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The Use of Hydration Measurements to Date Obsidian Materials from Sonoma County, California

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The refinement of cultural chronologies continues in the forefront of archaeological research in the North Coast Ranges. In the most recent archaeological synthesis for the area, Fredrickson (1973, 1974) proposed a sequence of cultural patterns based on the adaptive modes of prehistoric populations. Fredrickson (1973:118) characterized a pattern by:

a) similar technological skills and devices;

b) similar economic modes (production, distribution, consumption), including participation in trade networks and practices surrounding wealth (often inferential); and

c) similar mortuary and ceremonial practices.

In a sequence that spans approximately 12,000 years, Fredrickson identified five broad cultural patterns which, beginning with the earliest, consist of the provisional Post, Early Borax Lake, Late Borax Lake, Berkeley, and Augustine patterns. His approach has provided a solid organizational framework for ongoing studies in the North Coast Ranges. However, because of the broadness of these patterns, his framework does not provide details of specific cultural assemblages and their succession and duration in most localities in the North Coast Ranges.

Chronological refinement subsequent to Fredrickson's work has been complicated by the rarity of temporally diagnostic artifacts and the lack of suitable materials for radiocarbon dating from excavated sites.

Obsidian hydration analysis is a promising approach to this problem of chronology for it has been demonstrated to be of value as a relative dating tool (e.g., Meighan and Haynes 1970; Michels 1965). Large quantities of obsidian tools and tool manufacturing debris are present in archaeological sites in the southern North Coast Ranges due to the proximity of four natural obsidian deposits: Mount Konocti, Borax Lake, Napa Glass Mountain, and Annadel (Heizer and Treganza 1944). Hydration analysis of obsidian materials, therefore, appears to have great promise in the development of cultural chronologies. This report presents the results of two pilot studies carried out by the authors which compare the hydration rim values of Annadel obsidian from archaeological sites near Santa Rosa, California, with the cultural sequence proposed by Fredrickson (1973).[1]

As prior research has shown, chemical composition and temperature are major variables which influence the rate of hydration (Ericson 1978). While chemical composition is relatively easy to control through source analysis, control over temperature is more challenging. For example, high surface temperatures in the Great Basin can produce hydration rims on surface specimens which are up to twice that of their subsurface counterparts (Layton 1973). To gain control over these variables, two constraints were imposed in the selection of samples for the two studies.

First, to control chemical composition, only obsidian specimens originating from the Annadel source were used. Chemical determination was made through x-ray fluorescence spectrography that analyzed diagnostic trace elements rubidium, strontium, and zirconium.[2]

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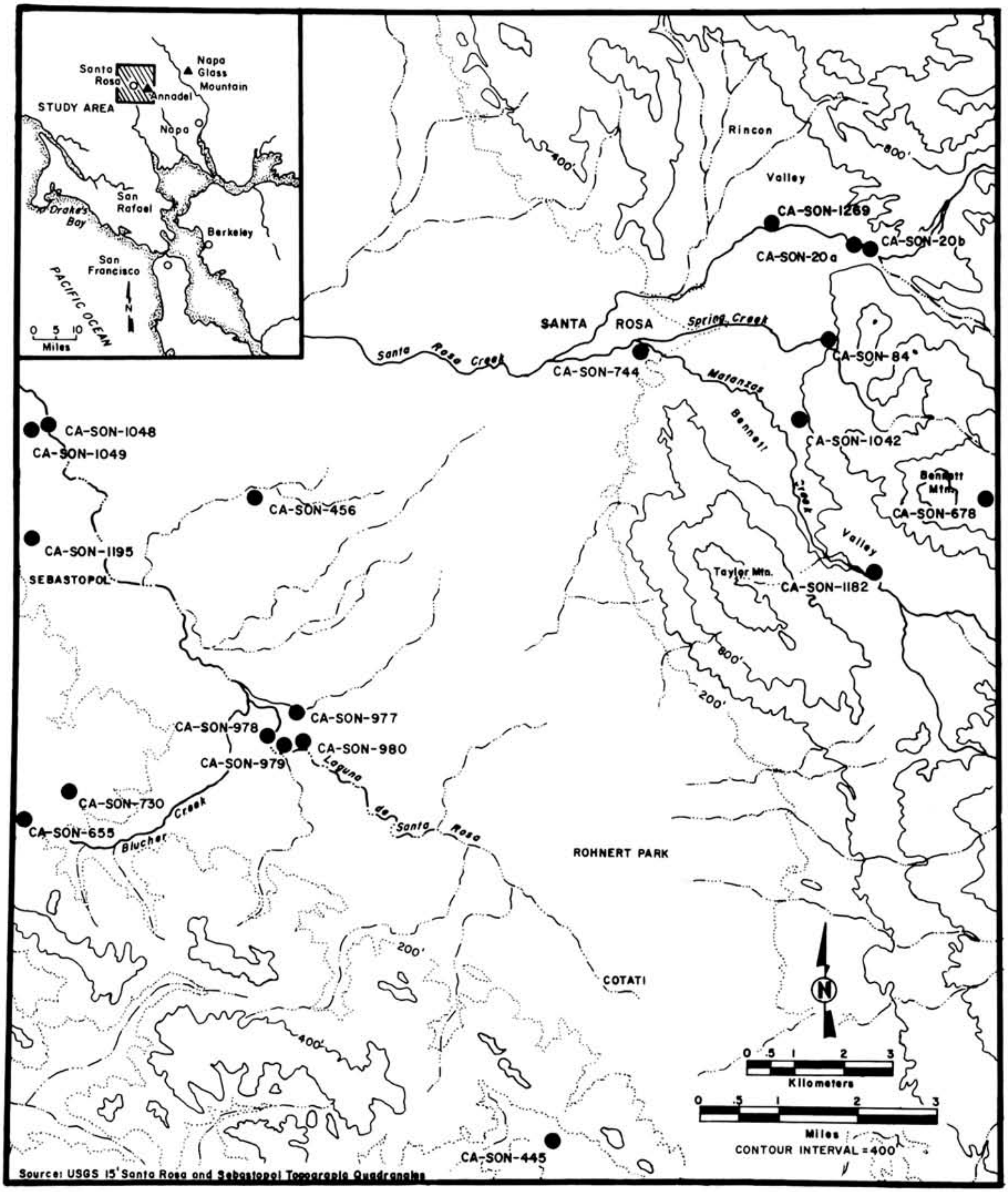

Fig. 1. Location of archaeological sites on the Santa Rosa Plain.

Second, to control temperature, the study area was restricted to a relatively small geographic locality, the Santa Rosa Plain, which exhibits a virtually uniform climatic regime (Fig. 1). Situated within the southern North Coast Ranges, the climate of the Santa Rosa Plain is greatly moderated by the nearness of the ocean, approximately 15 miles to the west over low hills.

The obsidian hydration measurements described in both pilot studies were made by the senior author at the Obsidian Laboratory, an adjunct of the Anthropological Studies Center, Sonoma State University. The laboratory procedures closely followed those described by Michels and Bebrich (1971). Following preparation of each thin-section, measurements were made at up to six locations on each specimen using an American Optical petrographic microscope equipped with a filar micrometer eyepiece and either a 45-power objective for normal use or a 100-power, oil-emersion objective for very thin hydration rims. Limitations of the equipment dictate that all measurements can be considered as having an error factor of ±0.2 microns.

The data for one study were derived from eleven independent site investigations carried out in response to environmental protection laws. A summary of the findings, the assigned cultural patterns, and the diagnostic material remains is presented in Table 1. The majority of the sites exhibit multiple components, spanning the Borax Lake, Berkeley, and Augustine patterns. Four sites feature single components assignable to these same patterns. All of the multicomponent sites lacked stratigraphic separation of their components.

The hydration results, shown in Fig. 2, were derived primarily from 166 waste flakes in addition to 17 utilized flakes, 11 projectile points, 3 bifaces, and 6 biface fragments. A comparison of the multicomponent sites showed no discrete groupings of hydration readings. Hydration readings from these sites

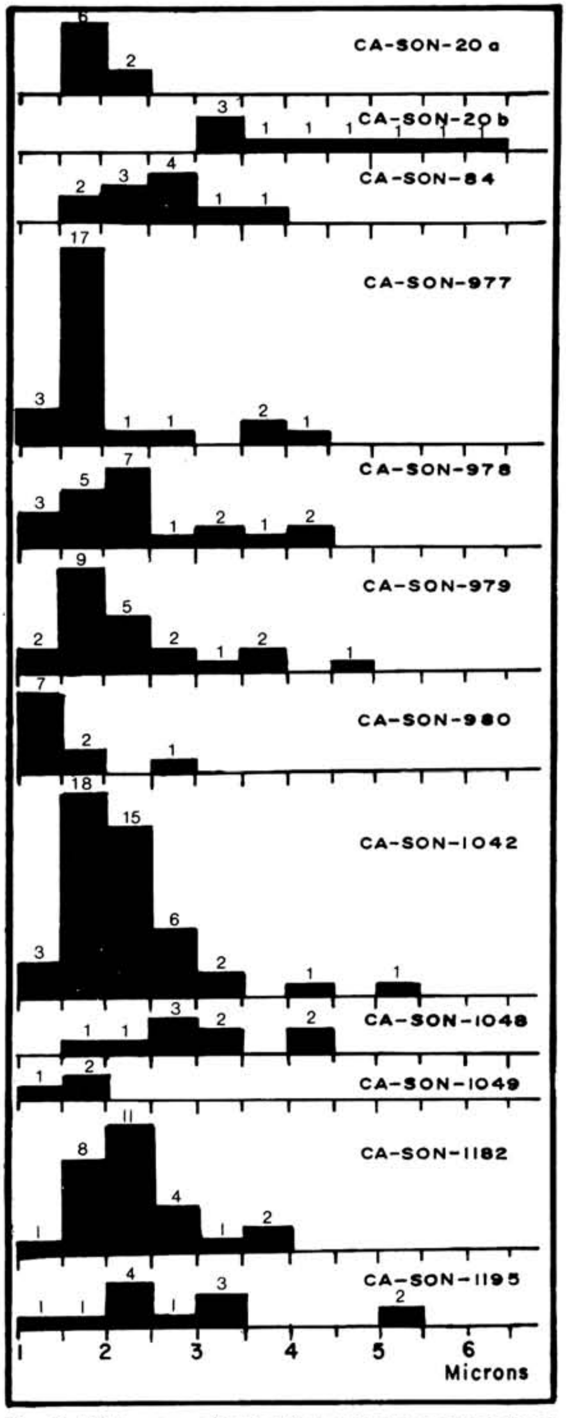

Fig. 2. Histogram of hydration measurements derived from flaking debris for all subject sites on the Santa Rosa Plain.

Table 1

SITES IN THE SANTA ROSA PLAIN AND THEIR CULTURAL ASSOCIATIONS

Site	Cultural Association	Materials
CA-SON-20	(1) Area A, Phase 1 Augustine Pattern (2) Area B, Borax Lake Pattern	(1) corner-notched point and pestle fragments (2) milling and hand stones
CA-SON-84	Berkeley Pattern	Excelsior points, *Olivella* square saddle bead and bowl mortar
CA-SON-977	(1) Early Phase 2 of the Augustine Pattern (500 to 1,500 B.P.) (2) Borax Lake Pattern (5,000 to 7,000 B.P.)	(1) corner-notched point and bowl mortar (2) chert effigy crescent fragments and high proportion of chalcedony and flake debitage
CA-SON-978	(1) Phase 1 of the Augustine Pattern (500 to 1,500 B.P.) (2) Houx Aspect of the Berkeley Pattern (1,500 to 2,500 B.P.) (3) Borax Lake Pattern (5,000 B.P.)	In stratigraphic position: (1) small corner-notched, triangular, and leaf-shaped points; "show" mortars (2) shouldered, leaf-shaped points and cobble mortars (3) wide-stemmed points, and hand stones
CA-SON-979	(1) Phase 1, Augustine Pattern (500 to 1,500 B.P.) (2) Terminal Berkeley Pattern (A.D. 506) (3) Berkeley Pattern (1,500 to 300 B.P.) (4) Borax Lake Pattern (3,000 to 5,000 B.P.)	In stratigraphic position: (1) expanding stem and serrated points, and a large corner-notched point (Annadel, 1.8 microns) (2) C14 date of 1,465 ± 80 B.P. in baked clay feature (3) Excelsior points (4) concave-based (Annadel, 4.6 microns) and flat-based points; milling stones
CA-SON-980	Phase 2, Augustine Pattern	Small corner-notched points, small point with wide side notches, fragments of bowl mortars, and only 2.1% of waste debris is chalcedony
CA-SON-1042	(1) Augustine Pattern (2) Berkeley Pattern (3) Borax Lake Pattern	Increase of chert to obsidian debitage with depth, Excelsior point base, obsidian and chert scraper planes, comparison of hydration range with other sites
CA-SON-1048	(1) Phase 1, Augustine Pattern (1,000 to A.D. 1,200) (2) Berkeley Pattern, Houx Aspect (500 B.C. to A.D. 500) (3) Borax Lake Pattern, Late Phase (before 500 B.C.)	(1) small serrated (Napa, 2.5 microns) expanding stem (Annadel, 1.6 microns), and small corner-notched (Napa 4.8? microns) points; *Olivella* thin rectangular bead (2) Excelsior point (Annadel, 3.3 microns), and charmstone (3) concave-based points (Napa, 4.3 and 3.1 microns)
CA-SON-1049	Same as CA-SON-1048	Due to trimodal stratigraphic distribution of obsidian and shell materials in both sites
CA-SON-1182	250 to 4,500 B.P.	Obsidian hydration rim analysis
CA-SON-1195	(1) Phase 1, Augustine Pattern (2) Phase 1, Augustine Pattern (3) Berkeley Pattern	(1) small corner-notched and side-notched points (Annadel, NVH, 2.2/1.4, and 1.6 microns) (2) long, narrow, expanding stemmed point (Annadel, 1.6 microns) and small corner-notched point (Annadel, 1.6 microns) (3) Excelsior forms (Annadel, 2.5 microns and Napa, 2.2 and 2.2 microns)

suggest varying intensities of obsidian working and the range of readings overlapped between sites. However, the single-component sites, as shown in Fig. 3, revealed distinct, sequential groupings of hydration measurements which were supported by t-test calculations (Table

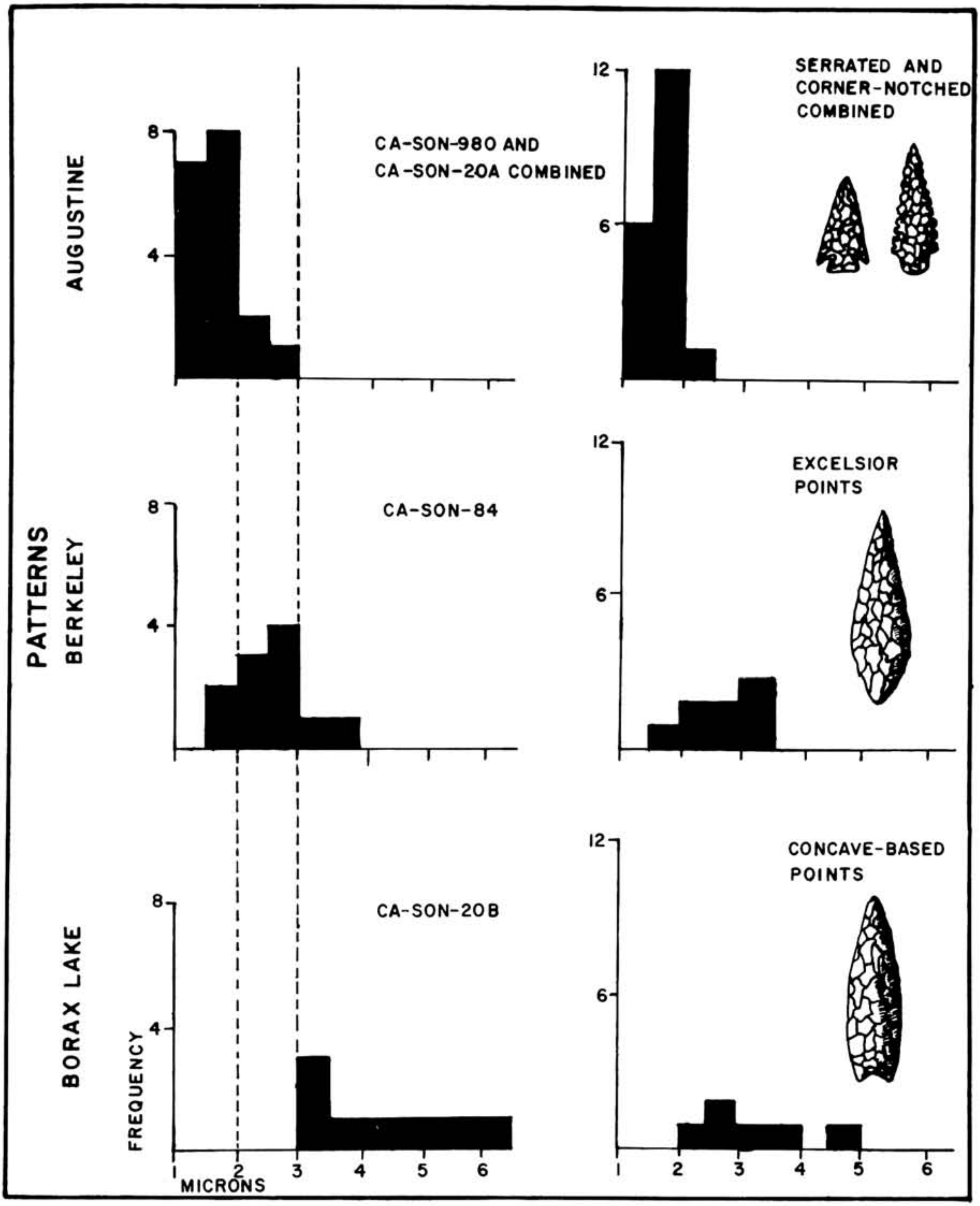

Fig. 3. Comparison of subsurface specimens from single-component sites and projectile point forms by cultural pattern.

2).[3] The interface of these patterns is suggested by the dashed vertical lines in Fig. 3. In addition, the multicomponent sites which contained identifiable materials diagnostic of these three patterns showed hydration measurement ranges which spanned those of the single-component sites.

The other pilot study focused on projectile points that included four morphologically distinct forms: concave base, shouldered lanceolate (Excelsior), small serrated, and small corner-notched. Previous research (Fredrickson 1973) suggests that these projectile point forms can be assigned to the Borax Lake, Berkeley, and Phase 1 and Phase 2 of the Augustine patterns, respectively. Of these forms, the Excelsior is probably the least sensitive temporally (Fredrickson 1973:199 *et seq.*).

Fig. 3 presents in histogram format the hydration measurements for each projectile point form. The corner-notched and serrated forms exhibit the smallest hydration measurements. The Excelsior form, although displaying a wider range, has larger hydration measurements. The concave-based form has the greatest range and generally largest hydration measurements. The t-test suggests that Augustine point forms (serrated and corner-notched) are significantly different from the Berkeley pattern Excelsior point form. However, as expected, the Excelsior point form measurements are not significantly different from those of the Borax Lake pattern concave-based form (Table 2).

The Augustine pattern projectile points were analyzed to determine if finer distinctions could be made and the results were compared with Wickstrom's waste flake data as shown in Fig. 4. The serrated point form, diagnostic of Phase 1 of the Augustine pattern, has larger hydration measurements,

Table 2

T-TESTS FOR SINGLE-COMPONENT SITES AND PROJECTILE POINT FORMS

Cases	N	Sample Mean	Standard Deviation	t Value	Degrees of Freedom	1-Tail Probability	Null Hypothesis H_o: Case 1 = Case 2, H_1: Case 1 $<$ Case 2 $\alpha = .05$
1. Augustine Sites	18	1.6	.43	4.47	27.00	.000	rejected
2. Berkeley Site	13	2.4	.54				
1. Berkeley Site	13	2.4	.54	4.2	8.87	.001	rejected
2. Borax Lake Site	9	4.4	1.24				
1. Subsurface Corner-notched and Serrated	19	1.5	.24	5,26	8.32	.000	rejected
2. Subsurface Excelsior	8	2.5	.53				
1. Subsurface Excelsior	8	2.5	.53	1.69	12.00	.058	accepted
2. Subsurface Concave-Based	6	3.1	.82				
1. CA-SON-980	9	1.4	.51	1.98	12.95	.034	rejected
2. CA-SON-20a	8	1.8	.22				
1. Subsurface Corner-notched	8	1.3	.17	4.97	10.88	.000	rejected
2. Subsurface Serrated	11	1.7	.13				
1. Subsurface Corner-notched	8	1.3	.17	0.40	9.00	.347	accepted
2. Surface Corner-notched	4	1.3	.13				
1. Subsurface Serrated	11	1.7	.13	1.24	18.00	.115	accepted
2. Surface Serrated	9	1.6	.25				

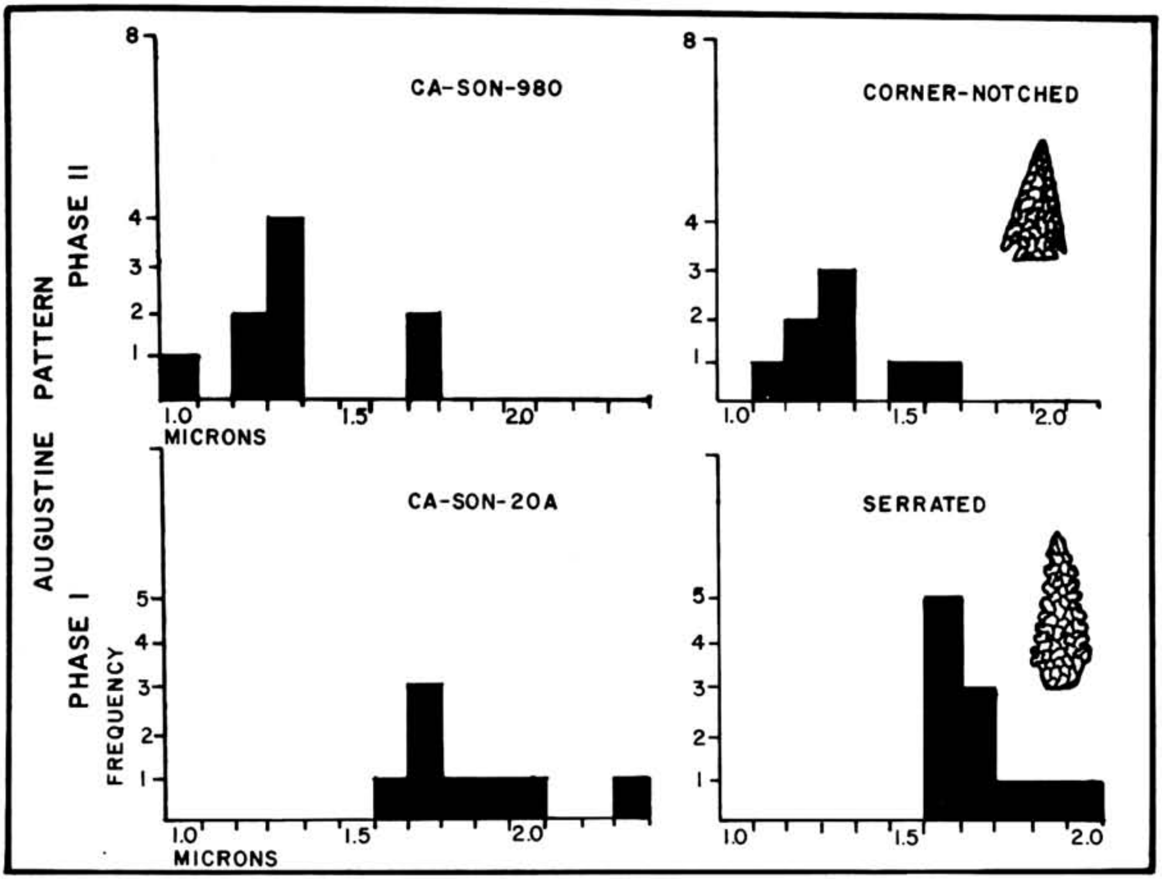

Fig. 4. Comparison of subsurface specimens from single-component sites and projectile point forms for Phase 1 and Phase 2 of the Augustine pattern.

whereas the corner-notched point form, diagnostic of Phase 2 of the Augustine pattern, has smaller hydration measurements. The results of statistical calculations suggests that these point forms are from significantly different populations (Table 2).

The preceding discussion is based on hydration measurements from subsurface specimens only and, therefore, pertains only to subsurface materials. In recognition of Layton's (1973) Great Basin findings, and since much of the archaeological work currently conducted involves surface survey and collection, the possibility of a discrepancy between surface and subsurface hydration measurements must be addressed.

In order to evaluate this possibility, the surface and subsurface proveniences of the two Augustine pattern projectile point forms were compared. Hydration measurements showing the comparison are presented in Fig. 5. While the range of hydration measurements for surface specimens is slightly larger than for subsurface specimens, the statistical tests suggest that surface and subsurface specimens for each form are from identical populations (Table 2).

The environment of the Great Basin is sufficiently dissimilar to that of the Santa Rosa Plain so that our results were not identical to those of Layton (1973). The arid soils of the Great Basin are generally shallow,

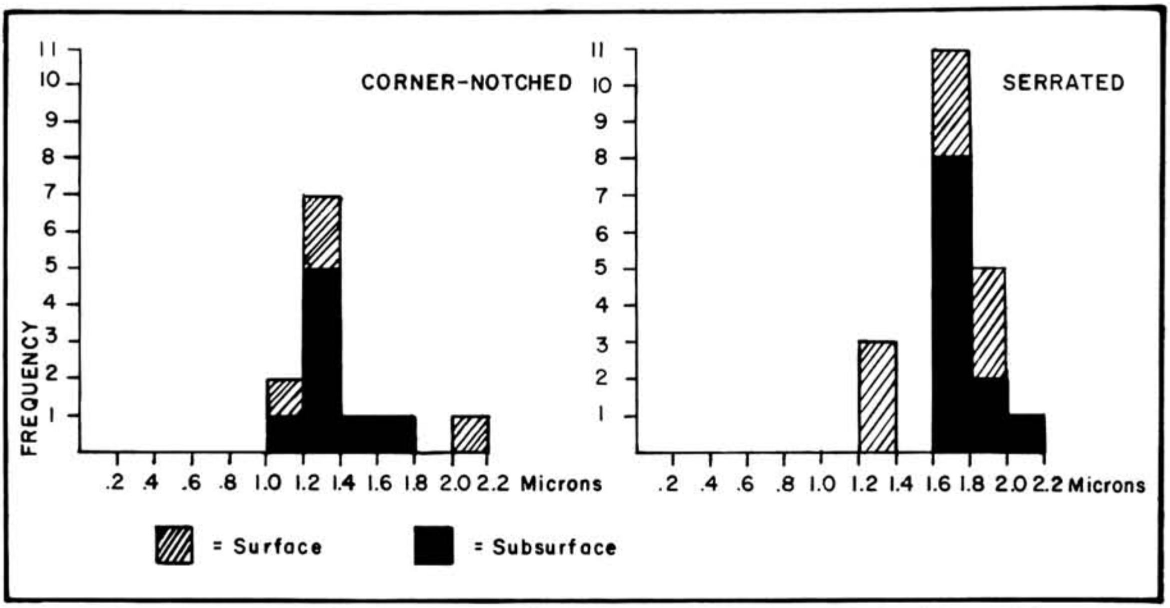

Fig. 5. Comparison of surface and subsurface specimens for Corner-notched and Serrated forms.

pavemented, and support widely dispersed bushes and some grasses with bare spots between patches of vegetation. Archaeological specimens lying on the ground surface are not insulated from solar radiation and when subjected to direct sunlight were described by Layton as too hot to hold in one's hand. In contrast, the soils of our study area are deep, often churned by a variety of disturbing agents (i.e., gophers, worms, erosion, and discing), and generally support grasses, forbs, and occasional scattered trees that serve to insulate archaeological specimens from intense solar radiation. It is suggested that exposure to extreme temperatures of the Great Basin influenced the hydration rate in Layton's study (Layton 1973), while the temperatures of the Santa Rosa Plain had much less affect since archaeological specimens are usually exposed to less intensive solar radiation.

CONCLUSIONS

The data presented herein support previous suggestions (Michels 1965, 1967) that obsidian hydration can be effectively used in the temporal ordering of archaeological materials. Although the present sample size is small, the data suggest that hydration measurements from both tool manufacturing debris and projectile points can be of equal value, as can materials from both surface and subsurface contexts. By combining the hydration values from the two studies reported here, tentative hydration measurement ranges for each cultural pattern can be identified for the cultural sequence on the Santa Rosa Plain. Note that the following hydration measurement ranges pertain to only Annadel source obsidian:

Augustine pattern		
Phase 2	1.0 - 1.5	microns
Phase 1	1.6 - 2.3	microns
Berkeley pattern	2.4 - 3.0	microns
Borax Lake pattern	3.1 - ?	microns

Although the range of hydration measurements (as shown in the histograms) overlapped for the various patterns, this is not viewed as a major problem and, in fact, should be expected. This overlap could be the result of measurement error (±0.2 microns), slightly different rates of hydration, or diminishing use of a point form with simultaneous adoption of succeeding forms.

Finally, the data suggest that this approach to temporal ordering of archaeological assemblages can yield reliable results. The potential exists for the temporal ordering of sites within discrete localities which would then facilitate the study of change in settlement patterns over time as well as the study of other cultural processes that are dependent upon successful temporal ordering of sites.

ACKNOWLEDGEMENTS

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NOTES

1. The junior author synthesized hydration data primarily from tool-manufacturing debris, while the senior author analyzed hydration measurements from temporally diagnostic projectile points.

2. Richard Hughes, University of California, Davis, and Trace Analysis Laboratory, Hayward, California, performed the source determinations.

3. Statistical calculations for t-tests were completed using the Statistical Package for the Social Sciences (SPSS). This test was employed to evaluate whether the samples are from different statistical populations. In this procedure, the null hypothesis was established that Case 1 was equal to Case 2 with the alternate hypothesis that Case 1 was smaller than Case 2. The null hypothesis was accepted when the probability given by SPSS was greater than the significance level of 0.05. If the probability was smaller than the significance level of 0.05, then the null hypothesis was rejected and the alternate accepted (Nie *et al.* 1975:267-275).

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