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An Obsidian Hydration Chronology of Late Pleistocene-Early Holocene Surface Assemblages from Butte Valley, Nevada

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WITH a few notable exceptions, archaeological sites of late Pleistocene-early Holocene age in the Great Basin are known only from surface contexts. For chronological study of these sites, archaeologists have relied almost exclusively on typological cross-dating using temporally diagnostic projectile points. Radiocarbon dates assembled from throughout the Great Basin suggest these point styles date from ca. 11,000 to 7,500 B.P. (Willig and Aikens 1988). Yet, for a number of reasons, typological studies of these points have failed to clearly demonstrate the duration and modal ages of these styles, to establish their chronological positions relative to one another, or to document regional variation attending these chronological attributes. As a consequence, late Pleistocene-early Holocene assemblages are routinely attributed only to very broad time periods, often encompassing as much as 3,000-4,000 years.

Our present studies in Butte Valley, Nevada, offer a case in point (Beck and Jones 1988, 1990). Artifact collections recovered by survey from fluvial and pluvial lake margin contexts are largely of late Pleistocene-early Holocene age based on associations with diagnostic stemmed and lanceolate projectile points. However, our chronological studies based on stylistic analyses of projectile points have not been successful and, as a result, none of the Butte Valley assemblages have proven amenable to finer temporal resolution such that they can be (1) assessed as to contemporaneity; (2) ordered serially; or (3) evaluated with respect to the continuity of occupation.

The inadequacy of typological approaches has led to our attempts to improve temporal resolution by means of obsidian hydration dating. Increasingly, archaeologists working in the Great Basin have adopted obsidian hydration dating as an adjunct to standard dating techniques, some regarding surface artifact dating as an acceptable extension of the approach (e.g., McGonagle 1979; Bettinger 1980, 1989; Jackson 1984a; Tuohy 1984; Zeier and Elston 1984). While we have reservations about the use of obsidian hydration dating for precise chronometric assessments of surface artifacts (cf. Leach 1988; Bettinger 1989), the technique appears to have merit as a relative dating tool (Michels 1967, 1973; Michels and Tsong 1980; Jackson 1984a). In this paper we report on a study of 115 obsidian artifacts recovered from seven archaeological sites of late Pleistocene-early Holocene age. We begin with general background of the dating method and of our Butte Valley studies, and then turn to the results of our obsidian source and hydration analyses. We conclude with an evaluation of obsidian hydration for delimiting chronological information for the surface archaeological record.

OBSIDIAN HYDRATION STUDIES OF SURFACE ARTIFACTS

Since its first archaeological applications nearly three decades ago (Friedman and Smith 1960; Evans and Meggers 1960), obsidian hydration dating has become commonplace in archaeological research in the arid western U.S. The method is based on the fact that freshly broken surfaces of obsidian gradually absorb moisture from their surroundings. The progress of this absorption is marked by a diffusion front that separates the denser, hydrated glass from unaltered glass. Measurement of the depth of the hydrated layer (rind), combined with knowledge of the rate at which the layer expands, provides a means of estimating the age of an artifact.

Two factors are known to influence the hydration process significantly: chemical composition and effective hydration temperature.[1] Control of compositional differences is routinely accomplished by trace element characterization techniques such as X-ray fluorescence (XRF) or neutron activation, which distinguish specimens (as to geologic source) based on their chemical makeup. The influence of temperature variation experienced by obsidian artifacts, however, is difficult to evaluate, and, left unconsidered, is reason to question the results of obsidian hydration dating.

While the effective temperature (Friedman and Smith 1960) of very deeply buried artifacts is thought to be fairly stable (daily and seasonal) at or near the mean annual air temperature (Friedman 1976), artifacts near the surface generally experience effective temperatures exceeding mean annual air temperatures while also encountering wider temperature fluctuations. On this last point, Trembour and Friedman (1984:80) cautioned that, given the temperature sensitivity of the hydration process, "even short exposures to abnormally high heat can severely distort the outcome of the dating analysis." Thus, it is appropriate to ask if the hydration process is not so sensitive to temperature variation as to yield uninterpretable information about the age of surface artifacts.

An early consideration of the effects of temperature variation on the hydration process was made by Michels (1965, 1969). Although his primary focus was in testing stratigraphic relationships in subsurface deposits, Michels made comparisons between hydration readings of deeply buried artifacts and those found near or at the surface, finding no significant differences. In a later study, however, Layton (1973) suggested that surface artifacts may hydrate at a much faster rate than those in subsurface contexts. In this work Layton compared small sets of buried (n = 13) and surface (n = 14) artifacts from northeastern Nevada in order to determine the utility of surface artifacts for obsidian hydration dating. Both samples consisted of time-sensitive projectile points of three different series. Layton argued that although surface artifacts appeared to hydrate at rates ranging from nearly equal to four or five times those of buried artifacts, relative orders of readings were consistent within each group (i.e., surface and subsurface). For example, Rose Spring points, judged youngest on stratigraphic grounds and by cross-dating, possessed the thinnest hydration rinds, while Humboldt specimens, the oldest style, had the thickest rinds. Thus, Layton concluded that chronological information can be obtained from artifacts in surface contexts. Subsequent studies of projectile points (e.g., Origer and Wickstrom 1982; Jackson 1984a) have confirmed this finding.

Jackson (1984b) cautioned that sample size and uncontrolled compositional effects play an uncertain role in Layton's data. Since source attributions were not archaeometrically established, conclusions concerning the hydration rate differences between surface and buried artifacts in this sample are suggestive at best. On experimental grounds, however, Friedman (1976) supported Layton's findings, suggesting that surface artifacts can be expected to hydrate at five times the rate of buried artifacts in a temperate climate. Yet in another comparison of projectile point data, Origer and Wickstrom (1982) found no statistical differences in the distributions of hydration values between surface and subsurface artifacts. Acknowledging Layton's findings, they suggested that surface specimens in their study might be better insulated from solar radiation, and hence extreme temperature fluctuations, by plant cover and bioturbation at the surface.

Layton and Friedman are undoubtedly correct that surface and subsurface obsidians may hydrate at substantially different rates (see also Friedman and Long 1976), and thus clearly it is unwise to apply rates established for buried artifacts to cases from surface contexts without first independently establishing the equivalency of the temperature regimes. In fact, attempts in general to supply absolute ages using obsidian hydration for surface artifacts seem problematic in view of current understandings of the hydration process. Yet, as a relative dating technique, obsidian hydration dating suffers far less for lack of precise knowledge about temperature-dependent rates. Nevertheless, effective temperature remains an important concern, since it is possible to misinterpret temperature effects as chronologic differences among artifacts. Thus, in selecting artifacts for comparison, only those recovered from the same geographic locality or from nearly identical topographic settings should be considered. Clearly, artifacts taken from different positions along gradients of latitude, elevation, or aspect, for instance, are poor candidates for study.

In a more recent exploration of relative dating by obsidian hydration dating, Raymond (1984-85) focused on the statistical properties of suites of hydration values (see also Bettinger 1980; Jackson 1984b). Raymond's contention was that a set of fully contemporaneous artifacts of the same geochemical source will display a range of hydration values, but these values will generally assume a narrow, symmetrical distribution (see Scott et al. 1986 for confirming evidence). He suggested this variation is attributable to minor chemical differences among the artifacts and to microenvironmental variation influencing the temperature history of each artifact. The individual hydration values exhibited by such a group of artifacts will converge around a single mode that describes the temporal position of those artifacts relative to other artifact groups. In contrast, artifacts that reference several distinct manufacture/discard events, provided those events are sufficiently separated in time, when combined, will create a multimodal distribution.

Building on these observations, several lines of chronological interpretation may be followed. First, it should be possible to assess contemporaneity across a group of artifacts as well as to detect temporal outliers. Second, those cases displaying symmetrical distributions of hydration values can be sequentially arranged according to average hydration value to create a relative chronological order. If, on the other hand, samples exhibit multiple modes and those modes are nonoverlapping, it may be possible to break apart multicomponent artifact mixtures (Michels 1969, 1973). Samples created by this partitioning can then be ordered on the basis of their individual hydration means. Third, artifacts assembled from low-density offsite settings can likewise be compared with each other and with site artifacts to establish their relative temporal positions. For each of these procedures, each geochemical source is treated separately. The presence of multiple sources provides an opportunity to develop cross-checking results.

With these chronological objectives in mind, we now turn to our current studies in

Butte Valley, Nevada, beginning first with a brief project description.

CURRENT RESEARCH IN BUTTE VALLEY

The assemblages discussed here were collected as part of the Butte Valley Archaeological Project which was initiated by the authors in 1986. The long-term goals of the project are to characterize human adaptive strategies of the late Pleistocene-early Holocene period and changes in those strategies over time, particularly in regard to: (1) patterns of landscape use; i.e., the ways in which different environmental settings were used; (2) scale of settlement patterns; i.e., the size of home-range territories; and (3) the frequency of settlement change; i.e., the degree to which populations were sedentary during this time frame (Beck and Jones 1988, 1990; Jones and Beck n.d.). Data presented here are the results of the first two field seasons.

Work thus far has been conducted in southern Butte Valley, an area about 50 km. north of Ely, Nevada (Fig. 1). Butte Valley is a predominantly north/south trending basin of about 1,870 km.^{2} with a basal elevation of ca. 1,900 m. The valley bottom contains lakebed and shoreline features associated with pluvial Lake Gale, which, at its maximum extent, covered nearly 411 km.^{2} and reached a depth of 25 m. (Mifflin and Wheat 1979). To date, no chronology has been developed for Lake Gale; however, other valleys in the Calcareous Province contained lakes apparently in phase with Lake Lahontan (Thompson 1984; Young and McCoy 1984; Benson and Thompson 1987) and these lakes probably experienced final high stands between 9,500 and 10,500 B.P. Typifying the modern valley setting are xerophytic plant associations that, in general, afford high ground-surface visibility.

Our 1986-87 field programs consisted of systematic pedestrian survey and site collection in the southern sub-basin of Butte Valley. Specifically, they included: (1) noncollection reconnaissance of randomly and judgmentally selected survey tracts (in 1986); (2) survey and collection of 24 randomly selected, 250 x 250 m. tracts, stratified by elevation (1987); and (3) controlled surface collection of nine sites (1986 and 1987). Survey was conducted by individuals spaced at 10-m. intervals; each surveyor searched a path 1 m. wide, keeping a record of landform, vegetation, and artifacts for each 25-m. linear interval along a traverse. During 1986, artifact locations were simply recorded, while in 1987 artifacts were collected.

In all, 14 sites were located (nine of which have been collected) and some 99 isolated artifacts were recovered from 24 survey tracts.[2] Of the 14 sites, eight appear to be primarily of late Pleistocene-early Holocene age, three contain both late Pleistocene-early Holocene and early Archaic associations, one contains a late Pleistocene-early Holocene component but is predominantly of early to mid-Archaic affiliation, and two contain no temporally diagnostic artifacts.

Late Pleistocene-early Holocene sites occur on both pluvial and fluvial landforms (Table 1). Sites of the former type are associated predominantly with the 1,907.5-m. and 1,912.5-m. shorelines, but they also occur on the 1,917.5-m. terrace. Two of the sites discussed here, HPL2 and WSWL1, lie in the northern end of the sub-basin on well-developed spits. In addition to complex distributional patterns of artifacts at both locales, HPL2 contains both late Pleistocene-early Holocene and Archaic point types suggesting a long, if punctuated, occupational history. Two other sites also lie in lakeside settings: HPL1 rests on the pronounced, but discontinuous, 1,912.5-m. shoreline in the northwestern sector of the sub-basin, while

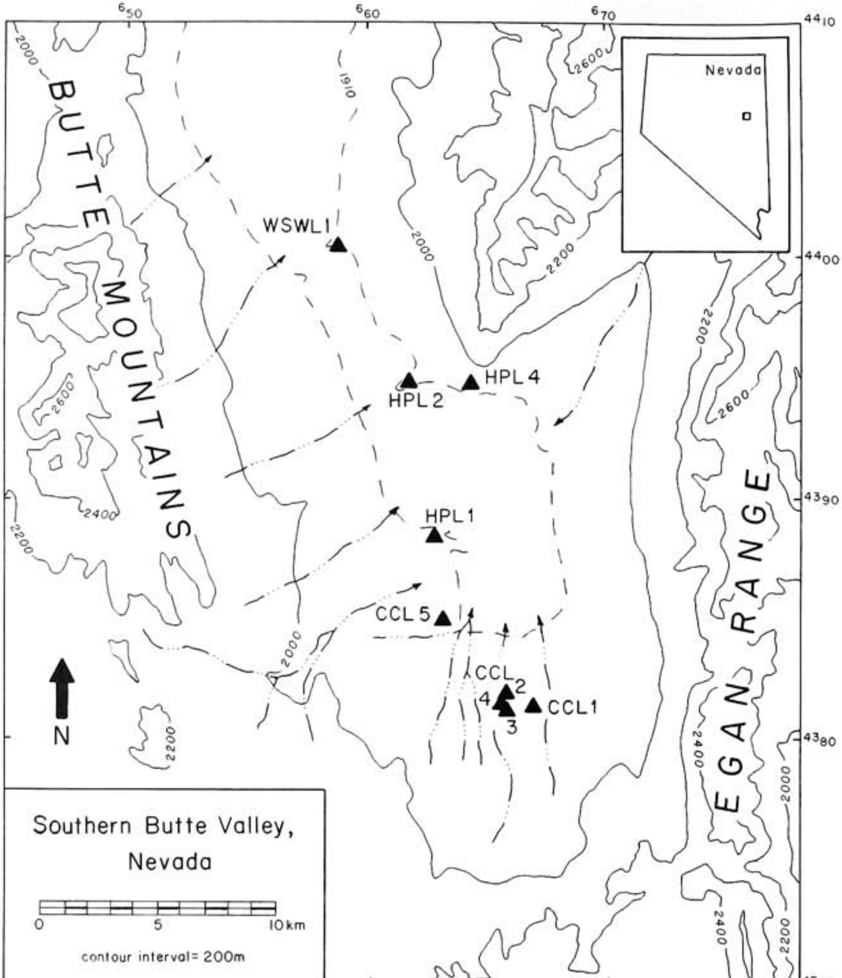

Fig. 1. Site locations in southern Butte Valley, Nevada.

HPL4 occurs 3 km. east of Hunter Point on the 1,917.5-m. shoreline.

Five sites (CCL1 through CCL5) are located in the southwestern part of Butte Valley at elevations ranging between 1,915 m. and 1,922.5 m., some distance south of any clearly demarcated pluvial features. Three of these sites (CCL2, CCL3, and CCL4) form a

Table 1
SUMMARY INFORMATION ON LATE PLEISTOCENE-EARLY HOLOCENE SITES LOCATED DURING 1986 AND 1987 IN BUTTE VALLEY, NEVADA

Site Number	Field Name	Elevation (m.)	Environmental Setting	Obsidian Number	Obsidian Percent	Artifact Total
26-Wp-2197	CCL1	1920-1922.5	Floodplain surface	30	9.1	324
26-Wp-2198	CCL2	1922.5-1925	Alluvial terrace	5	7.8	64
26-Wp-2199	CCL3	1922.5	Alluvial terrace	13	7.7	168
26-Wp-2193	CCL4	1922.5-1925	Alluvial terrace	9	1.8	499
26-Wp-2200	CCL5	1915-1917.5	Alluvial terrace	337	15.9	2,120
26-Wp-2192	HPL1	1912.5	Beach ridge	12	6.1	195
26-Wp-2194	HPL2	1905-1912.5	Spit	245	25.2	971
26-Wp-2206	HPL4[a]	1917.5	Beach ridge	2	6.7	30
26-Wp-2195	WSWL1[b]	1902.5-1907.5	Spit	23	7.6	301

[a] HPL4 was sampled on survey. Artifact total represents 10% coverage of the site.
[b] WSWL1 was collected as four clusters. Total is for all clusters.

cluster along a north-south trending stream terrace. CCL1 lies east of this group on an active floodplain; however, despite modern fluvial activity, this floodplain apparently is quite ancient, as suggested by temporally diagnostic artifacts from CCL1 and nearby survey tracts.

Eight of the sites were collected at 100% sample fractions, either by radiation (HPL1, HPL2, WSWL1) or 2 x 2-m. grid provenience (CCL1-5). HPL4 was sampled during survey at approximately a 10% fraction. Assemblage sizes range from 30 artifacts at HPL4 to 2,102 artifacts at CCL5.

ANALYTIC METHODS

Collections used in this study are from eight sites and 10 survey tracts. The sites differ in elevation by no more than 15 m. and have similar aspects and vegetation associations. The survey tracts are similarly distributed, but represent a slightly greater maximum elevation range of about 40 m. Some 4,558 lithic artifacts were collected from the sites, while another 99 artifacts (isolates) came from the survey tracts. Basalt and chert artifacts dominate the collections; obsidian artifacts total over 750 specimens and comprise anywhere from 2% to 25% of the site inventories (Table 1).

From this sample, 115 obsidian specimens (89 site and 26 offsite artifacts) were chosen for XRF and hydration analyses. A number of considerations were taken into account when the selection was made, and consequently this group does not constitute a probabilistic sample. This sample contains specimens from each late Pleistocene-early Holocene assemblage, and includes all temporally diagnostic specimens, e.g., projectile points, as well as a range of other typologic categories including debitage. Further, in an attempt to insure representation of a range of geologic sources, we selected artifacts from a number of visually distinct categories (based on color, inclusions, etc.) of obsidian. Finally, samples were chosen to maximize spatial dispersion over sites to enable an evaluation of chronological and source attributes of separate spatial clusters.

XRF Analysis

Richard Hughes (California State University, Sacramento) performed XRF analysis of the specimens (techniques follow Hughes 1986, 1988). Concentration values (ppm by weight) of seven elements (Rb, Sr, Y, Zr, Nb, Zn, and Ga) were obtained for each artifact. These analyses identified 13 chemical types (Tables 2 and 3).

Based on values of four diagnostic elements (Rb, Sr, Y, and Zr), Hughes made comparisons with reported geologic sources of obsidian in Nevada, Oregon, and Utah. Source matches were found for only two of the chemical types contained in the Butte Valley sample. One is a local obsidian (designated Butte Mountain) which occurs as a pebble lag on the alluvial fans that border the western edge of Butte Valley (a search for a point source in the Butte Mountains has not yet been successful). The other match is with the Brown's Bench glass, a northeastern Nevada/southwestern Idaho source (see Nelson 1984). Importantly, none of the other geochemistries match sources from western or central Utah, or types from the western Great Basin. It seems reasonable to suggest that isolated volcanic rocks of middle Tertiary age, like the ones in southern Butte Valley, contributed many of the glasses and welded tuffs in this sample. The lithologies of these centers are not described in sufficient detail to evaluate this point at present, however.[3]

Obsidian Hydration Analysis

Hydration rind measurements were made by Robert J. Jackson (Lithicron). Mounted thin-sections were normally examined under 500x magnification and measurements were made to the nearest 0.01 micron (measurement error = ±0.2 microns). An average hydration value for each specimen was created based on a minimum of four readings on two faces. In this set of 115 artifacts, 100 cases possessed measurable hydration rinds, and of these, 11 had secondary rinds. The hydration rinds of several geochemical types, e.g., "A," "C," and, to a lesser degree, Brown's Bench, proved difficult to measure owing to their optical properties.

ANALYTIC RESULTS

Chronological Ordering of Projectile Points

Projectile point styles represent a broad independent check of the chronological sensitivity of the hydration data. Minimally, it is expected that the hydration values will reflect age differences between point styles representing clearly distinct time periods. For example, among specimens of the same geochemical type, late Pleistocene-early Holocene points should exhibit thicker hydration rinds than Archaic points. Sizeable numbers of identical or reversed values, however, would imply a problem with the approach.[4]

Projectile points and point fragments of obsidian, numbering 17 specimens, comprise two chronological groups, late Pleistocene-early Holocene types (n = 11) and Archaic types (n = 3), and a third group (n = 3) with uncertain temporal affinities (Fig. 2). Members of the first group have been divided into three morphologic forms: (1) shouldered points with parallel-sided stems and straight or convex bases (e.g., Silver Lake [Amsden 1937] and Parman [Layton 1970] types); (2) points with long, tapering stems and minimal or no shouldering (e.g., Lake Mohave [Amsden 1937] and Cougar Mountain [Layton 1970] types); and (3) points with parallel-sided stems and concave bases. Archaic points include single specimens of Humboldt, Pinto, and Elko types. The third group is made up of stemmed forms that have no clear typologic affiliation. Figure 3 illustrates the ranges of hydration values displayed within these groups.

In examining these data we should first note that this sample does not lend itself to detailed evaluation. Small sample size generally limits the range of comparisons that can be made. One notable problem is that none of the Archaic points are made from the

Table 2
ELEMENT ABUNDANCES (PPM) OF BUTTE VALLEY OBSIDIANS

Source	Number of Samples	Element			
		Rb	Sr	Y	Zr
Butte Mountain[a]	10	160.7±8.2	315.6±9.4	23.9±1.4	117.4±3.4
Butte Mountain[b]	41	165.4±8.0	324.8±13.9	24.2±1.7	117.5±5.3
Brown's Bench	28	211.2±11.7	50.6±2.7	56.4±3.1	456.3±21.1
"A"	5	175.6±7.8	67.0±4.9	61.2±2.5	556.9±27.1
"B"	10	192.1±5.8	125.2±5.0	32.6±1.9	164.0±5.0
"C"	7	230.9±5.8	25.7±2.1	58.6±2.9	371.0±10.0
"D"	2	210.7±8.2	27.0±1.3	29.3±0.6	102.5±2.6
"E"	1	151.9	126.4	23.4	162.3
"F"	4	192.9±5.6	106.7±4.6	15.3±1.2	104.8±5.0
"G"	11	193.9±11.1	77.6±4.3	27.2±4.5	119.7±10.9
"H"	1	194.0	43.1	25.2	111.9
"I"	2	336.6±4.8	5.7±2.6	40.0±1.1	113.5±15.7
"J"	2	437.2±12.4	7.3±0.1	46.8±0.2	148.0±2.6
"K"	1	170.6	89.6	25.4	145.0

[a] Geological sample.
[b] Archaeological sample.

Table 3
OBSIDIAN REPRESENTATION IN BUTTE VALLEY ASSEMBLAGES[a]

Site	Source													
	BM	BB	"A"	"B"	"C"	"D"	"E"	"F"	"G"	"H"	"I"	"J"	"K"	Total
CCL1	7			7		2								16
CCL3	2								7	1				10
CCL4												1		1
CCL5	13	13	3		6		1							36
	(2)	(2)	(2)		(4)									
HPL1	3	5						4						12
HPL2		4		1	1				2			1	1	10
		(1)												
HPL4	1	1												2
		(1)												
WSWL1B			1											1
			(1)											
WSWL1C	1													1
Offsite	18	3	1	2					2		2			28
		(2)												

[a] Figures in parentheses refer to the number of unreadable specimens.

dominant obsidian geochemical type represented among the early styles, the Brown's Bench glass (n = 7). Another is that obsidian geochemical types "C," "D," and "K" are represented by single specimens only. Keeping these qualifications in mind, two aspects of these data are noteworthy. First, these data are properly distributed, with late Pleistocene-early Holocene point styles possessing thicker rinds than Archaic styles. Two specific comparisons are applicable. In one instance, the two Cougar Mountain points of obsidian geochemical type "B" possess thicker hydration rinds than the Pinto point of this same material. In the other case, two early points of obsidian geochemical type "G"

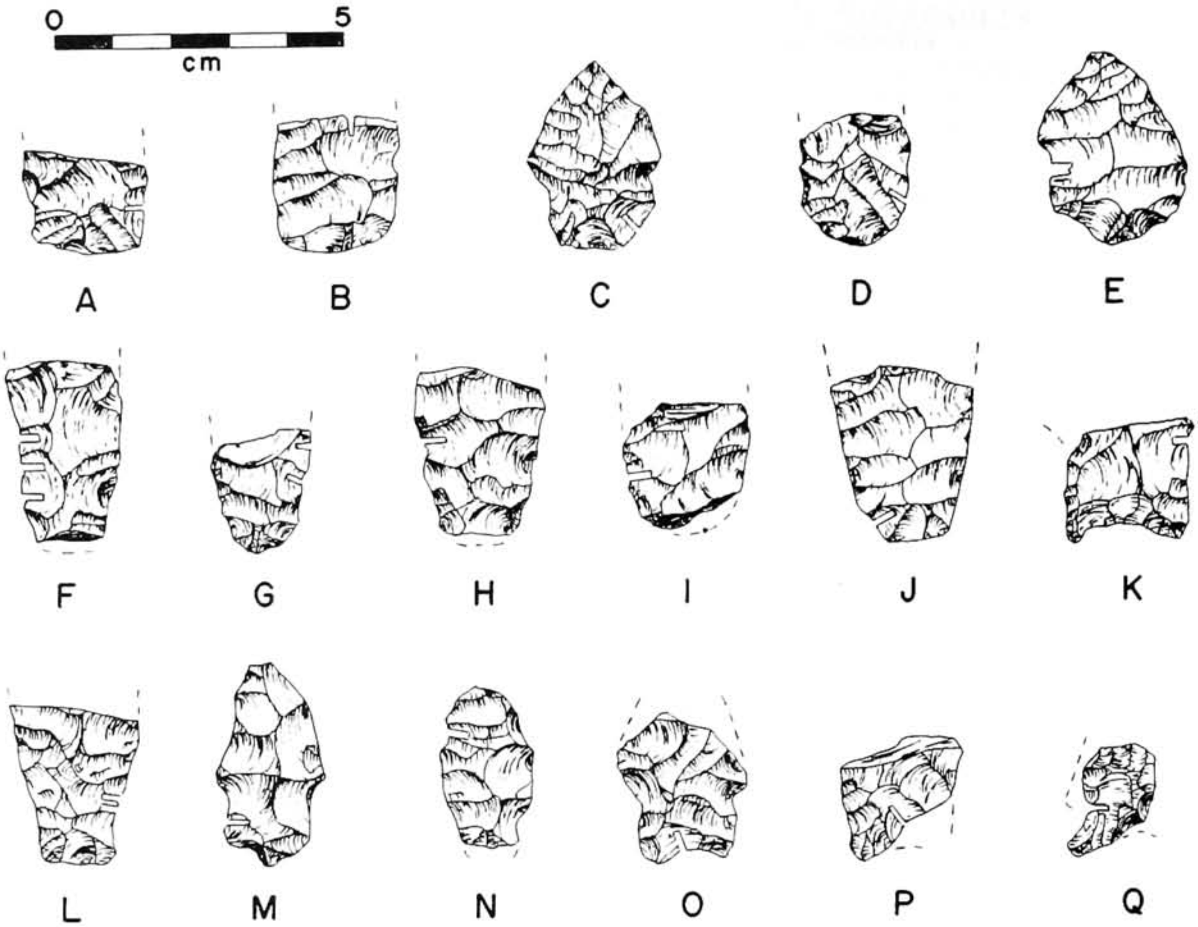

Fig. 2. Obsidian projectile points represented in the Butte Valley assemblages. A-E, Silver Lake-Parman; F-J, Lake Mohave-Cougar Mountain; K, stemmed with a concave base; L-N, untyped stemmed; O, Pinto; P, Humboldt; Q, Elko.

have thicker rinds than the Humboldt specimen. Second, the hydration values help to clear the uncertainty surrounding the temporal affinities of at least two of the untyped stemmed specimens; those made from Brown's Bench glass have rind thicknesses within the range for late Pleistocene-early Holocene specimens.

Unfortunately, no projectile points were manufactured from the Butte Mountain glass. Thus, we cannot argue on the basis of hydration values alone that its use was coeval with that of other artifacts for which we have this independent measure of age. Of course, this same qualification applies to all other nondiagnostic artifacts, specifically many chert and basalt artifacts. Age assessments for these require other types of associational arguments (see Jones and Beck n.d.). Almost certainly, however, where artifacts of Butte Mountain obsidian occur intermixed with artifacts exclusively of late Pleistocene-early Holocene age, we can make a strong case for them having been manufactured and used during this early period.

Chronological Ordering of Site Occupation

Moving from the examination of projectile points to artifact assemblages, we can create a possible chronological order by sequentially arranging assemblages according to the average hydration value each takes for a

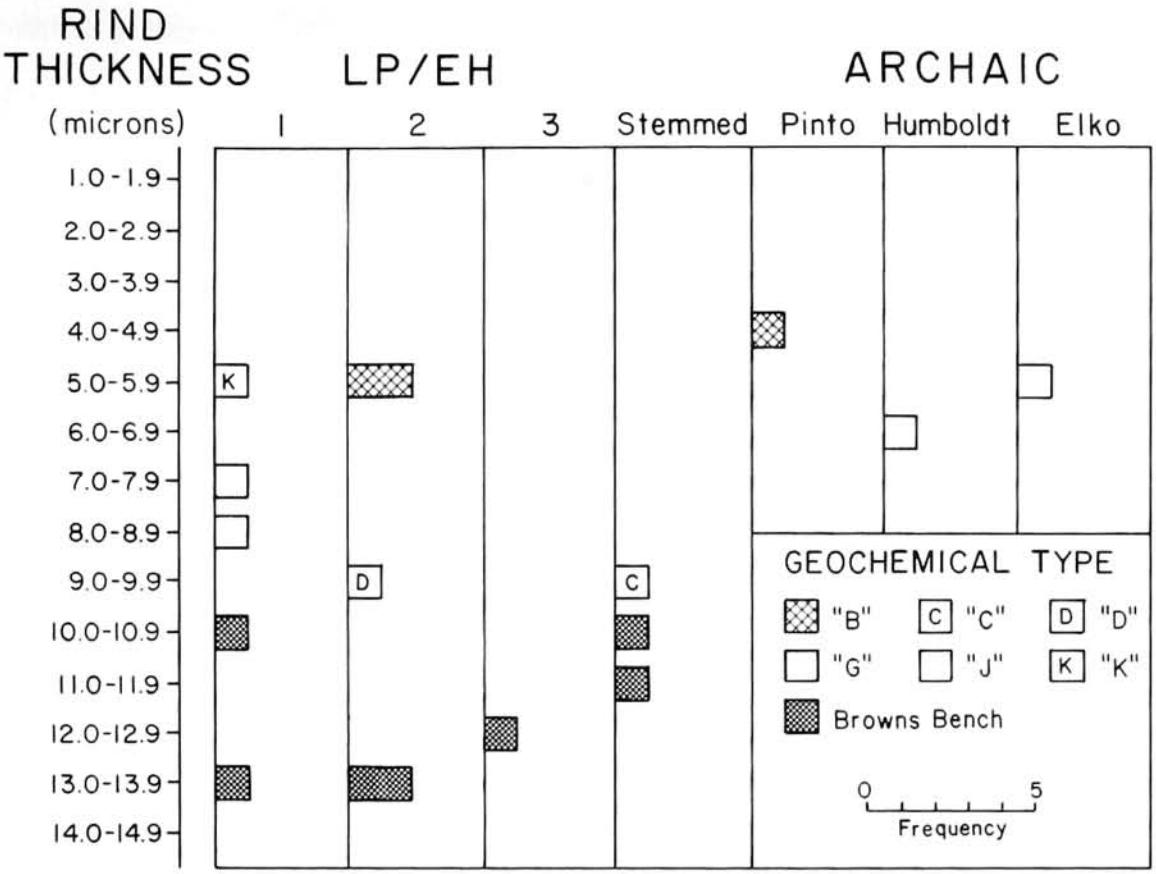

Fig. 3. Obsidian hydration measurements of projectile points.

particular geochemical type. This approach rests on the condition that the assemblages are of comparable duration (see discussion below). This condition is obviously met when all assemblages assume narrow, symmetrical distributions of hydration values. But comparability may also be accepted of distributions that are roughly symmetrical and have similar ranges of values (equal variances). When cases are arranged by the mean hydration values, however, it is possible to lose track of instances of temporal overlap, and thus the spread of hydration values must also be examined.

Figure 4 presents an ordering of six assemblages based on mean hydration values of the four most common geochemical types. Sites are arranged along the ordinate such that the means within each geochemical type decrease (to the right) along the abscissa. For entries based on three or more measurements, one-sigma error bars are shown.

This is the most parsimonious order of the assemblages, although the positions of CCL1 and CCL3 are uncertain since they share no obsidian types in common. The preferred explanation for this arrangement is that these obsidian samples differ in age and the order is chronological. This argument is weakened by small sample numbers, and also by the degree of overlap between pairs of assemblages as, for example, in the Brown's Bench components of HPL1 and HPL2. Instances like this might reasonably be ascribed to overlapping occupational periods. Thus, a more conservative interpretation of this order is that sites fall into three chronological units, each comprising a pair of assemblages. In any

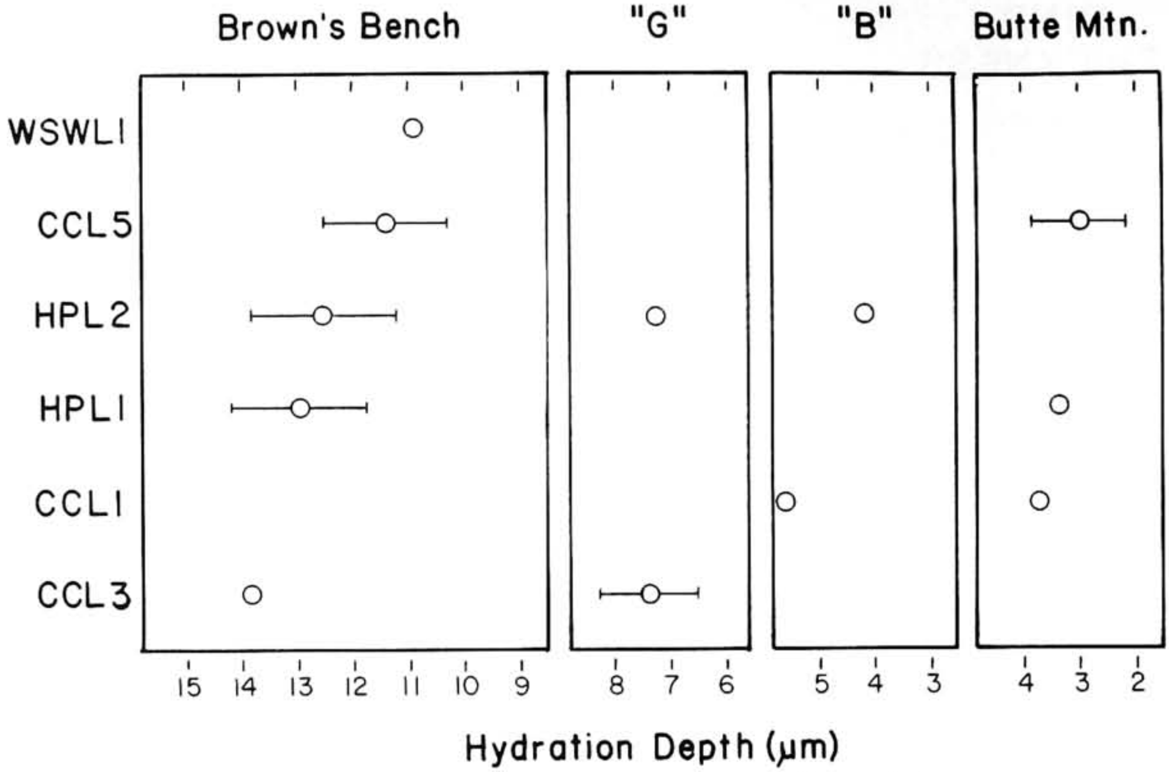

Fig. 4. An order of six Butte Valley assemblages based on obsidian hydration means.

event, this example points out the value of study of specimens of several geochemical types which can yield cross-checking orders.

Strictly speaking, of course, this chronological inference applies only to the particular obsidian subsamples studied here. A broader attribution of temporal order to the six assemblages must await other supporting evidence. For example, using refitting analysis and patterns of artifact clustering we may be able to make stronger claims of association among all parts of an assemblage.

Occupational Duration

Given conditions of identical temperature histories and composition, artifacts of the same age should possess hydration rinds of nearly equal thickness. As best we can tell, however, even fully contemporaneous artifacts like those recovered in lithic caches can be expected to display a range of values. Following Raymond's (1984-85) criteria, then, we expect that artifacts of the same age will form a narrow, symmetrical distribution of hydration values. If such a set contains more than a single geochemical type, the most rapidly hydrating types will tend to exhibit a less tightly clustered distribution of values, though still retaining symmetry. It follows that these distributional entailments will change if samples include specimens of significantly different age, perhaps the result of extended occupational spans or locality reuse. Thus, the range of hydration values for a geochemical type should provide information on the duration of use of a locality, while the shape of the distribution of values should reflect upon the continuity or discontinuity of use. For example, in a comparison of two samples, one with hydration values covering a broad range and the other with a narrower range, the latter reflects the briefer period of artifact deposition among the two samples, other things being equal. As noted before, when the latter distribution is both strongly peaked and symmetrical we may infer as well that deposition occurred during a very brief interval of time. In contrast, multiple peaks would argue against continuity in manufacture and discard, suggesting instead shifting use intensity. Prolonged episodes of site disuse would be reflected by absences of cases between modes. If distributions approximate these latter conditions, we would place little reliance on the mean of a distribution as a characterization for the age of the assemblage.

Table 4 and Figure 5 summarize the hydration data for several obsidian geochemical types with multiple occurrences. Although, with the exception of CCL5, sample sizes are too small for statistical assessments of symmetry, the distributions of hydration values seem to suggest complex occupational patterns at some localities. For example, the distribution of Brown's Bench values from both CCL5 and HPL1 suggests discontinuous use, while the distribution of Butte Mountain values from these same assemblages suggests continuous occupation. As stated earlier, since no temporal markers are made from the Butte Mountain glass, use of that material cannot be pinpointed in time. It is possible that use of these obsidians occurred at different times, in which case each glass references a distinct occupational phase. If, on the other hand, the use of these obsidian types was generally contemporaneous, these data might reflect temporal patterns of differential obsidian use during a single occupation span. In any event, if possible, these data need to be supplemented by additional hydration measurements to eliminate the possibility that the patterns represented here are conditioned by small sample sizes or reflect biases that arise from our sample selection procedure.

Since the ranges of hydration values among these assemblages are similar, our

Table 4
SUMMARY OF HYDRATION MEASUREMENTS

Site			Browns Bench	"B"	Source "G"	"F"	Butte Mountain
CCL1	n			7			7
	$\bar{x}$			5.6 ± 0.35			3.9 ± 0.80
	range			5.3-6.3			2.6-5.2
CCL3	n		2		7		
	$\bar{x}$		13.9 ± 0.50		7.3 ± 0.91		
	range		13.5-14.2		6.5-8.8		
CCL5[a]	n		10				11
	$\bar{x}$		11.4 ± 1.16				2.9 ± 0.87
	range		10.4-13.3				1.8-4.3
HPL1	n		5			4	3
	$\bar{x}$		12.9 ± 1.27			7.5 ± 0.62	3.4 ± 0.06
	range		11.7-14.5			6.8-8.3	3.4-3.5
HPL2	n		3	1	2		
	$\bar{x}$		12.6 ± 1.25		7.3		
	range		11.3-13.8	4.2	6.8-7.7		
HPL4	n						1
	range						3.0
WSWL1	n	1					
	range	10.9					

[a] One specimen with a hydration rind of 5.1 microns was not included in this sample.

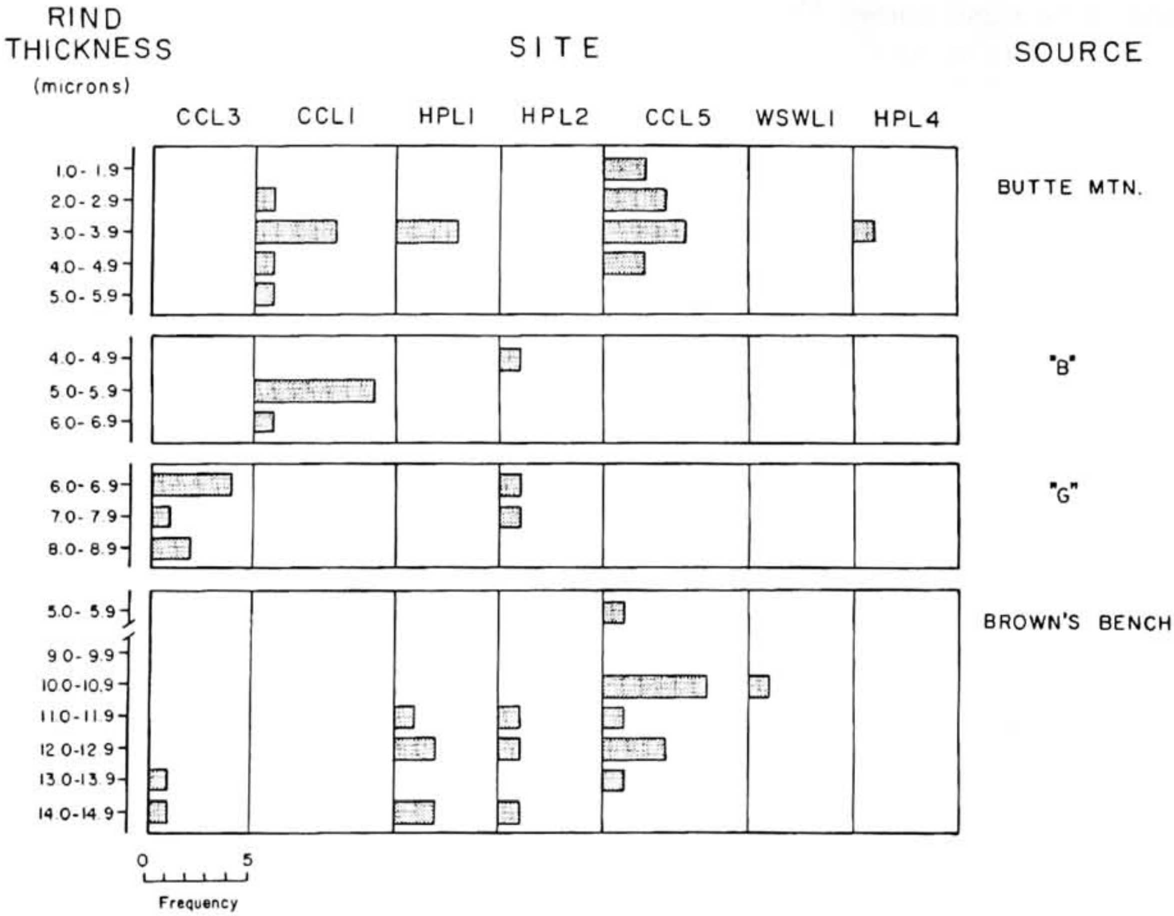

Fig. 5. Frequencies of obsidian hydration values in seven Butte Valley assemblages.

preliminary conclusion is that the occupational duration represented by these samples is roughly similar, although we cannot supply chronometric equivalents for these data. Moreover, the numerical dominance of deeply hydrated specimens in each sample suggests that use of these localities occurred principally in late Pleistocene-early Holocene times. It is also clear, however, that several localites saw at least limited use during the early Archaic and possibly later.

Site-Offsite Artifact Comparisons

A final issue that we have attempted to address through obsidian hydration dating concerns the chronology of offsite activity. Here we are interested in knowing if the land-use patterns responsible for the creation of isolated artifacts and small artifact clusters were coeval with late Pleistocene-early Holocene site use, or perhaps were associated with later Archaic practices. Whether they represent one or the other or are a highly dispersed palimpsest, is usually difficult to assess because isolates and small clusters tend to have very low temporal sensitivity. We can, however, draw some conclusions about the ages of these specimens through comparisons of hydration values with site specimens.

Figure 6 presents hydration data for artifacts from ten survey tracts. For this comparison, isolated artifacts (designated "survey") are arranged by sampling stratum. These data reveal the potential usefulness of isolates for evaluating temporal patterns of land use. For instance, since no sites are

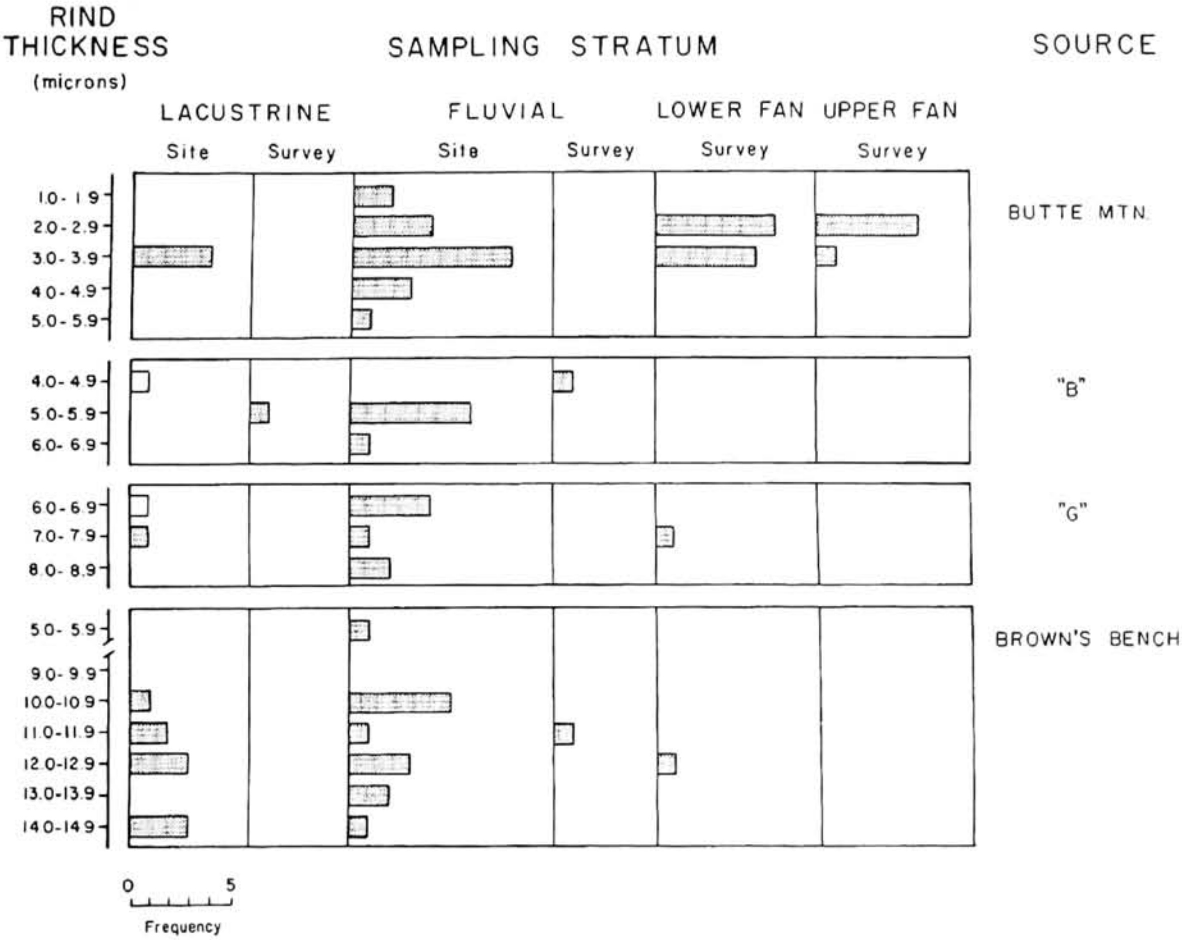

Fig. 6. Comparison of obsidian hydration values among sample types.

represented in alluvial fan settings, our only record of use is made up of isolates. Although these samples again are unfortunately small, their hydration values fall within the range of hydration values from sites. Importantly, for obsidian geochemical types "B," "G," and Brown's Bench, there is a precise match with the values obtained from late Pleistocene-early Holocene projectile points. Thus, we have a subtle suggestion that the early occupants of southern Butte Valley made forays beyond lake margin and streamside settings, creating a low-density artifact record over the alluvial fan zone.

CONCLUSIONS

To make progress in the study of late Pleistocene-early Holocene occupation of the Great Basin, improvements in chronological resolution are critical. Yet, because the great majority of archaeological expressions of this age lie on the surface, the number of available dating tools is small, and the most commonly used of these, typological cross-dating, has been a poor temporal discriminator. Recently, archaeologists have begun to explore the application of obsidian hydration dating to surface assemblages, finding that, with control over source variation and depositional setting, it may serve as an effective relative dating method.

We have reported here on the early phases of an obsidian hydration dating program focused specifically on surface artifacts of presumed great antiquity. The results show that obsidian hydration dating passes the first critical test: it is capable of clearly distinguishing between late Pleistocene-early Holocene and later archaeological materials. Through compilations of hydration measurements, we have been able further to (1) assess contemporaneity among assemblages; (2) evaluate continuity of site occupation/use; and (3) propose a chronological order of assemblages. While these efforts are promising, each result must be evaluated with larger samples of hydration measurements than present here. As we have found in this study, an abundance of geochemical types, which serve as a source of cross-checking comparative data, can exacerbate problems of small sample size. Yet this abundance is an interesting aspect of the archaeological record in its own right, potentially informing on diachronic variability in lithic resource procurement patterns.

The implications that temporal control might have for the study of the late Pleistocene-early Holocene archaeological record of the Great Basin are as numerous as the questions currently asked about it. One clear effect that it should have, however, is to refocus research away from interregional, comparative, typological studies to investigations of local archaeological variation, adaptation, and evolution.

NOTES

1. Friedman et al. (1990) reported that the rate of hydration also is humidity dependent. They suggested that buried obsidian artifacts are less affected by this factor since such artifacts experience relative humidities at or near 100%. Surface specimens, in contrast, may experience quite different humidity levels. Friedman et al. suggested this may be the principal factor contributing to the surprisingly slow hydration rates of surface artifacts in temperate arid settings. In effect, low humidity compensates for high temperatures.

2. Since 1986, each site discovered has been named for the 7.5 minute quadrangle on which it occurs and assigned a unique number. In previous publications, these field designations have been abbreviated; e.g., Combs Creek Locality 1 is referred to as CCL1. For ease of comparison with the published work, we have retained these abbreviated site names in this paper. Corresponding state site numbers are shown in Table 1.

3. In 1989, additional obsidian source survey was conducted south of the project area in the Indian Peak volcanic field (Best et al. 1989). Collections for source characterization were made at several localities. These have not yet been analyzed. It should be noted, however, that most are sources of pebbles and small cobbles which would not have supplied cores of sufficient size to account for many of the Butte Valley archaeological specimens.

4. This test of temporal sensitivity is recommended in only the broadest sense. Using obsidian hydration to elucidate the relative chronological position of each projectile point type, besides requiring far larger sample sizes, reverses the argument and leads to circularity, which is not our intent.

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