ESTABLISHING AN HYDRATION RATE FOR FISH SPRINGS OBSIDIAN

Robert L. Bettinger

DESPITE GROWING RELIANCE UPON OBSIDIAN hydration as a means for establishing archaeological chronologies, particularly in California and the Great Basin, many aspects of the method that directly bear on its utility as a tool for dating remain problematic. Two of these are crucial. Firstly, however unambiguous they may seem in theory, many elements of the hydration process are unresolved in practice. The basic shape of the hydration curve itself is one such example (e.g., Meighan 1983). These are exceedingly technical matters. Apart from working solutions that must from time to time be developed in desperation by archaeologists, they are on the whole best left to specialists: experimentalists and theorists familiar with the physical mechanics and theory of the diffusion process. The other nagging problem in contemporary obsidian hydrations studies is that of establishing hydration rates for individual glass sources or localities within certain areally extensive and chemically heterogeneous sources. This problem is substantially less technical than the first and more readily dealt with by archaeologists. Indeed, a case can be made that hydration rates are more readily determined by the archaeologist than by the physicist/chemist (cf. Meighan 1983).

The matter of hydration rates was less a problem in early applications of obsidian hydration dating because reliable means for chemical sourcing were generally unavailable. Lacking this information, it sufficed to establish a few rates for large regions (e.g., Friedman and Smith 1960; Clark 1964), primarily to control for temperature, which, along with time, was seen as a major variable contributing to hydration rind thickness. As early as the 1970's, however, improving means of, and access to, chemical sourcing applicable to natural glass (e.g., Jack 1976) showed that hydration rate varied between geological sources, presumably as an effect of chemical constitutents that speeded or slowed the diffusion process (Michels and Bebrich 1971). It was clear thereafter that source variability would have to be addressed if obsidian hydration were to be used as a means of archaeological dating. Of course, the sourcing methods that raised chemical composition as a problem in the first place were the obvious means for its solution.

Knowing that hydration rates vary by source and having the capability to assign glass to chemically distinguishable sources makes the method by which rates are obtained all the more important. Two fundamentally distinct approaches are available, one geochemical, the other contextual/archaeological. The first seeks to isolate the effect on hydration rate of certain glass constituents, for example, silica (e.g. Michels 1981). Prospects for this approach seem good. To date, however, in the instances where it has been attempted the results have been problematic, proving more than anything else that the approach is still in its infancy and not to be relied upon generally.

As an alternative to chemical analysis, hydration rates may be obtained empirically with reference to a suite of rind measurements from contexts independently dated by either physical, e.g., radiocarbon, or cultural means, e.g., time-marker artifacts. Other things being equal, dating by physical techniques is clearly the more preferable. This is not generally possible, however. Indeed, interest in obsidian hydration as a dating method arose directly in response to the limited applicability of most other physical methods, including radiocarbon, in many archaeological contexts — particularly in California and the Great Basin. The archaeologist must operate as best he can with what is left, calibrating hydration rates by means of cultural chronologies, aided here and there by dates obtained through other means.

BACKGROUND

Described below are the methodology and results of an attempt to develop an hydration rate for Fish Springs obsidian, the source of which lies a few miles south of the modern town of Big Pine in eastern California. The hydration rate for this glass is locally important in central Owens Valley where material from this source constitutes approximately 50% - 100% of all chipping waste (Bettinger 1982). It is, further, of more general regional importance in eastern California than its limited regional distribution might suggest because Fish Springs obsidian can be readily and reliably identified by visual means (Bettinger, Delacorte, and Jackson 1984). This makes it possible to eliminate the costly step of chemical sourcing when dating assemblages by hydration rind measurements (cf. Meighan 1983: 608).

Work with the hydration rate for Casa Diablo obsidian (Garfinkel 1980, Basgall 1983, Hall 1983, Hall and Jackson [this volume]), a source located 90 km. north of Fish Springs in Long Valley, Mono County, demonstrates the efficacy of calibrating the hydration rate for that material by cross-dating obsidian hydration rind measurements obtained from well-known projectile point forms against the well-established dates for those forms. In these studies projectile points of different types made of Casa Diablo obsidian were submitted for hydration analysis. Simple correlation between the mean date of the time-span for each type and the mean hydration rind thickness for points representing those types yielded an estimate of hydration rate for Casa Diablo obsidian.

A modified, and less direct, form of this procedure was used by Bettinger (1980) to propose a provisional hydration rate for Fish Springs obsidian. In this study obsidian hydration rind measurements were obtained from samples of debitage recovered from the surfaces of six Owens valley sites belonging to three separate settlement categories (cf. Bettinger 1977). The dating independently inferred for these categories on the basis of time- sensitive projectile points was then used to calculate an hydration rate. This was done by correlating dates that marked the inception or termination of use of the three categories and the largest (i.e., oldest) or smallest (i.e., youngest) hydration rind measurement for those categories (for details see Bettinger 1980). Following the generally accepted model of diffusion, to which in theory the hydration of obsidian conforms, the initial calculation presumed that rate of hydration rind growth decreases directly in proportion to the square root of the amount of time that has lapsed since the surface being measured for rind thickness was first exposed to the atmosphere. This gave:

$$Y = 189.7\,X^2 - 12.11, \quad (1)$$

where X is the observed hydration rind in microns and Y is the age of the rind in years before present. Although faithful to theory, this rate produced unacceptably large estimates of age for the obsidian specimen yielding the largest rind measurement observed in the study (10.9 microns = 22,526 years). The most parsimonious alternative assumed the rate of hydration to be linear. This gave:

$$Y = 985.4\,X - 963.1, \quad (2)$$

where X and Y are defined as in Equation 1, i.e., the hydration rind measurement and age in years B.P., respectively.

The working hydration rate for Fish Springs provided by Equation 2 was most useful despite its obvious shortcomings, most notably that: 1) the correlation derived from only three data points (1200 B.C. and 4.1 microns, A.D. 600 and 2.5 microns, and A.D. 1850 and 1.0 microns); and 2) the inferred temporal linkage between rind measurement and age was indirect and hence problematic for all three (i.e., in this study projectile points provided the dates for the settlement categories, which in turn provided the dates that were correlated with rind measurements to obtain the rate). Continuing archaeological research in Owens Valley and eastern California favored development of a new hydration rate more precise and more accurate than the first.

METHODOLOGY

Because there are still no well-stratified and reliably radiometrically dated sites or series of sites from which samples of Fish Springs obsidian can be

TABLE 1
OBSIDIAN HYDRATION MEASUREMENTS FOR TYPABLE PROJECTILE POINTS

Specimen Number	UCD Laboratory Number	Type/ Series	Hydration Reading
OX-10	543	Desert Side-notched	NVH*
O-1301	3578	Desert Side-notched	NVH*
O-1291	3576	Desert Side-notched	1.6
O-1651	3583	Desert Side-notched	1.7
O-8	3559	Desert Side-notched	1.8
O-1315	3579	Desert Side-notched	1.9
O-484A	3564	Desert Side-notched	2.2
O- 930	3573	Desert Side-notched	2.7
OX- 13	545	Cottonwood Triangular	NVH*
O- 127	3560	Cottonwood Triangular	NVH*
O- 315	3562	Cottonwood Triangular	NVH*
O- 792	3567	Cottonwood Triangular	NVH*
O-1717	3584	Cottonwood Triangular	NVH*
OX- 45	552	Cottonwood Triangular	1.0
O- 749	3565	Cottonwood Triangular	1.1
OX- 53	554	Cottonwood Triangular	1.6
O- 410	3563	Cottonwood Triangular	1.9
O- 764	3566	Cottonwood Triangular	2.2
O-1745	3585	Cottonwood Triangular	2.6
O- 803	3568	Cottonwood Triangular	2.8
O- 670/2	3586	Cottonwood Triangular	3.3
O-1004	3574	Cottonwood Triangular	3.3
OX- 39	548	Rose Spring series	1.2
OX- 7	541	Rose Spring series	1.6
X- 11	529	Rose Spring series	2.0, 2.7**
OX- 38	547	Rose Spring series	2.0
O-1292	3577	Rose Spring series	2.2
X- 12	530	Rose Spring series	2.2
O-1613	3582	Rose Spring series	2.5
O-1457	3580	Rose Spring series	2.6
O- 808	3569	Rose Spring series	2.7
O- 832	3571	Rose Spring series	3.3
O- 835	3572	Rose Spring series	3.7
O- 238	3561	Elko series	1.9
OX- 70	556	Elko series	3.1
O-1290	3575	Elko series	3.5
X- 49	535	Elko series	4.0
X- 5	528	Elko series	5.4
X- 50	536	Elko series	7.7
OV-872	557	Little Lake series	4.9
X- 36	532	Humboldt Concave Base "A"	6.5

* NVH = no visible hydration

** two distinct hydration bands; the larger, 2.7 microns, is assumed to correspond to the date of manufacture.

TABLE 2

Type/Series	Mean	S	Max	Min	NVH	n
Desert Side-notched	1.98	0.41	2.7	1.6	2	8
Cottonwood Triangular	2.20	0.87	3.3	1.0	5	14
Desert Side-notched and Cottonwood Triangular	2.11	0.71	3.3	1.0	7	22
Rose Spring series	2.43	0.71	3.7	1.2	0	11
Elko series	4.27	2.03	7.7	1.9	0	6
Little Lake series/ Humboldt Concave Base "A"	5.70	1.13	6.5	4.9	0	2

obtained for hydration rind measurement, as in previous work with eastern California obsidians, it was necessary to use well-known and well-dated projectile points types to develop the rate proposed here. Little about this was remarkable. Collections of obsidian projectile points recovered from sites in central Owens Valley during surface survey (e.g., Bettinger 1977) or excavation (e.g., Bettinger 1989) were examined visually (cf. Bettinger, Delacorte, and Jackson 1984) to segregate for further analysis ones that could be identified with certainty as having been made of Fish Springs obsidian. Out of these, 41 pieces that could be confidently assigned to time-sensitive projectile point types (cf. Bettinger and Taylor 1974; Thomas 1981) were submitted to R. Jackson for hydration rind measurement.

Represented in the sample were the following types and series: Desert Side-notched (n = 8), Cottonwood Triangular (n = 14), Rose Spring series (n = 11), Elko series (n = 6), Little Lake series (n = 1), and Humboldt Concave Base "A" (n = 1). It is generally accepted (Bettinger and Taylor 1974; Bettinger 1977, 1989) that in eastern California Desert Side-notched and Cottonwood Triangular points date between A.D. 1300 and historic times (1850; but see Rector, Swenson, and Wilke 1981), Rose Spring series points between A.D. 600 and A.D. 1300, and Elko series points between 1200 B.C. and A.D. 600. These dates are followed here. Themselves poorly dated, Humboldt Concave Base "A" points (cf. Heizer and Clewlow 1968) have often been assumed to be coeval with those of the Little Lake series, which are held to date between 3500 B.C. and 1200 B.C. Data summarized by Thomas (1981) put this temporal equivalence in doubt but so few Little Lake series points made of Fish Springs obsidian were available for study that we were forced provisionally to accept it. Both forms were assigned to the period from 2500 B.C. - 1200 B.C. This estimate is conservative but the one most consistent with the range of dates currently pertaining to the Little Lake series in the western Great Basin (cf. Thomas 1981). The hydration rind for the one Humboldt point examined is consistent with the traditional type of dating, the one proposed here, and the one proposed by Thomas.

Seven of the 41 points cut and microscopically examined lacked visible hydration bands. The remaining 34 exhibited bands ranging from 7.7 microns to 1.0 microns. A single specimen (X-11) showed two distinct hydration bands suggesting the possibility of re-use. The younger (smaller) of these two was ignored, since it is the earlier (larger) that presumably corresponds to the date of manufacture of the point. Individual measurements for each specimen are provided in Table 1 and summarized by relevant type or series in Table 2.

Given the well-established dating for selected Great Basin projectile points and a reasonable sample of archaeological pieces made from Fish Springs obsidian, the problem is to match the one to the other and derive an hydration rate therefrom. As noted earlier, this has often been done by correlation of the mean hydration rind thickness for a given point form with the mean date (i.e., the midpoint of the temporal span) for that form. In the case of the Elko series, for example, the mean of the hydration rind measurements for each piece representing the series would be matched against the date 2270 B.P., the midpoint of temporal span for that series (3170 B.P. to 1370 B.P.) in years before present, taken here to be 1970. This reduces our correlation problem to just four independent data points: 2.11 microns and 670 B.P. for the Desert Side-notched and Cottonwood types combined, 2.43 microns and 1020 B.P. for the Rose Spring series, 4.27 microns and 2270 B.P. for the Elko series, and 5.70 microns and 3820 B.P. for the Little Lake series and Humboldt Concave Base "A" type combined.

It seems a waste of useful temporal data to assume, as in effect the procedure outlined above does, that hydration rind measurements are indicative only of the midpoint of the temporal span of the type or series to which they belong. It is no less reasonable to assume that the range of hydration measurements for each form in some way corresponds to its temporal floruit, the larger readings denoting older pieces, smaller readings younger pieces. One might, therefore, add to the number of points in the hydration measurement-temporal date correlation by assigning to the largest hydration measurement for each type or series the oldest date for that type or series, and to smallest reading the youngest date. There are good reasons for not doing this. Myriad circumstances — sampling error and artifact reuse to name two — make any single hydration measurement simply too unreliable.

It is more reasonable to work with dates that define temporal boundaries between sequent types or series (e.g., the date of A.D. 1300 which divides the Rose Spring series from the Desert Side-notched and Cottonwood Triangular types) and seek an appropriate hydration value to match with this. This hydration value should be the one that marks the point of maximal divergence between the cumulative frequency distributions of hydration readings for the two point forms in question. This point is the same as the statistic D in the Kolmogorov-Smirnov two sample test (Siegel 1956):

$$D = \text{maximum } [Sn_1(X) - Sn_2(X)],$$

and

$$Sn_1(X) = K_1/n_1,$$

$$Sn_2(X) = K_2/n_2,$$

where K_1 is the number of cases greater than or equal to X in the first sample (n_1), and K_2 is the number of cases greater than or equal to X in the second sample (n_2).

TABLE 3

Hydration Reading (microns)	Date	Explanation
1.00	200 B.P.	Minimal limit of visible hydration.
1.95	670 B.P.	Maximal segregation of hydration measurements and temporal boundary between Desert Side-notched and Cottonwood type points and Rose Spring series points.
2.43	1020 B.P.	Hydration mean and time span midpoint for Rose Spring series points.
2.90	1370 B.P.	Maximal segregation of hydration measurements and temporal boundary between Rose Spring series and Elko series points.
4.27	2270 B.P.	Hydration mean and time span midpoint for Elko series points.
4.45	3170 B.P.	Maximal segregation of hydration measurements and temporal boundary for Elko series and Little Lake series and Humboldt Concave Base "A" type points.
5.70	3820 B.P.	Hydration mean and time span midpoint for Little Lake series and Humboldt Concave Base "A" points.

TABLE 4
CORRESPONDENCE BETWEEN FISH SPRINGS AND CASA DIABLO OBSIDIAN HYDRATION READINGS AS EXTRAPOLATED FROM CUMULATIVE FREQUENCY OF READING OBTAINED AT INY-2146

Fish Springs	Casa Diablo	Years B.P.*	Fish Springs	Casa Diablo	Years B.P.*
6.1	7.1	4109.1	4.0	4.6	2437.8
5.8	6.4	3641.1	3.9	4.3	2237.3
5.6	6.1	3440.6	3.8	4.3	2237.3
5.5	5.9	3306.9	3.7	4.2	2170.4
5.4	5.6	3106.3	3.6	4.1	2103.6
5.2	5.6	3106.3	3.5	4.0	2036.7
5.0	5.4	2972.6	3.4	3.9	1968.9
4.9	5.4	2972.6	3.3	3.8	1903.0
4.8	5.3	2905.8	3.2	3.7	1836.2
4.7	5.3	2905.8	3.0	3.7	1836.2
4.6	5.2	2838.9	2.9	3.6	1769.3
4.5	5.1	2772.1	2.6	3.5	1702.5
4.4	4.8	2571.5	2.5	3.4	1635.6
4.3	4.7	2504.7	2.3	2.9	1301.4
4.2	4.7	2504.7	2.2	2.6	1100.8
4.1	4.7	2504.7			

*estimated from hydration rate formula for Casa Diablo (Hall 1983):
$Y = 668.5X - 637.3$,

where X is the thickness of the hydration rind in microns and Y is the age of the rind in years before present.

Along with the four obtained by matching hydration means against time span midpoints, the three pairings of temporal boundaries and maximal hydration measurement segregation for sequent point forms given by the maximum value of D provide a total of seven data points that might be used to obtain a hydration rate for Fish Springs obsidian. Unfortunately, out of these seven, one is clearly inconsistent with the others. Specifically, the point that in theory ought to be the most recent, the one that matches mean hydration measurement with the time span midpoint for Desert Side-notched and Cottonwood Triangular points, has a hydration value (2.11 microns) which is substantially larger than the one associated with the temporal boundary between these types and the Rose Spring series (1.95 microns). Inspection of Table 1 shows this reversal is due to a few excessively large hydration values for Cottonwood points that skew the mean value for Cottonwood and Desert Side-notched points. Note that this has virtually no effect on the point of maximal segration between hydration measurements for these types and those of the Rose Spring series because this statistic is ordinal, as opposed to interval, in scale.

Rather than try to decide which of the anomalously large hydration values for Cottonwood points ought to be excluded, this data point (i.e., mean hydration and time span midpoint for Desert Side-notched and Cottonwood points) was itself excluded from further consideration. This reduces substantially information we can bring to bear on the rate of hydration in Fish Springs obsidian during the most recent time periods, those represented by samples in the early stages of hydration. This is a critical deficiency because in central eastern California much of the material in need of dating is from this period (cf. Bettinger 1977).

To compensate for the one deleted, an additional data point was added that estimated minimum time needed to form a visible hydration rim. The hydration value for this minimum temporal threshold is logically taken to be 1.0 microns — the smallest observed among the 34 measurable hydration rinds. In determining a date for this threshold, it was noted that many Cottonwood and Desert Side-notched points (32%) were without visible hydration bands and that no specimens of older types or series lacked them. This suggested that it must be the recency of the Cottonwood and Desert Side-notched types and not some other circumstance (e.g., fire, abrasion, or alkalinity of soil) that accounts for the absence of visible hydration on these pieces. Assuming this, assume also that the youngest points assayed in our sample (i.e., with no visible hydration) were made no later than historic contact, which is set here at 1850. It follows, then, that a span 120 years is too short to form a visible hydration layer; stated another way, it takes more than 120 years to form a hydration band 1.0 micron thick (but see Origer [this volume]). There are no concrete data to indicate exactly how much longer might be needed but 200 years seems a reasonable estimate. In sum, our last data point pairs the smallest hydration measurement in the study, 1.0 micron, with an estimated date of 200 years before present.

The seven points derived as outlined above (cf. Table 3) were used to calculate the hydration rate for Fish Springs obsidian by simple linear correlation. This was used in preference to a model in which hydration rate decreases exponentially, that model previously having been found lacking empirically in the Fish Springs case. This gives:

$$Y = 806.7\,X - 827.4\ , \qquad (3)$$

with an associated (Pearson's) correlation coefficient of r = 0.98, where, as before, X is the hydration reading of

FIGURE 1
CUMULATIVE FREQUENCY DISTRIBUTIONS OF CASA DIABLO AND FISH SPRINGS OBSIDIAN

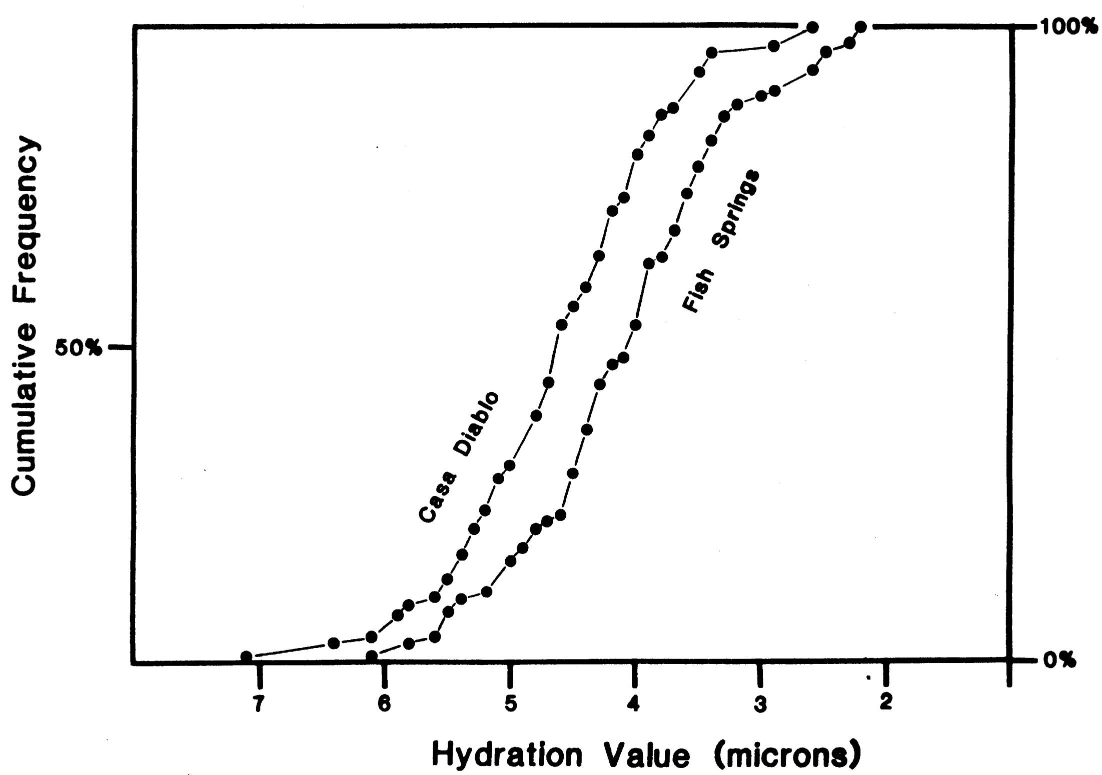
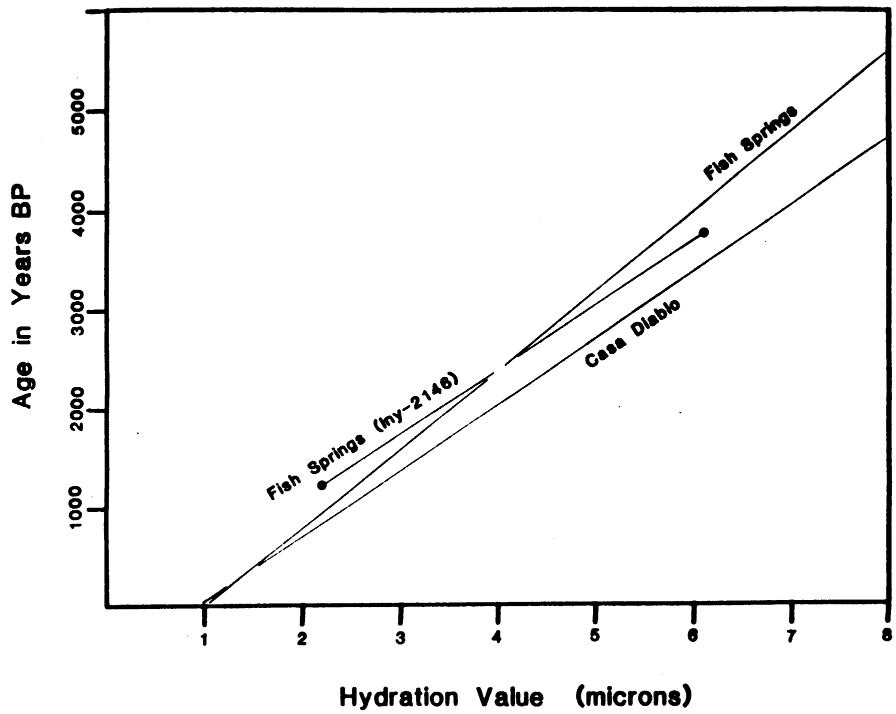


FIGURE 2
HYDRATION RATES FOR FISH SPRINGS AND CASA DIABLO OBSIDIAN



the specimen in microns and Y is the estimated antiquity of the exposed surface in years before 1970. For those wishing to conform to standard radiocarbon format, where B.P. is fixed in terms of years before A.D. 1950, Equation 3 may be corrected by subtracting 20 years (i.e., Y = 806.7 X - 847.4)[1].

EVALUATION OF RESULTS

Given the assumptions made above (e.g., regarding mean time- span, etc), it can be proved mathematically that Equation 3 is the best estimate of the amount of time needed to form an hydration band of given size on exposed surfaces of Fish Springs obsidian provided we consider only the sample of points from which the rate itself was calculated. The extent to which it is the best estimate for any other sample is unclear. This is so by definition. The problem here, common to all inductive generalizations, is that there are never any independent data against which such a formula can be checked because in developing it all such data are exhausted to assure it provides the "best estimate" given what is known. One can only apply the rate to novel data, hope that it works, and modify it as additional data become available. Ultimately, it is the pattern of modifications that must be made to make the rate fit new data that indicates its fundamental soundness or lack thereof. Successively diminishing modifications suggest improvement in predictive capacity until, ideally, there are no obvious discrepancies between the dates predicted by the rate and dates independently obtained by other means.

The only relevant set of independent data that has become available since the initial calculation of the Fish Springs rate given by Equation 3 is a large suite of hydration rind measurements for artifacts made of Fish Springs (73 readings from 66 specimens) and Casa Diablo (70 readings from 67 specimens) obsidian recovered at Iny-2146, the Partridge Ranch site, located between the modern towns of Big Pine and Bishop in central Owens Valley (Bettinger, Delacorte, and McGuire 1984). The manner in which the sample representing each source was drawn makes it reasonable to assume, at least for the sake of argument, that both faithfully represent the temporal distribution of the total population of material from that source at Iny-2146. That the cumulative frequency distributions for the two sources are so similar in shape (Fig. 1) suggests that this assumption is probably correct and further suggests that both sources were used almost interchangably, i.e., without bias or preference, by the inhabitants of the site. If this is assumed, the curves can be used to calculate an hydration rate for Fish Springs obsidian that can be checked against the one described above. That is, Figure 1 makes it possible to determine for an hydration reading of given size for Fish Springs obsidian its temporal equivalent for Casa Diablo obsidian, the hydration rate for which is comparatively well established (cf. Hall 1983; Hall and Jackson [this volume]). It remains only to perform a regression of specific Fish Springs hydration measurements on dates calculated for the equivalent hydration measurement for Casa Diablo obsidian. Table 4 summarizes the data relevant to these calculations: specific hydration rind measurements for Fish Springs obsidian and equivalent hydration measurement and estimated amount of time needed to form that hydration rim for Casa Diablo obsidian. This gave:

$$Y = 646.2\,X - 181.5 \quad (4)$$

where X and Y are defined as throughout the text (r= 0.99).

Figure 2 plots three hydration rates: 1) for Fish Springs as given by Equation 3; 2) for Casa Diablo as calculated in Table 4 following Hall (1983); and 3) for Fish Springs as given by Equation 4 (i.e., calculated from data obtained at Iny-2146). With respect to these rates, note that the Casa Diablo hydration rate of Hall (1983) is faster (i.e., the slope is lower) than the hydration rate proposed here for Fish Springs (Equation 3). This is consistent with the hydration data from Iny-2146 plotted in Figure 1, which, likewise, suggest that hydration rinds on Casa Diablo obsidian are larger than hydration rinds on temporally equivalent specimens of Fish Springs obsidian. Note also that the Fish Springs hydration rate as calculated from obsidian hydration data obtained from Iny-2146 (Equation 4) has about the same slope as the one calculated by Hall for Casa Diablo (roughly 650 years/micron) and differs from it primarily in terms of the Y - intercept. Specifically, according to these rates it takes approximately 450 years longer to form an hydration rind of given thickness on exposed surfaces of Fish Springs obsidian than it does to form a rind of equivalent thickness on Casa Diablo obisidian. This is consistent with the idea that Casa Diablo hydrates faster than Fish Springs obsidian.

Finally, observe in Figure 2 the relationship of all three rates within the interval between 2.2 and 6.1 microns, which is the one over which hydration data are available for Fish Springs obsidian from Iny-2146 and hence the one to which the application of the rate calculated in Equation 4 must be restricted. Within this interval, the rate specified by Equation 4 closely matches the rate specified by Equation 3. Indeed, the two rates intersect at 4.0 microns (i.e., they give the same date for an hydration measurement of that size), which is very near the midpoint of the interval over which the Fish Springs rate calculated from Iny-2146 is viable (4.2 microns). Put another way, while the slope of the hydration rate for Fish Springs obsidian given by Equation 4 differs from that given by Equation 3, the two produce very similar dates for hydration measurements greater than 2.1 microns and less than 6.2 microns. Equation 4 gives older dates than Equation 3 before 4.0 microns and younger dates thereafter. In any case, within this interval the two Fish Springs rates are more similar to each other than either is to the Casa Diablo rate proposed by Hall.

To summarize, then, data presently in hand suggest that Fish Springs obsidian hydrates at a rate sufficiently slower than Casa Diablo obsidian that hydration dates for it must be calculated separately by a different rate. The rate given by Equation 4 is unsuitable for this purpose owing to its limited metric range and its incorporation of all the uncertainties that surround attempts to determine the hydration rate for Casa Diablo obsidian. At the same time, Equation 4 offers strong evidence that the rate given by Equation 3 is for the moment the most reasonable approximation of the relationship between artifact hydration rind thickness and hydration rind antiquity on specimens of Fish Springs obsidian.

NOTE

1. This hydration rate differs negligibly from the one currently in use in Owens Valley (e.g. Bettinger 1989), which was previously calculated from the same data used here: Y = 800.3 X - 811.2. The slight difference owes to the hydration measurement for a single point that was first classified as representing the Rose Spring series and then reclassified as Desert Side-notched type subsequent to calculation of the rate given in the equation above. The rates differ in slope by less than one percent and in Y-intercept by scarcely two percent. They intersect at 2.53 microns or 1214 B.P.

REFERENCES CITED

Basgall, M. E. 1983. Archaeology of the Forest Service Forty site (CA-Mno-529), Mono County, California. Report on file, Inyo National Forest, Bishop, California.

Bettinger, R. L. 1977. Aboriginal human ecology in Owens Valley: prehistoric change in the Great Basin. **American Antiquity** 42 (1): 3-17.

____ 1980. Obsidian hydration dates for Owens Valley settlement categories. **Journal of California and Great Basin Anthropology** 2(2): 286-292.

____ 1982. Aboriginal exchange and territoriality in Owens Valley. **IN: Contexts for Prehistoric Exchange,** Ericson, J. E., and T. K. Earle (eds.). Pp. 103-127. New York: Academic Press.

____ 1989. The archaeology of Pinyon House, Two Eagles, and Crater Middens: three residential sites in Owens Valley, eastern California. **Anthropological Papers of the American Museum of Natural History** No. 67.

Bettinger, R. L., M. G. Delacorte, and R. J. Jackson 1984. Visual sourcing of central eastern California obsidians. **IN:** Obsidian Studies in the Great Basin, edited by R.E. Hughes. Pp. 63-78. **Contributions of the University of California Archaeological Research Facility** No. 45.

Bettinger, R. L., M. G. Delacorte, and K. R. McGuire 1984. Archaeological investigations at the Partridge Ranch site, Inyo County (CA-Iny-2146). Report on file, California State Department of Transportation, Bishop, California.

Bettinger, R. L., and R. E. Taylor 1974. Suggested revisions in archaeological sequences of the Great Basin and interior southern California. **Nevada Archeological Survey Research Paper** 5: 1-26.

Clark, D. L. 1964. Archaeological chronology in California and the obsidian hydration method: Part I. **University of California Archaeological Survey, Los Angeles, Annual Reports**, Vol. 6 pp. 139-225.

Friedman, I., and R. L. Smith 1960. A new dating method using obsidian. I; the development of the method. **American Antiquity** 25 (4): 476-493.

Garfinkel, A. P. 1980. An initial archaeological evaluation of CA-Iny-2146. Report on file, California State Department of Transportation, Bishop, California.

Hall, M. C. 1983. Late Holocene hunter-gatherers and volcanism in the Long Valley-Mono Basin region. Unpublished Ph.D. dissertation, Department of Anthropology, University of California, Riverside.

Heizer, R. F., and C. W. Clewlow, Jr. 1968. Projectile points from site NV-Ch-15, Churchill County, Nevada. **University of California Archaeological Survey Report** 71: 59-88.

Jack, R. N. 1976. Prehistoric obsidian in California I: geochemical aspects. **IN: Advances in Obsidian Glass Studies: Archaeological and Geochemical Perspectives,** edited by R. E. Taylor. Pp. 183-217. Noyes Press: Park Ridge, New Jersey.

Meighan, C. W. 1983. Obsidian dating in California: theory and practice. **American Antiquity** 48: 544-547.

Michels, J. W. 1981. **Mohlab Technical Report Series,** 1 - 4. State College, Pennsylvania.

Michels, J. W., and C. A. Bebrich1971. Obsidian hydration dating. **IN: Dating Techniques for the Archaeologist,** edited by H. N. Michel and E.K. Ralph. Pp. 164-221. M.I.T. Press: New York.

Siegel, S. 1956. **Non-parametic statistics for the behavioral sciences.** McGraw-Hill: New York.

Thomas, D. H. 1981. How to classify the projectile points from Monitor Valley, Nevada. **Journal of California and Great Basin Anthropology** 3 : 7-43.

Rector, C., J. D. Swenson, and P. J. Wilke 1981. Archaeological studies at Oro Grande, Mojave Desert, California. Report on file, Victor Valley