition from other courtyard groups. Courtyard groups presumably competed with one another for resources under their direct control (e.g., land, domestic labor), as well as for resources held jointly by the community (e.g., irrigation water). There can be little doubt that they also competed for prestige, influence, and power within the community.

There are further indications that activities related to ballcourt events provided an outlet for this competition. The large ballcourt investigated by Northland was constructed in the first half of the ninth century. Its construction coincided with the emergence of a permanent upper wealth stratum and the establishment of a communal cooking area directly adjacent to the GARP residential district (Craig 2004). Although it is not possible to link specific hornos or groups of hornos in the communal cooking area to specific courtyard groups, it seems likely that nearby courtyards, including the two wealthiest courtyards in occupation at the time, controlled access to the communal cooking area and sponsored feasts. Sponsoring courtyards presumably gained prestige and status as a result of their generosity. Feasting may have also served to reaffirm property rights, and thereby to sanction the advantages already held by the sponsors (Hayden 1995; Potter 2000). Feasting that took place in conjunction with ballcourt-related activities likely contributed to a sense of civic pride as well (Craig 2004).

In addition to sponsoring feasts associated with ballcourt construction and use, high-ranking courtyards may have subsidized craft production at Grewe. Among the crafts known to have been produced at Grewe and traded to other sites in the region were stone tools, pottery, cotton textiles, and shell jewelry (Abbott 2001; Henderson 2001c; Vokes 2001). Not all courtyard groups, however, participated in the production and distribution of these items. Evidence for craft production was found in only a few of the courtyards in the GARP residential district (Henderson 2001c), and most of those were small courtyards located on the margins of high-ranking courtyards. In contrast, high-ranking courtyards typically contained more finished products and more exotic items than craft producing courtyards.

A final indication that competition between courtyard groups was a driving social force at Grewe is that high-ranking courtyard groups near the communal cooking area were abandoned sometime around A.D. 1000. Although the GARP residential district continued to be occupied for another 70 to 100 years after these courtyards were abandoned, both the communal cooking area and the large ballcourt were no longer used. There was also a shift in the seat of power within the settlement: first to a residential district in another part of Grewe, and then later to Casa Grande Ruins. New ballcourts were built in both of these localities, with the ballcourt at Casa Grande being part of a ceremonial precinct that eventually included two platform mounds and the Great House (Wilcox and Sternberg 1983). Interestingly, pithouses have been identified beneath several of the Classic period compounds at Casa Grande (Fewkes 1912; Hayden 1930). The direct spatial association of pithouses and compounds suggests that the historical roots of the social groups involved extend back to the Pre-Classic period (Craig 2004).

Agent-Based Modeling

In an attempt to further explore the role of property rights in shaping Hohokam social relations, I devised a simple computer simulation that linked residential stability to the size of a household's property (land) holdings. The simulation represents an example of an agent-based or multi-agent approach to modeling. This approach holds great promise for archaeology, because it focuses on how individuals ("agents") evaluate information and make decisions, as well as how those decisions shape larger processes. It also provides a virtual landscape that can be manipulated in order to study how agents modify their behaviors in response to changing landscape conditions. In the northern Southwest, for example, detailed paleoenvironmental data have been used to create virtual landscapes that replicated the physical environment encountered by Ancestral Puebloan farmers living in northeastern Arizona (Axtell et al. 2002; Dean et al. 2000) and southwestern Colorado (Kohler et al. 2007). These landscapes were then populated by autonomous households who were instructed to move and settle near good agricultural land in response to changing environmental conditions. Demographic and social considerations (e.g., annual food consumption, household life span, age at marriage) were taken into account as well. The result was a computer simulation of long-term population and settlement dynamics that closely approximated real-world archaeological data.

Although I draw here on many of the assumptions and methods developed by researchers working in the northern Southwest, Hohokam farmers faced a very different set of challenges than their northern counterparts. Hence, my computer simulation is quite different. In particular, because Hohokam farmers invested heavily in large-scale irrigation technology, they likely held plots of land that they farmed intensively year after year (see Netting 1993). This investment in permanent infrastructure is in contrast to the behavior of Ancestral Puebloan farmers, who seem to have moved around on a fairly regular basis in search of good arable land. The main challenge for Hohokam farmers, then, was not searching for land but establishing ways to divide the land that they already had, a challenge that presumably became more and more difficult as population increased. I have therefore designed my simulation around this land allocation issue.

Landscape and Agent Attributes

The landscape for the model is a Hohokam village populated by autonomous, land-holding households. Because the arrangement of houses is the primary focus of analysis, no attempt was made to factor in the distance from houses to agricultural fields. Instead, it was assumed that fields were located a short distance from the village, similar to patterns reported for rural farming villages throughout the world (see Chisholm 1979; Gregory 1991).

Each household in the computer simulation is defined by numerous attributes, including age, residential location, amount of land owned, and amount of food required for subsistence (Table 2). Each household also has a life span and fertility rate, which are randomized along lines suggested by Dean et al. (2000), and each has the potential to reproduce ("fission") to form new households. Finally, each household has land holdings that it can pass down to its offspring.

For now, the model has been set up so that each household starts with the same amount of land, which is determined by dividing the land holdings of the village by the number of households in residence. Food requirements for individual households are determined on the basis of the household's age, which in turn reflects general trends in a household's developmental cycle. As currently modeled, young houses (1–10 years of age) require 1.25 ha of land to meet basic subsistence needs, middle-aged households (11–20 years) require 1.5 ha, and old households (21–30 years) require 1 ha. These figures assume a typical yield of 700–800 kg of corn per hectare per year, nutritional requirements of 160 kg of corn per person per year, and the recognition that roughly 35 percent of the total potential crop yield is typically lost due to pests, fallow requirements, and the need to set aside seed for planting (Dean et al. 2000; Van West 1994). All these parameters can be changed, of course, which is part of the beauty of this kind of simulation approach. But for now I wanted to keep things fairly simple in order to be able to track the effects of each factor.

Running the Simulation

In an attempt to replicate how archaeologists believe courtyard groups were formed, each time a parent household fissions and a new household is created, the offspring household establishes residence adjacent to the parent, as long as they stand a chance of inheriting land. If there is enough land to support the nutritional needs of the offspring household, then it continues to stay attached to the parents' courtyard; if not, it moves away. The time step in each run of the simulation is one year, so each household must decide on an annual basis whether to stay or to leave. When a household dies or moves away, its land is reallocated to related households, such as siblings or cousins. If there are no related households, it gets reapportioned to other households within the settlement.

Before the simulation begins, the observer sets the initial household values and the amount of available village farmland (Figure 7). The current model can support between 1 and 500 founding households and between 1 and 2,000 ha of village farmland. Based on these initial parameters, households are randomly arranged on the landscape in a dispersed rancheria pattern, similar to settlement patterns reported at

Table 2. Computer simulation agent attributes.

Parameter	Value
Minimum Household Initial Age	1 year
Maximum Household Initial Age	29 years
Initial Household Size	4–5 people
Minimum Household Fission Age	16 years
Maximum Household Age	30 years
Fertility (Fission) Rate	.250
Birth Spacing	2 years
Household Land Requirements	1–1.5 ha/year

many Hohokam Pre-Classic sites. The ages of the households are also randomly assigned, with values for individual households ranging from 1 to 30. Each household then executes a number of basic tasks and decisions on an annual basis. Task implementation begins with the decision to fission or not, and continues with an assessment of household property holdings and food requirements. All evaluations and resulting actions lead to the decision to stay or to leave.

Assuming they did not reproduce in the previous year, households between the ages of 16 and 30 have a one-in-four chance of reproducing in a given year, with each year corresponding to one time step in the simulation. Notably, in contrast to agent-based models developed for the northern Southwest, (e.g., Dean et al. 2000), which used a fertility rate of .125 to approximate the probability that a simulated prehistoric household would have daughters, the gender of the offspring is not factored into my simulation. The model nonetheless keeps track of the generation of both parent and offspring households, as well as the birth order of the offspring. All households from the same generation that are related to the same founding household are considered siblings-cousins and are viewed as potential heirs to the household land holdings. The model assigns each sibling-cousin an equal share of these land holdings; however, that share fluctuates as new household members are born and others die. Future versions of the model might consider weighting the shares based on gender or birth order.

Because new households are constantly being created ("hatched"), and old or poor households are constantly dying off, some form of reallocation of village farmland is necessary. Otherwise, the amount of farmland will slowly decrease as households die off and there will be no new households to replace them. To ensure that there is no overall decrease in the amount of land available to village residents, an adjusted farmland value is calculated and updated on an annual basis by dividing the village farmland total by the number

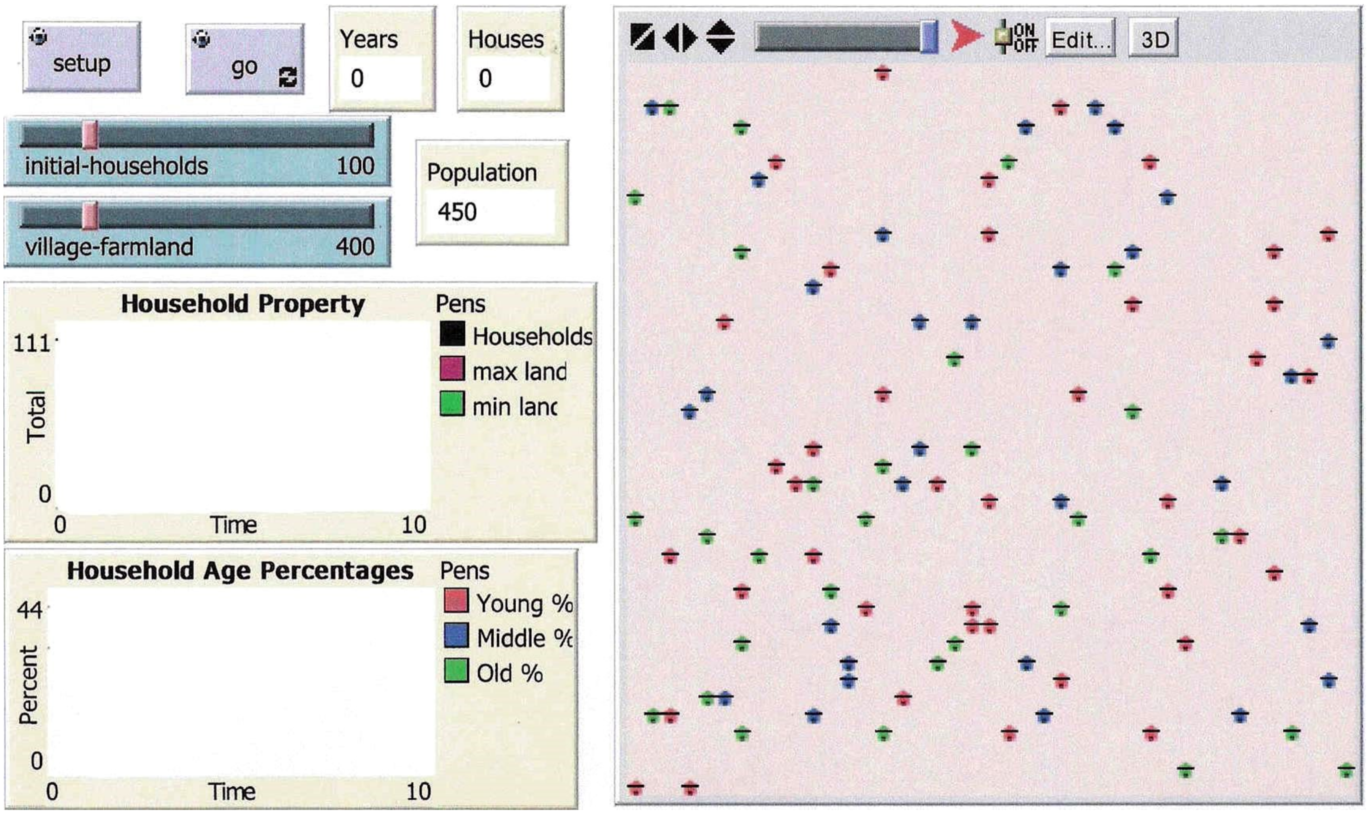


Figure 7. Example of computer simulation model, initial setup.

Table 3. Descriptive statistics based on 50 simulation runs, 400 time stops each.

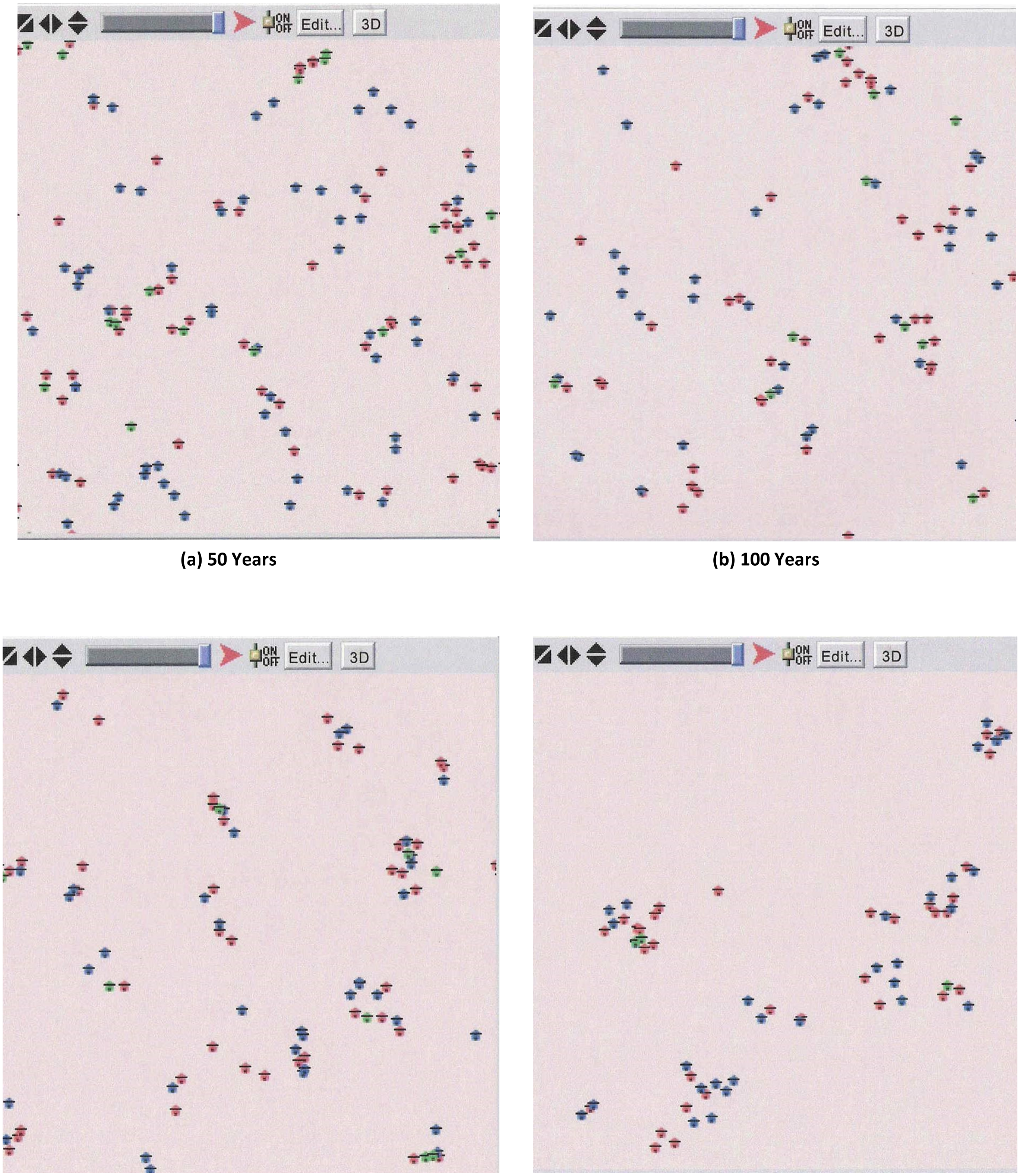
Variable	Mean	Median	Minimum	Maximum	Std. Dev.
Population Minimum	237	239	144	293	34.3
Population Maximum	650	649	504	743	49.8
Population Final	324	333	193.5	382.5	40.14
Final Houses	11	11	8.5	14.5	1.4
Maximum Land (ha)	75.9	74.2	40.0	123.9	17.7
Minimum Land (ha)	11.1	10.4	4.8	25.8	5.2

of households in residence. The amount of farmland in excess of a household's initial allotment is then added to the potential inheritance for each household. Other methods for reallocating village farmland can also be envisioned (e.g., making it available to immigrant households) and should be explored in future studies.

Results

The simulations were coded in NetLogo 3.1.4 and run on Windows PCs. To illustrate how the model works, Figure 8 presents a few simulation "snapshots" showing the layout of a hypothetical village—the same one shown in Figure 7—as it was transformed from a dispersed to an aggregated settlement over a 400-year period (i.e., time steps). Not surprisingly, the trend toward aggregation increases as the number of time steps increases.

Basic descriptive statistics are provided in Table 3 for several key variables that were tracked in 50 separate simulation runs, each over 400 time steps (i.e., years). These variables include the annual population of the settlement, the number of founding households in residence at any given point in time, and the amount of land controlled by the wealthiest and poorest houses.



(a) 50 Years

(b) 100 Years

(c) 200 Years

(d) 400 Years

Figure 8. Examples of computer simulation results for 50-, 100-, 200-, and 400-year time intervals.

Although the results reported above are based on an initial population of 100 households farming 400 ha of land, the use of other initial values has been found to produce generally similar results. However, a different result does occur when the initial population value is set too high for the amount of land being farmed. This initial state results in a population crash. In most other instances, the population reaches an equilibrium that is slightly below the initial population. If there is a lot more land than people, though, the equilibrium can be higher. Regardless, in virtually all simulation runs, unless land is extremely plentiful, only a few founding households are able to sustain themselves over the long term. In the case of the simulations discussed above, only ten to twelve of the founding 100 households, on average, still had descendants living in the village after 400 years.

There seem to be "winners" and "losers" in the land-holding department as well, even though everyone started out with the same amount (4 ha/ household). In the 50 simulation runs summarized in Table 3, the wealthiest group of related households (i.e., descended from a common ancestor) controlled, on average, about 20 percent of the village's farmland (75 ha) after 400 years. In at least one instance, they controlled more than 30 percent of the land (124 ha). Conversely, the land holdings of other groups of related households were more modest (10–11 ha, on average), even though they too could trace their ancestry back to one of the founding households. Thus, longevity by itself is no guarantee of economic prosperity.

Although the graphics for the current version of the model are admittedly crude, the long-term trend toward aggregation is still conveyed in a way that should look familiar to Hohokam researchers. Small "house groups" containing two to four houses typically start to form after just one or two generations (Figure 8a), much like Pre-Classic period courtyard groups. By 100–200 years, some house groups have become fairly large (six to eight houses), while others remain in the two to four range (Figure 8b, 8c). This pattern of household aggregation matches the configuration of courtyard groups found in the GARP residential district. Ultimately, after 400 years in the simulated environment, a few house groups have become very large (10 to 15 houses), while most groups remain in the four to six range (Figure 8d). This pattern appears to mirror the formation of Classic period compounds (or aristocratic houses). These similarities aside, it is the large house groups at 200 years that usually develop into the very large house groups at 400 years. The growth of specific households indicates that they were able to secure a competitive advantage early and maintain it for generations afterwards. It also bears emphasizing that house groups do not form in response to some organizational need. Rather, they are products of individual choice and historical circumstances. The competitive advantage gained by some house groups over others is the result of the self-serving behavior of individuals who take advantage of opportunistic moments, and not a consequence of power seizure or consolidation at some higher organizational level. Thus, house groups, as modeled here, are both the product and means of social transformation.

SUMMARY AND CONCLUSIONS

One of the biggest challenges facing researchers trying to understand Hohokam political development is the archaeological elusiveness of the key political actors, the leaders and elites. Consequently, discussions of leadership in Hohokam society tend to sidestep the issue of agency and focus instead on the strategic behaviors embedded in public architecture. It has been suggested, for example, that the shift from Pre-Classic period ballcourts to Classic period platform mounds was accompanied by a shift from a group-oriented (corporate) to an individual-oriented (network) leadership strategy (Elson and Abbott 2000:133–134; Harry and Bayman 2000:151). Likewise, the replacement of publicly accessible ballcourts by publicly restricted platform mounds is thought to signify a fundamental shift in the integrative ideology of leadership (Elson 2007:54; Fish and Fish 2000:162–163).

Drawing primarily on domestic architectural data, I have proposed an alternative path to power in this paper, one that recognizes greater continuity in leadership strategies than recognized in current interpretive models. I focused here on domestic architecture, partly because it represents a class of material remains that is well-preserved at most Hohokam sites, but also because cross-cultural studies have shown it to be an excellent marker of social differentiation (Abrams 1994; Feinman and Neitzel 1984). In addition, in the case of persistent courtyard groups there can be little doubt that we are dealing with the same time-transgressive domestic groups, as illustrated by the two case studies.

I build on this information to argue that the heads of large land-holding estates were key political actors in Hohokam society. Following the lead of Lévi-Strauss (1982, 1987), I refer to the social formations that were established to manage and perpetuate these estates as "houses." Although the evidence for houses is probably strongest for the Classic period, when platform mounds became widespread, it is my contention that securing and maintaining an estate was an important organizing principle in Hohokam society from the early Pre-Classic period onward. Thus, even though large, persistent courtyard groups, like those seen at Grewe, may not have been full-fledged houses, they still performed like houses in terms of the meaning attached to matters of property, place, and past. Their struggle for prestige and power also set the stage for organizational patterns observed in the Classic period.

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RECONSTRUCTING THE SACRED IN HOHOKAM ARCHAEOLOGY: COSMOLOGY, MYTHOLOGY, AND RITUAL

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ABSTRACT

This paper looks at the role of the sacred in Hohokam culture by exploring its expression in cosmology, mythology, and ritual. We argue that aspects of Hohokam cosmology and mythology can be seen in archaeoastronomical sites, cremation mortuary rituals, site layout, and other material associations with feathered serpents and other deities. These myths emphasize the sacred themes of sacrifice, transformation, and rebirth, with water and fire as main motifs. Some rock art panels may also represent mythological figures or events, or record powerful religious personages such as shamans. Life-transformation rituals associated with burials most likely involved ancestor veneration and reinforcing sacred links to land, water, and other valuable resources. The architecture and artifacts of platform mounds also provide insights into Hohokam sacred space and ritual activities. Reconstructing the sacred in Hohokam society allows a better understanding of how authority was defined and shared among different social groups by determining who controlled ritual knowledge and the sacred calendar.

Native religion in the American Southwest is rooted in a sense of place, and the natural world is intimately related to concepts of supernatural power and how ritual is to be used to support and sustain human life (Lamphere 1983; Underhill 1948). Our paper examines how ritual and ceremony are reflected in the Hohokam archaeological record and explores Hohokam cosmology and mythology. Reconstructing Hohokam sacred realms provides insights into the nature of power and status and how sacred space was organized and used in Hohokam society.

In Hohokam and Mesoamerican religious systems, there are complex connections among ballcourts, the agricultural year and calendrical cycles, water control, ancestors, and death (Bohrer 1994). The natural elements of earth, water, wind, and fire were symbolized in ritual performances, iconography, the built environment, and sacred landmarks. Therefore, we organize our conceptual scheme of Hohokam ritual activities around these four elements.

EARTH

In the American Southwest and Mesoamerica, the universe is depicted as a multi-layered structure, often with three separate worlds—(1) an Underworld, full of spirits and mythic creatures; (2) a Middle World, in which humans live; and (3) an Upper World, the realm of celestial beings. The three layers are interconnected by a central axis, called the axis mundi, which can be used to travel between the three worlds (Carrasco 1990). The Middle World is typically divided into four or six sacred directions, each with symbolic expressions, such as associated colors.

The general layout of this universe was based on the quadrilateral positioning of the solstice sunrise and sunset positions on the eastern and western horizons (Figure 1). Hohokam ceramic designs reflect this quadrilateral division. Buildings and public spaces were aligned accordingly. For example, Casa Grande's four-story Big House was designed with portals in several upper-story rooms that create sunlight interactions during solstice and equinox events (Malloy 1969; Wilcox and Shenk 1977). Two of the largest platform mounds, Pueblo Grande and Mesa Grande, have room openings that align with the summer and winter solstices, respectively (Bostwick and Downum 1994; Howard 1995).

At Snaketown, there appears to be a quartering of space with ballcourts located to the east and west, platform mounds laid out on a north–south axis, and a possible access corridor dividing the site into north and south (Wilcox et al . 1981). A north-south duality is

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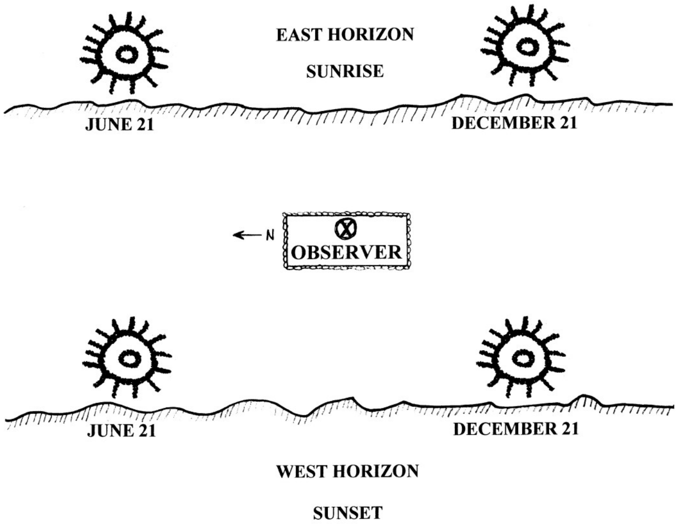

Figure 1. Four locations on the horizon where the sun rises and sets during the summer and winter solstices, creating the four corners of the universe.

also represented at Pueblo Grande, with the Big House in the northern part of the village and the platform mound to the south (Mitchell 1994). Overall, this layout could reflect the Mesoamerican quincunx, the equal-armed cross. This symbol represented space and time, unifying the earth and the cosmos, and the daily and calendrical cycles.

A circular stone compound located on a hilltop in the Phoenix Mountains has numerous solstice and equinox alignments, as well as light-and-shadow patterns that move across rock art panels and work like sundials (Bostwick and Plum 2005). Rock-art panels in the South Mountains also interact with solstice (Figure 2) and equinox events (Bostwick and Krocek 2002). The Hole-in-the-Rock formation in Papago Park served as a reliable summer solstice marker (Mixon and White 1991). During mid-day, a pointed beam of light fills a grinding slick and cupule in a dramatic display of light penetrating shadow and filling a shallow container.

Ball Games

Hohokam ball games played in oval-shaped depressions in the earth likely had ritual connotations. More than 200 ballcourts were built in Arizona over a 300-year period (Wilcox and Sternberg 1983). In Mesoamerica, the movement of the ball used in the ball game was considered an allegory related to the daily journey of the sun across the sky, represented by Quetzalcoatl (Feathered Serpent), and its defeat of darkness, symbolized by Tezcatlipoca (Smoking Mirror). The ballcourt was the symbolic access to the Underworld, and the game represented the concept of duality, or the union of opposites—light and dark (Uriarte 2001). For the Aztec, Venus the evening star was the patron deity of the ball game and the alter ego of Quetzalcoatl.

In addition to their primary ritual function, Hohokam ballcourts may have served as a ceremonial exchange system that helped choreograph the movement of ceramic vessels and other commodities among different communities (Abbott et al. 2007; Wilcox 1991). Many of the ballcourts are oriented north–south or east–west, which may have been “keyed to an annual progression of calendrical ceremonies designed to keep the universe running smoothly through its annual cycle” (Wilcox and Sternberg 1983:212).

Two ballcourts are present at Pueblo Grande in opposite parts of the village, one south of the platform mound and the other to the north. These courts may symbolize the principle of duality, perhaps representing different social or political groups. The northern ballcourt has a large, oblong stone embedded in the floor in the center of the court, as well as stones at each end, demarcating different zones (Bostwick 1994). A central marker is common in many Mesoamerican courts; they are symbolic of the human navel, which divides the body in half, and may represent the navel of the Earth (Harmon 2006).

Many traits typically associated with the Hohokam culture—iconography, mortuary rites, ceremonial par-

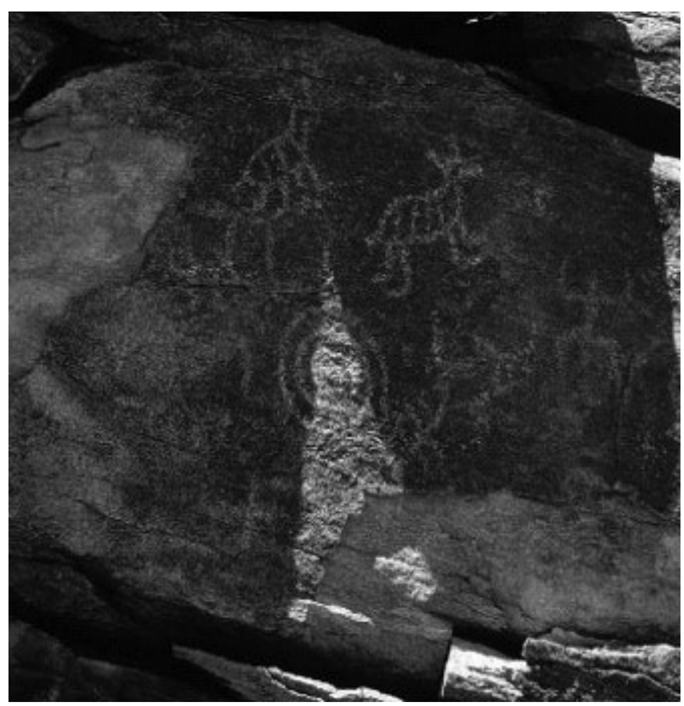

Figure 2. Pointed beam of light piercing a spiral petroglyph during mid-day summer solstice in the South Mountains; the spiral is surrounded by quadrupeds and human figures.

aphernalia, and the ball game—appeared at a time when the Quetzalcoatl cult in Mesoamerica emphasized a sky religion centered about the ball game (Brundage 1982). Wilcox (1991:51) has argued that from A.D. 750 to 1000, "a combination of Mesoamerican and local ideas were synthesized to form the first distinctively Hohokam religion." It was during this time period, which followed the collapse of the religious center of Teotihuacan, that the Quetzalcoatl cult spread throughout Mesoamerica and beyond to become a "world religion" (Ringle et al. 1998).

Platform Mounds

The Hohokam built low, plaster-capped mounds even before the Colonial period ball game appeared; they continued in use, along with the ball game, until the twelfth century. Haury (1976:94) suggested these circular-shaped mounds had ritual purposes, probably as dance platforms, with the plaster capping undertaken to reduce dust created by the dancing. In Mesoamerica, mounds served multiple ritual functions, including locations for sacrificial acts.

After the ball game was abandoned, the Hohokam built massive, rectangular-shaped platform mounds. Construction of the large platform mound at Pueblo Grande appears to express the concept of duality—two platform mounds built opposite each other. In addition, the first construction on top of the southern mound was two opposing, oval pit structures with doorways facing away from each other (Downum and Bostwick 2003: Figure 9.2).

The two platform mounds at Pueblo Grande were later merged into a single mound as much as 9 m in height. Periodic destruction of rooms on top of the mound, followed by new construction, suggests a ritual cycle of death and rebirth of the architectural spaces. Such renewal ceremonies were common in Mesoamerica and usually coincided with important calendrical events, such as the Aztec's 52-year New Fire ceremony. Unusual adobe features, such as altars with posts, arrangements of open and closed spaces, and sacred objects, indicate that the Pueblo Grande platform mound served a ceremonial rather than a domestic function.

One room on top of the platform mound had a black serpent painted on a sealed doorway. Serpent images permeate Mesoamerican and Southwestern iconographies, and the serpent is typically associated with rain and the rain gods, including Quetzalcoatl, the feathered serpent, and Tlaloc, the rain-storm-earth god with goggle-eyes (Miller and Taube 1993). Native people of the Sonoran Desert still associate springs and irrigations canals as the homes of powerful serpents (Griffith 1992; Whittlesey 2003).

Artifacts from the Pueblo Grande platform mound indicate that ceremonial rituals and specialized craft production took place there. These include imported red ware bowls with three or four legs, bone awls, caches of stone axes, wooden weaving tools, animal figurines, red and green processed minerals, bone whistles, quartz crystals, and stone concretions (Bostwick and Downum 1994).

Several features suggest feasting activities, including large red ware bowls, narrow storage rooms where foods were kept, cooking pits, and hornos in and near the platform-mound complex. Communal feasting in the Southwest is often conducted in a ritual context, and it stimulates the production and use of socially valuable goods that are symbolically charged objects (Spielmann 2002).

Sacred Landscapes

Platform mounds and ballcourts were only part of a larger sacred landscape tied together by trails and visual alignments that connected settlements and agricultural areas with sacred springs, caves, hilltops, and mountain peaks. Similar sacred trails are recorded in O'Odham songs (Darling and Lewis 2007).

Two Hohokam ceremonial caves are well known: Red Cave in southeastern Arizona and Double Butte Cave in Phoenix. Red Cave has four natural chambers, inside one of which there is a stone basin with a pool of water associated with numerous offerings, including cane cigarettes (Ferg and Mead 1993). Double Butte Cave, located 3.2 km (2 miles) south of Pueblo Grande, contained a remarkable collection of several hundred cane cigarettes and 75 painted wood prayer sticks and pahos (Haury 1945). Both caves may have represented openings into the Hohokam underworld and places where rituals related to water and ancestor veneration were carried out (Whittlesey 2004b; see also Ellis and Hammack 1968).

Mortuary Rites

The burial of a Hohokam individual at death was no doubt a solemn and sacred event where color, orientation, accompaniments, and other aspects of ritual were permeated with symbolism (McGuire 1992; Mitchell 1994). At many Classic period villages in the Phoenix region, the majority of graves were oriented east–west, with the person's head placed at the east or southeast end of the grave, the direction of the rising sun. Some of the exceptions are notable and may reflect special status.

Color symbolism has important ritual connotations (Riley 1963). Pueblo Grande burial objects, for example, exhibited multiple colors (Mitchell 1994). White marine shell ornaments, found in approximately one-third of the burials, represented the most common color. Red was manifested in the distinctive red ware pottery, red hematite used on the body, and red argillite bead and pendant offerings. Other highly visible colors in the burial offerings were blue and blue-green derived from turquoise, malachite, azurite, and other copper ores. Blue is associated with the sky, not surprisingly, and is a sacred color to many native peoples. It also is the color of Tlaloc (Markman and Markman 1992).

Clay Figurines

Clay figurines have been called the most ubiquitous Hohokam ritual artifact (Neitzel 1991). They appeared early in farming villages in the Sonoran Desert and generally resemble those found in northwestern Mexico. Many Hohokam figurines are representations of humans, and some appear to be pregnant females. Although figurines are often found in trash deposits, a context which suggests that they were "retired" from ritual service, some figurines occur in caches. These figurine caches include clay models of houses, miniature vessels, and grinding stones that appear to have been arranged into fertility or household scenes (Thomas and King 1985). Caches of quadruped animal figurines found at Hohokam villages may be stylized representations of dogs perhaps associated with a merchant class in Hohokam society (Chenault and Lindly 2006).

Figurines were heavily imbued with symbolic significance, simultaneously representing earth, water, and fire. Typically, they were made of fine clay collected from a river bed, canal, well, spring, or other water source. As such, they represented the combination of earth and water. Some figurines were lightly fired, perhaps as part of a crematory rite. This process could be seen as a union of opposites, fire and water. Figurines found in caches and tableaus may have represented ancestors or specific individuals, possibly expressions of an ancestor cult (Stinson 2005; Whittlesey 2004a).

WATER

Water was central to Mesoamerican and Southwestern religious systems and was well represented in their imagery and permeated their ideology. Two well-known Mesoamerican rain deities were Tlaloc and Quetzacoatl. Tlaloc was often associated with images of serpentine lightning bolts, water symbols, and corn. Quetzalcoatl was conceptualized as a duality, simultaneously representing spirit and matter, earth and heaven, water and fire. Abstract forms of both deities are represented in Hohokam imagery, including painted bird and snake images and quartered design layouts on ceramic vessels, as well as plumed serpents depicted in rock art (Figure 3).

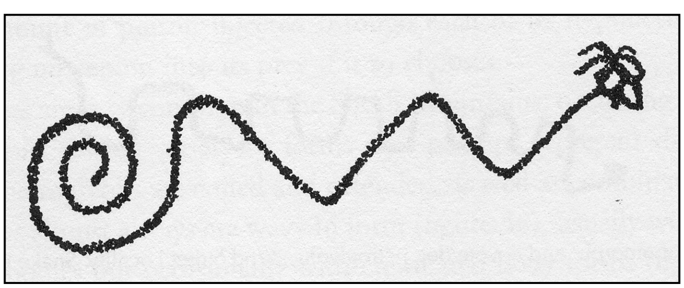

Figure 3. Plumed serpent petroglyph in the South Mountains.

In the Mesoamerican view of the universe, a mountain was a metaphor for a container of water (Zantwijk 1981). The mountain was home to Tlaloc and generated clouds and underground water, such as lakes and springs. Pyramids were considered symbolic mountains, the place of origin of their ancestors and home of their spirits. Hohokam platform mounds may have had similar symbolic meanings (Bostwick 1992). Some O'Odham stories identify platform mound leaders as rain priests. Perhaps Hohokam platform mounds symbolize the Rain House that figures so prominently in O'Odham oral traditions (Bahr et al. 1994).

Pools of water were analogous to mirrors, which were used in Mesoamerican divination rites and to reach the ancestors. Springs and water tanks in the South Mountains contain numerous Hohokam petroglyphs, including water symbols (Bostwick and Krocek 2002). Water reservoirs at Pueblo Salado, Las Colinas, and La Ciudad may have had ritual significance themselves, symbolizing the sacred mirror.

Whittlesey (2008) has suggested that Gila Butte held great symbolic significance for the residents of Snaketown. With the major irrigation canal heading at its base, the butte perfectly replicated the symbolism of the Coatepec myth, part of the Aztec creation story that has ancient roots in Mesoamerica. In their great migration from Aztlan to Tenochtitlán, the Aztecs stopped at Snake Mountain, on which they built a temple to their patron god, Huitzilopochtli. He then built a ballcourt at the base of the mountain containing a hole from which water flowed. The Aztecs dammed up the hole to create a well of water, and formed a lake at the base of Snake Mountain to provide water for cultivation and sustenance.

Headless Bird Jars

An intriguing water-related object found at Classic period Hohokam sites, and throughout southern Arizona, is a ceramic-effigy jar shaped like a headless duck (Figure 4). There are multiple examples of duck jars from several villages in the lower Salt River Valley, including Los Muertos, Pueblo Grande, Grand Canal Ruins, Casa Buena, La Ciudad/Los Solares, Pueblo Salado, and Dutch Canal Ruin. The Hohokam bird jars are primarily grave offerings, but a small number have been found in architectural spaces (e.g., Pueblo Salado, Pueblo Grande, Dutch Canal Ruin). Most are plain ware or red ware ceramics. All of them have handles.

Figure 4. Headless bird vessel containing water worn stones and placed inside a sub-floor pit in a Classic period adobe structure at Pueblo Salado.

Charred walls, ash-encrusted bases, and other wear on many of the jars indicate that these vessels were used to heat liquids. The duck jars are often placed with adult female burials, perhaps reflecting their involvement in the ceremonies associated with these special vessels.

An elaborate version of these avian ceremonial vessels was recovered from a burial at the Classic period site of Las Acequias. This headless-bird vessel exhibited clear overtones of Mexican influence with its elaborate handle in the form of a quadruped with a face and pierced ears (Hackbarth 1995:Figure 3.36, 83).

Among the Pueblo, ducks were considered sacred because they brought plant seeds (in their stomach) with them from distant locations, as well as clouds and rain. Consequently, duck images were often used in Pueblo rain making ceremonies. In Zuni myths, the rain spirit traveled in the form of a duck (Bunzel 1932:517).

A headless bird jar at Dutch Canal Ruin was found in a context that further suggests water symbolism. This vessel was located inside a bell-shaped storage pit in the floor of an adobe-walled structure. The bird jar was covered with 17 water-worn pebbles, and inside the jar were two more water-worn stones. Evidence of corn, cholla, and agave were present in the pit; they may have been offerings. More than a century ago, Frank Hamilton Cushing (1890) reported finding smooth stones in association with Hohokam canal banks and called them "water tamers," an expression of their association with water rituals.

WIND

In Mesoamerica, wind is "the ultimate source from which rain, maize, and human life are derived" (Taube 2001:102). The deity associated with the wind is Ehecatl, an avatar of Quetzalcoatl. In the American Southwest, wind carries the rain-bearing clouds as well as the prayers of humans to those clouds. Caves are typically associated with the wind because of their fluctuating air movements. O'Odham stories recount how Elder Brother, whose home was in the South Mountains, breathed out the winds that drove the clouds to bring rain (Russell 1975[1908]).

Spiral Designs

Spiral motifs in petroglyphs and on pottery and palettes may reflect wind symbolism. Quetzalcoatl in his guise as the wind god Ehecatl is represented by the conch shell because of its spiral interior, the spiral being common to whirlwinds and coiled snakes (Schaafsma 2001). Pueblo spirals have multiple meanings, representing the wind, water, and the journey in search of the center (Young 1988). Spiral designs are common on Hohokam pottery, in rock art, and on schist palettes (Figure 5). A study of Hohokam palettes revealed that many have spiral designs incised into their corners (Krueger 1993). Combined with the dia-

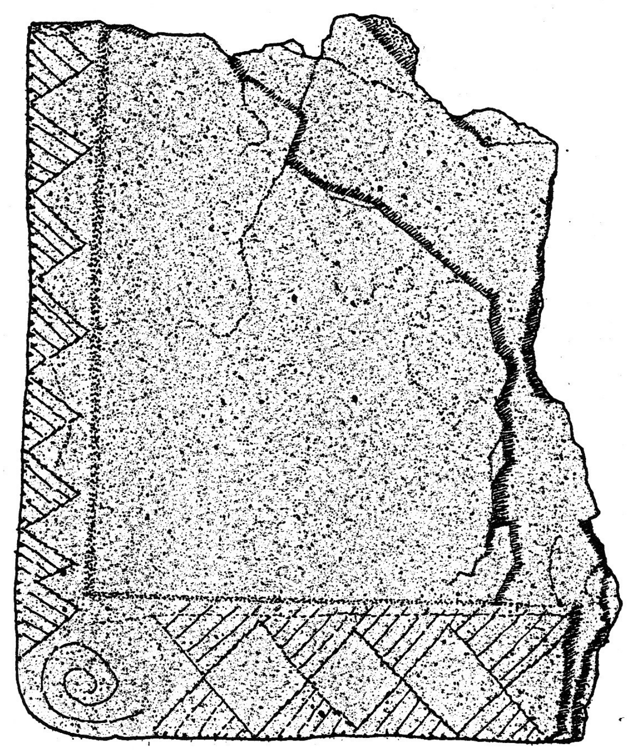

Figure 5. Broken schist palette from Pueblo Grande with diamond designs along its margins and a spiral in its corner.

mond patterns on the palettes' margins that resemble those of a rattlesnake, the palette designs may symbolize rain serpents encircling the rectangular-shaped depression which is a doorway into the Underworld. Haury (1976:288) speculated that palettes and censers were used together in burning lead during ritual performances, with the lead transforming in color from white to red, "the magical effect desired by Hohokam medicine men."

Tobacco

Tobacco has been an essential element in sacred rituals in the Southwestern since ancient times. Perhaps because it is a natural insecticide, tobacco has long been associated with purification. It also is intimately tied to wind and rain. The Hopi equate tobacco smoke with rain clouds (Loftin 1986).

Cultivated and native tobacco have been recovered from Hohokam sites, including the platform mound villages of Pueblo Grande and Las Colinas (Bohrer 1991; Kwiatkowski 1994). In addition, dozens of cane cigarettes have been found in Echo Cave in Phoenix, a rock shelter located 8 km (5 miles) due north of Pueblo Grande in the Papago Buttes. Some of these cut canes (Phragmities sp.) have woven cotton threads attached, similar to Pueblo prayer sticks. This shared characteristic suggests that the cut canes are Hohokam prayer offerings.

For the O'Odham, "everything about tobacco is sacred: its origin, its cultivation, its use" (Rea 1997: 316). O'Odham tobacco has been described as "a plant of divine origin that in its death (burning) released a spirit (odor and smoke) that was wafted by the breeze to the home of the magic beings that shape men's destiny" (Russell 1975[1908]:118). Tobacco smoke was intended to enhance vision or deepen perception and was used by shamans for diagnosing patients (Castetter and Bell 1942).

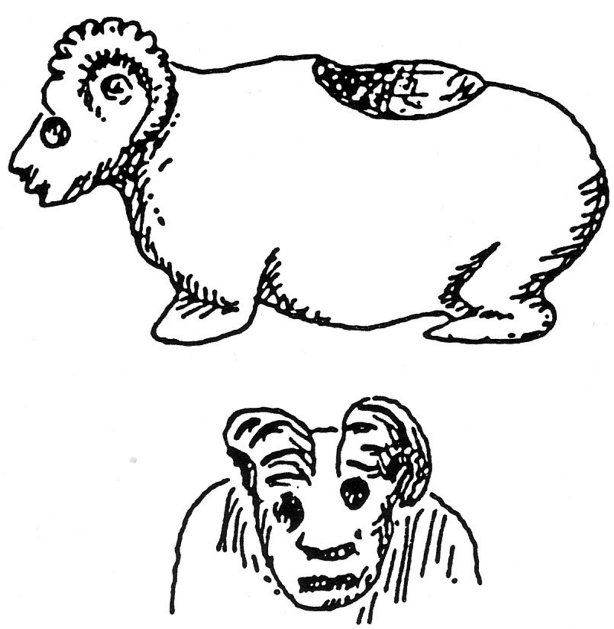

Figure 6. Carved mountain sheep effigy bowl placed in Colonial period burned cache at Pueblo Grande; illustration by Julian Hayden.

FIRE

Fire is the great purifier and transformer. It is dangerous and destructive, but essential for light, warmth, and cooking. Flickering flames take fantastic forms, and watching them can be hypnotic. Fire had great symbolic importance to many native peoples and is often mentioned in mythological stories (e.g., Russell 1975[1908]:216).

Cremation Burials and the Quetzalcoatl Myth

For more than 400 years, the Hohokam prepared their dead for the afterworld by cremating the body, presumably on a wooden platform set on fire. The cremation ritual was complex and protracted and involved burning of the deceased, the personal belongings, and any offerings (Beck 2005). Ritual destruction of offerings accompanied burial events. Dwellings and their contents, including food remains, often were burned as part of the mortuary rite or as a separate rite of purification and termination.

Fire was also used in ceremonies possibly associated with cremations, such as the palette-and-censer rituals. Offerings, such as ceramic vessels, were typically smashed and burned before inclusion in the burial pit.

An unusual burned cache at Pueblo Grande is laden with symbolism relating to fire, wind, and water. Inside a deep pit containing niches, an assortment of burned and smashed ritual materials were placed, but no human remains were present. The pit was dug deep into an ancient gravel deposit. Among the many ritual items were four sets of burned mountain-sheep horn cores. A Santa Cruz Red-on-buff jar and an imported Kana'a Black-on-white jar dated the offerings to the Colonial period. Also included were eight water-worn stones, eight projectile points (four obsidian), four carved-stone effigy bowls, four small pestles, two marine shells, a clay censer, many specialized ground stone objects, and nearly 3,000 sherds. One stone-effigy bowl was carved into a mountain-sheep figure (Figure 6), and a second was a bird; carved snakes, a human, and geometric designs decorated the other effigy bowls. Charcoal inside the pit indicates that wood from a pine tree was burned as part of this ritual burial.

The burning and burial of this cache represents a ceremony that involved sacrifice, offerings, and transformation through fire. Perhaps the groups of ritual items represent different social groups contributing sacred objects to a public ceremony as a demonstration of village unity and cohesion. Among the Pima, mountain sheep, and especially their horns, are associated with powerful winds and rain (Rea 1998 :253). It may not be coincidental that the cache burning and deposition took place in the ninth century, when Pueblo Grande experienced two major floods that threatened the stability of their complex irrigation systems (Graybill and Nials 1989).

In Mesoamerica, the dead did not automatically become ancestors, but were transformed into ancestors through the intent and behavior of the living. Hohokam cremation rituals may have been intended to affect this transformation of the deceased into ancestors. The location of cremation cemeteries near residential groups was meant to reinforce connections among the living and dead and perhaps to allow access to the dead for post-burial, ancestor-veneration rituals. Kinship-group members who have access to their deceased ancestor's remains are able to maintain their unique relationship with these powerful others, thus reinforcing the social order.

Ancestor veneration "drew power from the past, legitimized the current state of affairs, and charted a course for the future" (McAnany 1995:1). Strong links to the ancestors provided rights and privileges that included land, water, and other resources. The cremation ritual and ancestor veneration may have been a mechanism for land tenure and perhaps the beginnings of priestly lineages among the Hohokam.

Quetzalcoatl first appears at Teotihuacan in the third century and was associated with death, transformation, and rebirth. In the Nahuatl (Aztec) myth, Quetzalcoatl travels to the Land of the Dead and is involved in the theft of bones and ashes of those who had died in earlier worlds. As a culture-hero, he went eastward to the Place of Burning and sacrificed himself by self-immolation. When his ashes were extinguished, his heart rose as the morning star; he vanished into the underworld, and after eight days, reappeared as Venus, the Dawn Star. The connection among acts of cremation, transformation, and rebirth are clear. Outlined cross petroglyphs in the Hohokam region have been interpreted as Venus, providing additional support for the presence of Quetzalcoatl as a central deity in Hohokam religion (Bostwick and Krocek 2002; Johnson 1995). Outlined cross images also occur on Hohokam painted vessels and ceramic censers (Figure 7).

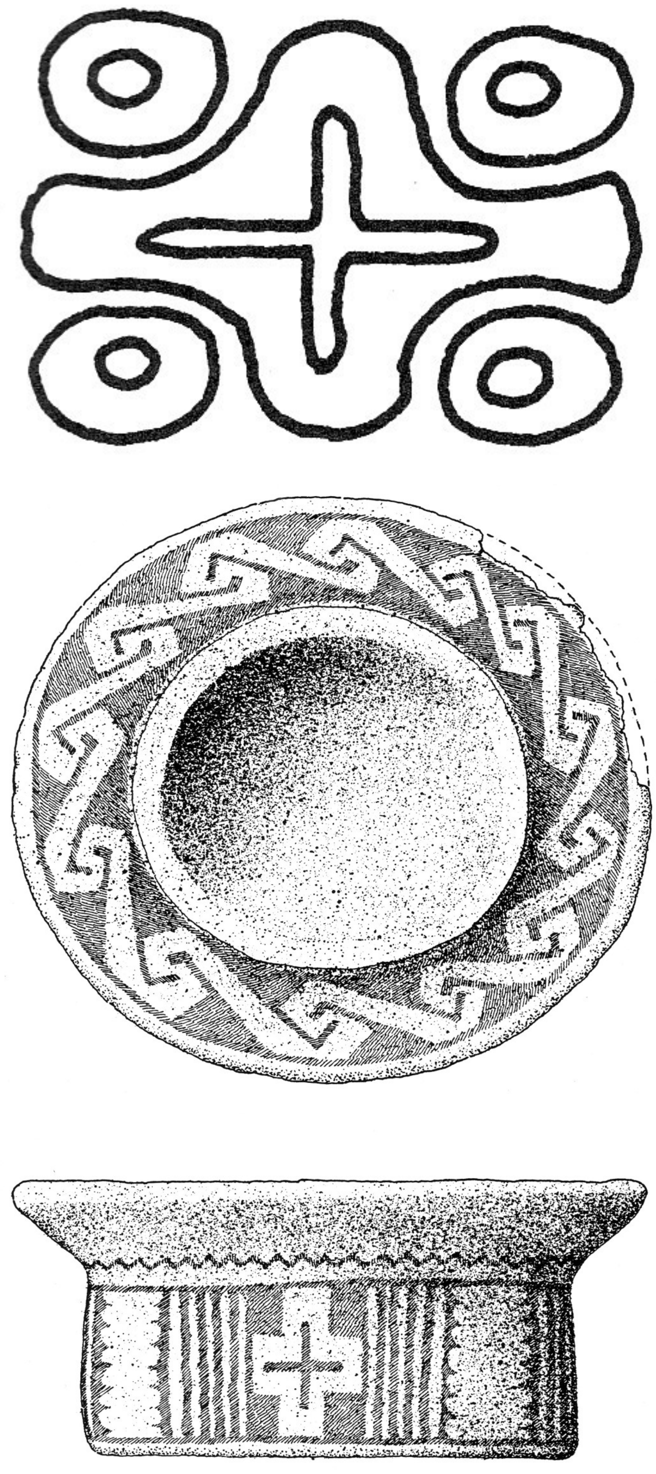

Figure 7. Mayan symbol for Venus (upper, from Di Peso 1974:409) and Hohokam painted ceramic censer with outlined cross design from Pueblo Grande (below, from Walsh-Anduze 1994:Figure 5.28).

HOHOKAM SHAMAN-PRIESTS

The study of Hohokam special objects, rock art, and human burials supports the presence of shaman-priests, similar to those proposed for Paquimé

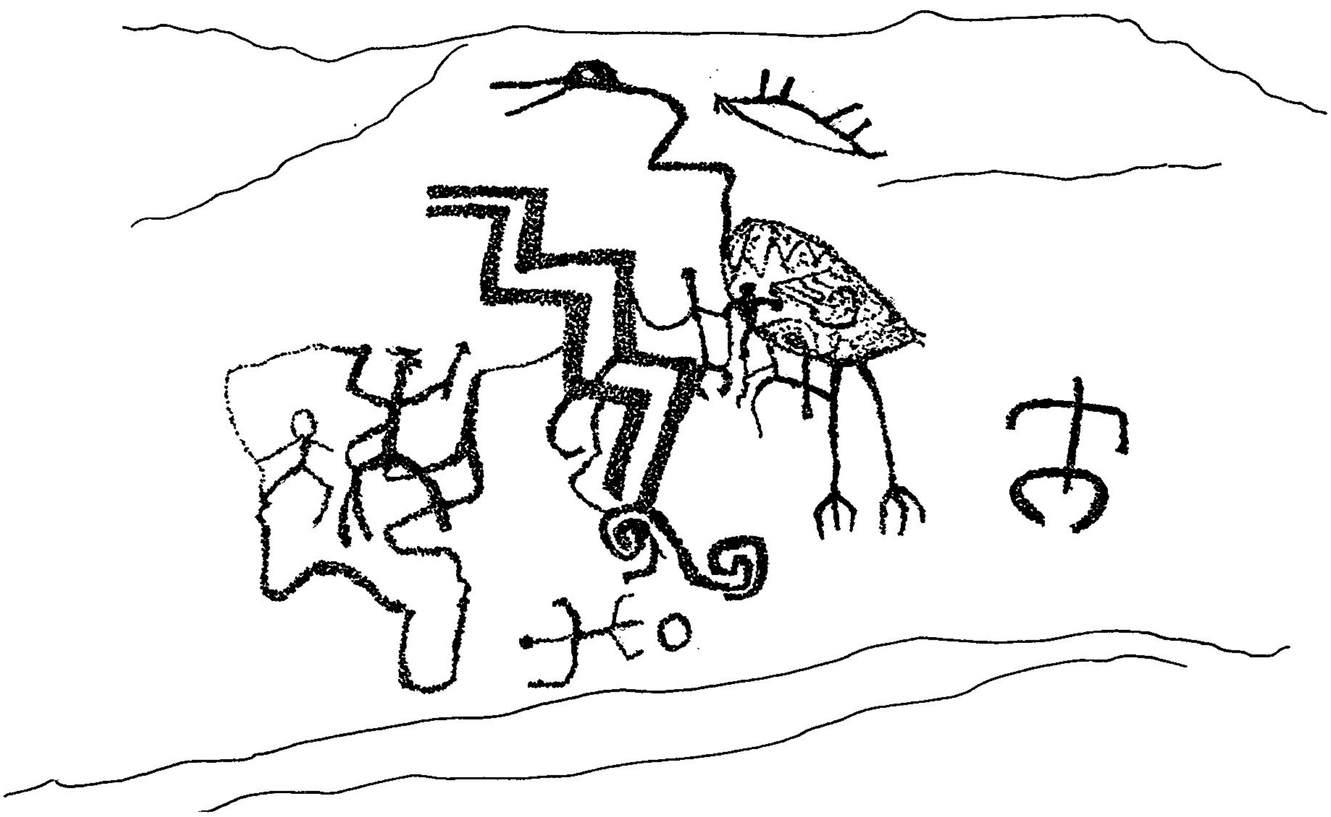

Figure 8. Petroglyph panel in the South Mountains that represents a shaman scene. Note human figures holding a staff, two lightning bolts, and a large water bird; an upside down quadruped is present above the water bird.

(VanPool 2003). Special objects, for example, include miniature knobbed ceramic vessels that resemble the thorny seed pods of the datura plant (Datura wrightii), also called jimson weed. Consumption of this plant produces powerful hallucinogenic effects, and it was commonly used by shamans and priests of the Southwest and Mesoamerica (Huckell and VanPool 2006). Datura seed-pod vessels occur throughout the Southwest and have been found at Pueblo Grande, Pueblo Salado, Las Colinas, the Marana Platform Mound site, and other Hohokam sites.

Hohokam petroglyphs located in mountain canyons appear to represent shaman activities. Shaman motifs include large mammals, birds, venomous insects, serpents, composite creatures, and spirit beings. Animals often have exaggerated, unrealistic, or anatomically incorrect body forms, possibly indicating dream animals. Some humans are part animal, have horns or sunrays coming out of their heads, are wearing animal or bird masks, or are holding snakes or large animals (Figure 8). Water creatures, including tadpoles and water birds, occur with human figures. These scenes suggest that some Hohokam shaman-priests were engaged in water-related rituals.

Certain individuals from four major Hohokam villages—Grand Canal Ruins, Pueblo Grande, Las Colinas, and Casa Buena—appear to have been shaman-priests based on their burial offerings and burial pit preparation (Mitchell 1994; Mitchell and Brunson-Hadley 2001; Mitchell 2003). A burial of a young adult male at Grand Canal Ruins with his head to the west was accompanied by a red ware jar containing stone concretions, turquoise, hawk-bone tubes, turtle carapaces (one painted blue), a quartz crystal, and various minerals in white, red, and blue colors.

A young male burial at Casa Buena was placed in an unusual seated position and included several vessels, one of which contained three bone awls on top of gypsum crystals, blue-green azurite or malachite, red hematite, asbestos, and chrysacolla minerals. An obsidian tool, two marine shell pendants, and a polishing stone also were among the offerings in this burial (Effland 1988).

At Las Colinas, a partially cremated, young male burial contained a stone pipe, a miniature stone ax, multiple whole marine shells, three ceramic vessels, a woven bag, and an incised bone wand. Morris and El Najjar (1971:34–35) argued that the pipe, incised wand, and whole shells were evidence the individual was a shaman. In addition, an adult female at Mound 8 in Las Colinas may have been a shaman (Bostwick 1992:79). In her burial was a pouch that contained quartz crystals, obsidian, worm molds, asbestos, and red hematite (Hammack 1969:25). The O'Odham are known to have women among their cadre of shamans (Bahr 1983).

A young adult male at Pueblo Grande, buried in a benched pit with his head to the west, was accompanied with ceramic vessels; shell beads, needles and pendants; bone hairpins; an obsidian projectile point; and quartz crystals. Two sets of golden eagle wings and one set of raven wings were found near his feet, and red hematite was found on the individual's leg and adjacent to the body. The presence of feathers from powerful birds suggests that this individual was a wind or rain shaman.

Eagle burials appear to have had special ceremonial status among the Hohokam. Eagle burials have been found on top of the platform mound at the Escalante Ruin (Doyel 1974), in plazas at Pueblo Salado and at Casa Grande, and in a village near Tucson. The bald-eagle burial in the Pueblo Salado plaza was a fully articulated skeleton carefully buried under a small boulder that had a form similar to the eagle skeleton; the eagle's head was facing to the east, similar to many of the human burials at the site (Bostwick 2008).

HOHOKAM SOCIO-POLITICAL ORGANIZATION AND THE SACRED REALM

We have shown that the sacred can be identified in the Hohokam archaeological record in relation to the elements of earth, water, wind, and fire. Another potentially informative method is to examine the distribution of symbols, such as zoomorphic ornaments, that may represent membership in social, religious, or political groups. Certain items may represent authority or the identity of a particular local group, or affinity with a clan moiety, or membership in sodality-based ceremonial cults.

Burial age, gender, and location support the idea that there was social inequality among the Classic period Hohokam. The presence of spatially restricted groups of burials containing more wealth at particular Hohokam villages indicates a social system with wealthy lineages. Segments of kinship-related groups may have attained sufficient wealth and authority to exert a disproportionate amount of control over other members of the community through exchange alliances or perhaps acquisition of important land and irrigation rights. Vertical differentiation within the population also appears to have been a result of ceremonial or religious responsibilities tied to the sacred realm. Such responsibilities allowed specific individuals, clans, lineages, or kin groups to acquire power and prestige. Community activities, such as those associated with the platform mounds and burial rituals, would have allowed for power accumulation by individuals who orchestrated or sponsored ritual events.

However, most artifact variability in Hohokam burials represents horizontal rather than vertical differentiation (Mitchell and Brunson-Hadley 2001:62). At Pueblo Grande during the Classic period, males tended to have more ceremonial objects and polychrome vessels, and women had more utilitarian offerings, although some elderly women also had access to elite items. Children had fewer artifacts than adults, with some impressive exceptions, including a subadult burial with multiple copper bells made in western Mexico. The burials of some Hohokam, young and old, male and female, appear to be distinctive, most likely reflecting differences in power or status.

But Hohokam inequality does not appear to have been translated into a highly structured, hierarchically ranked society. Wilcox (1991) has suggested there were high ranking corporate groups that lived on top of the platform mounds. We argue that there likely were multiple leaders representing different social units who shared power and authority. Ritual feasting may have been one of the ways in which different kin groups shared in important ceremonial activities. Elizabeth Brandt (1994) has noted that Pueblo ceremonial councils also controlled access to land, resource distribution, and irrigation technology, and that these councils discouraged individual aggrandizement.

CONCLUSIONS

Major transitions in the Hohokam culture may have been a result of the introduction of distinctive ideological and religious complexes from the Mesoamerican region. Tlaloc, a fertility god who dwelt on top of mountain peaks where clouds emerged from caves and brought life-giving rain, may have governed the lives and ritual practices of the early farmers of the Sonoran Desert. Although Tlaloc imagery is well represented at Teotihuacan and elsewhere, it has not been convincingly identified in Hohokam material culture and may not have been expressed in obvious ways. Hohokam petroglyphs called "pipettes" have been interpreted as the face of Tlaloc (Wallace and Holmlund 1986), but considerable variability in pipette forms suggests this identification is questionable (Golio et al. 1995).

Tlaloc appears to have been later replaced or absorbed by the ballcourt "sky religion" dedicated to Quetzalcoatl, the plumed serpent. This ballcourt-based religion is associated with various material traits in southern Arizona, such as red-on-buff pottery, that distinguish the Hohokam from other Southwestern cultures.

In the Classic period, the nature of the death ritual changed significantly from cremations to predominately inhumations. The ballcourts and certain ceremonial items such as palettes, carved stone bowls, and ceramic censers disappear. Bird, lizard, snake and human symbols no longer decorate their painted pottery, and were replaced by abstract geometric designs. Life forms also seem to decline in Hohokam rock art. Tezcatlipoca, the "Smoking Mirror," may have become a major deity at this time, with the Quetzalcoatl cult continuing to exert influence, perhaps in different iconographic expressions, such as the plumed or horned serpent frequently depicted on Salado Polychrome pottery (Crown 1994). Quetzalcoatl and Tezcatlipoca religious cults, as well as an older Tlaloc deity, were identified at Paquimé in northern Chihuahua during the Medio period (Di Peso 1974:547), contemporaneous with the Hohokam Classic period.

Tezcatlipoca was an Aztec warrior god associated with shamanistic magic and sacrifice who first appeared in the 10th century and became a wide-spread cult by the 15th century. Identified by his obsidian mirror, he is often depicted as the divine antagonist of Quetzalcoatl (Evans and Webster 2001:106). In his representation as earth and matter, Tezcatlipoca formed a dualistic relationship with Quetzalcoatl in his guise as wind and spirit (Miller and Taube 1993).

Although these major deities most likely had different names to the Hohokam, the religious concepts and rituals associated with each may well have been key components of Hohokam religion and they merit further study. Future Hohokam research may profit from examining the spatial context and distribution of different images, symbols, and colors associated with their cosmology, myths, and rituals.

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