

# Pavement Quarries, Gypsum Period Residential Stability, and Trans-Holocene Settlement Systems of the Mojave Desert: A Case Study at Fort Irwin

BRIAN F. BYRD

D. CRAIG YOUNG

KELLY R. McGUIRE

Far Western Anthropological Research Group, Inc.  
2727 Del Rio Place, Suite A, Davis, CA 95618

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*This paper takes a geoarchaeological contextual approach in arguing that pavement quarries—those assay and reduction events directed at cobbles that often litter expansive desert alluvial landforms—can provide a powerful index of changing trans-Holocene settlement organization. Focusing on multiple lines of evidence—age estimates of alluvial fan surfaces, quarry technology, patination profiles, and regional toolstone consumption trends at residential sites—we explore the temporal and technological development of quarry pavement use at the National Training Center at Fort Irwin, Mojave Desert. The analysis reveals that chert pavement quarrying was in ascendance during the early portion of the Late Holocene and had a strong biface production component. This landform-based model of Holocene pavement quarry development provides support for reconstructions that envision Gypsum period hunter-gatherers as residentially stable, and as undertaking increased logistical forays during which pavement quarry procurement took place.*

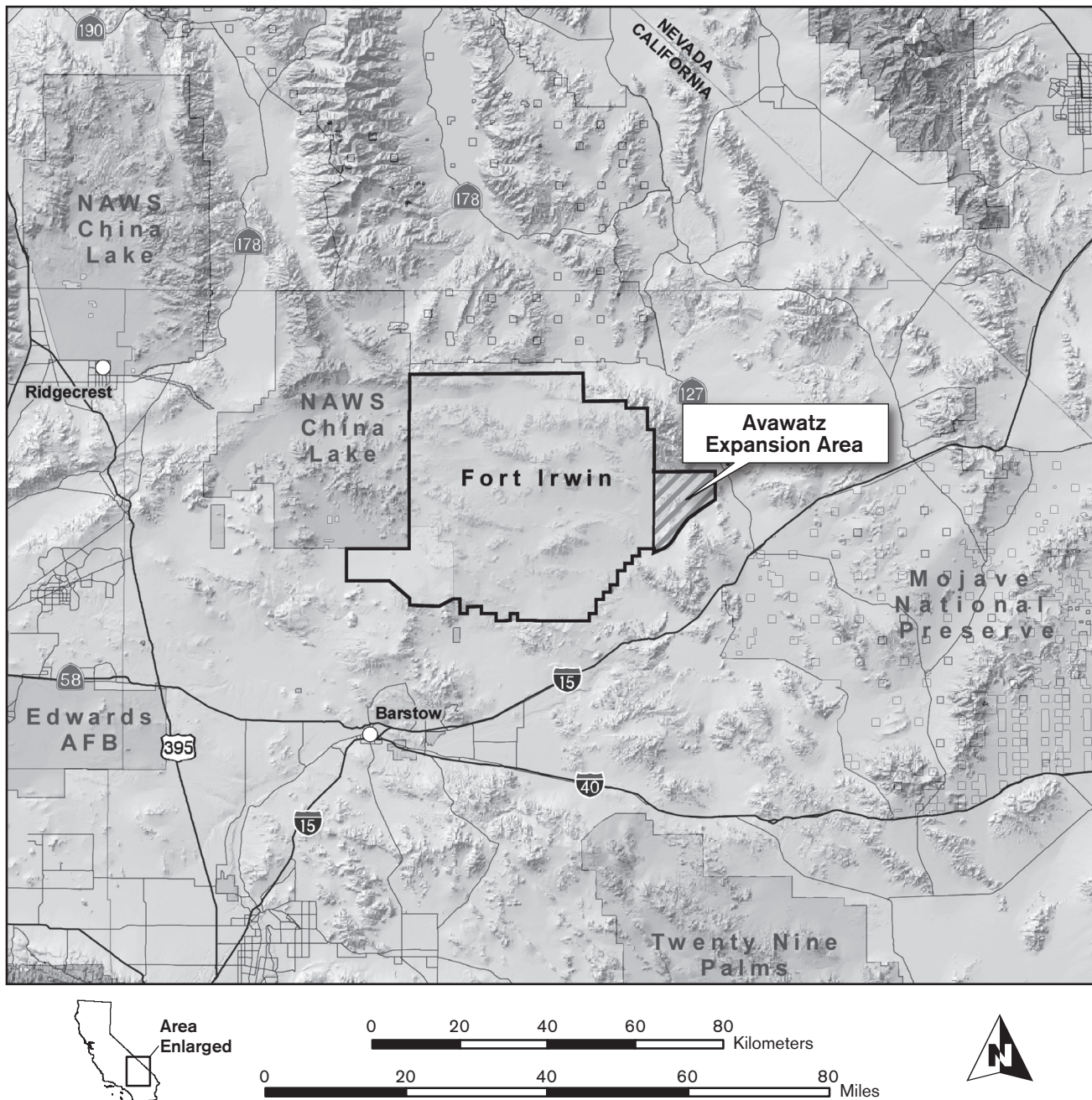
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ARCHAEOLOGISTS AND LAND MANAGERS  
A contemplating large-scale surveys in the Mojave Desert are often confronted with a need to document and evaluate pavement quarries—those assay and reduction events directed at cobbles that often litter expansive alluvial landforms common to the region. Unfortunately, these small quarries, frequently the dominant resource type, receive little interpretive attention due to their perceived ubiquity, atemporality, and lack of complexity.

Alternatively, we argue that by employing a geoarchaeological contextual approach, pavement quarries can provide a powerful index of changing trans-Holocene settlement organization. The key here is to assign pavement quarries to a series of well-dated Holocene landforms. Not surprisingly, pavement quarry phenomena are found to differ in type, density, and structure according to the age of the landform. No longer the archaeological record's step-child, the procurement, use, movement, and discard of this cobble toolstone is suddenly accessible within a temporal context.

In this paper, we present a landform-based model of Holocene pavement quarry development derived from a recent survey and evaluation of sites located in the Avawatz Expansion area of the National Training Center at Fort Irwin (Fig. 1; Byrd et al. 2005). Fort Irwin is unique because its long-running cultural resources management program has resulted in a massive, base-wide survey and excavation sample that allows for the kinds of trans-Holocene settlement reconstructions presented in the following pages (Basgall 2000; Sutton et al. 2007). Fort Irwin also represents a vast desert hinterland, situated at some distance from the Mojave River and other environmental sweet spots. While potentially a disadvantage in terms of less abundant archaeological resources, hinterland areas are perhaps more sensitive to subtle changes in toolstone procurement, mobility strategies, and settlement configuration.

Focusing on multiple lines of evidence—age estimates of alluvial fan surfaces, quarry technology, patination profiles, and regional toolstone consumption



**Figure 1. Location map of Fort Irwin and the Avawatz study area.**

trends at residential sites—we explore the temporal and technological development of quarry pavement use.

This analysis reveals that chert pavement quarrying was in ascendance during the early portion of the Late Holocene, had a strong biface production component, and was correlated with Gypsum-period logistical forays.

This emerging understanding of pavement quarries, when combined with other assemblage data from

Fort Irwin, allows commentary on several competing perspectives of Gypsum-period settlement organization in the Mojave Desert. Basgall and Hall (1993, 1994a; see also Basgall 1996, 2000) suggest that Gypsum-period deposits (4,500–1,400 cal B.P.) were formed by a generalized, residentially mobile pattern of land use (note that only calibrated ages are used throughout the text). They argue that this reflects a wide-ranging settlement system

similar to that of earlier periods, albeit geared to short-term occupation of generalized areas rather than specific locations. This perspective shares some characteristics with a long tradition of viewing Archaic lifeways in the arid West as characterized by small-group, residually mobile foragers (Jennings 1957; Steward 1938).

In contrast, McGuire and Hildebrandt (2005; Hildebrandt and McGuire 2002; McGuire et al. 2007) argue that the Gypsum period, far from representing residually mobile, wide-ranging foragers, may actually represent the trans-Holocene highpoint of *residential stability* in the Great Basin and Mojave Desert. In this scenario, the Gypsum period represented a settlement shift from band-level, mobile foraging of the preceding periods, to a more residually stable pattern that included increased levels of logistical procurement—particularly large-game procurement conducted by males (see also Warren 1984; Warren and Crabtree 1986)—emanating from larger base camps located near major drainages and other productive resource tracts.

The profile of pavement quarry use identified during this study strongly supports the latter perspective. We conclude this paper by placing this particular strain of quarry activity within its wider assemblage context at Fort Irwin, and considering its role in emerging settlement reconstructions for the Mojave Desert and Great Basin.

## UNDERSTANDING PAVEMENT QUARRY EVENTS

The study of prehistoric stone quarries is part of a long and productive research tradition in archaeology (e.g., Heizer and Treganza 1944; Holmes 1919). Much has been written about the economic importance of raw material sources, particularly toolstone quarries (e.g., Arnold 1992; Ericson and Purdy 1984; Torrence 1989; Vehik 1985). This research has examined the theoretical underpinnings of lithic toolstone economy and organization, with the recognition that toolstone procurement, production, processing, and distribution are distinctive aspects of the process (e.g., Andrefsky 1994; Beck et al. 2002; Ericson 1984; Purdy 1984; Skinner and Ainsworth 1991).

In California and the Great Basin, a number of important primary quarries have been documented and intensively researched (e.g., Bloomer et al. 1997; Elston and Raven 1992; Gilreath and Hildebrandt 1997;

McGuire et al. 2006). Although these have included scattered chert (also referred to as cryptocrystalline silicate or CCS) and basalt quarries, obsidian quarries have received the most overall attention (e.g., Gilreath and Hildebrandt 1997; Hughes 1986; Jackson 1986; Ozburn 1991). This is due in large part to the desirability of the raw material itself, as demonstrated by the quantities that were traded for considerable distances and by the preference for obsidian over other raw material types that were available in the same region.

Pavement quarries (also referred to as secondary quarries) have received considerably less research attention than primary quarries (but see Giambastiani 2008, and Wilke and Schroth 1989). Secondary quarries entail the use of raw materials that had been transported by natural processes away from a primary source location. There are several reasons for this situation to exist that are tied to research potential and site significance. The density of lithic raw materials in secondary contexts, such as on alluvial fans, is invariably much lower than at primary quarries. Thus, the intensity of quarrying for a given area was usually lower at secondary quarries than at primary quarries. This low density and spatially expansive use pattern tends to decrease opportunities to date secondary quarries, because there is less likelihood that temporally diagnostic tools were discarded at them. It also makes it more difficult to gain full insights into patterning and trends in secondary quarry use, since regional survey and testing data are needed rather than just site-specific investigations. Secondary quarries also tend to be associated with more ubiquitous flaked toolstone types, typically chert, although igneous and metamorphic materials may also be found as secondary sources. The difficulty in sourcing chert and the inability to directly date it have made chert quarry studies relatively unattractive for addressing important research questions.

Secondary quarries do, however, have some advantages over primary quarries. First, many secondary quarries, especially the pavement quarries of the Mojave Desert, tend to be aggregates of Segregated Reduction Locales (SRLs). As such, they are composed of a series of precise moments in time when individual cobbles were acquired, tested, and initially reduced. This allows reduction patterns to be more readily discerned (i.e., this is high-resolution data) because a mixing of reduction



events due to repeated use occurs less frequently than at primary quarries. The ubiquity of secondary quarries on some landforms also provides robust samples for examining regional trends, and these samples have the potential to be subdivided on the basis of a variety of attributes tied to context and content.

Pavement quarries are very common in a number of areas in the Mojave Desert, particularly at Fort Irwin. Basgall and Hall (1994b:9) note that:

Apart from specific geoarchaeological considerations, an important geologic feature of the north-central Mojave Desert are common cryptocrystalline silicate, basalt, rhyolite, felsite, and quartzitic outcrops and secondary boulder/cobble fields that served as ready toolstone sources for prehistoric human populations. A number of major raw material procurement loci are identified at the NTC and on immediately adjacent lands (Basgall 1991; Bouey and Mikkelsen 1989; Jones 1991; Mikkelsen and Hall 1990; Skinner 1984), and more undoubtedly occur in the general vicinity.

Previous investigations in and around Fort Irwin have documented pavement quarries in a number of settings. Prominent localities within Fort Irwin include the Bow Willow Wash area, the Goldstone region, the Langford Well area, the Nelson/McLean Lake Basin, and the Nelson Lake uplands (Basgall 1993; Bergin et al. 1985; Kelly 1985; Kelly and Warren 1984; Robarchek et al. 1984; Skinner 1984; Warren 1991). Pavement quarries were also documented immediately adjacent to Fort Irwin on surveys to the west in the China Lake Joint Use and Mojave B areas (Bouey and Mikkelsen 1989) and immediately south and east of Fort Irwin (Byrd 1998; Mikkelsen and Hall 1990).

To date, researchers working on ubiquitous chert pavement quarries in the Mojave Desert have achieved only limited research success despite the recognition that these sites played an important role in past human behavior (Basgall and Hall 1994a:9; Giambastiani 2008). Chert pavement quarries are rarely, if ever, assigned to a specific time frame, patterned technological variation in cobble reduction is only occasionally discerned, and formal models are rarely put forward that postulate how these sites functioned within a larger regional system (e.g., Basgall 1993; Basgall and Giambastiani 1997; Basgall and Hall 1994b; Bouey and Mikkelsen 1989; Giambastiani and Basgall 1999). The remainder of this discussion attempts to rectify this state of affairs.

## LITHIC PRODUCTION AT PAVEMENT QUARRIES IN THE SOUTHEAST AVAWATZ AREA

This study utilizes the results of recent archaeological investigations within the southeast Avawatz area of Fort Irwin, San Bernardino County, California (Byrd et al. 2005). The study area covers some 165 square kilometers in the north-central portion of the Mojave Desert, on the eastern edge of the Mojave Trough System just northwest of Silver Lake. The study area lies at the southeastern end of the Avawatz Mountains, with elevations ranging from 997 meters at Alvin Peak in the northwest to nearly 230 meters at Dry Lake in the northeast.

The southern Avawatz Mountains are the source material for the study area's alluvial fans. The local bedrock includes a variety of volcanic, sedimentary, and metamorphic rock types. The complex lithology is predominantly Jurassic or Triassic in age with later, possibly Pliocene and Miocene, "Breccia Facies" units (Henshaw 1939). These debris-avalanche deposits are shedding volcanic/meta-volcanic and cryptocrystalline silicate (CCS) clasts into adjacent fan systems and are the primary sources of toolstone in the study area.

Archaeological survey within this area covered 28.1 square kilometers (6,945 acres), concentrated on alluvial fans. Recorded archaeological sites included 42 pavement quarry sites. These surface sites are amalgams of SRLs, ranging from 3 to 21 per site, for a total of 275 SRLs. Collections were made from a sample of SRLs at each site. In addition, 584 isolated SRLs were documented and subjected to detailed field recording. In all, 859 SRLs were documented. Dominant material classes include (1) volcanic/meta-volcanics (mostly basalt but also including some rhyolite), and (2) cryptocrystalline silicates (CCS) of varying colors and textures.

In order to discern diachronic trends in pavement quarrying, we first construct an age model of the alluvial fan units. Next, we examine spatial patterns in the distribution of SRLs on fan units of varied ages. Finally, we explore patterns in SRL constituents to unravel temporally-linked reduction trends.

### *The Age of Alluvial Fans*

The construction of an age-based landscape evolution model provides temporal context and stratigraphic

resolution to landforms, based on the law of superposition and cross-cutting relationships—any site resting on a surface of a particular age post-dates the formation of that surface (Waters 1992). Fan surfaces and profile characteristics were examined in the study area, and surface mapping, augmented by photo interpretation, utilized transects that cut across each of the major fans. Chronological information was derived from stratigraphic and topographic positions, surface and soil morphology, and radiocarbon dating of packrat middens (for details see Byrd et al. 2005:42–65).

The Mojave Desert region of southern California has a long history of geomorphological research, and several of the broad alluvial fan systems in the terminal basins of the Mojave River have been mapped in detail. Significant research has been conducted addressing surface ages and correlations with dated lake stands in Silver and Soda lakes, as well as occasional connections of the Mojave River into the Silurian Valley and Amargosa River drainage system. Detailed mapping of the fans in the central Silurian Valley/northern Avawatz Mountains area (Anderson and Wells 2003; Wells and Anderson 1998; Wells and Ritter 1994), along with mapping and correlation of piedmont and shoreline landforms at Silver Lake and the Soda Mountains (McFadden et al. 1989; Wells et al. 1987, 1990, 2003), provided significant baseline information for our

study area in the southern Avawatz piedmont. Although these drainage systems vary significantly in size, McDonald et al. (2003) have shown that deposition and surface abandonment was chronologically synchronous across much of the central Mojave. These prior investigations in the piedmonts of the northern Avawatz and Soda mountains provided a foundation for delineating chrono-stratigraphic relationships for this study. Our research also placed considerable emphasis on the weakest aspect of prior investigations—dating the latter part of the Holocene fan sequence.<sup>1</sup>

The study area involves five major fans that vary in source area, sediment composition, slope, and depositional sequence. This fan system originates in the Avawatz Mountains and terminates in the southern Silurian Valley. As such, the parent material of each fan is nearly identical, derived from the same deposits of older, uplifted Tertiary-to Quaternary-age fan units. This is an important point, because toolstone-quality nodules of both volcanic or CCS material can occur with equal frequency on all fan units regardless of their age. Thus, variation in raw material use at pavement quarries from fan units of different ages is not due to raw material availability but instead is the result of changes in human behavior.

Five surface chronological units, termed fan units, were distinguished in the study area (Table 1). They were

**Table 1**

**ALLUVIAL FAN STRATIGRAPHY AND GENERALIZED CORRELATIONS IN THE VICINITY OF THE SOUTHERN AVAWATZ STUDY AREA**

Current Project Southern Avawatz	Relative Age	Features and Dating Evidence	Previous Investigations (Correlations)	
			Soda Mountains (Wells et al. 1987)	Northern Avawatz (Anderson and Wells 2003)
Qf5	Late Holocene	Deeply inset into Qf3, Qf2, and QTf1 of Soda Mtns. Moderate varnish and redding of clasts; Stage-I carbonate on clasts. Packrat midden dates provide minimum incision at approx. 1,800 years ago.	Qf4 & Qf5	Qf6
Qf4	Middle Holocene	Inset into Qf2 and QTf1 of Soda Mtns. Moderate varnish, minor interlocking clasts. Moderate varnish and redding of majority of clasts; Stage-I carbonate on clasts.	Qf3	Included in Qf5
Qf3	Late Pleistocene to Late Holocene (Avawatz Mtns.)	Extensive broad fan and fan segments, dissected by younger channels; weak to strong varnish, moderate inter-locking clasts, moderate bar-and-swale topography.	Qf2	Qf5
Qf2	Pleistocene	Isolated remnants at mountain front and in catchment basins; heavily dissected; moderate to strong varnish where preserved; rounded interfluvies; occasional strong pavements on broad, well-preserved interfluvies; strong soils; commonly faulted.	QTf1	Qf2-Qf4
QTf1	Plio-Pleistocene	Thick fanglomerates with ridge-and-ravine topography; isolated remnants along mountain front; commonly faulted; soils stripped but may show strong soil development or buried paleosol.	-	QTf1

Table 2

## RADIOCARBON DATING RESULTS—PACKRAT MIDDENS

Beta Sample No.	FW Field Sample No.	Parent Fan	Fan Surface*	Dated Material	Conventional C <sup>14</sup> Age	Calibrated Intercept
205761	401-PM-1	QTf1	Qf5	Dung	1,180 ± 70 B.P.	1,070 cal B.P.
205762	401-PM-2	QTf1	Qf5	Dung	1,200 ± 50 B.P.	1,116 cal B.P. (m)
205763	401-PM-3	QTf1	Qf5	Dung	760 ± 70 B.P.	680 cal B.P.
205766	401-PM-6	QTf1	Qf5	Dung	1,640 ± 70 B.P.	1,540 cal B.P.
205767	401-PM-7	Qf3	Qf5	Dung	390 ± 60 B.P.	480 cal B.P.
205768	401-PM-8	Qf2	Qf5	Dung	510 ± 60 B.P.	530 cal B.P.
205769	401-PM-9	Rock Outcrop	Qf5	Dung	1,810 ± 50 B.P.	1,720 cal B.P.
205770	401-PM-10	Qf2	Qf5	Dung	150 ± 60 B.P.	128 cal B.P. (m)

Notes: \*Surface associated with headward erosion and downfan deposition; minimum age for this surface. (m) – Multiple intercepts, averaged.

numbered from one to five, with one being the oldest and five being the youngest (note that QTf stands for Quaternary to Tertiary fan, while Qf stands for Quaternary fan). These fan units correlate well with previous, adjacent studies (Anderson and Wells 2003; Wells and Anderson 1998; Wells et al. 1987). It should be noted that the fan surfaces may be considerably younger than the underlying deposits. For example, a Late Pleistocene fan unit may have eroded significantly in the middle Holocene, basically resetting the age of the fan's surface and removing any associated archaeology, even though much of the subsurface morphology remained unaltered. As such, the age of the fan surface is the key factor in determining the age of pavement quarry surface sites.

Two fan units are pre-Holocene in age (QTf1 and Qf2) and three date to the Holocene age (Qf3, Qf4, and Qf5). QTf1 fan units are several million years old. Qf2 fan units have been stable since the Late Pleistocene, as evidenced by the development of dark surface weathering and pavement formation. Qf3 fan units began forming near the end of the Pleistocene in high energy regimes, where large clasts were transported into levee and berm features, and then stabilized in the early Holocene by 10,000 cal B.P. (McDonald et al. 2003). Qf4 fan units developed during the middle Holocene around 5,000 (cal B.P.). In some instances, mapping resolution was unable to distinguish Qf3 and Qf4 fan units, resulting in the identification of either amalgam Qf3/Qf4 (Qf3-dominant) or Qf4/Qf3 (Qf4-dominant) surfaces. The onset of the Qf5 fan unit, at about 1,800 years ago, was dated using packrat middens built within channels after incision (Table 2).

The distribution of these fans across the study area is displayed in Figure 2. The dates associated with the formation of each fan, as well as the time spans they have constituted stable surface land forms, are displayed in Figure 3. To reiterate, archaeological materials found on QTf1 and Qf2 fans may date to any point during the Holocene and late Pleistocene; materials on Qf3 and Qf3/4 fans postdate 10,000 years ago, during the Early Holocene; materials on Qf4 and Qf4/3 fans date only from the last 5,000 years; and materials on the Qf5 fan are restricted to the last 1,800 years of the Late Holocene.

#### *Broad Spatial Patterning and Temporal Context of Pavement Quarrying*

The frequency of volcanic/meta-volcanic and crypto-crystalline silicate (CCS) SRLs by fan unit is shown in Table 3. The percentage frequency of each SRL by material class and fan unit is then compared against their expected frequency, based on the percentage survey conducted in each unit (Fig. 4). Thus, for example, over 68% of all volcanic/meta-volcanic SRLs documented in the project area were found on the Qf3 and Qf3/4 landforms, even though they comprised less than 29% of the total survey area.

Two other important findings are evident in this figure. The first, and perhaps the most surprising, is that virtually no pavement quarrying activity occurred on fan surfaces that were formed after 1,800 cal B.P.; i.e., this form of toolstone procurement ceased at the Gypsum/Saratoga Springs transition. The second major finding is that while CCS pavement quarrying activity continued on fan surfaces that were formed after 5,000 cal B.P. (Qf4

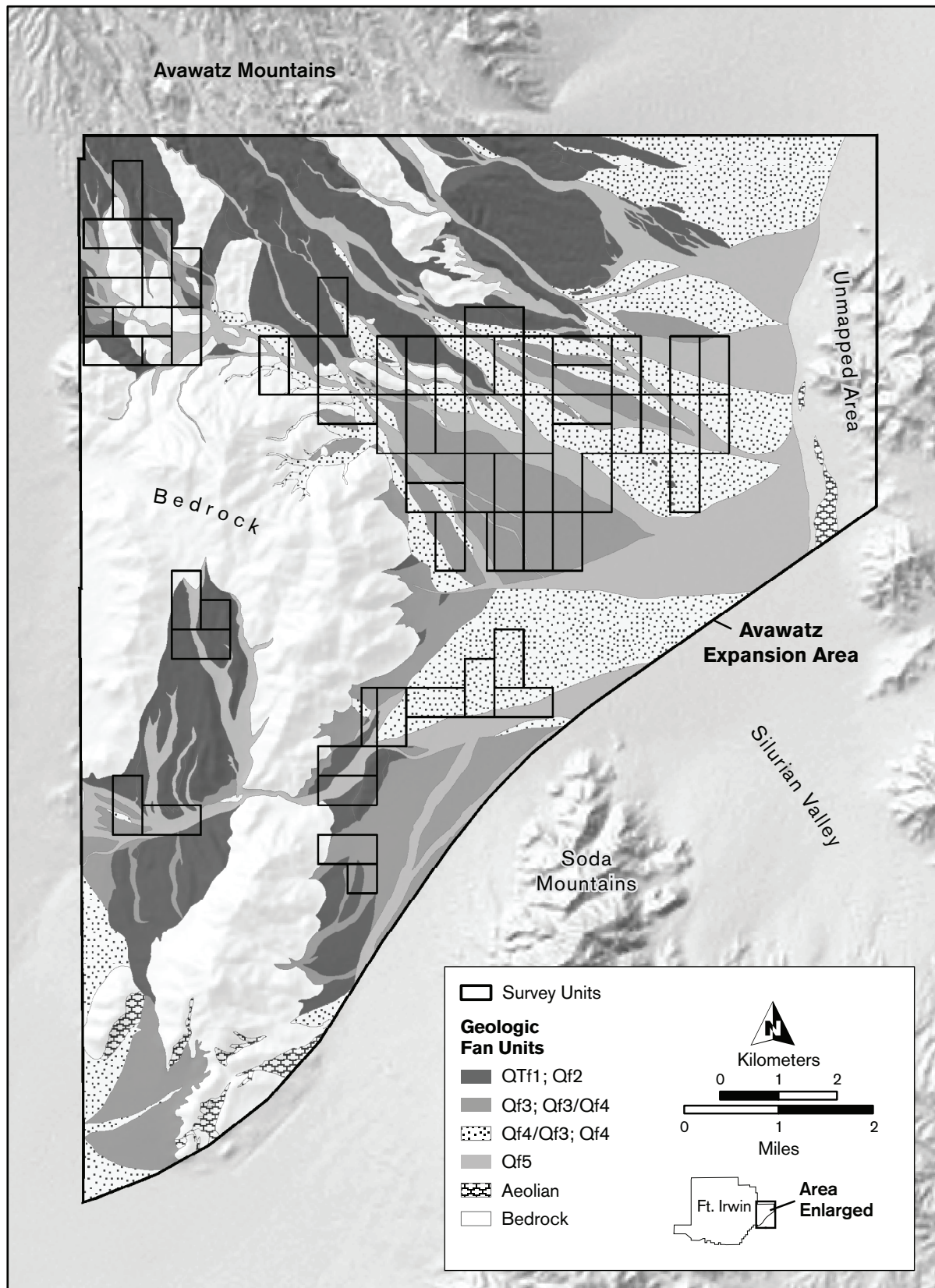
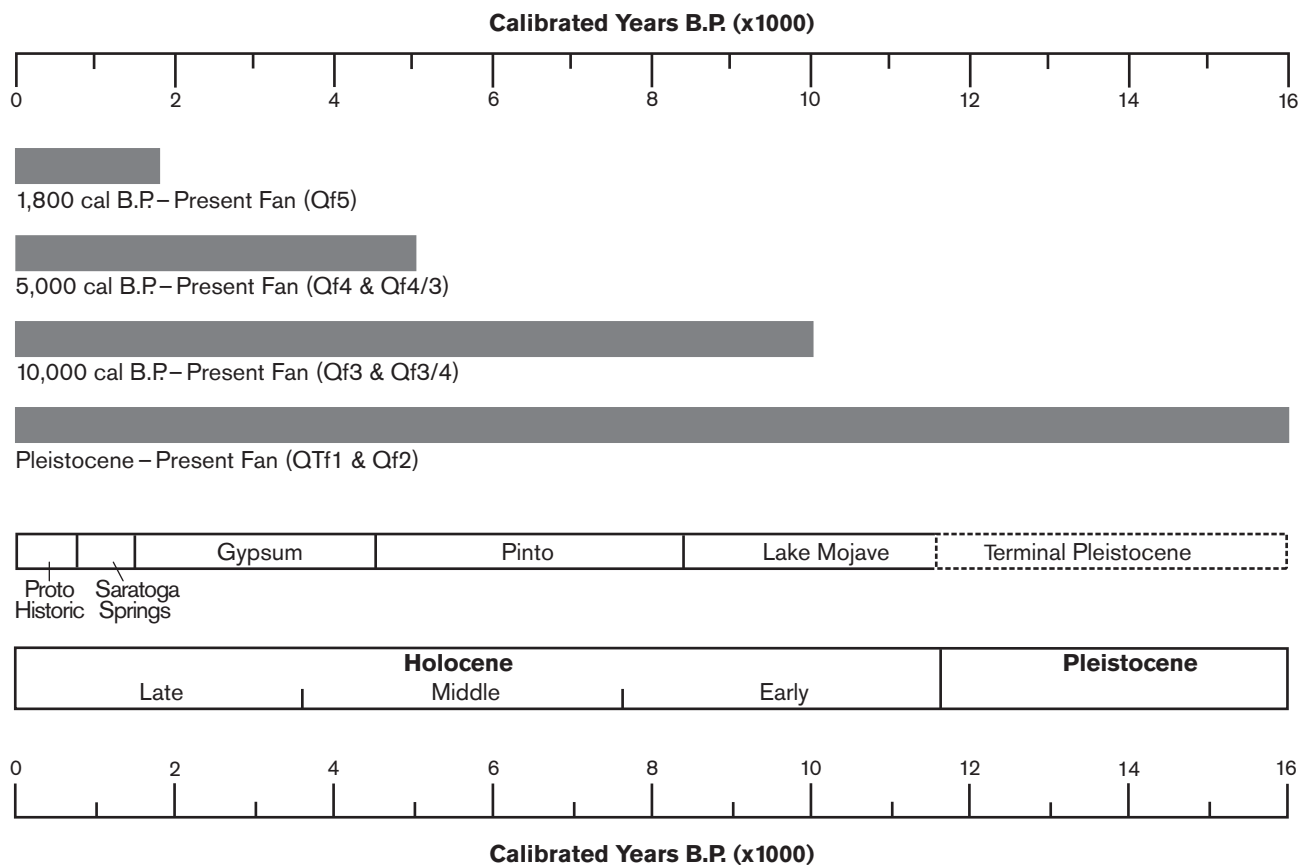


Figure 2. Map of dated alluvial fans within the study area.



**Figure 3.** Age/duration of stable alluvial fan surfaces within the study area.

and Qf4/3), volcanic/meta-volcanic quarrying was greatly diminished. In fact, it may have ceased altogether, given that the mapping resolution between Qf3 and Qf4 is problematic in certain parts of the project area.

The dominant use of basalt and other volcanic/meta-volcanic materials in archaeological assemblages dating to the early and middle Holocene at Fort Irwin is well documented (Basgall 1996, 2000; Basgall and Hall 1994a,

Hall and Basgall 1994); the pavement quarry data support this pattern unequivocally. The task remains, however, of further pinning down the temporal profile of CCS pavements; in this regard, the extent of relative patination can provide further insight. Patina forms primarily on the undersides of artifacts, and the degree of patina is conditioned by minerals in the source sediments, the length of exposure, disturbances, and artifact raw material.

**Table 3**

**THE FREQUENCY OF SRLS BY FAN UNIT AND MATERIAL TYPE**

Fan	Survey Area	Total CCS SRLs		Total Volcanic SRLs		Total	
		N	%	N	%	N	%
Pleistocene (QTf1-Qf2)	19.4	256	33.4	13	27.7	269	33.0
Early Holocene (Qf3 & Qf3/4)	27.2	309	40.3	32	68.1	341	41.9
Middle Holocene (Qf4 & Qf4/3)	28.2	199	25.9	2	4.3	201	24.7
Late Holocene (Qf5)	25.1	3	0.4	0	0.0	3	0.4
<b>Total</b>	<b>99.9</b>	<b>767</b>	<b>100.0</b>	<b>47</b>	<b>100.0</b>	<b>814</b>	<b>100.0</b>

**Note:** SRL, Single Reduction Locus; CCS, Cryptocrystalline Silicate; Volcanics include various basalts and meta-volcanic material.



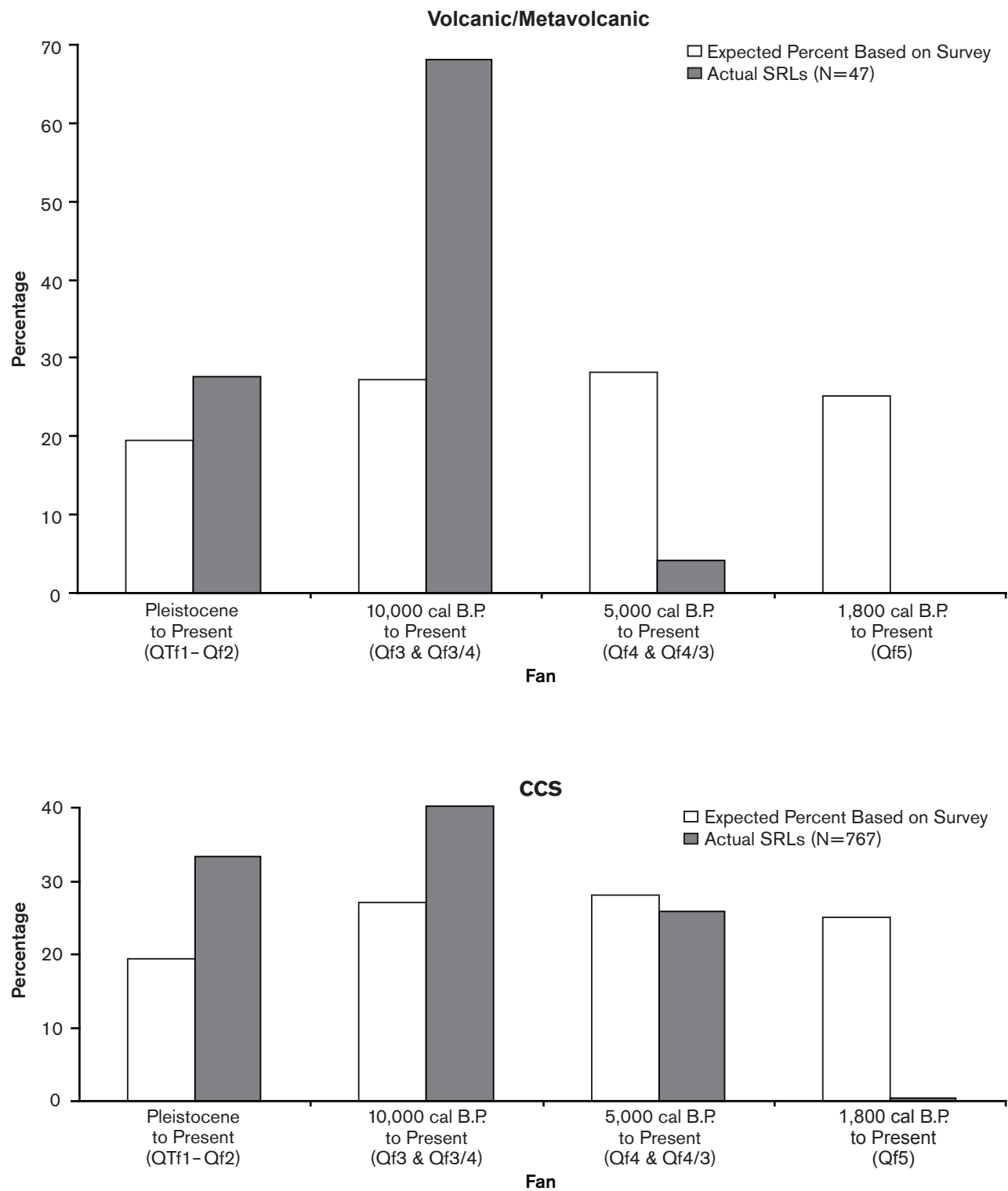


Figure 4. Observed and expected frequencies of SRLs by fan unit and material class.

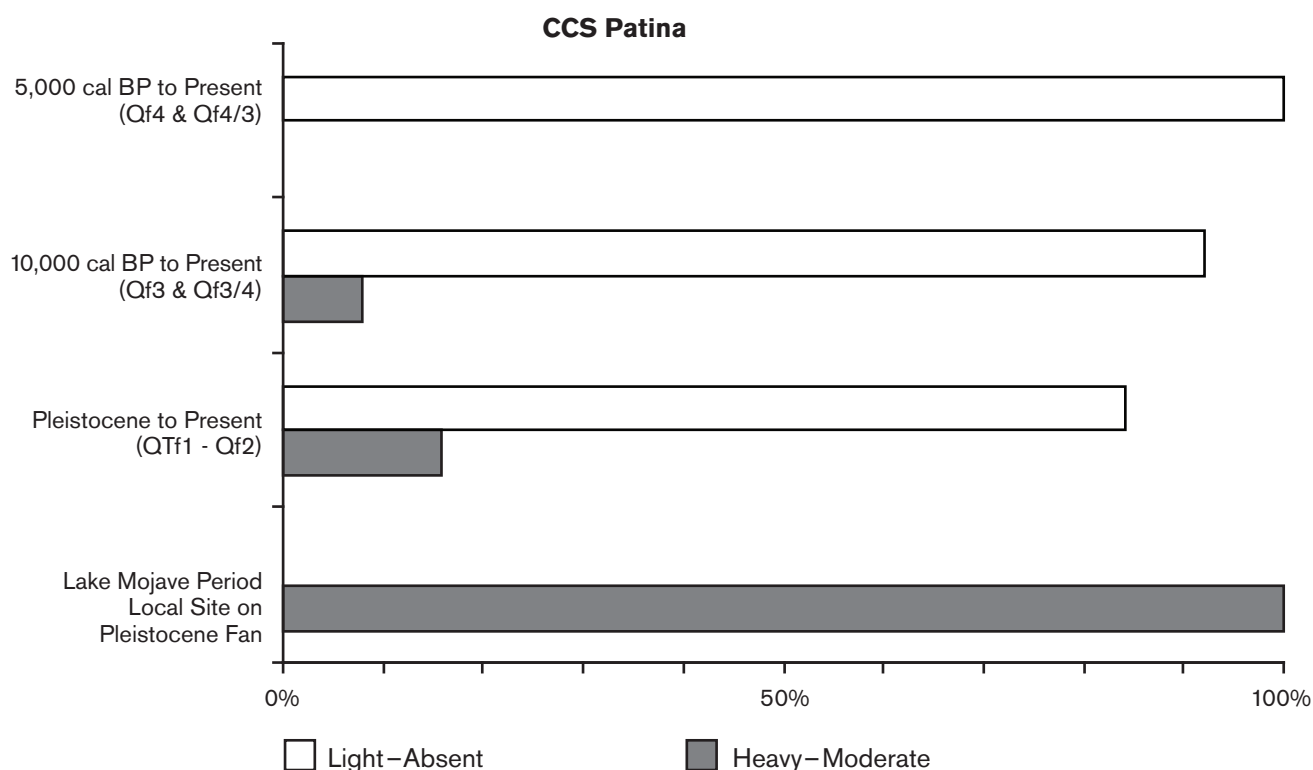


Figure 5. Relative patina frequencies at SRLs by fan unit and at Lake Mohave period components.

When source locality and raw material are held constant, then older artifacts generally have a heavier patina.

Two patina categories were developed for CCS—absent/light and moderate/heavy; their percentage frequencies on SRLs have been graphed across fan units, as well as at a series of occupation sites firmly dated to the Lake Mohave Period (Fig. 5). As might be expected, patina is either light or absent altogether on materials from SRLs found on the youngest fans in this sequence (Qf4 and Qf4/3, post-5,000 cal B.P.). Also as expected, patina is uniformly moderate to heavy on CCS materials from Lake Mohave sites firmly dated to the Early Holocene. What is interesting is the ratio of absent/light to moderate/heavy patina on SRLs identified on the oldest fan surfaces—QTf1-Qf2 and Qf3-Qf3/4. Both of these fan units are dominated by SRLs with absent/light patina. This suggests that most of the CCS pavement quarrying activity on these older landforms occurred after 5,000 cal B.P., resulting in an overall patina profile more similar to that documented on the younger, Qf4 and Qf4/3, fan surfaces.

If most CCS pavement quarrying activity occurred after 5,000 cal B.P. and ceased altogether at 1,800 cal B.P.,

it follows that this type of CCS toolstone procurement was predominately a Gypsum Period phenomenon.<sup>2</sup> Moreover, CCS SRLs outnumber their older volcanic/meta-volcanic counterparts by a factor of more than 16:1. This suggests that early Holocene pavement quarrying activity directed at volcanic/meta-volcanic toolstone was a much more limited affair compared to the explosion of CCS production that occurred in Gypsum times.

#### *The Role of Biface Production at Pavement Quarries*

The majority of CCS SRLs contain only debitage, revealing successful reduction events that typically resulted in the acquisition of a biface or a core (Table 4). Cores are well represented, followed by bifaces. Most cores represent rejections during initial unidirectional shaping or, less commonly, rejections during initial bifacial shaping. As such, many represent precursors to bifaces that terminated early due to failure. SRL bifaces are overwhelmingly early stage (also referred to as stages 1 and 2: 92.4 percent, n=163), with few middle stage bifaces (76%, n=10), and no late stage (4 or 5) bifaces. Overall, these patterns suggest initial biface reduction (through Stage 2) took place at quarry sites to

**Table 4****CCS SRL ASSEMBLAGE COMPOSITION**

Qf	With Bifaces	With Cores	With Bifaces and Cores	Debitage Only	Total
Pleistocene – Present (QTf1-Qf2)	10.6	28.1	1.9	59.4	160.0
10,000 cal B.P. – Present (Qf3 & Qf3/4)	3.8	25.8	4.8	65.6	209.0
5,000 cal B.P. – Present (Qf4 & Qf4/3)	7.1	40.6	5.2	47.1	155.0
1,800 cal B.P. – Present (Qf5)	0.0	66.7	0.0	33.3	3.0
<b>Total (%)</b>	<b>6.8</b>	<b>31.1</b>	<b>4.0</b>	<b>58.1</b>	<b>100.0</b>
<b>Total (n)</b>	<b>36</b>	<b>164</b>	<b>21</b>	<b>306</b>	<b>527.0</b>

Note: CCS – Cryptocrystalline Silicates.

ensure material suitability, decrease the likelihood of later reduction failure, and reduce mass for transport. Stage 3 and later reduction was carried out at more distant residential sites. This is consistent with the dearth of late-stage biface thinning flakes and discarded, exhausted tools (bifaces, points, or others) indicative of immediate retooling at SRLs.

### PAVEMENT QUARRIES AND GYPSUM PERIOD LIFEWAYS AT FORT IRWIN

How did these quarrying activities fit into larger regional land-use patterns? We explore this issue by delving into possible factors that conditioned the Gypsum-period spike in chert biface quarrying activities in the Avawatz area. In doing so, we place the Gypsum period of this portion of the central Mojave in a broader temporal and spatial context.

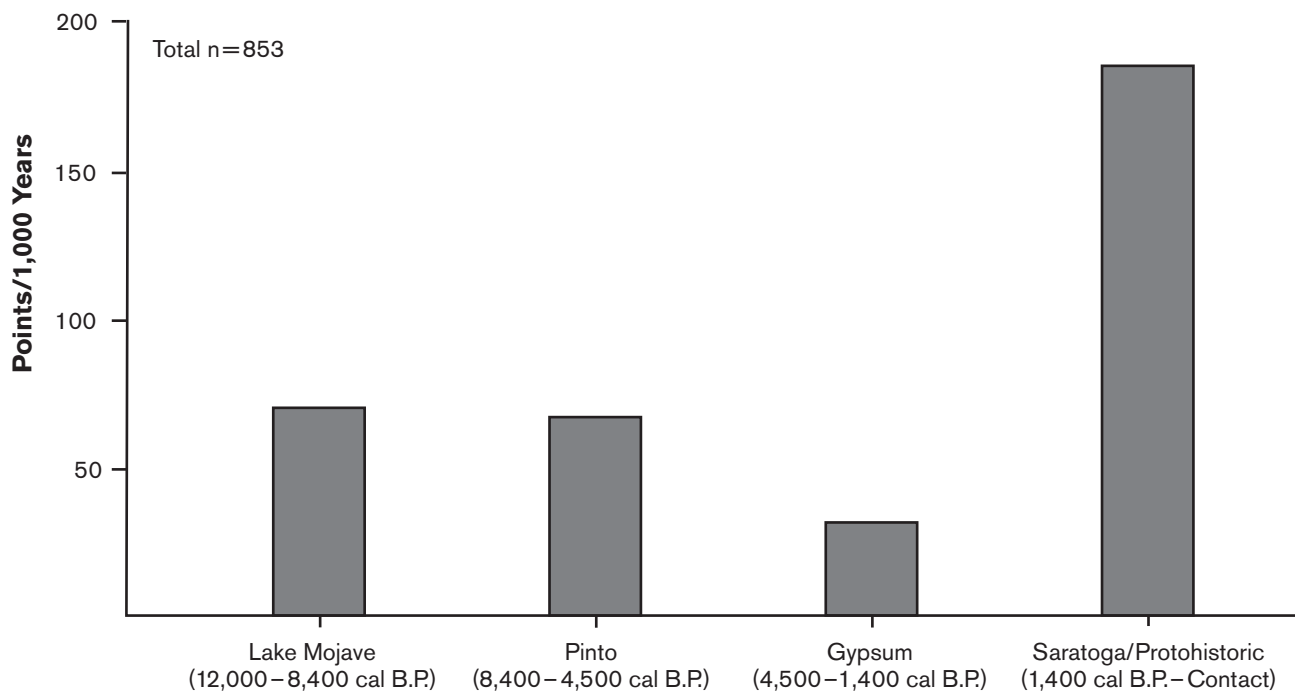
If it is possible to identify changes in prehistoric land use in the Mojave Desert, Fort Irwin is probably one of the better locations to do so, given the amount of archaeological study that has occurred there over the last three decades. As of 1994, nearly 700 of its 2,590 square kilometers have been subject to systematic survey. More than 600 sites have been recorded, and more than 200 locations have been excavated, involving more than 1,100 cubic meters of deposit (Basgall 2000:123). Fort Irwin thus has generated a large amount of assemblage data, at least in comparison to other regional geographic contexts. This effort has facilitated the development of series settlement and other land-use reconstructions.

Despite this level of study, the Gypsum period remains the most enigmatic at Fort Irwin, as well as in the

greater central Mojave Desert. Based on the findings of large-scale CRM-studies conducted at the facility in the early 1980s, Warren et al. (1984) characterized prehistoric occupation during this period as essentially non-existent. Later, and in many ways more comprehensive, survey and excavation programs conducted in the late 1980s and early 1990s (see summaries in Basgall 2000; Gilreath et al. 1987; Hall and Basgall 1994) succeeded in identifying somewhat more substantial evidence of occupation, while pointing out that occupations were both more sporadic and qualitatively different than those which pre- and post-dated this time period.

Moreover, this diminution of occupational intensity is paradoxical, given the fact that there is every indication that climate and local resource productivity improved with the onset of Neoglacial climatic conditions near the onset of the late Holocene (i.e., roughly the start of the Gypsum period; see Koehler et al. 2005; Wells and Anderson 1998). While the basic structure of the Mojavean floristic regime may not have changed drastically, there can be little doubt that increased spring discharges, more frequent episodes of high water in local basins, and greater riparian production, to name but a few possible benefits, were more favorable for human habitation than were conditions during the preceding mid-Holocene warm period. A fundamental re-organization of land use seems to have taken place at this time; the evidence is reviewed below.

With respect to indices commonly used to measure occupational intensity, there seems little doubt that Gypsum period occupation was comparatively more sporadic and ephemeral. As displayed in Figure 6, the time-adjusted frequency of projectile points dating to



**Figure 6. Fort Irwin projectile point frequency by time period (points/1,000 years; see Basgall 2000).**

this time reach their lowest Holocene levels—in some instances lower by several orders of magnitude. The trend is repeated for base-wide radiocarbon dates; only 8% (total sample = 59) of assays fall into the Gypsum period, and most of these at the very recent end of this time span (Gilreath et al. 1987:88–92). This latter trend is consistent with reductions in milling, plant processing, and residential activity.

This diminution of archaeological visibility and implied reduced occupational intensity, however, does not appear to be simply a throttling back of an otherwise static Holocene desert land-use pattern. In fact, it appears tied to fundamental shifts in settlement strategies and work organization corresponding to the Gypsum period. The initial evidence for this is found in the comparative frequencies of milling equipment (millingstones and handstones) represented at Fort Irwin for each of the major time periods (Fig. 7). The presence (or absence) of milling equipment is particularly sensitive to resource patch, site function, work and gender organization, and residential patterns.

As can be seen, the accumulation of milling tools during the Gypsum period at Fort Irwin was substantially diminished. If one assumes milling equipment is generally

an indicator of women who are plant processing and foraging, and that where it occurs with a range of other artifact classes some degree of residential behavior can be inferred, then it stands to reason that reduced amounts of milling gear imply reduced residential activities. As such, these types of uses may have been less frequent at Fort Irwin during the Gypsum period.

What, then, were Gypsum-period folk doing on Fort Irwin? A more detailed review of the composite assemblage structure at Fort Irwin sites using tool class/frequency profiles provides several clues (Fig. 8). The bar graphs in this figure display the percentages of major stone tool classes represented in archaeological components dating to each of the three main periods. A review of these artifact profiles reveals that Pinto and Saratoga Springs/Protohistoric composite assemblages tend to be more evenly balanced among major artifact classes. Conversely, the Gypsum composite assemblage appears to be much more specialized, dominated by one major artifact type, namely bifaces. These differences are statistically significant for both the Gypsum versus Pinto assemblages ( $\chi^2 = 211.2$ ;  $p < 0.0001$ ), and the Gypsum versus Saratoga Springs/Protohistoric assemblages ( $\chi^2 = 286.2$ ;  $p < 0.0001$ ). It is in this sense that the



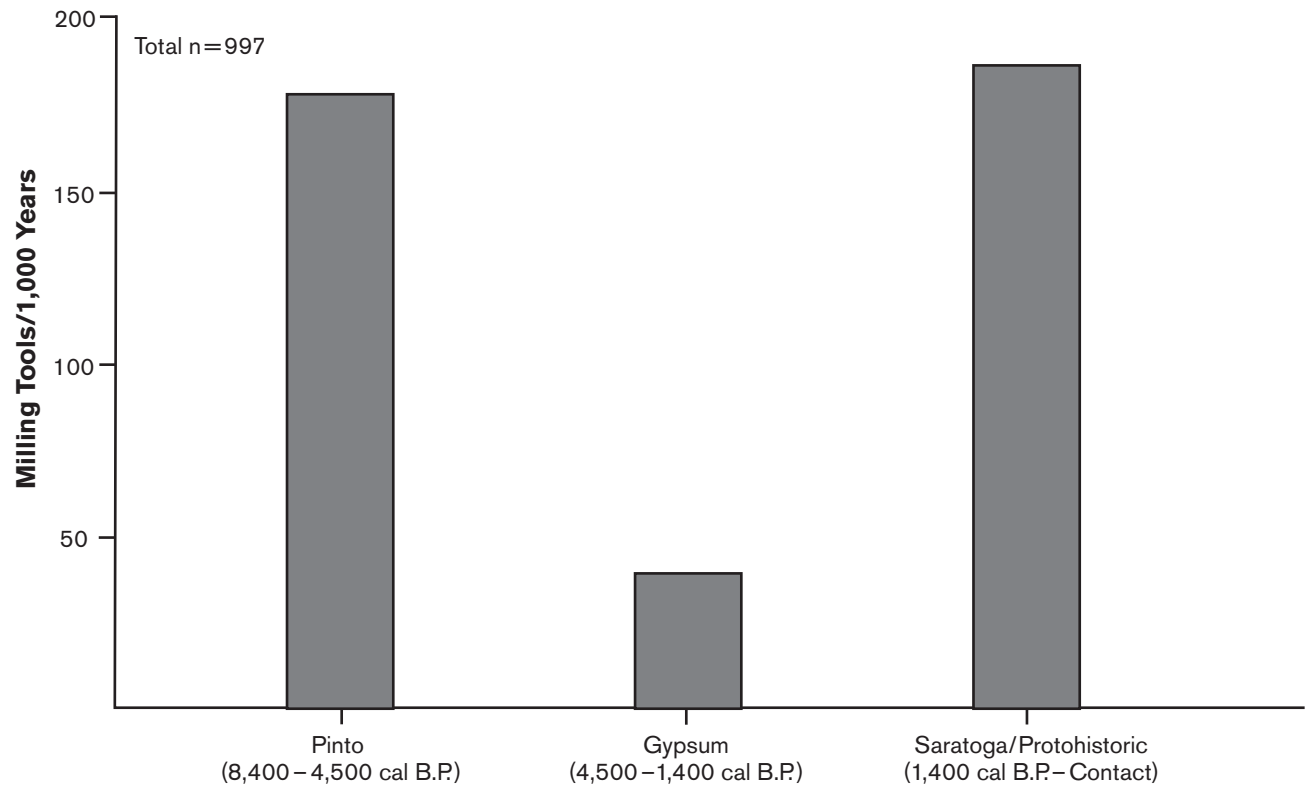


Figure 7. Fort Irwin milling tool frequency by time period (tools/1,000 years; see Basgall 2000).

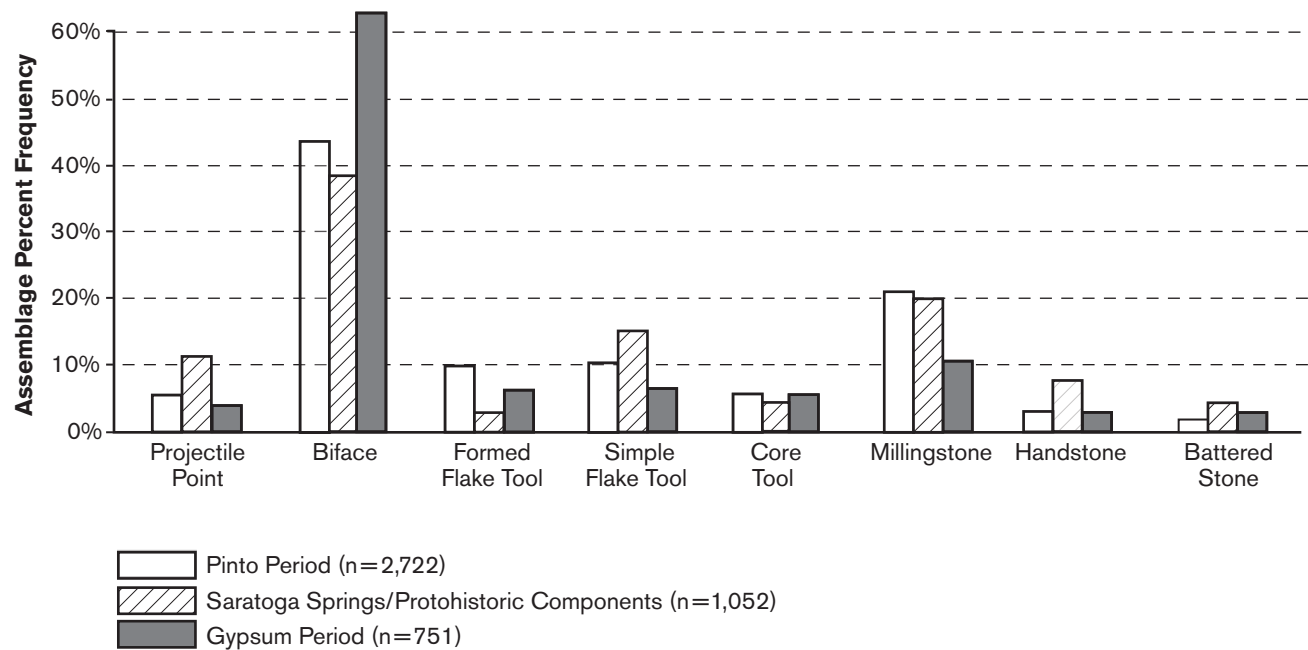


Figure 8. Fort Irwin assemblage structure by time period (see Basgall 2000).

explosion of biface production at pavement quarries witnessed during the Gypsum period ties in to the overall assemblage structure for this same time period at sites observed across Fort Irwin.

### **A MODEL OF TRANS-HOLOCENE LAND-USE IN THE MOJAVE DESERT**

We started this discussion by suggesting that an understanding of pavement quarries, when combined with other assemblage data, might help us unravel several competing perspectives on trans-Holocene land-use in the Mojave Desert, in which an understanding of the Gypsum period proves crucial. On the one hand, Basgall and Hall (1993, 1994b; see also Basgall 1996, 2000; Basgall and McGuire 1988; Bettinger 1999; Bettinger and Baumhoff 1982) suggest that Gypsum-period deposits were formed by a generalized, residentially mobile pattern of land use. They argue that this reflects a wide-ranging settlement system similar to that of earlier periods, albeit geared to short-term occupation of generalized areas rather than specific locations. By contrast, McGuire and Hildebrandt (2005; Hildebrandt and McGuire 2002; McGuire et al. 2007) argue that the Gypsum period may actually represent the trans-Holocene highpoint of residential stability in the Great Basin and Mojave Desert, bracketed by earlier and later foragers exhibiting greater residential mobility.

Let us begin with an analysis of those periods that bracket the Gypsum period. We interpret the comparatively more heterogeneous composite assemblages typical of the Pinto period as representative of a settlement system characterized by relatively brief, generalized occupations by small, residentially mobile, band-like foragers. This would tend to produce a series of redundant assemblages reflecting the eclectic foraging efforts of both men and women (see Fig. 8 and discussion above). Similar assemblage profiles dating to this time have been observed elsewhere in the Mojave Desert (Delacorte 1999:359–389) and the wider Great Basin (McGuire et al. 2004:125). Of course, differences in the composition of Early Holocene assemblages have been noted in certain contexts. For example, both short-term general-use camps and specialized logistical camps dating to the Early Holocene have been documented at China Lake (Eerkens et al. 2007; Rosenthal and

Eerkens 2003). Similarly, Early Holocene sites near Red Pass represent small, short-term residential camps that differ significantly from contemporaneous larger, longer-term residential sites in the uplands of Fort Irwin (Byrd and Berg 2007).

Although different in several important ways, a similar profile re-emerges in Saratoga Springs/Protohistoric components at Fort Irwin. In this latter case, although there may be important differences between Saratoga Springs and Protohistoric lifeways, these foragers may bear some similarity to the family bands described for Numic groups by Steward (1938), among others. While potentially much more territorially restricted, the Numic pattern is also characterized by a series of residential moves by small family units consisting of men, women, children, and perhaps several other relatives. Again, we would expect—and indeed we find—that such a land-use pattern would produce relatively heterogeneous, albeit relatively redundant, component assemblages. Note that Eerkens (1999) has suggested some Protohistoric land use may have entailed seasonal forays by populations based well outside Fort Irwin. These groups may have had artifacts with distinctive stylistic forms and geochemical signatures indicative of their home bases.

By contrast, and as we have previously reviewed, bifaces dominate the Gypsum composite assemblage, with reduced levels of other artifact classes—particularly milling equipment that might indicate more generalized and possibly more gender-balanced residential activities. This focus on bifaces and flaked stone reduction has been noted by other researchers, and appears to have involved a switch to cryptocrystalline source materials, as well as a more systematic reliance on biface thinning and pressure flaking manufacturing techniques (Hall and Basgall 1994:82–94). The net result is that many Gypsum components also are characterized by comparatively high concentrations of reduction debris. Hall and Basgall tie this, as well as other data, to a geographically expansive land-use pattern, albeit one that they characterize as “residentially mobile.” But as we have argued above, there is every reason to believe that both settlement intensity and residential activity were substantially reduced throughout Fort Irwin during the Gypsum period.

Gypsum assemblages at Fort Irwin are decidedly specialized, and this specialization revolves around

bifacially flaked stone tools and their manufacture. This emphasis on biface production has been observed at a number of obsidian quarries where production increased during the late Gypsum period (Gilreath and Hildebrandt 1997:180–181; Hildebrandt and McGuire 2002:239–243). At the Coso Volcanic Field at China Lake, primary flows were more heavily utilized than lag deposits during this time frame (Gilreath and Hildebrandt 1997). Increased obsidian production during the late Gypsum period was focused on bifaces, as evidenced by the presence of numerous nearby sites with extensive biface reduction debris. Significant quantities of the resulting obsidian bifaces were then traded to coastal southern California, the Owens Valley, and the southern Sierra Nevada.

The rise of pavement quarries at this time appears to be part of this specialization. Insofar as the majority of the flaked stone tools were used to both procure and process game, subsistence emphasis appears to have been placed on hunting. Along these lines, there is some archaeological evidence from Fort Irwin that large game procurement may have increased somewhat during the Gypsum period (Basgall et al. 1988:311–312; Warren et al. 1984; see also Hildebrandt and McGuire 2002). Coupled with the documented artistic/ceremonial focus on large game at this time—inferred from nearby sites such as Newberry Cave (Davis and Smith 1981), Coso-style rock art sites in Petroglyph Canyon (Fort Irwin), and elsewhere in the Mojave Desert (Gilreath and Hildebrandt 2008)—it is likely that both the subsistence and symbolic dimensions associated with the hunt were important to Gypsum populations. This emphasis raises the possibility that much of the Gypsum Period archaeological record at Fort Irwin reflects the residues of logistically-organized hunters pursuing game and acquiring toolstone as a part of travel to distant resource patches. Such long-range logistical forays by Gypsum period hunters into what was effectively a buffer zone may have been more pervasive during periodic brief intervals of increased precipitation when large game populations increased (see also Eerkens et al. 2008).

Evidence for the rise of logistical hunting at this time has been observed elsewhere in California and the Great Basin (Hildebrandt and McGuire 2002, 2003; McGuire and Hildebrandt 1994, 2005; McGuire et al. 2007). In this view, the high mobility associated with Gypsum settlement patterns may more accurately reflect long-range logistical

(as opposed to residential) activity practiced by male hunters. But travel to these distant patches was often very costly with regard to time, energy, and technological investment, and required a great deal of skill. Relying on a theoretical framework rooted in human behavioral ecology, these researchers argue that these seemingly inefficient types of behaviors can establish themselves, as long as these behaviors communicate a series of underlying qualities—physical strength, cognitive skills, leadership abilities, generosity—that are of interest to potential mates, allies, and competitors. In this way, the sharing of prestige goods by certain male hunters with non-kin members of their group may have led to increased mating opportunities and a variety of other social benefits (see Bird et al. 2008; Bliege Bird and Bird 2008; Bliege Bird and Smith 2005; Bliege Bird et al. 2001; Hawkes and Bliege Bird 2002; Smith et al. 2003).

Prestige, however, cannot feed people; thus, it is presumed that intensified provisioning efforts aimed at other resources underwrote this system (McGuire and Hildebrandt 2005; Zeanah 2004). The settlement anchors for these logistical hunting forays may have been larger, seasonally occupied base camps, their location conditioned more by the foraging efforts of women, the elderly, and children (see also Zeanah 2004).

In this view, almost all of Fort Irwin would qualify as a marginal hinterland, at least compared to the adjacent Mojave River Valley. It appears more likely that major base camps would have been concentrated within the latter or at other sweet spots such as the Mojave River, perennial springs, and mesquite groves that could sustain longer seasonal stays and support an intensification in the use of plant and small animal resources. Hinterlands, such as most of Fort Irwin, would have been the domain of periodic longer-range logistical forays, many of which would have been hunting-focused, with more limited residential activities resulting in overall reductions in archaeological visibility.

The one exception to this visibility argument is, of course, the remarkable increase in CCS pavement quarries during the Gypsum period. But this pattern is wholly consistent with a toolstone procurement strategy embedded within a long-distance logistical procurement system, fueled by increasing demand for hunting weaponry fashioned from high-quality CCS bifaces. Lacking the point-source exposures of high-quality CCS or obsidian

in primary geological context typical of other regions, pavement quarrying embedded within a long-range logistical round may have been the only means to increase lithic production. It is no surprise that pavement quarries in the Avawatz area are concentrated along the only two east-west travel corridors that link Fort Irwin with the Silurian Valley/Mojave Sink and more easterly localities.

The question remains, however, as to where these putative Gypsum period residential camps—those from which long-distance hunters were accessing the hinterlands of Fort Irwin—were actually situated. Here, the record is less clear, as candidate sites have yet to be identified in potentially productive habitats adjacent to Fort Irwin, such as along the Mojave River. It is also always possible that additional investigations on Fort Irwin may one day reveal the presence of major Gypsum period habitation sites. More intensive investigations at major springs, some of which have had limited fieldwork, may document significant Gypsum-age midden deposits.

However, a number of large, Gypsum period base camps have been identified in the wider Mojave Desert. For example, Wallace identified a series of large settlements located along a dry lake margin at Mesquite Flat (Death Valley) that contained a profusion of Elko-series projectile points and other flaked stone artifacts, hearths, and mortars and pestles (Warren 1984:386). At Surprise Spring, the one major extant spring on the Twentynine Palms military installation, initial test excavations have revealed a large complex of midden deposits, surface and subsurface features, a broad array of flaked, ground, and battered stone implements, and abundant faunal remains (Basgall 2003:34). The most intact and securely dated of these deposits appears to be primarily of Gypsum age. At Lovejoy Springs east of Palmdale, Price et al. (2005) describe a major village site that exhibits a midden several meters thick, a cemetery, hearth features, and a range of flaked and ground stone artifacts; the authors characterize the site as a “notable example of the Gypsum-era development of semi-sedentary settlement.” Elsewhere in the western Mojave Desert, Sutton (1996) has described the rise of “village” settlements at about 1,600 cal B.P. at Koehn Lake, or toward the latter end of the Gypsum period. Similar late-dating Gypsum encampments have been described for Owens Lake (Basgall and McGuire 1988; Byrd and Hale 2003) and Coso (Byrd and Reddy 2004;

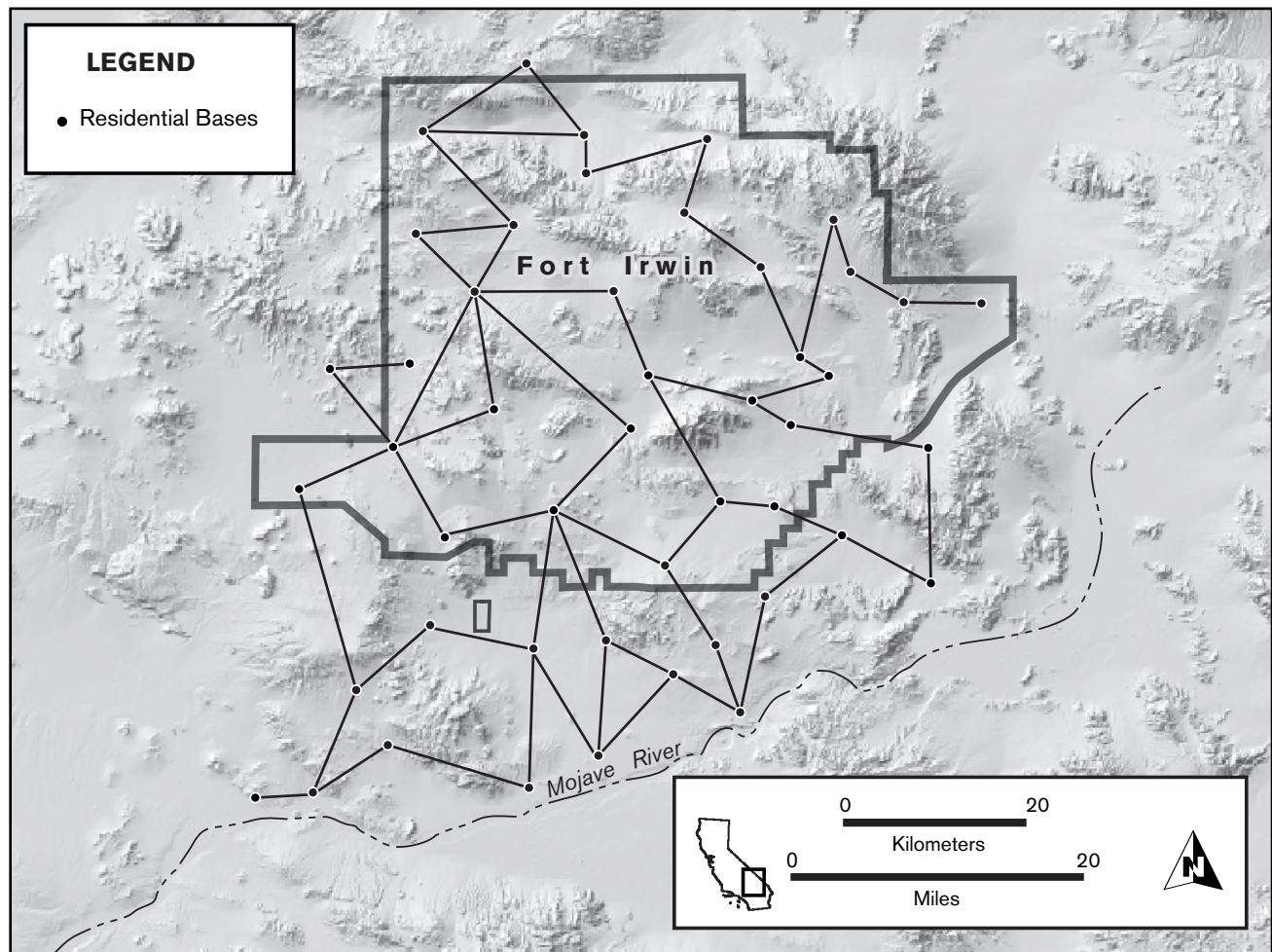
Whitley et al. 1987). Although by no means exhaustive, these examples suggest a substantial, Mojave Desert-wide, Gypsum period residential pattern strategically positioned near key resource tracts.

We are not advocating, however, the idea that Fort Irwin was entirely the domain of logistical hunters during this time. It is clear that it sustained some level of more generalized and presumably gender- and age-balanced residential occupation, as indicated by the presence of some millingstones and handstones in some Gypsum components (Basgall 2000:131). However, the frequency of these tools reaches their lowest average levels in sites during this time of any post-early Holocene time period. This compares with results elsewhere in the Mojave Desert, where (as for example at China Lake Basin) Gypsum components are limited to mostly hunting-related flaked stone tools and biface thinning debris, and are virtually devoid of milling and processing tools characteristic of more generalized residential use (Rosenthal et al. 2001). As pointed out by others (e.g., Binford 1983), residential and logistical land-use patterns exist along a continuum even within a single social group, and most certainly as measured through centuries of archaeological time (during which fluctuations in land use undoubtedly varied due to varied environmental and social factors). We simply argue that the Gypsum period in the Mojave Desert may have been more logistically oriented than earlier and subsequent periods.

## DISCUSSION

It is noteworthy that the most substantial records of prehistoric occupation at Fort Irwin and certain areas elsewhere in the Mojave Desert were produced by what most researchers have identified as small, residentially mobile foraging groups. This extensive, low-bulk foraging strategy simply may have been the default settlement pose assumed by desert foragers for most of the Holocene, including both an early/middle Holocene manifestation and late prehistoric variant. While lifeways reflective of these time periods clearly differed in several fundamental respects, each was probably better suited to respond quickly to certain types of seasonal spatial and temporal variations in desert resources by moving entire residential aggregates to productive resource patches. Figure 9 provides a schematic representation of a Lake





**Figure 9. Schematic representation of Lake Mojave/Pinto period settlement patterns at Fort Irwin.**

Mojave-Pinto settlement system that shows how such a land-use pattern may have worked in the Fort Irwin area. Saratoga Springs/Numic land-use systems (not illustrated) may not have been much different, but were probably less territorially expansive and targeted perhaps a different profile of resources.

By contrast, Gypsum populations were tethered to larger, more centrally located base camps (Fig. 10). Their use of hinterlands, such as Fort Irwin, was mostly restricted to long-distance logistical forays, thus reducing their residential footprint. This is not to say that there was a reduction in populations during the Gypsum period, only that people's use of desert landscapes fundamentally changed.

And it is in the context of this change that we come full-circle, back to the humble pavement quarry. Their newly delineated temporal and functional parameters

provide a coherency to the wider land-use changes that marked the Holocene in the Mojave Desert. This form of toolstone production appears to have been embedded in the long-range logistical systems that were in ascendance during the Gypsum period. With this temporal control, the missing or attenuated archaeological record of this time period is suddenly more robust, and a "static" desert culture appears much more dynamic.

## NOTES

<sup>1</sup>Mapping included qualitative and quantitative measures of surface morphology, depositional features, general lithology, and topographic position. This information was then used in conjunction with aerial photo information to choose type-sections for detailed field description.

Type sections (profiles) were chosen from each of the mapped units on the southern Avawatz piedmont. Sample sections were representative of the lithology, fan structure, and

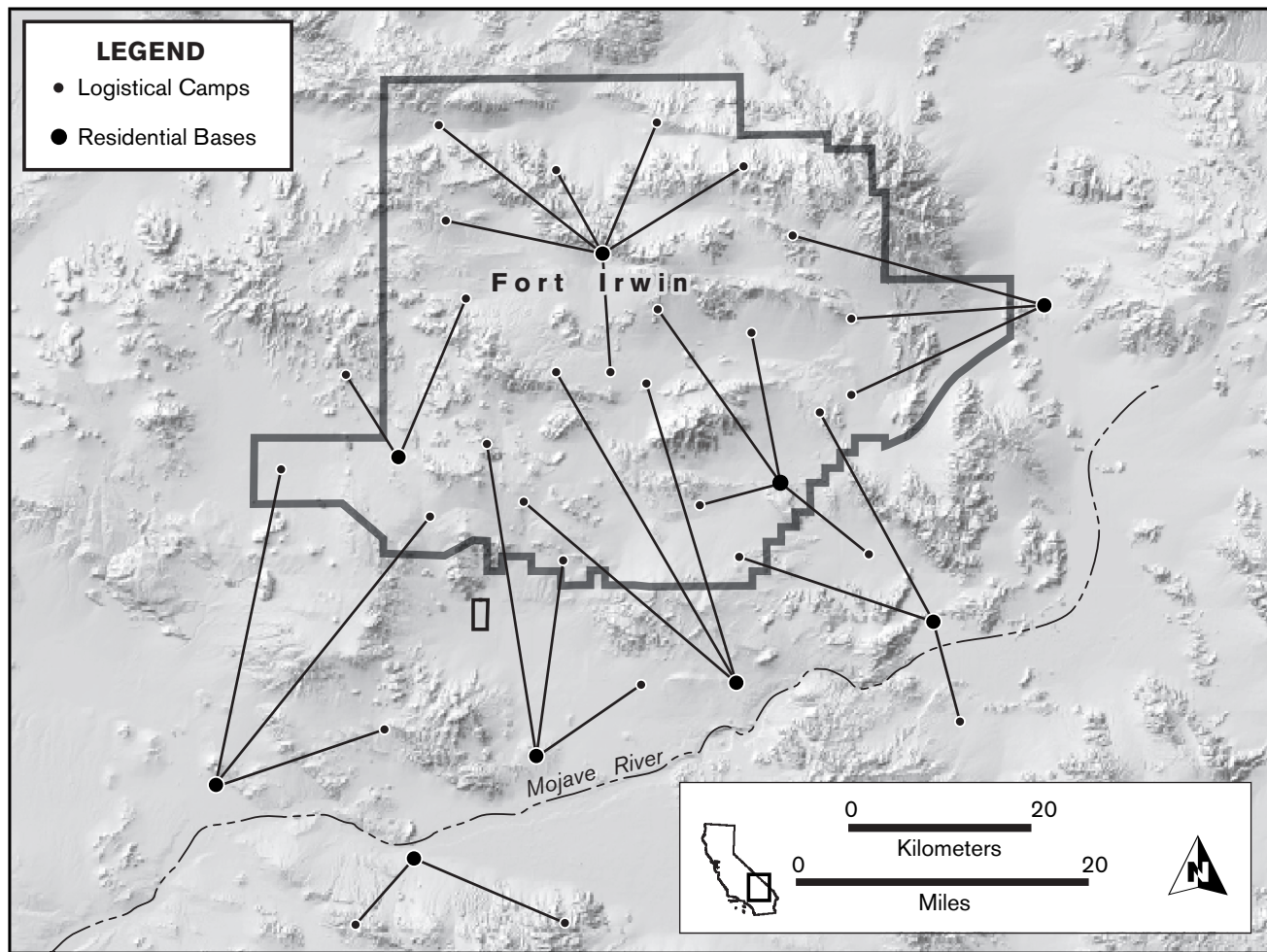


Figure 10. Schematic representation of Gypsum period settlement patterns at Fort Irwin.

soil-formation processes for each mapped unit. Sections were described according to the field guidelines established by the Soil Survey Staff (2003); digital photographs accompanied all section descriptions. Type sections also were described in locations that provided organic residues, charcoal, wood fragments, or other materials suitable for radiometric dating. Other locations of interest or showing particular geomorphic events, including natural exposures near archaeological sites, were also fully described. A total of ten type sections were described for locations with relatively even distribution throughout the project area.

Type sections were used along with general stratigraphic and morphological descriptions from landform mapping to derive a suite of characteristics that substantiate the detailed chrono-stratigraphic relationships across the project area. They assisted in the development of a preliminary map of chronologically segregated surfaces that provided contextual information during the in-field evaluation of archaeological sites discovered during inventory. Geomorphic surfaces were compiled in a GIS layer that depicts the mapped units by time.

Chronological control of depositional events and of time-transgressive processes such as soil formation and pavement

development was critical to defining the stratigraphic relationships between fan surfaces. Topographic and stratigraphic superposition data were first used to develop a relative landform chronology. However, absolute chronological relationships provided by radiometric methods, such as radiocarbon dating, increased the resolution of stratigraphic and spatial relationships. Samples were collected for radiocarbon dating from *in situ* organic residues, packrat middens built on alluvial fan cuts, charcoal, and other suitable materials whenever possible. A total of eight samples were processed for analysis.

<sup>2</sup> It is possible, but considered unlikely, that the majority of CCS reduction could have happened between 4,500-5,000 years ago, and would not technically have been Gypsum period. However, it should be emphasized that the start of the Gypsum period around 4,500 years ago is a coarse-grained approximation based on existing radiocarbon dates. Given the current level of temporal resolution for both the Qf4 fan formation and the onset of Gypsum period archaeological sites, we consider our interpretation of the timing of archaeological and geological events to be consistent with all available temporal data.



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