OBSIDIAN HYDRATION RATES IN CALIFORNIA

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IN SPITE OF LIMITED, OFTEN SKEPTICAL, INITIAL applications, both hydration and geologic-provenance analyses of obsidian artifacts are today relatively common facets of prehistoric hunter-gatherer archaeological investigations throughout California (Meighan 1983:600-601). Advances over the past quarter-century in hydration dating and the trace element chemical "fingerprinting" of geologic sources are enabling archaeologists to track obsidian procurement, tool production, and tool use on a diachronic basis (Hughes 1984a; Taylor 1976). Although systematic, problem-directed integration of hydration measurement and source determination data on a broad geographic basis remains in its infancy (cf. Bouey and Basgall 1984; Ericson 1977a; Hall 1984), obsidian studies have already provided insight into several outstanding, regional archaeological problems. These include the nature of prehistoric subsistence-settlement systems in northern and eastern California (Basgall and Hildebrandt 1987; Basgall and McGuire 1987; Fredrickson [this volume]; Hall n.d., 1983; Hughes 1986; R. Jackson 1985), the development and structure of trans-Sierra Nevada economic exchange networks (Bouey and Basgall 1984; Ericson 1977a, 1977b, 1982; Hall 1984; T. Jackson 1974; T. Jackson and Dietz 1984), patterns of sociopolitical organization and interaction (Bettinger 1982a; Hughes and Bettinger 1984; T. Jackson 1986, [this volume]), and processes of site formation and post-depositional stratigraphic transformations (Basgall, Hall, and Hildebrandt 1988; Bouey and Mikkelsen 1988; Weaver and Hall 1984).

It is also apparent, however, that as hydration and source analyses emerge as typical ingredients in archaeological research recipes in both California and other obsidian-bearing regions, there is a need for consumers of the resultant data to appreciate certain inherent technical and analytical issues. Among these are the comparability of results obtained on the same or similar samples by different laboratories (cf. Green 1986; Hughes 1984b, Stevenson et al. 1989), sampling strategies and methods of data manipulation appropriate to the research questions under examination, formats for reporting analytical results and, ideally, their standardization, and coordination of investigative efforts (Hall 1983, 1985; R. Jackson 1984a; Meighan 1983, 1984). For sourcing studies in particular, problems of note are intra-source chemical variability (cf. Hall 1983; Hughes 1988a) and identifying the geochemical signatures of lesser known, or small nodule, "pocket" sources. In eastern California and southwestern Nevada, for example, there are now more than a dozen major and minor obsidian sources, represented in archaeological deposits, that have been either physically located or inferred to exist based on the results of trace element chemical analyses (cf. Basgall [this volume]; Hall n.d.; Hughes 1988b).

Issues relating to hydration studies include: (1) the detection and measurement of very thin (1.0 microns or less) hydration bands (Findlow and DeAtley 1976; T. Jackson 1984; Origer [this volume]); (2) the possible error inherent in the measurement process (Scheetz and Stevenson 1988); (3) procedures that distinguish multiple, chronologically divergent bands on the same specimen, as opposed to a single, perhaps highly variable diffusion front (cf. Kaufman 1980); (4) depositional variables influencing the hydration process, such as geographic or stratigraphic differences in effective hydration temperature and soil chemistry (Ericson [this volume]; Friedman and Long 1976; Friedman and Trembour 1978; Kaufman 1980; Michels and Tsong 1980; Trembour and Friedman 1984); and (5) construction, evaluation, and use of source-specific hydration rates. It is this latter topic, rate derivation, that is of concern here although all of the problem areas mentioned are currently the subject of directed research. In the following discussion, emphasis is placed on the importance of "careful evaluation" (Ericson 1978:45) of rates prior to their interpretive application. By way of example, the use of temporally diagnostic obsidian artifact forms is also explored as an alternative strategy (cf. Basgall 1983; Hall 1983, 1984; R. Jackson 1984b) to the conventional rate-building methodology in which correlations are made between hydration measurements and radiocarbon assays obtained on stratigraphically "associated" sample materials.

OBSIDIAN HYDRATION RATES

There are three fundamental approaches to the derivation of obsidian hydration rates. On one hand, there are geophysicists and archaeologists who attempt to develop a rate based on the chemical properties of a particular glass or by experimentally inducing hydration and extrapolating a source-specific (even specimen-specific) rate (cf. Friedman and Long 1976; Friedman and Trembour 1978, 1983; Michels and Tsong 1980; Michels, Tsong, and Smith 1983; Stevenson [this volume]). In the long run, these efforts may well pay off handsomely; one can envision the availability, for a given obsidian type, of a "standard" rate which will yield acceptable absolute age estimates once adjustments are made for certain variables (e.g., effective hydration temperature). However, aside from technical matters in its implementation (cf. Sheetz and Stevenson 1988; Stevenson and Scheetz [this volume]), the problem with the induced approach has been — and continues to be — an at times glaring lack of concern on the part of some of its advocates with the need for comprehensive rate verification against archaeological materials of known (or indirectly well-established) age. All too often it seems, so-called "laboratory" rates are promulgated without any consideration of their cultural historical ramifications. Thus, for example, according to rates proposed by Michels (1982, 1983), initial human exploitation of the Casa Diablo and Coso obsidian sources in eastern California (based on typical hydration values of 10 and 18 microns, respectively, for early Holocene artifacts fashioned from these glasses) took place some 25,000-30,000 years ago — clearly erroneous estimates by most accounts (cf. Elston and Zeier 1984:136-137; Hall 1983:172; R. Jackson 1984b: 176). Moreover, just because a rate may result in a believable date for a given time interval or in one not so blatantly inconsistent with the known time-depth of human occupation does not mean that the date or rate are even roughly accurate. In terms of absolute-age conversion, without customized justification source-specific rates must be at least reasonably meaningful at either end of and throughout the cultural chronological continuum.

On the other hand, there are those archaeologists who, pending the development of laboratory-derived rates of demonstrable utility, construct hydration rates using available archaeological data. Assuming sufficient evidence of their relative reliability, so-called empirical or "rough and ready" (Meighan 1984:229) rates have the advantage of being immediately applicable in ongoing studies. One disadvantage of this third approach is the necessity of periodically upgrading a rate in light of new data. Archaeologists are, however, in the business of finding out precisely what happened when, and why, and these goals demand constant refinement of the chronological tools used to establish temporal frameworks.

As noted above, the empirical approach usually entails the correlation of hydration values and radiocarbon determinations obtained on respective sample materials found in presumed stratigraphic association. Major difficulties with this strategy are: (1) ensuring that such associations are, in fact, real; and (2) of those that are, having enough to provide a reasonable basis for rate calibration (cf. R. Jackson 1984b; Meighan 1983). Complex prehistoric site formation processes in California and the Great Basin preclude a simplistic assumption of association based on spatial co-occurrence (cf. Basgall, Hall, and Hildebrant 1988). Inadequate appreciation of this problem can easily lead to specious correlations and the computation of invalid hydration rates (Hall 1988). For example, Koerper et al. (1986) apparently did not consider the issue of sampling error with respect to the hydration/radiocarbon associations they used in constructing a logarithmic hydration rate for Coso obsidian. Five of the 17 "data points" employed by Koerper et al. (1986:51, Figs. 14-

15) in their calculations appear to represent the equating of ca. 8.5-8.0 microns of hydration with ca. 4500-2000 B.P. Given the unlikelihood that half of a micron of hydration on Coso glass (from later Holocene archaeological contexts) can be correlated with the passing of 2500 years, it seems highly probable that certain of the hydration/radiocarbon associations made by Koerper et al. (1986) are spurious. Not surprisingly, the Coso rate proposed by these authors yields age conversions grossly out-of-line with other forms of archaeological evidence; e.g., 9059 years for 10 microns, and 196,509 years for 18 microns.

RATE DERIVATION USING TIME-DIAGNOSTIC ARTIFACT FORMS: A CASE STUDY

Recognizing that the day when archaeologically verifiable and consistent laboratory-produced obsidian hydration rates are available may not arrive for some time, a modified version of the empirical approach is presented here in which temporally diagnostic obsidian artifact forms (specifically projectile points) are used to formulate a rate for the Casa Diablo source in east-central California. Described below are procedures that, hopefully, take some of the "rough" out of the "rough and ready" strategy of calibrating source-specific rate curves against archaeological data.

GEOLOGIC AND CULTURAL SETTING

The Casa Diablo obsidian source is located in the western portion of Long Valley, a massive, 17x32-km elliptically-shaped caldera at the base of the east-central Sierra Nevada. A cataclysmic eruption of more than 600 cu km of rhyolitic magma, and subsequent crustal subsidence, created the caldera approximately 700,000 years ago (Bailey, Dalrymple, and Lanphere 1976; Gilbert et al. 1968). Intracaldera volcanism resumed within 40,000 years after subsidence. Silica-rich, unusually fluid rhyolite tuffs and flows were emplaced in the west-central area of the caldera (Bailey, Dalrymple, and Lanphere 1976:732). These extrusions form a complex "resurgent dome" that at the close of magmatic activity ca. 600,000 B.P. had risen 500 m above the caldera floor (Smith and Bailey 1968:646; Bailey, Dalrymple, and Lanphere 1976:735). Obsidian flows and inclusions in the dome, manifested as more than 20 sq km of discontinuous outcrops and exposures, constitute the Casa Diablo obsidian source (Ericson, Hagan, and Chesterman 1976:226, Fig. 12.1).

According to some estimates (Ericson 1977a:209), Casa Diablo obsidian was supplied to hundreds of thousands of prehistoric hunter-gatherers in central California. At the time of Euroamerican penetration of the region, Long Valley does not appear to have supported a sizable, indigenous population and may have served as a general resource procurement area exploited by several, geographically distinct hunter-gatherer groups (cf. Bettinger 1977; Hall 1983; R. Jackson 1985). Considerable archaeological evidence attests to a long prehistory of extensive use of both the Casa Diablo obsidian source as well as surrounding environs (Basgall 1983, 1984; Bouscaren and Wilke 1987; Hall n.d., 1983, 1984; R. Jackson 1985; Michels 1965).

HYDRATION DATA ON PROJECTILE POINTS OF CASA DIABLO OBSIDIAN

The Casa Diablo obsidian hydration rate described below was derived in late 1984 on the basis of extant hydration values for 108 time-sensitive projectile point forms from 24 prehistoric sites in east-central California (Hall 1984). All of the points were fashioned from Casa Diablo glass, as determined by x-ray fluorescence spectroscopic trace element analysis. Expectably, archaeological work in the source area since 1984 has increased the number of points of Casa Diablo origin for which hydration measurements are available. Table 1 summarizes, as of this writing (1987), all currently reported hydration data for projectile points from east-central California attributed to the Casa Diablo source, including values obtained on point forms of unclear temporal affiliation (234 total specimens, 54 locations [all open-air]). For two reasons, however, the Hall (1984) rate is not revised here: first, substantial samples of Casa Diablo obsidian points are presently undergoing hydration analysis (e.g., Hall n.d.) and it would seem more practical to postpone rate refinement until these results can be incorporated; and second, a marginal upgrading of the rate may be inappropriate at this time given the wide acceptance it has won with practicing archaeologists in surrounding regions of California and the Great Basin.

There are, nonetheless, a few observations that should be made in light of the hydration measurements arrayed in Table 1. First, although these data were generated by several different technicians operating with optical equipment of varying quality and design, on the whole the compatibility in the range of values per projectile point form is both quite close and encouraging from a methodological perspective. Second, with respect to Casa Diablo glass, the surface versus subsurface provenience of obsidian samples would not seem to be as critical a hydration variable as has been advocated by some archaeologists (e.g., Bouscaren and Wilke 1987; cf. R. Jackson 1984a; Layton 1973). At issue here are the insolation and

TABLE 1
HYDRATION MESAUREMENTS ON OBSIDIAN PROJECTILE POINTS FROM EAST-CENTRAL CALIFORNIA CHEMICALLY ASCRIBED TO THE CASA DIABLO SOURCE

C-14 Age B.P.	PrPt	Hydration	Site	Elev	Provenience Asp	Provenience Depth	84R	Ref
650-100	DSN	1.20	MNO-458*	2164	S	20-30	-	(1)
	DSN	1.20	MNO-714	2399	ENE	20-30	-	(2)
	DSN	1.21	MNO-584	2085	SW	20-30	+/+	(3)
	DSN	1.23	MNO-529	2430	E	surface	+	(4)
	DSN	1.30	MNO-458	2164	S	30-40	-	(1)
	DSN	1.44	MNO-382	2195	S	30-46	+/+	(5,6)
	DSN	1.50	MNO-458	2164	S	10-20	-	(1)
	DSN	1.73	MNO-11	2250	NE	20-30	+/+	(7)
	DSN	1.80	MNO-458	2164	S	10-20	-	(1)
	DSN	1.91	INY-1386	1341	NE	0-15	-	(8)
	DSN	2.00	MNO-458	2164	S	0-10	-	(1)
	DSN	2.00	MNO-1826	2140	SSE	0-10	+/+	(6)
	DSN	2.10	MNO-458	2164	S	surface	-	(1)
	DSN	2.10	MNO-458	2164	S	10-20	-	(1)
	DSN	2.60	INY-2146	1253	ESE	surface	+	(9)
	DSN	2.90	MNO-458	2164	S	0-10	-	(1)
	DSN	3.10	MNO-458	2164	S	0-10	-	(1)
	CT	1.30	MNO-458	2164	S	10-20	-	(1)
	CT	1.40	MNO-458	2164	S	10-20	-	(1)
	CT	1.58	MNO-529	2430	E	surface	+	(4)
	CT	1.70	INY-30	1143	ESE	13	-	(10)
	CT	1.80/6.10	MNO-458	2164	S	surface	-	(1)
	CT	1.80	MNO-1811	2620	ENE	surface	+	(6)
	CT	2.10	MNO-1878	2244	NW	surface	+	(6)
	CT	2.20	MNO-1827	2287	S	surface	+	(6)
	CT	2.65	MNO-382	2195	S	?	+	(5,6)
	CT	2.71	MNO-382	2195	S	46-61	+/+	(5,6)
	CT	2.80	MNO-1869	2195	ESE	surface	-	(6)
	CT	3.10	MNO-458	2164	S	20-30	-	(1)
	CT	3.42**	MNO-382	2195	S	46-61	+	(5,6)
1250-650	EGES	1.40	MNO-458	2164	S	10-20	-	(1)
	EGES	1.60	MNO-458	2164	S	20-30	-	(1)
	EGES	2.10	MNO-1799	2896	W	surface	+	(6)
	EGES	2.32	MNO-529	2430	E	surface	+	(4)
	EGES	2.40	MNO-458	2164	S	40-50	-	(1)
	EGES	2.60	MNO-1826	2140	SSE	surface	+	(6)
	EGES	3.30	MNO-1799	2896	W	surface	+	(6)
	EGES	3.60	MNO-703	2244	SE	surface	-	(11)
	EGES	3.70	MNO-458	2164	S	20-30	-	(1)
	EGES	4.30	MNO-458	2164	S	surface	-	(1)
	EGSS	3.75	MNO-382	2195	S	30-46	+/+	(5,6)

TABLE 1, CONTINUED

C-14 Age B.P.	PrPt	Hydration	Site	Elev	Provenience Asp	Depth	84R	Ref
	EGSS	3.94	MNO-382	2195	S	15-30	+/+	(5,6)
	EGSS	3.98	MNO-382	2195	S	0-30	+/+	(5,6)
	RSCN	1.80	MNO-1878	2244	NW	surface	+	(6)
	RSCN	2.90	MNO-1644	2288	ESE	10-20	+/+	(7)
	RSCN	3.17	MNO-382	2195	S	15-30	+/+	(5,6)
	RSCN	3.23	MNO-561	2392	E	10-20	+/+	(12)
	RSCN	4.00	INY-2596	1463	E	38	-	(13)
	RSCN	4.20	MNO-561	2392	E	surface	+	(12)
	RSCN	4.30	INY-2146	1253	ESE	surface	+	(9)
3250-1250	EE	2.21**	MNO-11	2250	NE	40-50	+	(7)
	EE	2.89	MNO-561	2392	E	30-40	+/+	(12)
	EE	2.90	MNO-382	2195	S	0-15	+/+	(5,6)
	EE	3.70	MNO-186	2659	SW	surface	+	(6)
	EE	3.75	MNO-561	2392	E	0-10	+/+	(12)
	EE	3.80	MNO-11	2250	NE	60-70	+/+	(7)
	EE	3.80	MNO-1795	2679	NNW	surface	+	(6)
	EE	3.86	MNO-561	2392	E	10-20	+/+	(12)
	EE	3.89	MNO-561	2392	E	40-50	+/+	(12)
	EE	4.00	MNO-1529	2475	E	surface	+	(14)
	EE	4.00	MNO-1799	2896	W	surface	+	(6)
	EE	4.00	4-51-542***	2976	SSE	surface	+	(6)
	EE	4.21	MNO-382	2195	S	76-91	+/+	(5,6)
	EE	4.27	MNO-382	2195	S	0-15	+/+	(5,6)
	EE	4.40	MNO-1809	2634	SSW	surface	+	(6)
	EE	4.43	MNO-561	2392	E	10-20	+/+	(12)
	EE	4.50	MNO-782	2683	SSW	surface	+	(6)
	EE	4.83	MNO-382	2195	S	46-61	+/+	(5,6)
	EE	4.88	MNO-382	2195	S	0-15	+/+	(5,6)
	EE	5.00	INY-382	2195	S	61-76	+/+	(5,6)
	EE	5.14	INY-1386	1341	NE	15-30	-	(8)
	EE	5.50	INY-2146	1253	ESE	surface	+	(15)
	EE	6.97	INY-1386	1341	NE	0-15	-	(8)
	ECN	2.70	MNO-1529	2475	E	surface	+	(14)
	ECN	3.02	MNO-446	2185	NE	10-20	+/+	(16)
	ECN	3.10	MNO-1809	2634	SSW	surface	+	(6)
	ECN	3.17	MNO-561	2392	E	50-60	+/+	(12)
	ECN	3.28	MNO-561	2392	E	30-40	+/+	(12)
	ECN	3.37	MNO-561	2392	E	30-40	+/+	(12)
	ECN	3.40	MNO-1851	2295	SSW	surface	+	(6)
	ECN	3.60	MNO-1529	2475	E	0-10	+/+	(14)
	ECN	3.60	MNO-1869	2195	ESE	surface	+	(6)
	ECN	3.84	MNO-561	2392	E	30-40	+/+	(12)
	ECN	3.86	MNO-11	2250	NE	50-60	+/+	(7)
	ECN	3.93	MNO-561	2392	E	20-30	+/+	(12)

TABLE 1, CONTINUED

C-14 Age B.P.	PrPt	Hydration	Site	Provenience Elev	Asp	Depth	84R	Ref
	ECN	3.96	MNO-561	2392	E	10-20	+/+	(12)
	ECN	4.06	MNO-382	2195	S	30-46	+/+	(5,6)
	ECN	4.18	MNO-11	2250	NE	20-30	+/+	(7)
	ECN	4.38	MNO-382	2195	S	46-61	+/+	(5,6)
	ECN	4.50	INY-1386	1341	NE	15-30	+/+	(8)
	ECN	4.56	MNO-382	2195	S	30-46	+/+	(5,6)
	ECN	4.68	MNO-382	2195	S	76-91	+/+	(5,6)
	ECN	5.00	MNO-1529	2475	E	surface	+	(14)
	ECN	5.04	MNO-382	2195	S	76-91	+/+	(5,6)
	ECN	5.10	MNO-382	2195	S	15-30	+/+	(5,6)
	ECN	5.25	MNO-561	2392	E	30-40	+/+	(12)
	ECN	5.31	MNO-446	2185	NE	70-80	+/+	(16)
	ECN	5.32	MNO-529	2430	E	30-40	+/+	(4)
	ECN	5.53	MNO-382	2195	S	107-122	+/+	(5,6)
	ECN	5.79	MNO-561	2392	E	30-40	+/+	(12)
	ELK	3.54	MNO-561	2392	E	50-60	+/+	(12)
	ELK	3.60	MNO-458	2164	S	surface	-	(1)
	ELK	3.78	MNO-382	2195	S	30-46	+/+	(5,6)
	ELK	3.82	MNO-561	2392	E	20-30	+/+	(12)
	ELK	3.86	MNO-382	2195	S	61-76	+/+	(5,6)
	ELK	3.94	MNO-561	2392	E	0-10	+/+	(12)
	ELK	4.05	MNO-382	2195	S	61-76	+/+	(5,6)
	ELK	4.40	MNO-529	2430	E	surface	+	(4)
	ELK	4.51	MNO-382	2195	S	61-76	+/+	(5,6)
	ELK	4.80	MNO-1529	2475	E	surface	+	(14)
	ELK	4.80	INY-30	1143	ESE	60-70	-	(10)
	ELK	5.40	INY-30	1143	ESE	40-50	-	(10)
	ELK	5.60	MNO-458	2164	S	surface	-	(1)
	ELK	5.60	INY-30	1143	ESE	50-60	-	(10)
	GCS	3.60	MNO-1871	2244	N	surface	+	(6)
	GCS	3.72	MNO-382	2195	S	61-76	+/+	(5,6)
	GCS	3.80	MNO-1529	2475	E	surface	+	(14)
	GCS	3.84	MNO-382	2195	S	46-61	+/+	(5,6)
	GCS	3.96	MNO-561	2392	E	40-50	+/+	(12)
	GCS	4.00	MNO-382	2195	S	61-76	-	(5,6)
	GCS	4.00	MNO-458	2164	S	10-20	-	(1)
	GCS	4.03	MNO-382	2195	S	76-91	+/+	(5,6)
	GCS	4.24	MNO-382	2195	S	46-61	+/+	(5,6)
	GCS	4.38	MNO-446	2185	NE	20-30	+/+	(16)
	GCS	4.41	MNO-382	2195	S	46-61	+/+	(5,6)
	GCS	4.49	MNO-382	2195	S	46-61	+/+	(5,6)
	GCS	4.52	MNO-11	2250	NE	40-50	+/+	(7)
	GCS	4.64	MNO-382	2195	S	46-61	+/+	(5,6)
	GCS	5.00	MNO-382	2195	S	107-122	+/+	(5,6)
	GCS	5.49	MNO-382	2195	S	76-91	+/+	(5,6)
	GCS	5.56	MNO-382	2195	S	76-91	+/+	(5,6)
	GCS	5.80	INY-1386	1341	NE	46-61	-	(8)
	GCS	6.00	INY-1386	1341	NE	surface	-	(8)

TABLE 1, CONTINUED

C-14 Age B.P.	PrPt	Hydration	Site	Elev	Provenience Asp	Depth	84R	Ref
4950-3250	LLSS	3.75	MNO-561	2392	E	30-40	+/+	(12)
	LLSS	4.04	MNO-561	2392	E	80-90	+/+	(12)
	LLSS	4.80	MNO-1826	2140	SSE	surface	+	(6)
	LLSS	4.90	MNO-1789	2713	NW	surface	+	(6)
	LLSS	6.00	4-52-217	2200	ESE	surface	+	(6)
	LLSS	6.50	MNO-1789	2713	NW	surface	+	(4)
	LLSS	6.82	MNO-529	2430	E	surface	+	(4)
	LLSS	6.85	MNO-561	2392	E	50-60	+/+	(12)
	LLSS	7.80	MNO-458	2164	S	surface	-	(1)
Inde-definite	RSCS	2.50	MNO-1871	2244	N	surface	-	(6)
	LSN	3.80	MNO-1529	2475	E	surface	-	(14)
	LSN	4.00	MNO-1529	2475	E	surface	-	(14)
	LSN	4.40	MNO-1529	2475	E	surface	-	(14)
	LSN	5.40	MNO-382	2195	S	surface	-	(17)
	LSN	5.40	MNO-458	2164	S	50-60	-	(1)
	LSN	5.50	MNO-382	2195	S	30-46	-	(5,6)
	LSN	5.82	MNO-561	2392	E	70-80	-	(12)
	WSBS	4.10	4-51-557	2963	SW	surface	-	(6)
	WSBS	4.40	MNO-186	2659	SW	surface	-	(6)
	WSBS	4.40	4-52-872	2159	S	surface	-	(11)
	WSBS	4.97	MNO-561	2392	E	20-30	-	(12)
	WSBS	5.78	MNO-561	2392	E	10-20	-	(12)
	WSBS	6.20	MNO-382	2195	S	46-61	-	(5,6)
	WSBS	6.40	MNO-1822	2159	SSE	surface	-	(6)
	WSBS	6.51	MNO-382	2195	S	30-46	-	(5,6)
	WSBS	7.00	MNO-458	2164	S	surface	-	(1)
	WSBS	8.16	MNO-382	2195	S	91-107	-	(5,6)
	WSBS	8.18	MNO-584	2085	SW	50-60	-	(3)
	WSBS	8.80	4-52-874	2221	S	surface	-	(11)
	WSNS	5.00/5.40	4-51-519	2756	NNE	surface	-	(6)
	WSNS	6.01	MNO-446	2185	NE	70-80	-	(16)
	WSNS	6.32	MNO-561	2392	E	50-60	-	(12)
	WSNS	7.24	MNO-561	2392	E	50-60	-	(12)
	WSNS	7.80	4-52-208	2128	E	surface	-	(6)
	WSNS	8.50	MNO-680	2195	ESE	surface	-	(6)
	WSNS	9.00	MNO-680	2195	ESE	surface	-	(6)
	MCNS	1.34	MNO-382	2195	S	?	-	(5,6)
	MCNS	1.65	INY-1386	1324	NE	0-15	-	(8)
	MCNS	1.80	MNO-1878	2244	NW	surface	-	(6)
	MCNS	1.90	4-52-203	2293	WNW	surface	-	(6)
	MCNS	2.60	MNO-1878	2244	NW	surface	-	(6)
	MCNS	2.60	MNO-1809	2634	SSW	surface	-	(6)

TABLE 1, CONTINUED

C-14 Age B.P.	PrPt	Hydration	Site	Elev	Provenience Asp	Depth	84R	Ref
	MCNS	3.14	MNO-382	2195	S	46-61	-	(5,6)
	MCNS	3.36	MNO-382	2195	S	46-61	-	(5,6)
	MCNS	3.50	MNO-1789	2713	NW	surface	-	(6)
	MCNS	3.70	MNO-1872	2146	NE	surface	-	(6)
	MCNS	4.70	4-51-580	2378	SSE	surface	-	(6)
	MCNS	5.90	4-51-587	2930	SW	surface	-	(6)
	MCNS	6.00/8.10	4-15-532	2659	ENE	surface	-	(6)
	MCNS	7.60	4-52-211	2119	E	surface	-	(6)
	MCNS	8.00	MNO-800	2146	E	surface	-	(6)
	HBN	1.20	MNO-714	2399	ENE	10-20	-	(2)
	HBN	3.10	MNO-574	2317	W	surface	-	(18)
	HBN	3.60	INY-30	1143	ESE	67	-	(10)
	HBN	3.80	MNO-458	2164	S	surface	-	(1)
	HBN	3.91	MNO-823	2238	ENE	30-40	-	(7)
	HBN	4.57	INY-1386	1341	NE	30-46	-	(8)
	HBN	4.60	MNO-458	2164	S	surface	-	(1)
	HBN	5.50	INY-2146	1253	ESE	surface	-	(15)
	HBN	5.50	MNO-382	2195	S	15-30	-	(5,6)
	HBN	6.20	INY-30	1143	ESE	40-50	-	(10)
	HCB	2.56	MNO-382	2195	S	122-137	-	(5,6)
	HCB	3.38	MNO-382	2195	S	15-30	-	(5,6)
	HCB	3.50	MNO-458	2164	S	surface	-	(1)
	HCB	3.52	MNO-561	2392	E	40-50	-	(12)
	HCB	3.60	MNO-458	2164	S	surface	-	(1)
	HCB	3.60	MNO-1811	2620	ENE	surface	-	(6)
	HCB	3.67	MNO-561	2392	E	20-30	-	(12)
	HCB	3.69	MNO-561	2392	E	70-80	-	(12)
	HCB	3.70	4-51-576	2290	SSW	surface	-	(6)
	HCB	3.72	MNO-382	2195	S	30-46	-	(5,6)
	HCB	3.72	MNO-382	2195	S	76-91	-	(5,6)
	HCB	3.76	MNO-561	2392	E	10-20	-	(12)
	HCB	3.80	MNO-1529	2475	E	0-10	-	(14)
	HCB	3.80	MNO-1817	2512	SSE	surface	-	(6)
	HCB	3.92	MNO-561	2392	E	10-20	-	(12)
	HCB	4.00	4-52-210	2146	SSE	surface	-	(6)
	HCB	4.04	MNO-584	2085	SW	60-70	-	(3)
	HCB	4.10	4-52-208	2128	E	surface	-	(6)
	HCB	4.17	MNO-561	2392	E	70-80	-	(12)
	HCB	4.28	MNO-561	2392	E	80-90	-	(12)
	HCB	4.39	MNO-561	2392	E	50-60	-	(12)
	HCB	4.40	MNO-1833	2256	SSW	surface	-	(6)
	HCB	4.51	MNO-561	2392	E	30-40	-	(12)
	HCB	4.52	MNO-382	2195	S	91-107	-	(5,6)
	HCB	4.60	MNO-1789	2713	NW	surface	-	(6)
	HCB	4.76	MNO-382	2195	S	46-61	-	(5,6)
	HCB	4.78	MNO-561	2392	E	40-50	-	(12)

TABLE 1, CONTINUED

C-14 Age B.P.	PrPt	Hydration	Site	Elev	Provenience Asp	Depth	84R	Ref
	HCB	5.20	4-52-216	2213	E	surface	-	(6)
	HCB	5.40	MNO-382	2195	S	15-30	-	(5,6)
	HCB	5.50	MNO-1794	2779	NE	surface	-	(6)
	HCB	5.52	MNO-382	2195	S	0-30	-	(5,6)
	HCB	5.74	MNO-561	2392	E	70-80	-	(12)
	HCB	5.87	MNO-561	2392	E	40-50	-	(12)
	HCB	5.90	MNO-186	2659	SW	surface	-	(6)
	HCB	6.03	INY-1386	1341	NE	30-46	-	(8)
	HCB	6.49	INY-1386	1341	NE	0-15	-	(8)
	HCB	7.92	MNO-382	2195	S	15-30	-	(5,6)
	HCB	8.13	INY-1386	1341	NE	30-46	-	(8)
	GBCB	10.00	MNO-1847	2299	SW	surface	-	(6)
	GBCB	10.20	MNO-679	2186	ENE	surface	-	(6)

KEY:

C-14 Age	Radiocarbon chronology as largely defined by Thomas (1981) for certain projectile point forms in the central and western Great Basin (cf. Bettinger and Taylor 1974; Heizer and Hester 1978; Holmer 1986); evidence indicates that in east-central California large, contracting-stem points (GCS) are more characteristic of the period ca. 3250-1250 B.P. than ca. 4950-3250 (as in central Nevada); B.P. = radiocarbon years before A.D. 1950.
PrPt	Point type: DSN, Desert Side-notched; CT, Cottonwood Triangular; EGES, Eastgate Expanding-stem; EGSS, Eastgate Split-stem; RSCN, Rose Spring Corner-notched; EE, Elko Eared; ECN, Elko Corner-notched; ELK, Elko series (indistinguishable EE and ECN fragments); GCS, Gypsum Contracting-stem; LLSS, Little Lake Split-stem; RSCS, possible Rose Spring Contracting-stem; LSN, large side-notched; WSBS, large wide-stemmed, shoulders broad, pronounced; WSNS, large wide-stemmed, shoulders narrow, rounded; MCNS, miscellaneous, untypable corner-notched or shouldered forms (usually large); HBN, Humboldt Basal-notched; HCB, Humboldt Concave-base; GBCG, Great Basin Concave-base series.
Hydration	Measurement in microns
Site	(MNO-, Mono County; INY-, Inyo County)
Elev	Approximate elevation (m) above mean sea level
Asp	Aspect
Depth	Depth (cm) below ground surface
84R	+, considered but not used in computation of Hall (1984) Casa Diablo hydration rate; +/+, used in 1984 rate derivation; -, data not available in 1984.
Ref	Reference: 1, Burton 1985a; 2, R. Jackson 1986; 3, Garfinkel and Cook 1979; 4, Basgall 1983; 5, Michels 1965; 6, R. Jackson 1985; 7, Bouscaren, Hall and Swenson 1982, and Bouscaren and Wilke 1987; 8, Bouscaren 1985; 9, Bettinger, Delacorte and McGuire 1984; 10, Basgall and McGuire 1987; 11, Burton 1986a; 12, Hall 1983; 13, Burton 1986b; 14, Basgall 1984; 15, Garfinkel 1980; 16, Bettinger 1981; 17, Burton 1985b; 18, Mone 1986.
*	also recorded as MNO-630
**	statistically extreme outlier value in Hall (1984) hydration rate derivation experiment
***	Inyo National Forest isolate designation, Mono County (4-51-, Mono Lake Ranger District; 4-52-, Mammoth Ranger District)

TABLE 2
HYDRATION SUMMARY STATISTICS FOR CASA DIABLO OBSIDIAN PROJECTILE POINTS FROM MONO COUNTY, CALIFORNIA (35 SITES, 15 ISOLATES, 2000-3000 M)

SUBSURFACE

Proj Pt	N	Range	Medn	Mean	SD
DSN+CT	18	1.20-3.42	1.77	1.97	0.75
DSN	13	1.20-3.10	1.73	1.81	0.62
CT	5	1.30-3.42	2.71	2.39	0.98
EG+RSCN	10	1.40-3.98	3.20	3.01	0.93
EG	7	1.40-3.98	3.70	2.97	1.14
RSCN	3	2.90-3.23	3.17	3.10	0.18
ELK+GCS	56	2.21-5.79	4.06	4.21	0.74
ELK***	41	2.21-5.79	4.05	4.14	0.79
EE	13	2.21-5.00	3.89	3.92	0.84
ECN	21	3.02-5.79	4.18	4.34	0.84
GCS	15	3.72-5.56	4.38	4.42	0.56
LLSS	3	3.75-6.85	4.04	4.88	1.71

SURFACE

Proj Pt	N	Range	Medn	Mean	SD
DSN+CT	8	1.23-2.80	1.95	1.95	0.47
DSN	2	1.23-2.10	1.67	1.67	0.62
CT	6*	1.58-2.80	1.95	2.05	0.43
EG+RSCN	8	1.80-4.30	2.95	3.03	0.96
EG	6	2.10-4.30	2.95	3.04	0.84
RSCN	2	1.80-4.20	3.00	3.00	1.70
ELK+GCS	18	2.70-5.60	3.90	4.00	0.70
ELK***	16	2.70-5.60	4.00	4.04	0.73
EE	7	3.70-4.50	4.00	4.06	0.29
ECN	5	2.70-5.00	3.40	3.56	0.87
GCS	2	3.60-3.80	3.70	3.70	0.14
LLSS	6	4.80-7.80	6.25	6.14	1.16

TOTAL

Proj Pt	N	Range	Medn	Mean	SD
DSN+CT	27	1.20-3.42	1.80	1.99	0.67
DSN	15	1.20-3.10	1.73	1.79	0.60
CT	12**	1.30-3.42	2.15	2.24	0.69
EG+RSCN	18	1.40-4.30	3.20	3.02	0.92
EG	13	1.40-4.30	3.30	3.00	0.97
RSCN	5	1.80-4.20	3.17	3.06	0.86
ELK+GCS	74	2.21-5.79	4.00	4.16	0.73
ELK***	57	2.21-5.79	4.00	4.11	0.77
EE	20	2.21-5.00	4.00	3.97	0.69
ECN	26	2.70-5.79	4.01	4.19	0.89
GCS	17	3.60-5.56	4.24	4.33	0.58
LLSS	9	3.75-7.80	6.00	5.72	1.40

*a second value of 6.10 microns for one CT (Table 1) dismissed as aberrant (remnant surface)
**total includes hydration measurement on one specimen of unknown stratigraphic provenience
***ELK encompasses measurements on EE and ECN points, and identifiable, but indistinguishable fragments of each form

TABLE 2, CONTINUED

SUBSURFACE					
Proj Pt	**N**	**Range**	**Medn**	**Mean**	**SD**
RSCS	-	-	-	-	- -
LSN	3	5.40-5.82	5.50	5.57	0.22
WSBS	6	4.97-8.18	6.36	6.63	1.30
WSNS	3	6.01-7.24	6.32	6.52	0.64
MCNS	2	3.14-3.36	3.25	3.25	0.16
HBN	3	1.20-5.50	3.91	3.54	2.17
HCB	23	2.56-7.92	4.17	4.42	1.11
GBCB	-	-	-	-	-
SURFACE					
Proj Pt	**N**	**Range**	**Medn**	**Mean**	**SD**
RSCS	2	2.50-3.80	3.15	3.15	0.92
LSN	3	4.00-5.40	4.40	4.60	0.72
WSBS	6	4.10-8.80	5.40	5.85	1.88
WSNS	4*	5.20-9.00	8.15	7.63	1.69
MCNS	12**	1.80-8.00	4.20	4.70	2.36
HBN	3	3.10-4.60	3.80	3.83	0.75
HCB	12	3.50-5.90	4.05	4.33	0.81
GBCB	2	10.00-10.20	10.10	10.10	0.14
TOTAL					
Proj Pt	**N**	**Range**	**Medn**	**Mean**	**SD**
RSCS	2	2.50-3.80	3.15	3.15	0.92
LSN	6	4.00-5.82	5.40	5.09	0.72
WSBS	12	4.10-8.80	6.30	6.24	1.59
WSNS	7	5.20-9.00	7.24	7.15	1.38
MCNS	15***	1.34-8.10	3.50	4.28	2.31
HBN	6	1.20-5.50	3.86	3.69	1.46
HCB	35	2.56-7.92	4.10	4.39	1.01
GBCB	2	10.00-10.20	10.10	10.10	0.14

*values of 5.00 and 5.40 microns reported for one specimen (Table 1) averaged here as 5.20 microns
**both values (6.00, 8.10) reported for one specimen (Table 1) treated independently here
***total includes hydration measurement on one specimen of unknown stratigraphic provenience

Key: DSN, Desert Side-notched; CT, Cottonwood Triangular; EG, Eastgate series (10 Expanding-stem, 3 Split-stem); RSCN, Rose Spring Corner-notched; ELK, Elko series; EE, Elko Eared; ECN, Elko Corner-notched; GCS, Gypsum Contracting-stem; LLSS, Little Lake Split-stem; RSCS, possible Rose Spring Contracting-stem; LSN, large side-notched; WSBS, large wide-stemmed, shoulders broad, pronounced; WSNS, large wide-stemmed, shoulders narrow, rounded; MCNS, miscellaneous, untypable corner-notched or shouldered forms (usually large); HBN, Humboldt Basal-notched, HCB, Humboldt Concave-base; GBCB, Great Basin Concave-base series.

TABLE 3
REVISED HYDRATION SUMMARY STATISTICS FOR CASA DIABLO OBSIDIAN PROJECTILE POINTS FROM MONO COUNTY, CALIFORNIA (EXTREME OUTLIERS ELIMINATED)

SUBSURFACE

Proj Pt	N	Range	Medn	Mean	SD
DSN+CT	17	1.20-3.10	2.00	1.88	0.68
DSN	12	1.20-2.90	1.62	1.70	0.50
CT	5	1.30-3.42	2.71	2.39	0.98
EG+RSCN	9	1.60-3.98	3.94	3.19	0.79
EG	7	1.40-3.98	3.70	2.97	1.14
RSCN	3	2.90-3.23	3.17	3.10	0.18
ELK+GCS	55	2.89-5.79	4.06	4.25	0.70
ELK***	40	2.89-5.79	4.01	4.19	0.74
EE	12	2.89-5.00	4.05	4.06	0.69
ECN	21	3.02-5.79	4.18	4.34	0.84
GCS	13	3.72-5.00	4.24	4.25	0.36
LLSS	3	3.75-6.85	4.04	4.88	1.71

SURFACE

Proj Pt	N	Range	Medn	Mean	SD
DSN+CT	7	1.23-2.20	1.80	1.83	0.34
DSN	2	1.23-2.10	1.67	1.67	0.62
CT	5*	1.58-2.20	1.80	1.90	0.25
EG+RSCN	8	1.80-4.30	2.95	3.03	0.96
EG	5	2.10-3.60	2.60	2.78	0.64
RSCN	2	1.80-4.20	3.00	3.00	1.70
ELK+GCS	17	2.70-5.00	3.80	3.91	0.59
ELK***	15	2.70-5.00	4.00	3.93	0.62
EE	6	3.70-4.40	4.00	3.98	0.24
ECN	4	2.70-3.60	3.25	3.20	0.39
GCS	2	3.60-3.80	3.70	3.70	0.14
LLSS	5	4.80-6.82	6.00	5.80	0.92

TOTAL

Proj Pt	N	Range	Medn	Mean	SD
DSN+CT	26	1.20-3.10	2.50	1.93	0.62
DSN	13	1.20-2.10	1.50	1.60	0.37
CT	12**	1.30-3.42	2.15	2.24	0.69
EG+RSCN	18	1.40-4.30	3.20	3.02	0.92
EG	13	1.40-4.30	3.30	3.00	0.97
RSCN	3	2.90-3.23	3.17	3.10	0.18
ELK+GCS	73	2.70-5.79	4.00	4.19	0.70
ELK***	56	2.70-5.79	4.00	4.14	0.73
EE	19	2.89-5.00	4.00	4.06	0.57
ECN	26	2.70-5.79	4.01	4.19	0.89
GCS	15	3.60-5.00	4.03	4.18	0.39
LLSS	9	3.75-7.80	6.00	5.72	1.40

*a second value of 6.10 microns for one CT (Table 1) dismissed as aberrant (remnant surface)
**total included hydration measurement on one specimen of unknown stratigraphic provenience
***ELK encompasses measurements on EE and ECN points, and identifiable, but indistinguishable fragments of each form

TABLE 3, CONTINUED

SUBSURFACE					
Proj Pt	**N**	**Range**	**Medn**	**Mean**	**SD**
RSCS	-		-	-	-
LSN	3	5.40-5.82	5.50	5.57	0.22
WSBS	6	4.97-8.18	6.36	6.63	1.30
WSNS	3	6.01-7.24	6.32	6.52	0.64
MCNS	2	3.14-3.36	3.25	3.25	0.16
HBN	3	1.20-5.50	3.91	3.54	2.17
HCB	22	2.56-5.87	4.11	4.26	0.83
GBCB	-	-	-	-	-
SURFACE					
Proj Pt	**N**	**Range**	**Medn**	**Mean**	**SD**
RSCS	2	2.50-3.80	3.15	3.15	0.92
LSN	3	4.00-5.40	4.40	4.60	0.72
WSBS	5	4.10-7.00	4.40	5.26	1.34
WSNS	3*	7.80-9.00	8.50	8.43	0.60
MCNS	12**	1.80-8.00	4.20	4.70	2.36
HBN	3	3.10-4.60	3.80	3.83	0.75
HCB	11	3.50-5.50	4.00	4.18	0.68
GBCB	2	10.00-10.20	10.10	10.10	0.14
TOTAL					
Proj Pt	**N**	**Range**	**Medn**	**Mean**	**SD**
RSCS	2	2.50-3.80	3.16	3.15	0.92
LSN	5	4.40-5.82	5.40	5.30	0.53
WSBS	12	4.10-8.80	6.30	6.24	1.59
WSNS	7	5.20-9.00	7.24	7.15	1.38
MCNS	15***	1.34-8.10	3.50	4.28	2.31
HBN	5	3.10-5.50	3.91	4.18	0.91
HCB	34	2.56-5.90	4.07	4.28	0.81
GBCB	2	10.00-10.20	10.10	10.10	0.14

*values of 5.00 and 5.40 microns reported for one specimen (Table 1) averaged here as 5.20 microns
**both values (6.00, 8.10) reported for one specimen (Table 1) treated independently here
***total includes hydration measurement on one specimen of unknown stratigraphic provenience

Key: DSN, Desert Side-notched; CT, Cottonwood Triangular; EG, Eastgate series (10 Expanding-stem, 3 Split-stem); RSCN, Rose Spring Corner-notched; ELK, Elko series; EE, Elko Eared; ECN, Elko Corner-notched; GCS, Gypsum Contracting-stem; LLSS, Little Lake Split-stem; RSCS, possible Rose Spring Contracting-stem; LSN, large side-notched; WSBS, large wide-stemmed, shoulders broad, pronounced; WSNS, large wide-stemmed, shoulders narrow, rounded; MCNS, miscellaneous, untypable corner-notched or shouldered forms (usually large); HBN, Humboldt Basal-notched, HCB, Humboldt Concave-base; GBCB, Great Basin Concave-base series.

direct exposure to solar radiation of surface materials, factors which presumably increase effective hydration temperature and thereby enhance the hydration process. Comparison of hydration summary statistics for Casa Diablo obsidian projectile points from the source area in Mono County, California (Tables 2-3), reveals relatively minimal divergence between hydration values obtained on surface and subsurface specimens. By individual point form, with few exceptions, hydration means are consistently larger for subsurface than for surface specimens — ceteris paribus, an expectable stratigraphic relationship. Across the major point groups represented (Desert Side-notched/Cottonwood Triangular, Eastgate/Rose Spring, Elko/Gypsum, Little Lake, and Humboldt Concave-base series), and including statistically outlying point values, the average difference (Table 2) between surface and subsurface means is a negligible 0.32 microns (0.09 microns when the small number of Little Lake forms are excluded). Perhaps the most interesting disjunctions in surface/subsurface artifact hydration patterns, though magnitudes are only vaguely discernable given the few available analyzed examples, hold for point forms that tend to yield values of 7.0 microns or more (Tables 1-3, Fig. 1). These indications suggest that stratigraphic position may become a more significant hydration variable insofar as Casa Diablo glass in early Holocene cultural assemblages.

What is apparent generally, rather, are potentially meaningful differences in hydration measurements for specific point types (of Casa Diablo obsidian) from Owens Valley (Inyo County, 1100-1500 m) and the higher (2000-3000 m) Mono County localities to the north. Albeit the Owens Valley sample sizes are limited (Table 1), there is marked tendency for points of a particular morpho-chronological category to display thicker hydration bands than in the Casa Diablo source area (Fig. 1). This probably can be attributed to higher effective hydration temperatures in the Owens Valley region. It can also be noted that the absence of appreciable differences in hydration values for similar point forms from 2000-2500 and 2500-3000 m elevations in Mono County could reflect, conceivably, the predominantly surface provenience of specimens recovered in the latter contexts (i.e., solar-enhanced hydration of surface materials might mask the otherwise retarded hydration of samples due to lower effective temperatures above 2500 m). In sum, then, while inter-sample variation in effective hydration temperature is certainly an important consideration, for four reasons (cf. Hall 1984; R. Jackson 1984a) excessive concern with surface/subsurface provenience on a local level may be inappropriate.

First, the thermal history of an obsidian artifact after it entered the archaeological record (tool curation and post-deposit material scavenging factors notwithstanding) is virtually impossible to ascertain in most instances. Second, it thus cannot be assumed a priori that the respective stratigraphic positions of surface and subsurface debris have remained unchanged through time. Third, actual effects of varying effective temperatures are difficult to document and probably more relevant on an areal (elevational) basis. Fourth, there is, after all, a broader, principal interest in large-scale, multi-site trends in source-specific hydration data, patterns not likely to be measurably affected by microenvironmental temperature differentials.

Lastly, in our opinion, the Casa Diablo obsidian hydration data presented in Tables 1-3 provide a fairly convincing endorsement of the reliability of certain projectile point forms as at least relative, if not absolute (in many cases), time-markers in eastern California and the western Great Basin. Hydration measurements on arrowpoints, dartpoints, and possible spearpoints of Casa Diablo glass do seem to sort out well in a manner accordant with arguable, but stratigraphically established morpho-chronological schemes (Bettinger and Taylor 1974; Clewlow 1967; Heizer and Hester 1978; Holmer 1986; Lanning 1963; Thomas 1981, 1983). Crucial to this assessment is an explicit understanding that these points achieve chronological value primarily when considered as populations of specific kinds of artifacts. As with a single hydration measurement, which alone cannot be viewed as necessarily temporally significant due to such factors as tool curation and material scavenging, because of its unique techno-morphological trajectory (resharpening, rejuvenation, etc.) a single projectile point also cannot be taken as an unequivocal chronological indicator (cf. Flenniken and Raymond 1986; Flenniken and Wilke 1986). Duly incorporating the reality of temporal gradations afforded by hydration data, therefore, and excluding type-specific outlying values (never more than one or two per morphological category [compare Tables 2 and 3], and as determined by Chauvenet's criterion [Long and Rippeteau 1974] where $p[x] < 1/2n$ [i.e., the probability (p) of obtaining a given value (x) is less than the inverse of twice the subject sample size (n)]), micron ranges (cf. Tables 1, 3) can be estimated for hydration on the following point forms of Casa Diablo obsidian in Mono County:

1.3-2.6	Desert Side-notched/Cottonwood Triangular;
2.1-3.9	Eastgate series/Rose Spring Corner-notched;

3.3-5.3	Elko series/Gypsum Contracting-stem/Humboldt series;
4.5-7.5	Little Lake Split-stem/"Pinto-like" large wide-stemmed forms with broad, pronounced shoulders;
6.0-9.0	large wide-stemmed forms with narrow, rounded shoulders — comparable to Lake Mohave/Silver Lake/Parman/Great Basin Stemmed series (cf. Amsden 1937; R. Jackson and Bettinger 1985; Layton 1979; Pendleton 1979; Tuohy 1974; Tuohy and Layton 1979); and
9.0-10.0	large, relatively thin,basally- and edge-ground concave-base forms (Great Basin Concave-base series) of apparent early Holocene age (cf. Basgall [this volume], n.d., 1987; Clewlow 1968; Pendleton 1979; Tuohy 1974).

Hence, while there is undoubtedly a need to exercise caution in using artifact cross-dating on a site-specific basis, especially when strictly surface assemblages are involved (Basgall, Hall, and Hildebrandt 1988; Flenniken and Raymond 1986; Thomas 1986), the Casa Diablo obsidian hydration projectile point profiles confirm an overall time-diagnostic utility to these artifacts that cannot be empirically discounted.

RATE CONSTRUCTION

Prior to 1984, the most archaeologically useful hydration rates proposed for Casa Diablo obsidian consisted of linear functions calibrated against hydration values for temporally-sensitive projectile point forms (Basgall 1983:130-134; Garfinkel 1980:25-26; Hall 1983:193-196). Of these, only the Hall (1983) formulation controlled for specimen geologic origin and the resultant rate also appeared to yield the widest range of apparently acceptable absolute age estimates (Bouey and Basgall 1984: 136-137). There were, however, two critical problems with the derivation and use of this rate. First, the least- squares regression performed to obtain the rate was based primarily on hydration measurements for points from a single site, CA-MNO-561 (Hall 1983), located on Mammoth Creek in southwestern Long Valley. Consequently, it was necessary to assume that the range in values for a given point series at the site encompassed the region-wide hydration span for the same point series (R. Jackson 1984b:178). Since such an assumption may be invalid, the calculated hydration rate could contain a significant temporal bias. Second, the Hall (1983) linear rate tends to produce age estimates unacceptably too recent when used to convert hydration values of less than ca. 1.2 microns or more than ca. 7.0 microns (cf. R. Jackson 1984b:181). The linear rate does appear to provide reasonable age estimates for intermediate values between ca. 2.0 and 7.0 microns — a characteristic of many proposed source-specific rates in California (cf. Bouey and Basgall 1984:Table 2; Ericson 1978:Tables 1-2; R. Jackson 1984b:Table 2; Meighan 1983:603, 1984:229-230).

In developing the Hall (1984) Casa Diablo hydration rate, each of the subject 108 projectile points (Table 1) was assigned to one of four temporal periods depending upon its morphological classification. Period definition was based on the radiocarbon chronology outlined by Thomas (1981) for certain point forms in the central and western Great Basin. Though similar in most respects, the point chronology offered by Bettinger and Taylor (1974) for interior southern California was not employed because it was established using "corrected" radiocarbon dates. A reluctance to adopt a "corrected" chronology stems from the uncertainties involved in calibrating secular variations in radiocarbon production over time, and in the methods of applying a given calibration scheme (R. E. Taylor, personal communication 1983). The four temporal periods and diagnostic point forms consist of: 4950-3250 B.P., Little Lake Split- stem; 3250-1250 B.P., Elko series (Corner-notched, Eared, indistinguishable fragments thereof) and Gypsum Contracting-stem; 1250-650 B.P., Rose Spring Corner-notched and Eastgate series (Split-stem, Expanding-stem); and 650-100 B.P., Desert Side-notched and Cottonwood Triangular. Gypsum Contracting-stem points, sometimes also referred to as Elko or Gatecliff contracting-stem (Clewlow 1967; Thomas 1981, 1983), were grouped together with Elko series forms since hydration values on Casa Diablo obsidian specimens in east-central California (Tables 2-3) both span and are encompassed by the range in values for Elko series points made from this glass in the region.

It can also be observed that the Casa Diablo hydration profiles for Humboldt series points (in particular, the concave-base form [Fig. 1]) substantially parallel the Elko pattern (Tables 2-3). Questions regarding their chronological placement (cf. Thomas 1981:17-18), however, precluded inclusion of Humboldt points as contemporaneous artifacts in deriving the Hall (1984) rate. For the same reason (poorly established temporal position), along with as yet unclear morphological definition, various, putatively

FIGURE 1

Figure 1. Depositional context and hydration histograms of Casa Diablo obsidian projectile points from east-central California.

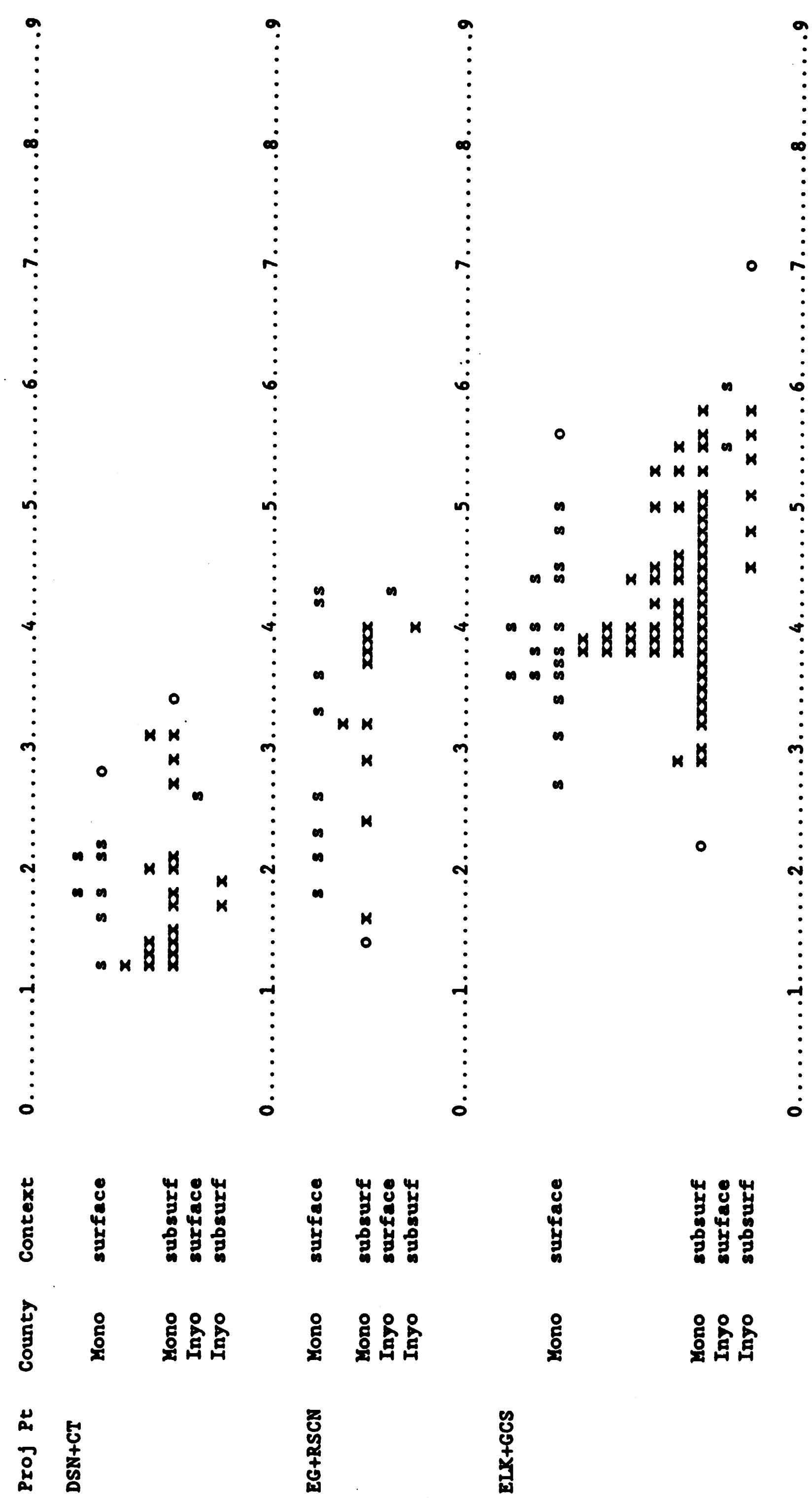
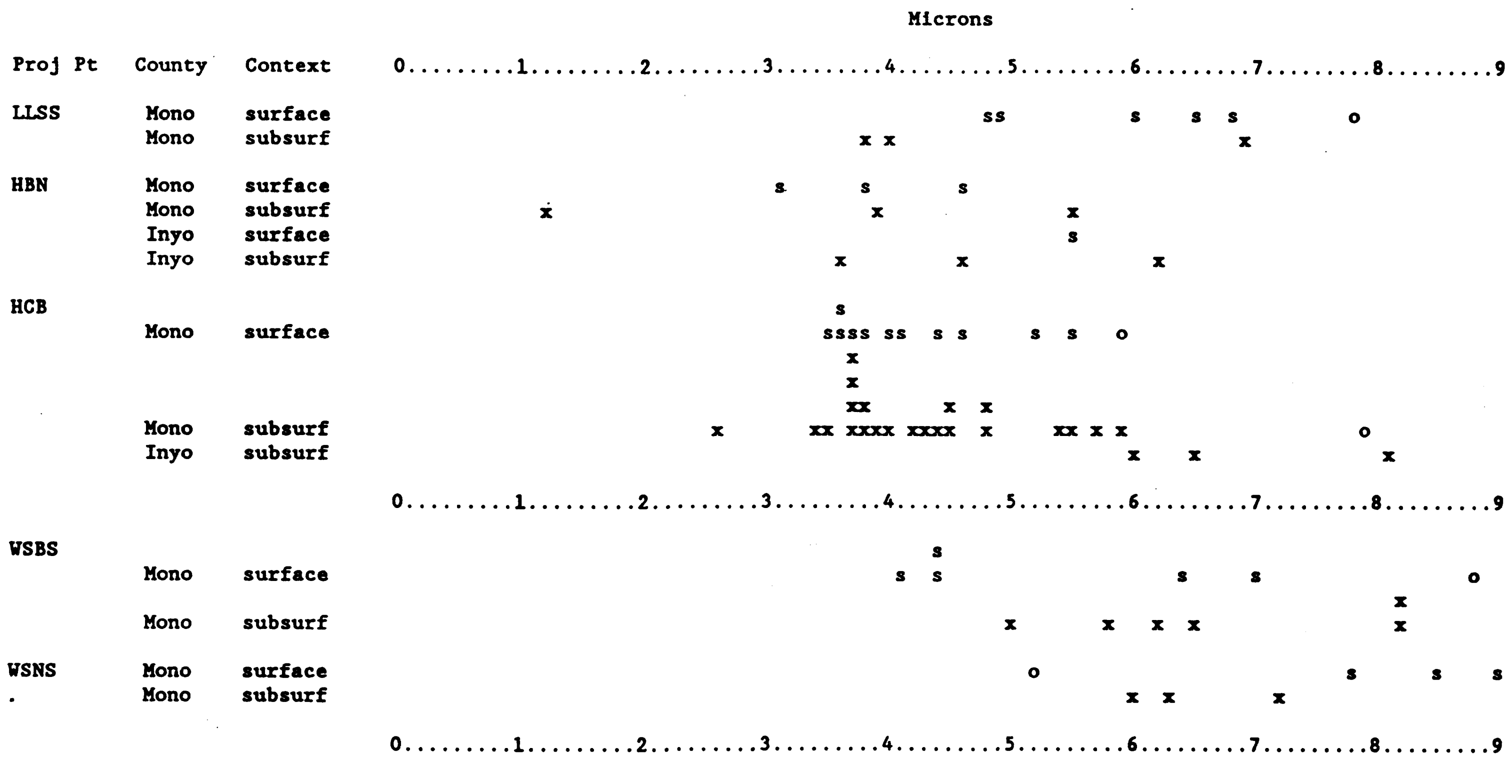


FIGURE 1, CONTINUED

Figure 1 (Continued)



KEY: Four Inyo (1100-1500 m) and 41 Mono (2000-3000 m) county locations; s, surface; x, subsurface; o, statistical outlier; DSN, Desert Side-notched; CT, Cottonwood Triangular; EG, Eastgate series (Expanding-stem, Split-stem); RSCN, Rose Spring Corner-notched; ELK, Elko series (Eared, Corner-notched, indistinguishable fragments thereof); GCS, Gypsum Contracting-stem; LLSS, Little Lake Split-stem; HBN, Humboldt Basal-notched; HCB, Humboldt Concave-base; WSBS, large wide-stemmed, shoulders broad, pronounced; WSNS, large wide-stemmed, shoulders narrow, rounded (values of 5.00 and 5.40 microns for one of latter specimens [Table 1] averaged here as 5.20 microns [outlier]).

early Holocene wide-stemmed (cf. Great Basin Stemmed) and concave-base (cf. Great Basin Concave-base) point forms were excluded in rate formulation. It should as well be noted that although artifact typology is a major consideration here, the categorical consistency supplied by the Thomas (1981) morphological key, the large numbers of specimens involved, and the continuity in multi-laboratory, multi-analyst hydration results, far outweigh the consequences of possible, but incidental point form misclassifications.

To generate variate pairs for calculating experimental, "potential" Casa Diablo rates, period-specific point hydration measurements (from Mono County) were manipulated in three steps (Hall 1984). All numerical operations were performed with a handheld Texas Instruments Programmable 58C calculator. First, correlations were made between the mean and then median values for a given period and the temporal midpoint of that period, or between a value representing, in hydration terms, the maximum proportional separation of two periods and the transition date between the two periods. In the latter instance, the procedure requires determining a hydration measurement above or below of which appropriately fall the greatest proportions of measurements for points assigned to two sequential periods. Second, to derive values for mean, median, and maximum separation variate pairs, period-specific hydration measurements were categorized in four ways: (1) as are, without regard for surface or subsurface provenience; (2) as are, without regard to surface/subsurface provenience, but with extreme "outliers" excluded by applying Chauvenet's criterion; (3) values for specimens found only in a buried context; and (4) values for specimens found only in buried context, but with extreme outliers excluded. The latter two categories of hydration values were included in the analysis, despite the foregoing discussion, out of due consideration to the surface/subsurface provenience vz. effective hydration temperature issue. Third, each of the 12 sets of variate pairs developed during the first two steps was used to calculate a total of 48 "potential" rates based on four functions (where y = years B.P., x = microns, b = y-intercept, and m = slope of fitted line):

linear	$y = b + mx$
exponential	$y = be^{mx}$
power	$y = bx^{m}$
logarithmic	$y = b + m \ln x$

RATE EVALUATION

Correlation coefficients (r) for the 48 experimental Casa Diablo hydration rates thus derived range from 0.86 to 1.00, with most (75%) greater than 0.95. The small number of actual variate pairs, per rate, no doubt underlies the uniformly high co-efficients (cf. Meighan 1983: 601-603). Of interest, nonetheless, is that coefficients above 0.95 were obtained for all exponential and power rates (24), whereas four linear and four logarithmic functions yielded r values of 0.90-0.95, and four of the latter form a value under 0.90. These admittedly minor differences could be construed as supportive of the classical diffusion model of Friedman and Smith (1960), and may reflect the ultimate, general ineffectiveness of logarithmic and, perhaps to a lesser degree, linear hydration rate configurations. To evaluate the accuracy of the 48 potential rates relative to each other, a multi-step strategy was used (cf. Hall 1984) that involved the following statistical manipulations:

(1) per rate, determine proportion of rate-construction, period-point hydration values correctly assigned (by age-conversion and stipulated temporal framework) to said period;
(2) per rate, determine proportion of <u>all</u> period specific values correctly assigned to said period;
(3) per rate, determine cross-period averages of proportions calculated in steps (1) and (2);
(4) per period, rank proportions obtained in steps (1) and (2); ordinal control introduced to the evaluation system in order to dampen proportional distortions due to period-specific, sample-size inequalities;
(5) per rate, determine cross-period averages of ranks formulated in step (4);
(6) repeat steps (1) through (5), but exclude Little Lake Split-stem values given small sample sizes (Tables 1-3);
(7) use cross-period proportion and rank averages to organize rates from most to least effective (eight separate orders); and
(8) determine mean of ordinal ("best-fit/worst-fit") positions (eight) established for each rate in step (7).

Overall, power functions fared well in the evaluation process (seven of 10 best-fit rates), while linear approximations performed poorly (seven of 10 worst-fit rates). Without going into unnecessary quantitative detail, two other observations can be made with respect to the 48 experimental rates. First, the best-fit rates are

TABLE 4
COMPARISON OF AGE ESTIMATES BY PROPOSED HYDRATION RATES FOR CASA DIABLO OBSIDIAN

x	A	B	C	D	E	F	G	H
0	0	+637	0	+934	+745	0	0	0
1	130	32	229	+234	+80	200	220	128
2	460	700	637	466	586	800	440	321
3	964	1369	1158	1166	1251	1800	660	551
4	1630	2037	1770	1866	1917	3200	880	808
5	2450	2706	2459	2566	2582	5000	1100	1087
6	3417	3374	3218	3266	3247	7200	1320	1385
7	4528	4043	4040	3966	3913	9800	1540	1700
8	5779	4711	4919	4666	4578	12800	1760	2031
9	7165	5380	5853	5366	5244	16200	1980	2375
10	8685	6048	6837	6066	5909	20000	2200	2732
11	10337	6717	7869	6766	6575	24200	2420	3102
12	12117	8022	8946	7466	7240	28800	2640	3482

Rates (y = years B.P.; x = microns)

A	$y = 129.656x^{1.826}$	(Hall 1984)
B	$y = 668.54x - 637.000$	(Hall 1983)
C	$y = 229.002x^{1.475}$	(R. Jackson 1984b)
D	$y = 700.0x - 933.6$	(Basgall 1983)
E	$y = 665.41x - 745.00$	(Garfinkel 1980)
F	$y = 1000x^2/5$	(Friedman and Smith 1960)
G	$y = 200x$	(Meighan 1978)
H	$y = 127.806x^{1.33}$	(Ericson 1977a; Clark [1964] model)

TABLE 4, (CONTINUED)

x	I	J	K	L	M	N	O
0	0	0	0	0	0	0	0
1	487	111	285	40	1000	0	6
2	689	222	1140	158	2000	94	51
3	844	333	2564	356	3000	283	174
4	975	444	4558	633	4000	566	412
5	1090	555	7123	988	5000	943	804
6	1194	666	10256	1423	6000	1414	1389
7	1289	777	13960	1937	7000	1979	2206
8	1378	888	18234	2530	8000	2639	3293
9	1462	999	23077	3202	9000	3393	4689
10	1541	1110	28490	3953	10000	4241	6432
11	1616	1221	34473	4783	11000	5184	8561
12	1688	1332	41026	5693	12000	6221	11114

Rates (y = years B.P.; x = microns):

I	$y = 487.28x^{0.50}$	(Ericson 1977a)
J	$y = 111x$	(Ericson 1977a; Meighan, Foote and Aiello [1968] model)
K	$y = 1000x^2/3.51$	(Michels 1982)
L	$y = 39.532x^2$	(Ericson 1977a; Friedman and Smith [1960] model)
M	$y = 1000x$	(Michels 1965; Ericson 1982)
N	$y = 47.126(x^2 - x)$	(Ericson 1977a; Findlow et al. [1975] model)
O	$y = 6.432x^3$	(Ericson 1977a; Kimberlin [1976] model)

three to four times more accurate than the worst-fit rates in placing period-specific point hydration values in their expected chronological position. Second, differences in the accuracy of the top four rates (all power functions) are quite negligible (2-4%). The most effective rate identifed with these procedures is:

$$y = 129.656x^{1.826}$$

In terms of its derivation the top-ranked rate was based on a correlation of period-specific hydration medians with period midpoints and, interestingly, on hydration values for projectile points recovered from subsurface contexts with extreme outlier measurements excluded. Although this in no way documents a significant difference in the rate of hydration between buried obsidian specimens and those found on the surface, as regards Casa Diablo glass in the east-central Sierra Nevada it should satisfy those archaeologists who might argue abjectly that hydration values obtained for surface materials cannot be used in calculating an empirical hydration rate.

Including the Hall (1984) formulation, then, 15 hydration rates have been proposed for or considered generally applicable to Casa Diablo obsidian (Tables 4-5). Ideally it would be possible to evaluate the accuracy of these rates against a broad range of alternative, direct radiometric data. The latter are unfortunately both limited (a reflection of poor organic preservation at most Casa Diablo obsidian-bearing sites) and of commonly questionable applicability (the radiocarbon/hydration sample association problem alluded to above). What is left are indirect methods of rate evaluation, of which two are considered here.

On the premise of fairly well-established maximum (ca. 12,000- 10,000 B.P.) hydration values of 12-10 microns on Casa Diablo obsidian artifacts in the source area (cf. Basgall n.d., 1987; Hall n.d., 1984, 1986; R. Jackson 1984b, 1985), an initial assessment can be made by simple comparison of rate-specific age-conversions. Of the 15 rates depicted in Table 4, two (F, K) might be dismissed as "too slow" (yielding estimates of 41,026-20,000 years for 12-10 microns of hydration [see Endnote 1]). Three others, all linear functions (B, D, E), translate small hydration measurements (less than ca. 1.2 microns) either to the future or the immediate (by decades) past. Six of the rates (G, H, I, J, L, N) are apparently "too fast" (12-10 microns convert to a maximum of 6221 and a minimum of 1110 years). One of the four remaining rates (O, a cubic model) appears to be simultaneously too fast at the recent end of the cultural hydration range and too slow at the early end. The last three, perhaps most reasonable rates from this generalistic evaluation perspective, consist of the Hall (1984) proposal (A), a second power function (C) submitted by R. Jackson (1984b), and a simple, one micron = one thousand years formula (M) used by Michels (1965) and Ericson (1982). Among these, the Hall (1984) rate seems superior; the R. Jackson (1984b) power function provides age estimates possibly too young for roughly eight or more microns of hydration (this may be a consequence of the inappropriate use of 0,0 [no time, no hydration] as a [false] variate pair in actual rate calculation). Relative to all of the proposed rates, the y = 1000x linear approximation appears much too slow for values under 3-5 microns (Table 4).

A second, more particular, yet still indirect way of evaluating the accuracy of proposed Casa Diablo rates focuses on hydration measurements for time-diagnostic projectile point forms of this glass. As might be anticipated logically, the five rates (Basgall 1983 [D]; Garfinkel 1980 [E]; Hall 1983 [B], 1984 [A]; R. Jackson 1984b [C]) constructed with such data place proportionally more points in their "correct" temporal order (as determined by cross-period means, and with the Hall [1984] formulation thus adjudged most effective) than the other 10 subject rates (Tables 4-5). However, it is imperative to understand that these specimen-specific hydration values represent chronological reality (absolute or relative) and are of distinct archaeological relevance. Further, the proportions given in Table 5 were calculated on the basis of extant (Mono County) Casa Diablo point hydration values (Table 1), and not only on those employed directly in developing the five artifact- derived rates. Hence, the fact that, on average, the Hall (1984) rate (A) is nearly three times (58% vs. 20%) more accurate in projectile point temporal assignment than the experimentally induced (Michels 1982) rate (K) cannot be attributed casually to statistical bias (see Endnote 2). To interpret otherwise would require disputing point morpho-chronological sequences in east-central California, sample-specific hydration measurements, or both — alternative arguments of which none seems very likely practicable.

TABLE 5

PROPORTIONS OF HYDRATION VALUES FOR TIME-DIAGNOSTIC PROJECTILE POINT FORMS OF CASA DIABLO OBSIDIAN CONVERTED TO CORRECT CHRONOLOGICAL PERIOD BY PROPOSED SOURCE-SPECIFIC HYDRATION RATES (SPECIMENS FROM SOURCE AREA [MONO COUNTY] LOCATIONS)

Rate	Period IV	Period III	Period II	Period I	Average
A	0.741	0.278	0.865	0.444	0.582
B	0.519	0.222	0.973	0.556	0.568
C	0.593	0.278	0.919	0.444	0.559
D	0.444	0.222	0.919	0.556	0.535
E	0.444	0.278	0.946	0.444	0.528
F	0.519	0.167	0.514	0.333	0.383
G	0.889	0.556	0.014	-	0.365
H	0.963	0.389	0.041	-	0.348
I	0.407	0.889	-	-	0.324
J	1.000	-	-	-	0.250
K	0.333	0.111	0.122	0.222	0.197
L	0.630	0.111	0.014	-	0.189
M	-	-	0.095	0.444	0.135
N	0.407	0.056	0.014	-	0.119
O	0.259	-	-	-	0.065
Average	0.543	0.237	0.362	0.230	0.343

Key:

Period IV, 650-100 B.P. (Desert Side-notched and Cottonwood Triangular points [27 specimens]);
Period III, 1250-650 B.P. (Rose Spring Corner-notched and Eastgate series points [18 specimens]);
Period II, 3250-1250 B.P. (Elko series and Gypsum Contracting-stem points [74 specimens]);
Period I, 4950-3250 B.P. (Little Lake Split-stem points [nine specimens]); see Table 4 legend for rate and origin.

CONCLUSIONS

It is perhaps unfortunate that yet another Casa Diablo obsidian hydration rate has been formulated and proposed, and that the probability of settling upon an acceptable, permanent rate remains small. Nevertheless, the rate advocated here (Hall 1984), as well as appearing to be archaeologically more accurate, has distinct advantages over the apparently usable "rough and ready" Casa Diablo linear rates in that it does not erroneously date small hydration values to this century or in the future, and that it does recognize a substantial, but reasonable, absolute age difference between specimens with values in the 5.0-6.0 micron range and those measuring over seven microns. According to the Hall (1984) rate, of over a thousand hydration values on Casa Diablo obsidian artifacts in the eastern Sierra Nevada, the smallest converts to ca. 130 B.P. (see Endnote 3) and the largest to ca. 12,000 B.P. Moreover, when simple percentage adjustments (cf. Trembour and Friedman 1984) are made for (areal/elevational) differences in effective hydration temperatures, this rate yields age estimates that correspond well with radiocarbon-dated sample contexts in southern Owens Valley (Basgall and McGuire 1987; M. Basgall, personal communication 1988) and the western Sierra Nevada (T. Jackson, personal communication 1985).

The obsidian hydration rate derivation procedure described above, tailored as it is to a particular archaeological/ geological situation, is only one of several, potentially effective approaches. Continued, problem-oriented research will no doubt improve the efficacy of hydration dating, but it is evident that real returns on judicious, careful use of the technique have already been realized. Until "perfect" laboratory-derived rates are available, however, to be successful hydration dating will be necessarily dependent upon a clear appreciation of local and regional archaeological records (cf. Meighan 1983:607). For source-specific hydration rates, in particular, the criterion of archaeological relevance is paramount and must be satisfied before interpretive application can proceed.

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ENDNOTES

1. In this discussion, it is assumed (reasonably) that humans did not occupy the Casa Diablo obsidian source area any earlier than ca. 12,000-10,000 B.P. (cf. Basgall n.d., 1987; Bettinger 1982b; Hall n.d., 1984; Haynes 1967; Payen 1982).

2. The generally low proportions (Table 5) of correctly temporally placed projectile point hydration values, across all rates, for two of the four time periods (I, III) is most probably a function of limited sample sizes (cf. Table 2).

3. T. Jackson (1984:122-124) recently considered the virtual lack of hydration values under one micron in the western Sierra Nevada (cf. Origer [this volume]). He reasoned that since there was no specific technical explanation for why such small bands could not be detected, the lack of values less than one micron constituted "some culturally-related phenomenon and not some product of the chemical or physical aspects of the hydration process" (1984:124). Hence, it was suggested that one micron of hydration could be roughly equated with about 250 years B.P. and that the absence of smaller values reflected the massive, disease-induced depopulation (and consequent cessation of obsidian tool-use) of indigenous California following establishment of Spanish missions in southern California in the late 18th century. Several comments are appropriate. First, the infrequency of hydration values of a micron or less is common wherever hydration studies have been pursued and, therefore, may have nothing at all to do with whether or not obsidian-using populations were ravaged by epidemics. Second, there may well be physical and technical factors that tend to prevent measurement of such small hydration bands. For example, mechanical strain between the hydrated rind and unaltered interior of an obsidian specimen may not be sufficient at depths of less than ca. 1.0 microns to produce the strain birefringence that optically demarcates the diffusion front. Also, commonly employed magnifications (500 to 1200X) may be inadequate to separate a diffusion front at depths of under a micron from the surface undergoing hydration, and there is no assurance that higher magnifications would make consistent, reliable separation possible. Finally, and this assumes that hydration bands smaller than a micron could be measured if present, Cook (1978:93) concluded that significant depopulation as a result of Euroamerican colonization did not occur in regions of the Sierra Nevada until the mid-19th century gold rush. In this regard, using the power function Casa Diablo hydration rate discussed in the present paper, one micron converts

to a data of ca. 130 B.P. If radiocarbon and sidereal temporal scales are more-or-less compatible for such modern age estimates, the lack of hydration values under a micron would represent a period of time after ca. A.D. 1820, which correlates well with the Euroamerican impact on Sierra populations as dated by Cook (1978).

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