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Obsidian Hydration Dates for Owens Valley Settlement Categories

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Archaeology has recently undergone a fundamental transformation of perceived goals, central to which is the decreased emphasis on culture chronology and the increased emphasis on models of prehistoric adaptation and theories of culture process. Paradoxically, with more detailed subsistence

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and settlement reconstructions and more rigorous tests of processual theory has come the need for increasingly precise temporal placement of cultural events. Establishing chronology, thus, continues to be a basic archaeological task.

In just this sense, and for just these reasons, the central concern here is chronology, specifically, the dating of aboriginal occupation at archaeological settlement categories in Owens Valley, eastern California. On its own terms, the problem is of local interest at best. Nevertheless, there is a broader perspective in which it assumes larger importance because it provides an essential test of existing subsistence-settlement models proposed for this locality, which have potentially critical implications for understanding man-land relationships over a much larger part of the Desert West.

BACKGROUND

Since 1972, Owens Valley has been the setting for a long-term archaeological research project, a central purpose of which is to reconstruct regional subsistence and settlement patterns and to define changes in these patterns through time (Bettinger 1975, 1976, 1977). To this end, probabilistic surface surveys were carried out within a large sample transect encompassing all major biotic communities represented in the valley. Sites located during these surveys were subsequently divided into major settlement categories based on their archaeological assemblages and natural settings. Time-sensitive projectile points recovered from these sites were then used to determine the intensity of aboriginal occupation for each settlement category during four prehistoric phases spanning the interval from 3500 B.C. to historic times, and, in turn, this evidence was used to construct simple subsistence-settlement models for each of these phases (for a more detailed discussion see Bettinger 1975, 1977).

The results of this analysis showed that certain basic elements of prehistoric adaptive patterns in Owens Valley changed relatively little through time. In particular, it was suggested that in all phases large, permanent lowland villages were occupied virtually year-round, and that lowland plant resources furnished the bulk of the subsistence intake. In contrast to the stability observed in these respects, there was also evidence of at least three successive adaptive shifts, each one disclosed by the addition or deletion of one or more settlement categories in the settlement system.

Only two of these adaptive changes are of interest here. The first is an inferred shift in the emphasis of lowland plant exploitation from riverine resources to dryland resources, which is reflected by a change in the location of lowland occupation sites from riverine settings to desert scrub settings (i.e., desert scrub occupation sites replaced riverine occupation sites); this is thought to have taken place roughly between 1200 B.C. and A.D. 600, most probably late in this interval. The second major adaptive shift in Owens Valley was the inception of intensive pinyon exploitation sometime between A.D. 600 and A.D. 1000, as evidenced by the appearance of pinyon camps within the settlement system during that time. In sum, according to this interpretation, in Owens Valley the aboriginal use of riverine occupation sites is relatively early and that of pinyon camps relatively late; the initial use of desert scrub occupation sites is intermediate, beginning before that of pinyon camps, but, along with that category, lasting until contact times.

The proposed models of Owens Valley subsistence and settlement patterns are probably the most economical interpretation of the archaeological data now in hand, but they are vulnerable to criticism in several respects, perhaps the most serious that of chronology. In particular, the reliance on pro-jectile point forms characteristic of relatively long time spans results in only crude control over adaptive change through time, a problem further aggravated by the relative scarcity of projectile points in Owens Valley surface assemblages. In addition, it can be argued that as items of hunting gear, projectile points might be inappropriate to the task of dating adaptive changes that revolve around the use of plant, rather than animal, resources.

To partly overcome these uncertainties, obsidian hydration analysis was performed on flake samples from a group of sites that represent three settlement categories, riverine occupation sites, desert scrub occupation sites, and pinyon camps, the dating of which is crucial to the two adaptive shifts discussed earlier. Within each category, two sites were selected for study based on the degree to which their assemblages and time-sensitive projectile points reflected the range of variation within the category as a whole.

PROCEDURE

In order to diminish the erroneous temporal mixing that might result had the aboriginal inhabitants of these sites reused artifacts retrieved from sites much older than their own, the obsidian hydration samples were selected from collections of unretouched waste flakes recovered at the six sites. Since larger flakes of this kind might also occasionally have been collected and reused, preference was given to pieces less than 1.5 cm. in maximum dimension. Finally, since it is still possible that even small flakes might be waste from the reworking of tools or large flakes obtained from long abandoned sites, the ventral surface of each flake—which would represent the time of resharpening rather than of the original working of an older piece—was designated as the surface from which the primary hydration measurement was to be taken.

All specimens were visually inspected for color and texture and only those pieces dis-

playing the green color or blue iridescence characteristic of obsidian from Fish Springs, a source near the modern town of Big Pine, were chosen for study (cf. Bettinger 1980). Pending more definitive chemical sourcing, it is assumed that all the hydration samples are from this source.[1]

The samples were prepared and measured for hydration rind thickness according to standard procedures (cf. Michels 1973) by M.C. Hall at the Archaeometry Laboratory of the University of California, Riverside. Hydration rind measurements were obtained for both the designated ventral (primary) surface and the opposing dorsal (secondary) flake surface of every sample. In a few cases, rind measurements were also made for a third (tertiary) flake surface.

Of 56 specimens submitted for analysis, 5 were rejected by the laboratory as being too small to be cut, mounted, and ground for rind measurement. A total of 105 measurements were obtained from the remaining 51 specimens: 51 from primary surfaces, 51 from secondary surfaces, and 3 from tertiary surfaces. Table 1 indicates for each site the number of samples initially submitted, the number actually processed, the laboratory designations for the samples, and summary statistics for their rind measurements.

RESULTS

All three tertiary hydration rinds were in excess of 16.0 μm. thick. These values are anomalously large in comparison to those from primary and secondary surfaces and probably represent original cortical surfaces or old, natural fractures; they are eliminated from consideration here.

The primary and secondary flake surface hydration rinds ranged in thickness from 0.0 μm. (no rind) to 10.88 μm. In most cases,

Table 1
**RESULTS OF OBSIDIAN HYDRATION MEASUREMENTS FOR DEBITAGE SAMPLES
FROM SIX ARCHAEOLOGICAL SITES IN OWENS VALLEY**

Site	Site Type	Number of Samples Submitted	Number of Samples Processed	Hydration Measurement Range	Hydration Measurement Mean	Samples With No Observable Rind	UCR Laboratory Numbers
A2/1	Riverine occupation site	10	9	10.88 - 4.14 μm.	7.06 μm.	0	821 - 830
A1/2	Riverine occupation site	10	10	7.70 - 2.52 μm.	3.75 μm.	0	811 - 820
B68/2	Desert scrub occupation site	10	9	4.08 - 1.51 μm.	2.58 μm.	1	841 - 850
B25/2	Desert scrub occupation site	10	9	3.83 - 2.85 μm.	3.41 μm.	2	831 - 840
C9/2	Pinyon camp	10	8	4.58 - 1.01 μm.	2.15 μm.	1	851 - 860
C25/2	Pinyon camp	6	6	2.22 - 1.06 μm.	1.63 μm.	1	861 - 866

the hydration value for an individual specimen is taken to be the mean of its primary and secondary surface rinds; in no case where rinds were visible on both surfaces did their measurements differ significantly (.05 alpha level) in terms of a standard two sample *t*-test, where the standard deviation for each measurement is determined by the optical limitations of the instrument used and the observed variation of the rind under repeated measurement. Where either a primary or secondary flake surface showed no visible rind, the single visible rind is accepted as the measurement for the specimen. In five cases, both the primary and the secondary surfaces showed no hydration rind; these pieces are presumed to have been subject to chemical, mechanical, or physical conditions affecting either the hydration process or the

hydration rind that render them chronometrically useless.

When the 46 readable specimen measurements are plotted by site (Fig. 1), they order the riverine occupation sites, desert scrub occupation sites, and pinyon camps in a chronological sequence consistent with proposed Owens Valley subsistence-settlement models. As suggested in these models, the riverine occupation sites, where values are from 10.88 to 2.52 μm., are earlier than desert scrub occupation sites, where values are from 4.08 to 1.51 μm. Both are earlier than pinyon camps, where, with the exception of a single, apparently anomalous reading of 4.58 μm., values are from 2.49 to 1.01 μm. The replacement of riverine occupation sites by desert scrub occupation sites seems to have been
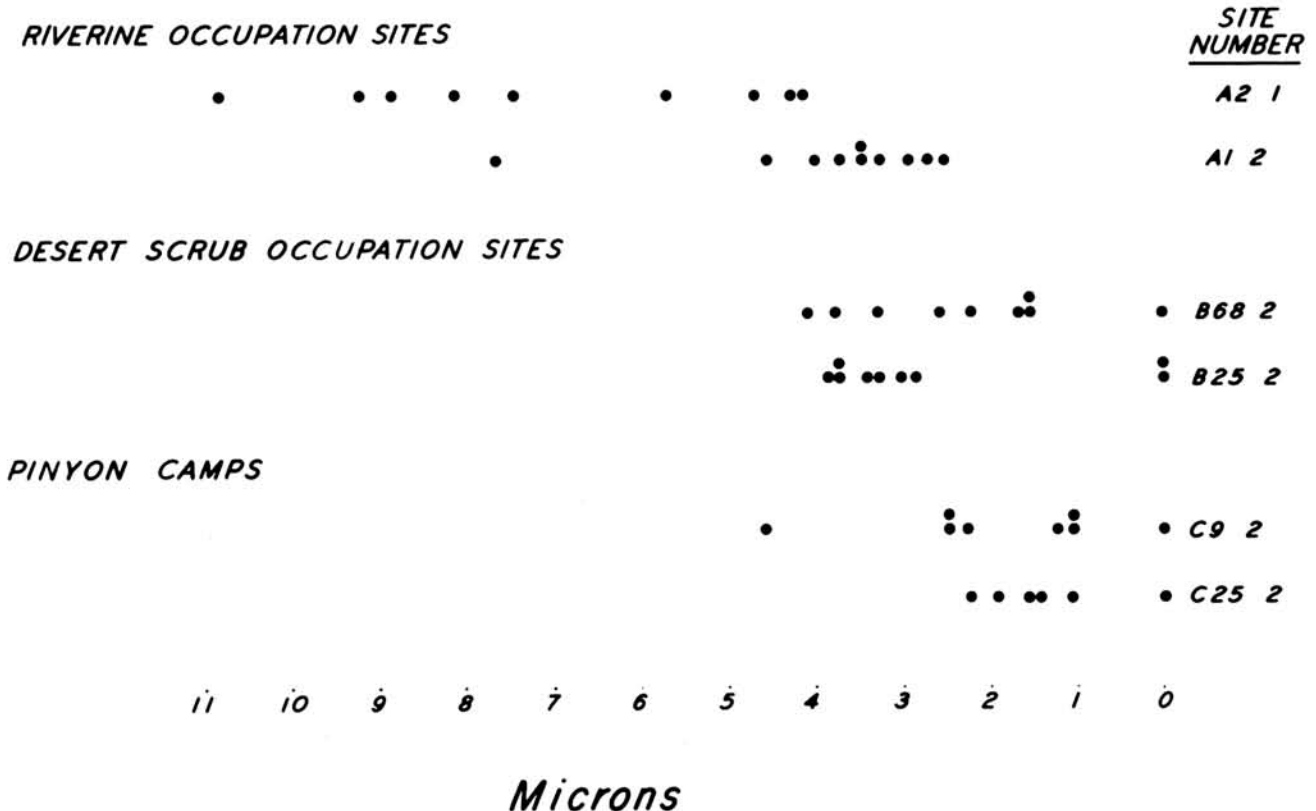

Fig. 1. Distribution of obsidian hydration measurements for six archaeological sites representing three major Owens Valley settlement categories.

achieved gradually over a long transitional period marked by hydration values of from 4.08 to 2.52 μm., when both categories were in use. There is also substantial temporal overlap between desert scrub occupation sites and pinyon camps; but here the pattern is not one of replacement (their terminal occupation being roughly the same), but merely one in which the initial use of pinyon camps is substantially later than the initial use of desert scrub occupation sites.

Perhaps these data can best be characterized as showing an *early period,* denoted by rind values of about 10.88 to 4.10 μm., when only riverine occupation sites are represented; a *middle period,* denoted by values between 4.10 and 2.5 μm., when both riverine occupation sites and desert scrub occupation sites are represented; and a *late period,* denoted by values of from 2.5 to 1.00 μm., when both desert scrub occupation sites and pinyon camps are represented.

If it is assumed that not only the relative sequence, but also the actual time placement of these settlement shifts is comparable to that proposed in the Owens Valley subsistence-settlement models, then the *early period* defined by obsidian hydration would be roughly equivalent to the Clyde phase (3500-1200 B.C.), the *middle period* to the Cowhorn phase (1200 B.C.-A.D. 600), and the *late period* to the Baker (A.D. 600-A.D.1300) and Klondike (A.D. 1300-historic) phases. This would equate an obsidian hydration reading of 1.0 μm. to a date of about 100 B.P., a reading of 2.5 μm. to a date of 1350 B.P., and a reading of 4.1 μm. to a date of about 3150 B.P.

Predictably, these three fixed points will fit any one of several variations of the general hydration rate formula: $x = kt^n$, where x is the observed hydration, k is the hydration rate, t is time, and n is an exponential value for which several differing values have been proposed based on either empirical or theoretical criteria (cf. Michels and Tsong 1980). Whether n is set

at 1.0, .66, .57, or .50, or the hydration formula put in the modified form, $x^2 - x = kt$ (cf. Findlow *et al.* 1975), the observed correlation between hydration rind and time for the points noted is uniformly greater than $r = .99$.

There are, however, strong theoretical reasons favoring the use of the standard rate formula with n set at .5 as proposed by Friedman and Smith (1960; cf. Ambrose 1976). The linear regression for this function is $Y = 189.7 X^2 - 12.11$, where Y equals the date B.P. and X equals the hydration value. Unfortunately, this would place the initial occupation of Owens Valley, as indicated by an hydration reading of 10.88 μm., prior to 20,000 B.P., which is certainly too old. Of the alternative functions considered, only a linear rate, where n is equal to 1, yielded acceptable age estimates for the earliest occupation. Its linear regression is $Y = 985.4 X - 963.1$, where Y equals the date in years and X equals the hydration value. This would fix the initial use of the riverine occupation sites at about 8000 B.C., which is earlier than previously thought, substantially pre-dating the Clyde phase, but nevertheless consistent with abundant evidence of occupation in the region during early post-Pleistocene times (Borden 1971).

One serious objection to applying either formula lies in the possibility that hydration rates, which are highly sensitive to temperature, might vary substantially between site categories which are at widely divergent elevations and consequently are exposed to disparate thermal regimes in contrast to sites within a single category which are much the same in this respect. Indeed, because between the three settlement categories, the riverine sites are lowest in elevation, and pinyon camps the highest, it follows that the relative placement of these categories by hydration—riverine sites first and pinyon camps last—is precisely the ordering that would be expected if all three categories were contemporaneous and differences in their rind values reflected

nothing more than increasing hydration rate with decreasing altitude (i.e., increasing temperature).

It is unlikely, however, that the observed hydration data can be entirely explained in this way. For one thing, if it is assumed that the smallest rind value for each settlement category represents exactly the same point in time (i.e., that the terminal occupation indicated by their endpoints is the same), then, under the Friedman and Smith (1960) hydration model, the riverine sites, where the minimum value is 2.5 μm. would have a hydration rate 2.8 times that of the desert scrub sites, where the minimum value is 1.51 μm., and 6.22 times that of pinyon camps where the minimum value is 1.01 μm. This discrepancy seems too great to be adequately explained by temperature differences between the sites from which these values were obtained. If we extrapolate mean annual site temperature based on site elevation in relation to regional climatic data (cf. Curry 1971), and take this as the effective hydration temperature, then the riverine site in question (A1/2) would have an effective temperature of 13.5° C., the desert scrub site (B68/2) one of 11.2° C., and the pinyon camp (C9/2) one of 8.4° C. According to experimental and theoretical research (cf. Friedman and Smith 1960), given differences of this size within this temperature range, the hydration rate for riverine sites should only be about 1.3 times that of the desert scrub site and about 1.7 times that of the pinyon camp—values substantially lower than those indicated by assuming that the categories are contemporaneous. It is worth noting in this regard that in the absence of more conclusive studies relating temperature to hydration rate it would probably be premature to correct the present hydration values based on these temperature estimates.

CONCLUSION

The small sample sizes in this study make it unwise to draw firm conclusions from these results or to regard hydration rates based on them, either corrected or uncorrected for temperature, as anything but provisional. Nevertheless, the weight of present evidence indicates that the obsidian hydration ordering of these sites is consistent with proposed Owens Valley subsistence-settlement models and that temperature differences between the categories probably cannot explain this ordering. There is, in addition, more ambiguous evidence that the temporal placement (i.e., absolute dating) of these categories by obsidian hydration is compatible with existing subsistence-settlement models, but temperature differences between the categories, in combination with small sample sizes and incomplete understanding of the effect of temperature on the hydration process, particularly in regard to surficial materials, make this proposition more tenuous.

NOTE

1. This assumption is supported by the hydration measurements, which are tightly clustered for individual sites (Fig. 1), suggesting uniformity of source within these samples.

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