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Terminal Pleistocene-Early Holocene Spatio-Temporal and Settlement Patterns Around Pluvial Lake Mojave, California

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Multiple lines of evidence are used to establish terminal Pleistocene-early Holocene (TP-EH) spatio-temporal patterns and settlement strategies around pluvial Lake Mojave, California. Pedestrian surveys and in-field lithic analyses at an area of ancient shorelines as well as an alluvial fan adjacent to Soda Lake provide new insights regarding the role Lake Mojave played in the regional settlement system. Surface lithic scatters identified along the Lake Mojave shoreline form three spatially separated, dense artifact bands that follow the ancient shorelines and reflect a time-transgressive shift in habitation closer to the receding water-level. Analysis of surface lithic artifacts from an alluvial fan indicates the manufacture of pre-5,000 cal B.P. felsite bifacial and unifacial implements. Despite evidence for a palimpsest of lithic assemblages in each survey area, we conclude that the underlying TP-EH spatial and temporal patterns remain largely intact and representative of early human technology and settlement strategies around Lake Mojave.

Pluvial Lake Mojave[1] (modern day Soda and Silver Lake playas), in California's eastern Mojave Desert (Fig. 1), is one of the many pluvial lakes dotting the intermountain western United States whose shorelines were inhabited by terminal Pleistocene and early Holocene (TP-EH) foragers. Lake Mojave became an early hub of archaeological interest (Antevs 1937, 1952; Campbell 1936; Campbell et al. 1937; Davis 1967; Rogers 1939; Warren and De Costa 1961; Warren and Ore 1978) because of the rich archaeological record that formed along its shorelines and on adjacent alluvial fans, with research continuing to this day (Knell 2014; Warren and Schneider 2003). Early foragers repeatedly visited Lake Mojave because it had potable water, aggregated floral and faunal resources, and fine-grained volcanic (FGV) quarries, which resulted in the many surface chipped-stone artifact scatters found today. Though researchers have long studied these surface scatters, the current analyses provide new insights regarding the spatio-temporal and—ultimately—settlement patterns around Lake Mojave. To reconstruct these patterns, pedestrian surveys and in-field lithic analyses were undertaken along the east shoreline of Soda Lake near Little Cowhole Mountain, and on an alluvial fan of the Soda Mountains on the west side of Soda Lake (Fig. 1).

Like our predecessors (e.g., Warren and De Costa 1961; Warren and Ore 1978; Warren and Schneider 2003),

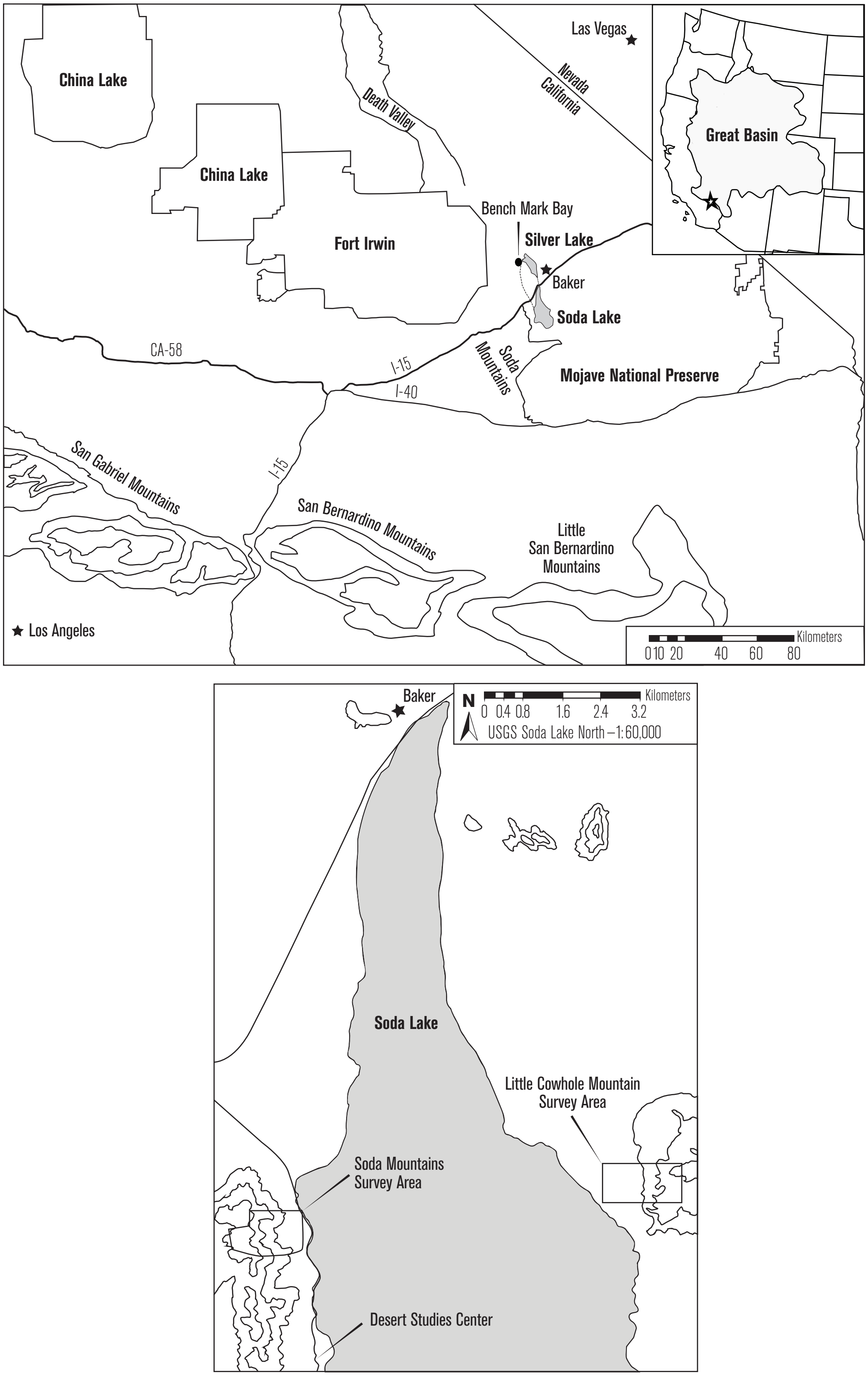


Figure 1. (Top) Overview of the central and eastern Mojave Desert and environs, including the location of key lakes, cities, mountains, roads, and government managed lands noted in the text. (Bottom) Map of Soda Lake depicting the location of the Little Cowhole Mountain and Soda Mountains survey areas. Adapted from Knell (2014).

we struggle with understanding the age of the surface archaeological expressions around Lake Mojave due to impacts by erosion, reoccupation, and past collection of temporally diagnostic artifacts by archaeologists and collectors. In this study, we attempt to establish a relative age sequence of these artifact concentrations using multiple lines of geological and archaeological evidence, including dated shorelines and alluvial fans, temporally diagnostic projectile points and lithic raw material types, variations in lithic technology, and patina and weathering. The results of this study ultimately provide justifiable relative ages for the surface scatters, and important insights regarding TP-EH settlement and land use strategies around Lake Mojave.

SODA LAKE STUDY AREA

Lake Mojave covered 300 km.^{2} and held more than 7 km.^{3} of water at its late Pleistocene maximum, though early Holocene drying between 10,500 and 9,600 cal B.P.[2] led to the creation of the modern Soda and Silver Lake playas (Wells et al. 2003). The Soda Lake study area is in the northwestern corner of the Mojave National Preserve in San Bernardino County (Fig. 1). Baker, the nearest town, is about 10 km. north of the Little Cowhole Mountain and Soda Mountains survey areas.

Two pedestrian survey areas were established around Soda Lake (Fig. 1). The 1.29 km.^{2} Little Cowhole Mountain survey area includes the western edge of Little Cowhole Mountain (a low elevation [500 m. asl], isolated mountain on the east shoreline of Soda Lake) and the TP-EH age shorelines that formed between the 287 and 285.5 m. contours west of Little Cowhole Mountain. The 0.83 km.^{2} Soda Mountains survey area includes the north-south trending Soda Mountains (~1,000 m. asl) and its alluvial fans, which enclose Soda Lake on the west. The Soda Mountains underwent an episode of deformation during the Mesozoic era that created the FGV-bearing Soda Mountain formation, which has major bedrock and secondary exposures of knappable black and green felsite in the survey area (Grose 1959:1526; Walker and Wardlaw 1989:1580). The Soda Mountains survey area includes part of a quarry/workshop complex with 14 bedrock quarries, workshops, and lithic scatters (Knell 2014).

PRIOR RESEARCH

Lake Mojave Shoreline Chronology

Researchers have long attempted to establish spatio-temporal patterns for the shorelines and surface artifact scatters on the shorelines around Lake Mojave (see Warren et al. 1980 and Byrd et al. 2010 for thorough historical sketches), with the earliest period of research occurring between the 1930s and 1960s (Antevs 1937, 1952; Bode 1937; Brainerd 1953; Campbell et al. 1937; Rogers 1939; Wallace 1962; Warren and True 1961). This research culminated in the work of Warren and True (1961), who provided specific elevations for the beaches, bars, terraces, and spits that formed around Lake Mojave. However, these early researchers could only estimate the age of the shorelines (e.g., Antevs 1937, 1952; Wallace 1962). In the 1960s–1970s, the addition of radiocarbon-dated organic material (*Anodonta* shell; Hubbs et al. 1962) from the shorelines helped establish our modern understanding of the shoreline sequence (see Ore and Warren 1971 and Warren and Ore 1978).

Our current understanding of when and at what elevation the shorelines formed around Lake Mojave has advanced over the last 20 years or so (e.g., McFadden et al. 1992; Owen et al. 2007; Warren and Schneider 2003; Wells et al. 1987, 2003). Following Wells et al. (2003; see Table 1), Lake Mojave filled before 27,000 cal B.P. and episodically flooded until 21,900 cal B.P. (Intermittent I phase), causing the lake level to intermittently drop and rise in elevation. The lake level stabilized when pluvial conditions returned from 21,900–19,750 cal B.P. (Lake Mojave I phase), during which Lake Mojave more consistently filled to its maximum elevation (288–287 m.) and created the A-shoreline. Episodic flooding returned during Intermittent phase II (~19,750–16,850 cal B.P.), with the 287 m. or A-shoreline reached occasionally. Pluvial conditions and lake level stability resumed during the early part of the Lake Mojave II phase (16,850–13,850 cal B.P.) when the water level fairly consistently reached the 287 m. shoreline. This was followed by repeated episodes of flooding that down-cut the outlet spillway leading north to Silver Lake, which lowered the water level to the 285.5 m. contour or B-shoreline by the late Lake Mojave II phase (13,850–13,250 cal B.P.). Drier conditions prevailed after 13,250 cal B.P. (Intermittent

Table 1

SUMMARY OF WELLS ET AL. (2003) PHASES, DATES, AND SHORELINE ELEVATIONS FOR LAKE MOJAVE

Phase	Date (^{14}C B.P.)	Date (cal B.P.)	Shoreline Letter[a]	Shoreline Elev. (m.)	Summary
Intermittent III	11,400–8,700	13,250–9,600	B	285.5	Episodic flooding; playa lake at end of phase
Lake Mojave II	13,700–11,400	16,850–13,250	A & B		Pluvial period; persistent high lake stands; high precipitation and annual large floods; lake less filled than Lake Mojave I
	12,000–11,400[b]	13,850–13,250	B	285.5	Lake persistently filled, but at lower level than earlier in Lake Mojave II and Lake Mojave I; most shoreline features evident today are from this period as older shorelines have eroded
	13,700–12,000[b]	16,850–13,850	A	287.0	Period of down-cutting from A to B shoreline; lake at highest level during Lake Mojave II
Intermittent II	16,600–13,700	19,750–16,850	A	287.0	Episodic flooding
Lake Mojave I	18,400–16,600	21,900–19,750	A	288–287.0	Pluvial period; persistent high lake stands; high precipitation and annual large floods
Intermittent I	<22,600–18,400	<27,300–21,900	A	287.0	Episodic flooding

Note: data from Wells et al. (2003) and Harvey et al. (1999:261).

[a] = corresponds with letter designations in Wells et al. (2003).

[b] = subphases within Lake Mojave II extrapolated from Wells et al. (2003).

III phase), and by 9,600 cal B.P. Lake Mojave had transformed into the playa lake it is today.

Establishing the age of the archaeological surface scatters along the shorelines of Lake Mojave is complicated by repeated occupations and the resulting palimpsest of artifact assemblages. Warren and coauthors (Ore and Warren 1971:2561; Warren and Ore 1978:179; Warren and Schneider 2003) suggested that the surface scatters around Lake Mojave are palimpsests, and attempted to circumvent the palimpsest issue (but see Foley 1981:170) by dating *in situ* buried archaeological deposits at Bench Mark Bay in northwestern Silver Lake (Fig. 1). They found that artifacts from 0–60 cm. below surface were older than 10,270 ± 160 ^{14}C yrs B.P. (Y-2406; *Anodonta* shell; 11,925 cal B.P.; Warren and Ore 1978:181) and that others were dated to 12,700–11,925 cal B.P. (Warren and Schneider 2003), leading them to conclude that the Lake Mojave area was first inhabited after 12,700 cal B.P.

Dating subsurface artifacts avoids some of the "messy" aspects of dating surface scatters, but ignores the many surface expressions that must be dated using other means. Perhaps the most common way to date surface scatters is by the presence of temporally diagnostic projectile points. For example, Great Basin Stemmed (GBS) projectile points, like Lake Mojave and Silver Lake points, are ubiquitous around Lake Mojave and date between ca. 10,000 and 8,000 cal. B.P. (Sutton et al. 2007:236). Moreover, archaeologists working at the Ft. Irwin National Training Center (see Fig. 1) indicate that certain lithic raw material types are temporally diagnostic and can be used to date surface scatters (e.g., Basgall 1993a, 1993b; Basgall and Hall 1993; Byrd 2010; Byrd et al. 2009; Duke 2010:562; Gilreath et al. 1987; Hall 1993). These studies indicate that pre-5,000 cal B.P. projectile points (GBS and Pinto) and bifaces typically were fabricated from FGV (basalt, dacite, felsite, rhyolite) stones, whereas most post-5,000 cal B.P. projectile points (Elko/Gypsum and after) and bifaces were made from cryptocrystalline (CCS; chalcedony, chert, and jasper) stones. These studies also indicate that most unifacial flake tools were made from CCS through time, though pre-5,000 cal B.P. sites have somewhat more flake tools of FGV. These Ft. Irwin-based expectations seem to apply to Lake Mojave, based on the results of this analysis and those of Knell (2014).

Soda Mountains Alluvial Fan Chronology

Several geologic studies have established the paleoenvironment and dated the 15 alluvial fan complexes that abut the eastern flank of the Soda Mountains (Harvey et al. 1999; Harvey and Wells 2003;

McFadden et al. 1989; Wells et al. 1987). Harvey and Wells dated the Johnny Fan, which is located in the Soda Mountains study area, by analyzing the shoreline and fan morphology, sedimentation, topography, and stratigraphy. They assigned each fan surface to an age group, summarized here and in Table 2 (also see Fig. 5):

- Qf0, the oldest age group (>68,000 years old), consists of calcrete located in the higher elevations of the prominent drainage.
- Qf1–Qf2 occurs on higher reaches of the Johnny Fan and developed before 10,525 cal B.P. The first demonstrated inhabitants of the eastern Mojave Desert (Clovis) arrived during the latter part of Qf1–Qf2 (by 13,125 cal B.P. following Waters and Stafford [2007] or by 12,700 cal B.P. following Warren and Schneider [2003]).
- Qf3a–Qf4 is exposed in the lower reaches of the Johnny Fan and formed between 10,525 cal B.P. (early Holocene) and 3,770 cal B.P. (early part of the late Holocene).
- Qf5, the youngest age group, developed after 1,750 cal B.P. and is exposed in the major drainages and dissected lower reaches of the Johnny Fan.

Once formed, the fan surfaces remained exposed through to the present, implying that artifacts on the fan surface units accumulated any time after its initial date of formation and the present. The fan surfaces thus provide a means to obtain *terminus post quem* (limit after which) dates for the surface artifact scatters.

Dating surface artifact scatters on alluvial fans is often achieved using temporally diagnostic artifacts and dated alluvial fan surface sequences (e.g., Basgall 1993b; Byrd et al. 2009; Hall 1993). Byrd et al. (2009), for example, established a date range for each fan surface in the Avawatz expansion area of extreme eastern Ft. Irwin to assess diachronic trends in desert pavement quarrying behaviors. They found that CCS artifacts with heavy patina occur on older alluvial fan surfaces and those with less patina on newer fan surfaces, implying that artifacts with heavy patina, varnish, or rubification are older (also see Harvey and Wells 2003:Table 2; Helms et al. 2003). Their data also fit the regional pattern in which most FGV bifaces and biface production debris came from pre-5,000 cal B.P. fan surface sites, with most post-5,000 cal B.P. sites dominated by CCS bifacial and flake tool production debris. We date the surface artifact scatters on the Johnny Fan using the temporally diagnostic lithic raw material types, fan surface dates, and other analyses.

Table 2

SUMMARY OF HARVEY AND WELLS (2003:218) SEDIMENTARY UNITS, DATES, AND SHORELINE ELEVATIONS FOR THE SODA MOUNTAINS ALLUVIAL FANS

Sedimentary Unit	Date (^{14}C B.P.)	Date (cal B.P.)	Lake Mohave Phase[a]	Shoreline Elev. (m.)[a]
Qf5	<1,800	<1,750		
Qf4	4,300 – 3,500	4,850 – 3,770		
Qf3	9,300 – 5,200	10,525 – 5,950		
L2	10,000 – 9,300	11,470 – 10,525	Intermittent III; youngest shoreline[b]	~ 280[b]
Qf2	11,500 – 9,300	13,350 –10,525	Intermittent III	285.5
L1	14,000 – 11,500	17,000 –13,350	Lake Mojave II	285.5
L1	18,400 –16,600	21,900 –19,770	Lake Mojave II	288
Qf1	34,000 –18,400	39,200 – 21,900		
Qf0	>68,000			

[a] = from Wells et al. (2003).

[b] = from Harvey and Wells (2003).

METHODS AND RESULTS

This section describes the relevant methods and results of the pedestrian surveys and in-field lithic analyses, with the objective of establishing spatio-temporal trends and reconstructing aspects of the TP-EH settlement pattern around Lake Mojave. We achieve this by considering the geological and archaeological records in our survey areas along the shoreline near Little Cowhole Mountain and Johnny Fan in the Soda Mountains (see Fig. 1).

Shoreline: Little Cowhole Mountain Survey Area

The 1.61 km. (1 mi.) east-west by 0.8 km (0.5 mi.) north-south Little Cowhole Mountain survey area (1.29 km.^{2}) includes the western edge of Little Cowhole Mountain and the adjacent TP-EH shorelines that formed between the 287 and 285.5 m. contours (Fig. 1). The pedestrian survey revealed that Little Cowhole Mountain itself is devoid of artifacts; however, the TP-EH shorelines contain an estimated 4,000 lithic artifacts, 1,060 of which were analyzed in-field during the survey. Prior researchers observed artifacts along these same shoreline contours around the lake (see above), but newly discovered is the fact that the artifacts near Little Cowhole Mountain

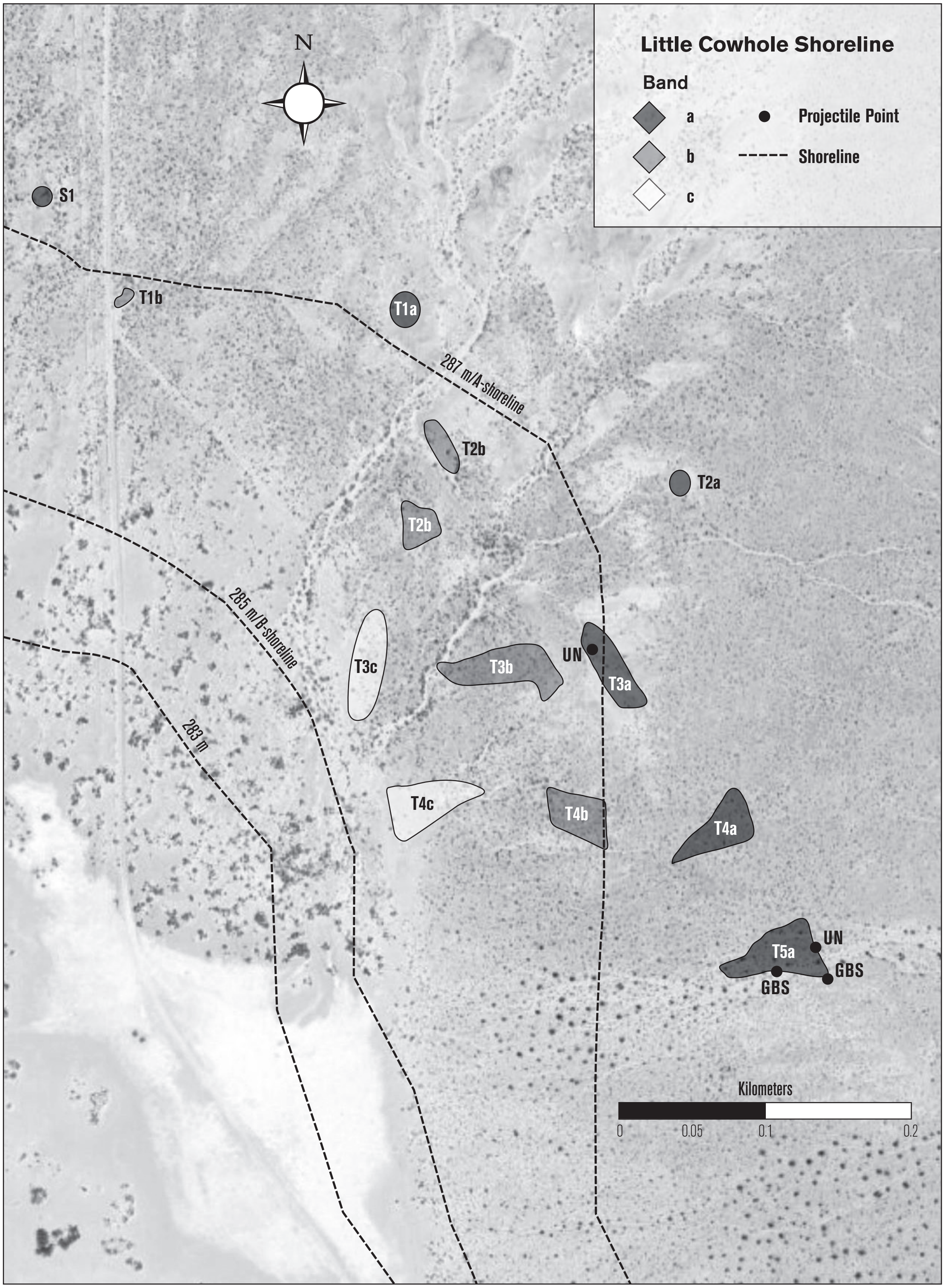


Figure 2. Map depicting segments of each band along the Little Cowhole shoreline labeled by transect unit number (T1–T5) and band letter (a–c). The boundary of most bands was determined using a Garmin 60CSx GPS unit; the remainder are estimated (ellipses and circles).

form three spatially separated, northwest-southeast trending bands (areas of concentrated artifacts) that correspond to the ancient shorelines (Fig. 2; Table 1). The highest elevation artifact band—the A-band—is at or slightly above the A-shoreline or 287 m. contour interval. The B-band is between the A-shoreline/A-band and the C-band at the B-shoreline or 285.5 m. contour interval.[3]

To evaluate the spatio-temporal patterns and chipped stone technology of each artifact band, the senior author (see Knell 2014 for methods) analyzed 1,060 lithic artifacts in the field. This sample of artifacts was selected from the center 50 m. of eight 100-m.-wide transect units established along the 0.8 km. north-south axis of the study area (Fig. 2). Transects 1 through 5 (hereafter T1, T2, etc.) have the densest concentration of artifacts; T6 and T7 lack artifacts; and T8 has too few artifacts (n=9) to warrant further analysis. We also include in the analysis the chipped stone artifact concentration located just outside the survey area boundary north of T1 (designated Site 1 or S1). The bands appear discontinuous in Figure 2 because of the 50-m.-wide spacing of the sample units, though generally the bands continue seamlessly northwest-southeast across the transect units (particularly T2–T4). To summarize, the A-band was observed in T1a–T5a and S1; the B-band in T1b–T4b; and the C-band in sand dunes or hardpans between dunes in T3c and T4c (Fig. 2; Table 3).

Table 3

FREQUENCY OF ARTIFACTS IN EACH BAND AND TRANSECT BY RAW MATERIAL AND PATINA/WEATHERING TYPE

			Raw Material			Patina/Weathering	
Band	Transect	# Artifacts	CCS	FGV	OT	Absent/Light	Heavy/Moderate
A	S1	45	2	43	0	45	0
	T1	18	0	18	0	1	17
	T2	3	0	3	0	1	2
	T3	69	46	23	0	56	13
	T4	19	15	4	0	11	8
	T5	625	364	246	15[a]	371	254
	TOTAL	**779**	**427**	**337**	**15**	**485**	**294**
B	T1	3	0	1	2	3	0
	T2	73	56	16	1	60	13
	T3	82	43	39	0	55	27
	T4	25	20	5	0	18	7
	TOTAL	**183**	**119**	**61**	**3**	**136**	**47**
C	T3	20	9	11	0	14	6
	T4	50	40	10	0	32	18
	TOTAL	**70**	**49**	**21**	**0**	**46**	**24**

CCS = cryptocrystalline silicate; FGV = fine-grained volcanic; OT = other

[a] = all obsidian.

Given the progressive lowering of the shorelines through time and the close association of the artifact bands with these shorelines, we hypothesize that TP-EH foragers gradually shifted their habitation areas closer to the water. If this is correct, we expect the highest elevation or A-shoreline/A-band to be the oldest, the lowest elevation or B-shoreline/C-band to be the youngest, and the B-band temporally between these. We evaluate this hypothesis using multiple lines of evidence: dated shorelines, diagnostic projectile points and temporally-sensitive lithic raw material types, technological strategies, and degree of patina/weathering.

The shoreline data support the hypothesis. Geologic studies indicate that the A-shoreline (287 m.) formed before 27,000 cal B.P. and was last reached by water at 13,968–13,750 cal B.P. (13,850 cal B.P., midpoint) (Table 1). This predates the earliest established human occupation in the region (Clovis complex; but see Beck and Jones 2010 and Davis et al. 2012), suggesting that the TP-EH foragers who discarded the A-band artifacts preferentially settled on high ground near the A-shoreline. As early Holocene warming progressed and the lake level receded, TP-EH foragers camped along progressively lower shorelines, judging by the position of the B-band between the A- and C-bands and the location of the C-band at the post-13,850–9,600 cal B.P. or B-shoreline. Thus, the spatial distribution of the artifact bands along progressively lower and more recent shorelines supports the time transgressive hypothesis.

Further support for the time transgressive hypothesis comes from the dated subsurface artifacts recovered from Bench Mark Bay (Warren and Schneider 2003). The oldest (~11,500 cal B.P.) subsurface artifacts are from higher elevation excavation units, and more recent (~9,200 cal B.P.) subsurface artifacts from lower elevation excavation units. This indirectly implies that the artifact bands near Little Cowhole Mountain on the higher shorelines are older than those from the lower shorelines.

Support also comes from the distribution of temporally diagnostic projectile points along the dated shorelines. The three diagnostic points recovered during

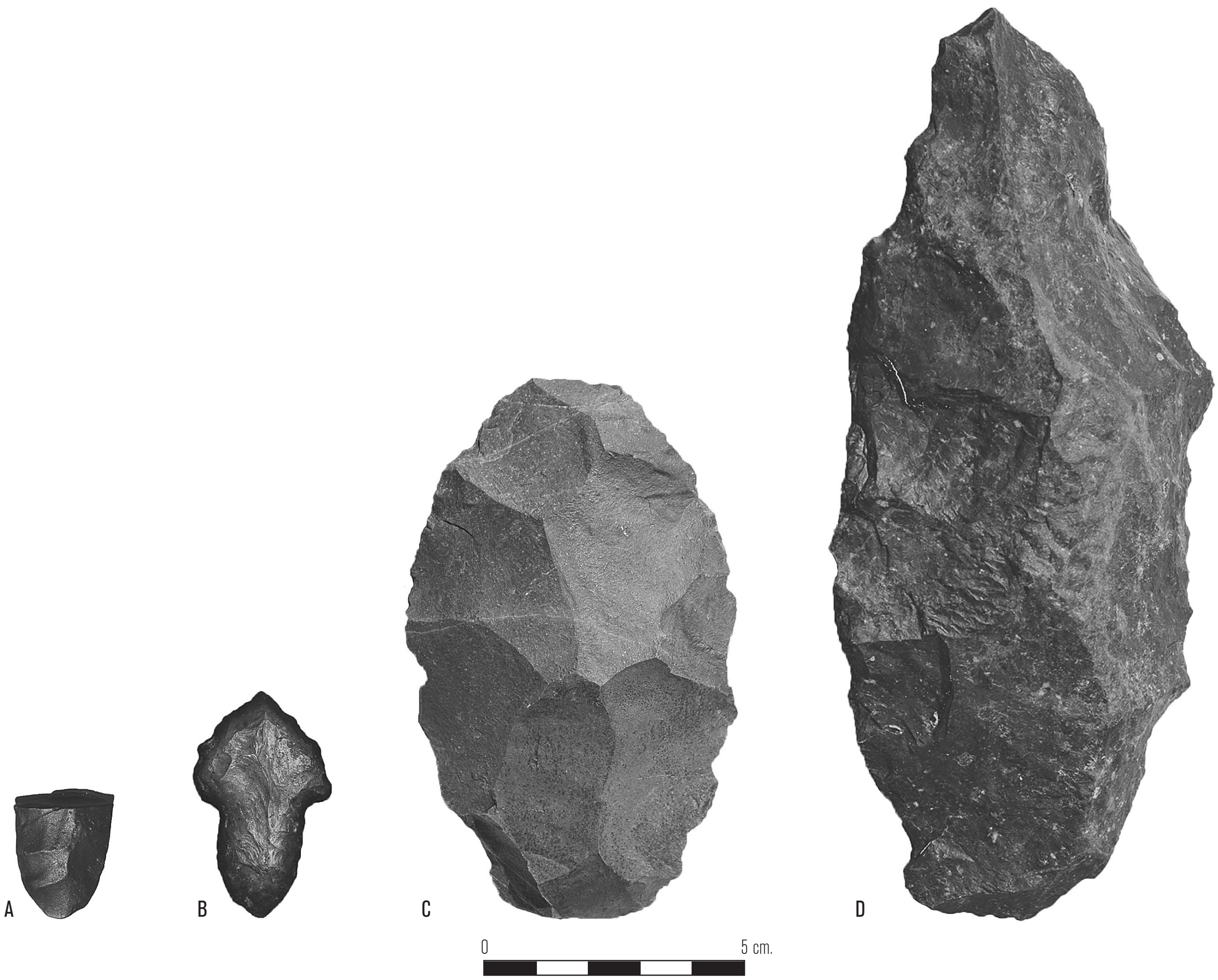


Figure 3. Selected artifacts: (A) Lake Mojave projectile point base, Little Cowhole Mountain survey area; (B) Lake Mojave projectile point, Little Cowhole Mountain survey area; (C) early stage unfinished biface, Soda Mountains survey area; (D) biface core, Soda Mountains survey area.

the survey are GBS varieties, all from the A-band. They include the base of an obsidian Lake Mojave point (Fig. 3A), a complete CCS Lake Mojave point (Fig. 3B), and the tip of an unspecified type of GBS point of FGV stone. This indicates that the A-band is TP-EH in age. The lack of more recent temporally diagnostic projectile points or GBS points in the B- and C-bands provides few clues to distinguish between the bands, making other lines of archaeological evidence necessary.

One way to distinguish between the bands is to consider the proportion of temporally diagnostic lithic raw material types. Recall that pre-5,000 cal B.P. sites have more FGV than CCS artifacts (especially bifaces and projectile points), and post-5,000 cal B.P. sites more CCS artifacts. Most (59.7%) A-band artifacts (all types and classes) are FGV, whereas most B- and C-band artifacts are CCS (each 80%; Table 3). The difference in proportion of CCS and FGV artifacts between the three bands is significant ($\chi^2 = 10.25$; $df = 2$; $p = .006$). Analysis of the adjusted residuals indicates that the A-band has a significant over-representation of FGV (3.12), as occurs at many TP-EH sites, whereas the B- and C-bands have a significant over-representation of CCS (2.24 and 2.00, respectively) as occurs at more recent sites. This suggests that the A-band is older than the B- and C-bands, though the amount of elapsed time remains unknown.

The bands can be further distinguished by comparing differences in lithic technology. We divide the

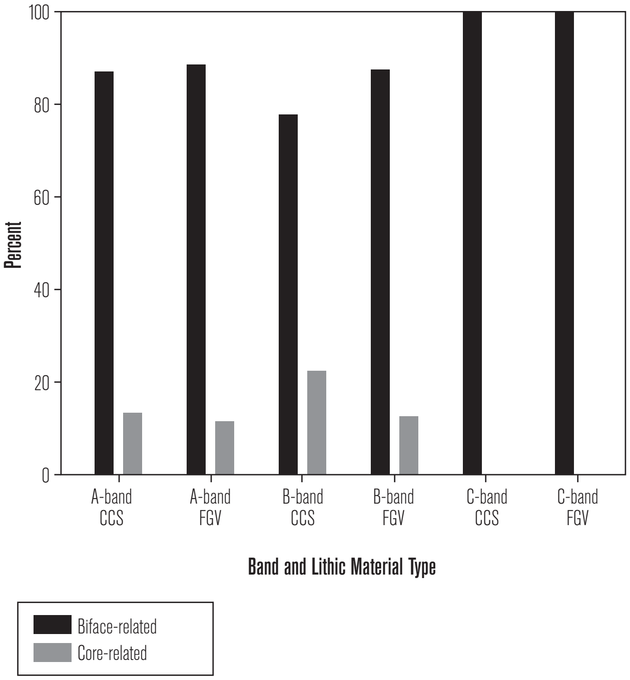


Figure 4. Percent of CCS and FGV biface- and core-related artifacts in each band.

Table 4

FREQUENCY OF ARTIFACTS IN EACH BAND BY RAW MATERIAL AND TECHNOLOGY TYPE

		Technology	
Band	Raw Material	Biface-related	Core-related
A	CCS	105	16
	FGV	109	14
B	CCS	21	6
	FGV	14	2
C	CCS	9	0
	FGV	3	0

CCS = cryptocrystalline silicate; FGV = fine-grained volcanic.

chipped stone into biface-related artifacts (unused bifaces, projectile points, biface cores, and biface thinning or shaping [pressure] flakes) and core-related artifacts (unifacial flake tools, non-bifacial cores, core reduction and core rejuvenation flakes), and assume that pre-5,000 cal B.P. sites have a higher proportion of FGV biface-related artifacts than the typically CCS-dominated post-5,000 cal B.P. sites. CCS and FGV biface technology is important in the three bands (Fig. 4, Table 4) and does not differ significantly between them ($\chi^2 = 4.17$; $df = 2$; $p = .12$). This implies that technological differences, when considered by lithic raw material type, do not differentiate the bands. Despite this finding, only the A- and B-bands have FGV core-related artifacts. This tentatively (due to the small sample size) suggests that FGV usage was more common earlier in time, and may distinguish the A- and B-bands in time from the C-band.

The relative amount of patina/weathering on artifacts provides yet another means to assess spatio-temporal patterns between the bands. Following Byrd et al. (2009:129–130), a value of absent/light (hereafter “light”) or heavy/moderate (hereafter “heavy”) patina/weathering was assigned to each artifact, assuming that artifacts with heavy patina are older than those with light patina (see Harvey and Wells 2003:Table 2 and Helms et al. 2003 for a similar pattern regarding rubification). The Little Cowhole shoreline artifacts generally lack patina, but often are modified by sandblasting or wave-action (see Davis 1967). Consequently, if the bands are time transgressive, significant differences should and do occur in the proportion of artifacts with light and heavy weathering (Table 3) in the three bands ($\chi^2 = 9.46$; $df = 2$; $p = .009$). The adjusted residuals indicate a significant over-representation of heavily weathered artifacts in the A-band (2.77), and significantly more lightly weathered artifacts in the B-band (3.04). Our analysis indicates the C-band artifacts are statistically indistinguishable from those in the other two bands. As expected, more heavily weathered artifacts are more common in the older A- than B-band.

We interpret this cautiously, however, as weathering may develop differently depending on lithic raw material type. Chi-square tests (2×2) indicate that a moderate to extremely significant difference occurs in the degree of weathering on the CCS and FGV artifacts by band. The adjusted residuals indicate each band is over-represented by lightly weathered CCS artifacts and over-represented by heavily weathered FGV artifacts. Thus, the significantly higher proportion of heavily weathered A-band FGV artifacts seemingly results from the higher proportion of FGV itself rather than from the age of the band; conversely, the high proportion of lightly weathered CCS artifacts skews the interpretation towards the B- and C-bands. The patina/weathering data thus provide anecdotal evidence at best for a time-transgressive pattern.

To summarize, our data largely support the hypothesis that the artifact bands represent time-transgressive habitation zones. The association between the A-band and A-shoreline (early) and the C-band and B-shoreline (more recent) strongly suggests a gradual, but time-transgressive shift in TP-EH habitation areas closer to the receding shoreline. The conformity between the artifact bands and geologically dated shorelines in many ways provides the best evidence (not to mention evidence independent of the archaeological record) for a time-transgressive pattern of habitation along the Little Cowhole shoreline. This pattern is strengthened by the Warren and Schneider (2003) subsurface archaeological investigations at Bench Mark Bay, which indicate that artifacts from higher elevation levels are older than those closer to the shoreline.

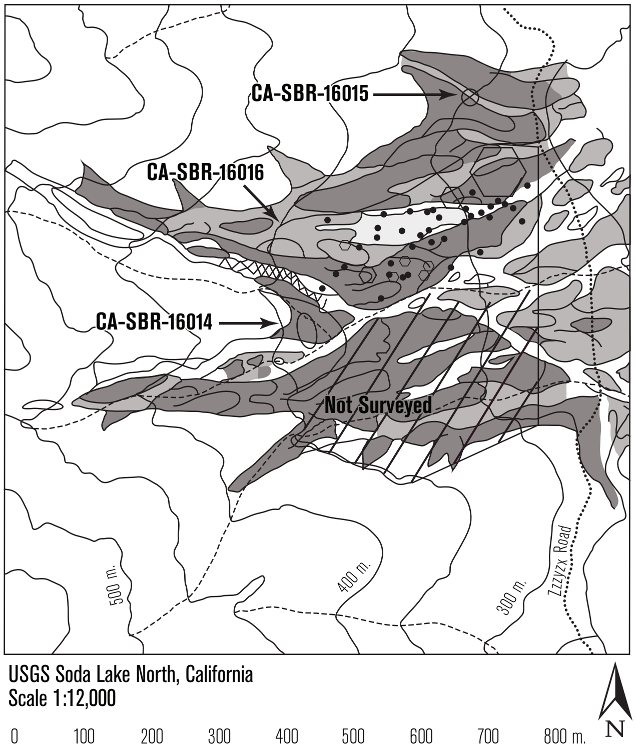
The surface archaeological data likewise indicate that the A-band artifacts were discarded before the B- and C-band artifacts. The A-band is oldest because it has (1) GBS points (the only band with diagnostic TP-EH projectile points); (2) significantly more FGV lithic raw material than the B- and C-bands, as is typical among pre-5,000 cal B.P. sites in the area; (3) FGV core-related artifacts; and (4) significantly more heavily weathered FGV artifacts (though this evidence is probably anecdotal). A difference in age between the B- and C-bands is less certain; however, the presence of FGV core-related artifacts in the B- and not C-band provides the best (yet tentative) archaeological difference. Consequently, the variance in elevation between the B- and C-bands probably provides the strongest evidence for a difference in age. The data, therefore, generally support the time-transgressive hypothesis for the formation of the artifact bands, though the amount of time that elapsed between formation episodes is unknown. Regardless, the association between the bands and TP-EH shorelines, and the similarity of the overall lithic assemblage to other TP-EH sites in the region (Ft. Irwin and China Lake Naval Air Weapons Station; Fig. 1; Knell 2014), indicate that the artifacts date to, or mostly date to, the TP-EH.

Thus far we have purposefully avoided the issue of multiple occupations or the palimpsest effect (Aston and Rowley 1974:14) in an attempt to establish the initial trends without added confounding factors, and because the lack of post TP-EH projectile points makes precise chronometric comparison difficult. Like prior researchers (e.g., Ore and Warren 1971:2,561; Warren and Ore 1978:179), we think that the Soda Lake surface archaeology results from multiple occupations. However, the overall conformity of our data to expectations suggests that the underlying TP-EH settlement strategy and inference for time-transgressive habitations generally holds, and was not overwhelmingly influenced by the palimpsest effect. As such, the surface archaeology is still able to provide useful information that can further the goals of archaeology and future planned studies around Lake Mojave. We return to this issue later.

Alluvial Fan: Soda Mountains Survey Area

The 0.83 km.^{2} Soda Mountains survey area encompasses part of a large quarry/workshop complex with 14 bedrock quarries, workshops, and lithic scatters. Huge numbers of lithic artifacts are present in this area, including more than 400,000 artifacts collected by Semenza (1984) from surface and subsurface test pits at quarry CA-SBR-5193. Excluding SBR-5193, we conservatively estimate that the Soda Mountains survey area has more than 20,000 chipped stone artifacts. Of these, 2,073 were analyzed in the field by the senior author. These artifacts are from three surface sites located on the geologically dated Johnny Fan (Harvey and Wells 2003) (Fig. 5); the remaining sites are on adjacent ridges and not readily dateable due to the lack of temporally diagnostic projectile points. The dated fan surfaces—like the dated shorelines in the Little Cowhole survey area—are used, in part, to estimate when the artifacts from the three lithic scatter sites on the Johnny Fan were discarded.

The three sites on the Johnny Fan are CA-SBR-16014, -15, and -16. SBR-16014 is an 85 × 40 m. lithic scatter with 95 chipped stone artifacts on the toe of a ridge with Qf1-2 (Pleistocene to present) sediments. SBR-16015 has 10 chipped stone artifacts in a 20 × 21 m. area that straddles the Qf1–2 (Pleistocene to present) and Qf3–4 (early Holocene to present) fan surfaces; we consider SBR-16015 part of the Qf3–4 fan surface. The 0.25 km.^{2} SBR-16016 has at least 5,000 chipped stone artifacts. Survey revealed 44 spatially-proximate lithic scatters or loci (mostly segregated reduction locales where individuals or small groups tested lithic materials and created tools [sensu Byrd et al. 2009]) from the northern half of this site (the south half was not surveyed or analyzed for sampling purposes), each with



Age Groups	Date (^{14}C B.P.)	Date (cal B.P.)
□ Qf 5	<1,800	<1,750
▒ Qf 3–4	9,300–3,500	10,525–3,770
▓ Qf 1–2	18,400–9,300	21,900–10,525
▩ Qf 0	>68,000	

Figure 5. Location of Soda Mountains archaeological sites (designated by trinomial) and loci (black dots and hexagons) on the Johnny Fan (Harvey and Wells 2003:211) by surface age group (see Wells et al. 2003).

Table 5

FREQUENCY OF SITES AND ARTIFACTS IN EACH FAN AGE GROUP BY TECHNOLOGY TYPE

Site	Fan Age Group	# of Loci	# of Artifacts	Technology		
				Biface	Core	Mixed
SBR-16014	Pleistocene to Present (Qf1-2)	1	95	0	1	0
SBR-16015	Early Holocene to Present (Qf3-4)	1	10	0	1	0
SBR-16016	1750 cal B.P. to Present (Qf 5)	8	187	0	8	0
	Early Holocene to Present (Qf3-4)	4	97	0	3	1
	Pleistocene to Present (Qf1-2)	32	969	0	26	6
	TOTAL (SBR-16016)	44	1,253	0	37	7
TOTAL (all sites)		**46**	**1,358**	**0**	**39**	**7**

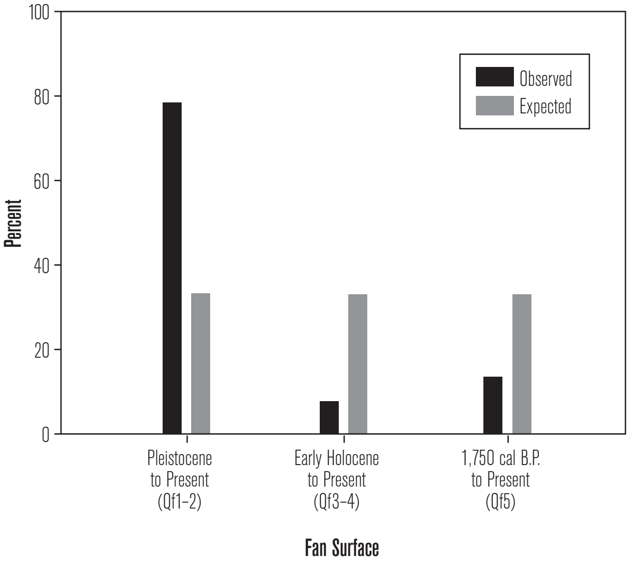


Figure 6. Percent of observed and expected sites/loci by fan surface age group.

a minimum of 10 artifacts. The sample of 1,253 analyzed artifacts from the 44 loci ($\bar{x} = 28.5$ artifacts/locus; $s = 17.6$) was obtained by analyzing all artifacts from loci with <50 specimens, and at least 50 percent (usually much more) from loci with >50 specimens.

The distribution of all sites (including the 44 loci from SBR-16016) is uneven across the fan surfaces (Table 5, Fig. 5). The oldest fan surface (Qf1–2; Pleistocene to present) has the most sites/loci (n = 33, 71.7 percent) and artifacts (n = 1,064, 78.4 percent); the youngest fan surface (Qf-5; 1,750 cal B.P. to present) has many fewer loci (n = 8, 17.4 percent) and artifacts (n = 187, 13.8 percent); and the intermediate age fan surface (Qf3–4; early Holocene to present) even fewer loci (n = 5, 10.9 percent) and artifacts (n = 107, 7.9 percent). However, the proportion of sites/loci to artifacts between the three fan surfaces does not differ significantly ($\chi^2 = 1.17$; $df = 2$; $p = .56$).

A better way to assess variability between the fan surfaces is to compare the percentage of observed versus expected loci by age group (Fig. 6). We analyze SBR-16016 because the fan surfaces have a similar proportion of each age group represented (about 33.3 percent; see Fig. 5), and therefore each fan surface should have 33.3 percent of the 44 loci. Figure 6 plots the percentage of expected and observed sites, revealing that the observed Qf1-2 fan surface (Pleistocene to present) sites far exceed the expected percentage of sites; the more recent fan surfaces have many fewer observed loci than expected. We contend that this pattern reflects human settlement and raw material preferences through time (see below), but we first eliminate or discount alternative explanations.

The possibility exists that the higher proportion of loci/artifacts on the oldest or Qf1–2 fan surface accumulated because of the longer length of time it was available for human occupation. If length of exposure influenced the patterning, we anticipate that proportionally fewer loci/artifacts will occur on the intermediate (Qf3–4; early Holocene to present) than the oldest fan surface and proportionally more loci/artifacts on the intermediate than the recent fan surface. This is not the case—the intermediate age fan has the fewest loci/artifacts of any fan surface. Moreover, since human occupation of the oldest fan surface began no more than a few thousand years before the intermediate fan surface formed during the early Holocene (~10,500 cal. B.P.), the proportion of loci on the oldest and intermediate fans should be similar. To account for the effect of elapsed time on the frequency of loci on the fan surface age groups from SBR-16016, we use the following index: divide the frequency of loci attributed to each age group by the length of elapsed time since the fan formed or that people occupied the fan and multiply by 1,000 to move the decimal. For example, divide the 32 loci on Qf1-2 by 13,000 (roughly the start date for Clovis in cal B.P. years) and multiply by 1,000; divide the 4 loci on Qf3–4 by 10,525 and multiply by 1,000. The result is 2.5 for the oldest fan, 0.38 for the intermediate fan, and 32.0 for the newest fan. Controlling for elapsed time, the oldest fan has 6.5 times more loci than the intermediate fan, increasing the likelihood that most felsite quarry activities at Soda Mountain occurred early in time. The high index value for the newest fan is an aberration due to its recent formation date (1,750 cal B.P.; i.e., low denominator in the index) and erosion (see below).

The geomorphology of the Johnny Fan might explain the higher proportion of artifacts on the Qf1–2 fan surface (Fig. 5). The Qf1–2 (oldest) fan surface has broad, flat terraces incised by many small drainages and rivulets. Presuming that flintknappers preferred flat working surfaces, the Qf1–2 fan surface was best suited for this activity. The intermediate age (Qf3–4) fan surfaces cover the flanks of prominent ridges, making them steeper and less ideal for human activity, as well as the dissected lower reaches of the Johnny Fan where artifacts potentially moved (eroded) downslope due to gravity, water, or both. Qf5 (recent) fan surfaces occur in drainages and the dissected lower reaches of the Johnny Fan, increasing the likelihood that any surface artifact scatters are in secondary context. While erosion undoubtedly influenced the distribution of sites/loci, the several refitted chipped stone artifacts—four from the Qf1–2, and one each on the Qf3–4 and Qf5 fan surfaces—indicate that erosion alone does not entirely explain the distribution of loci and artifacts, and that the preference for tool manufacture on the oldest fan surface is a cultural phenomenon.

The proportion of temporally-diagnostic lithic raw material types provides yet another way to distinguish between the alluvial fans. Assuming, again, that most pre-5,000 cal B.P. projectile points (GBS and Pinto) and bifaces are FGV, the possibility exists that most of the Soda Mountains felsite (FGV) quarry and production debris is also pre-5,000 cal B.P. Though far from conclusive, the considerably higher frequency of felsite artifacts on the Qf1–2 (oldest) fan surface (Table 5) indeed coincides with the projected period of heaviest use.

If our assumption is correct that most pre-5,000 cal B.P. projectile points in the region are FGV, we anticipate continuity in the types of blanks used to manufacture these points. Most GBS projectile points in the Great Basin were manufactured from large bifaces, flake blanks, or both (e.g., Beck and Jones 1988, 1990, 2009; Duke 2011; Pendleton 1979; Willig and Aikens 1988). Knappers in the Soda Mountains manufactured large or heavy ($\bar{x} = 180.1$ gm.; $s = 129.7$ gm.) early stage felsite bifaces (Fig. 3C) and struck large flakes ($\bar{x} = 123.3$ gm.; $s = 133.8$ gm.) from large ($\bar{x} = 420.3$ gm.; $s = 311.4$ gm.) felsite bifacial (Fig. 3D) and multidirectional cores, the blanks of which in many cases likely were manufactured into projectile points away from the quarry/workshop (see Knell 2014). If projectile point manufacture was important to the TP-EH technological strategy, the oldest fan surface should have the largest (heaviest) tool blanks. The median weight of artifacts from the 44 SBR-16016 loci significantly varies by age group

(Kruskal-Wallis ANOVA; $H=8.31$, $df=2$, $p=0.02$), with the difference largely a result of significantly heavier artifacts on the oldest (Qf1–2) rather than intermediate (Qf3–4) fan surfaces. Heavier artifacts are expected if knappers desired large lithic material packages to meet their needs, with the manufactured items (e.g., early stage bifaces and flake blanks) concordant with the types of blanks commonly used to create GBS points. The preference for producing large Soda Mountain felsite blanks on the oldest fan surface suggests continuity in the overall production of GBS projectile points from FGV lithic material.

The SBR-16016 loci and fan surface artifacts were further evaluated to assess whether the primary technological strategy was biface manufacture or flake blank production. As above, we grouped the artifacts into biface-related and core-related, with each locus assigned a technological strategy as follows: if ≥75 percent of the diagnostic artifacts employ the same technology it is biface-related or core-related (respectively); loci not meeting this threshold are considered mixed (i.e., biface- and core-related) (Table 5). The percentage of loci assigned to each technological strategy is shown in Figure 7: none are primarily biface manufacture loci, whereas most are core reduction and mixed technology loci on the oldest fan surface (Qf1–2; Pleistocene to present). Core reduction and biface manufacture (included in the mixed technological strategy) are thus best represented on the oldest fan surface, fitting the pre-5,000 cal B.P. pattern of manufacturing large bifaces and flake tool blanks from FGV lithic material. Though this age assessment is not definitive because of the *terminus post quem* dating method, these data do suggest, as expected, that the manufacture of large bifaces and flake blanks was the dominant production strategy on the oldest fan surface.

To summarize, multiple lines of evidence suggest that most felsite quarry and workshop debris in the Soda Mountains study area is on the earliest fan surface (Pleistocene to present) and was discarded pre-5,000 cal B.P. The high proportion of loci and artifacts on the old fan surface likely results from cultural rather than taphonomic processes related to length of fan surface exposure. We suggest this based on (1) the higher than expected percentage of loci on the early fan surface when controlling for fan surface size and elapsed time; (2) the regional preference for GBS points made of FGV; and (3) the high percentage of large, early stage felsite bifaces and flake blanks on the oldest fan surface, many of which likely became projectile points away from the quarry area. Establishing a more specific date range is currently not possible given the *terminus post quem* dating method for the fans, and the lack of temporally diagnostic projectile points and other direct dating methods.

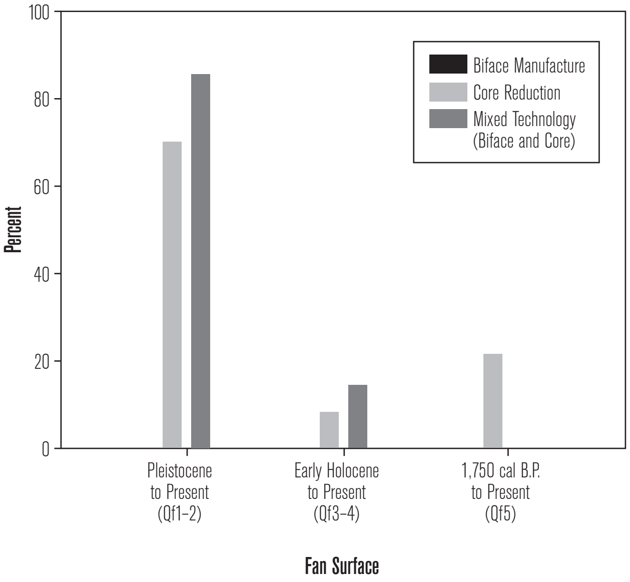


Figure 7. Percent of sites/loci identified to technological strategy (biface manufacture, core reduction, or mixed) by fan surface age group.

DISCUSSION AND CONCLUSIONS

The two study areas at Soda Lake—Little Cowhole Mountain and Soda Mountains—are proxies in our quest to understand TP-EH settlement patterns around pluvial Lake Mojave. We find that the surface lithic scatters along the shorelines near Little Cowhole Mountain closely follow the ancient shoreline contours. The evidence indicates that TP-EH foragers inhabited the oldest and highest shoreline earliest in time, leaving behind the A-band artifacts. As the lake level gradually lowered, subsequent TP-EH foragers camped along Lake Mojave's lower and more recent shorelines, leaving the artifacts associated with the B-band sometime before the C-band/B-shoreline formed. When these spatial shifts occurred remains uncertain, but they likely ended by 9,600 cal B.P. when Lake Mojave became a playa lake.

The time-transgressive settlement pattern identified at Lake Mojave occurs at other pluvial lakes in the Great Basin. Fenner (2011:109), for example, found most GBS projectile points at Mud Lake Basin, Nevada on ridges and shorelines, and concluded that TP-EH groups followed "the water's edge, as well as its resources, as water levels gradually receded down to the modern playas." The study by Adams et al. (2008:637) of several basins around Lake Lahontan indicated that "lake-level fluctuations played a role in controlling the distribution of early [i.e., TP-EH, *added*] archaeological sites." Estes (2009; Jakes Valley, Nevada) and Rosenthal et al. (2001; Airport Lake [China Lake], California) likewise found that TP-EH foragers adjusted settlement strategies according to the water level, with Great Basin concave (GBC; western fluted) points occurring along shorelines closer to the water's edge during the purported Clovis drought, and GBS points primarily found at higher elevations as the lake-level increased during the early part of the early Holocene. We found no direct evidence for GBC occupation in our study area, but for later time periods there is a time-transgressive TP-EH settlement pattern at Little Cowhole Mountain similar to that found at other intermountain pluvial lakes.

Why TP-EH foragers occupied the shoreline near Little Cowhole Mountain is a separate question, about which we know little at present. We do know that TP-EH foragers subsisted on marsh resources that occurred near shore at many Great Basin pluvial lakes (e.g., Bedwell 1973; Eiselt 1997), and that others hunted terrestrial resources like lagomorphs and artiodactyls (e.g., Basgall 2000:127; Douglas et al. 1988; Hockett 2007; Pinson 2007), and some processed seeds (e.g., Rhode and Louderback 2007). Foragers potentially obtained these resources during logistical forays from shoreline encampments; however, Mojave Desert faunal acquisition seemingly was location specific (Douglas et al. 1988), increasing the likelihood that TP-EH foragers at Little Cowhole Mountain targeted marsh resources. Whether this was the case remains unknown due to poor faunal preservation; however, future research will seek to locate potential TP-EH marsh habitats around Lake Mojave and further assess the subsistence strategies employed.

The analyses also suggest that most felsite (FGV) quarry/workshop activities in the Soda Mountains study area occurred before 5,000 cal B.P. (i.e., Lake Mojave and Pinto periods). TP-EH foragers on the oldest fan surface created many early stage bifaces and flake blanks that (for the most part) were modified into projectile points away from the quarry. Foragers likely transported many of these northwest onto Ft. Irwin (and beyond), where some became bifacial implements and scrapers, while many more became utilized and/or minimally retouched flakes (Knell 2014).

Combining the settlement pattern inferences for each survey area provides some clues about the role Lake Mojave played in the regional TP-EH settlement strategy. Along the shorelines, fluctuations in the water-level influenced TP-EH settlement strategies and site locations through time. While camped along the shorelines, TP-EH foragers prepared and refurbished bifacial and unifacial tools, possibly made short-distance forays for terrestrial animals (likely lagomorphs and some artiodactyls [likely bighorn sheep]) into the nearby mountains and piedmonts, but given the close proximity to the lake also presumably subsisted on marsh animals, fish, plants, and birds. While in the Soda Mountains, TP-EH foragers quarried felsite to make bifacial and unifacial implements, some of which they manufactured and used on the east shoreline of Lake Mojave (e.g., Little Cowhole Mountain), and some of which they transported elsewhere.

Finally, like prior researchers, we think that the surface scatters result from multiple occupations (i.e., the palimpsest effect) and as yet largely unevaluated post-depositional processes like wind, water, erosion, and artifact collection. These factors are far from unique to Lake Mojave (e.g., Beck 1994; Jones and Beck 1999; Lewarch and O'Brien 1981; Sullivan 1998), and they at times lead archaeologists to the refrain best stated in (but not supported by) Davis (1975:39; italics original): "Too bad it's all on the surface; you can't *do* anything with it." Having recognized at the outset of this study that the TP-EH sites around Lake Mojave likely included multiple or palimpsest occupations and contained few diagnostic artifacts due to extensive collecting by prior researchers (e.g., Campbell et al. 1937), we designed a study based on multiple lines of evidence to tease apart the underlying patterns. Though not all of our expectations were statistically supported, we contend that the underlying TP-EH spatio-temporal record is largely intact. This finding will provide, in forthcoming studies, a baseline for better understanding diachronic trends in technology, settlement patterns, and land use around Lake Mojave.

NOTES

[1] Originally called Lake Mohave.

[2] Radiocarbon dates were calibrated using CALIB 6.0 based on the INTCAL09 calibration curve (Reimer et al. 2009). Unless specified, calibrated dates in the text and figures are the midpoint (slightly rounded) at 2-sigma.

[3] Figure 2 depicts the 285 m. contour interval rather than the 285.5 m. contour interval associated with the maximum extent of the B-shoreline. The B-shoreline thus was closer to the C-band than Figure 2 shows.

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