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Changes in Prehistoric Land Use in the Alpine Sierra Nevada: A Regional Exploration Using Temperature-Adjusted Obsidian Hydration Rates

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Despite being flanked by the Great Basin and cismontane California, the Sierra Nevada has not played a prominent role in discussions of hunter-gatherer land use in either region. A key reason is the lack of archaeological data from pristine alpine areas, where little archaeological research has occurred. This study investigates high-elevation sites in the southern Sierra Nevada using temperature-adjusted obsidian hydration rates and comparisons to adjoining regions. Two distinct archaeological patterns are identified. The earlier (ca. 3,500 B.P.–1,350 B.P.) limited-use pattern is characterized by dense lithic scatters related to obsidian procurement and logistical hunting forays, most likely by small groups of men. The later (ca. 1,350 B.P.—historic contact) intensive-use pattern is typified by a greater variety of artifact and feature types indicative of a wider range of activities performed by more diverse groups. These broad archaeological patterns are compared to regional cultural developments on either side of the Sierra to investigate how large-scale changes in mobility, subsistence-settlement patterns, and obsidian procurement in core lowland areas influenced prehistoric use of the southern Sierra Nevada alpine zone.

Throughout several decades of academic and Cultural Resource Management (CRM) archaeology in the western Great Basin and Sierra Nevada, great strides have been made in understanding the basic structure of the archaeological record and the broad outlines of prehistoric culture change (Basgall and McGuire 1988; Bettinger 1975, 1989, 1999; Delacorte 1990, 1999; Hull and Moratto 1999; Moratto 1972; Moratto et al. 1988). Unfortunately, much of the intervening alpine Sierra Nevada remains a hinterland about which little of substance is known. The region is usually given only cursory attention by most archaeologists, who alternately view it as a seasonal hunting ground, trade corridor, or ethnolinguistic boundary. However, given the profound changes in prehistoric land use, technology, and trade relations documented throughout the late Holocene both east and west of the Sierra, it is likely that the upland Sierra Nevada harbors a similarly dynamic prehistory.

This study attempts to integrate current understanding of cultural change in both the western Great Basin and southern Sierra Nevada by examining data from a group of archaeological sites along the crest of the southern Sierra Nevada (Figure 1). New data from Taboose Pass, at an elevation of 3,353 m. (11,000 ft.) in Kings Canyon National Park, were compared with a regional sample of obsidian hydration readings in order to explore how land use changes in adjacent areas affected the use of the alpine zone throughout the late Holocene. Because of the environmental extremes present throughout this region, temperature-adjusted hydration rate equations were constructed, thus allowing regional archaeological patterns to be compared using a common temporal scale.

LATE HOLOCENE DEVELOPMENTS EAST AND WEST OF THE SIERRA CREST

The late Holocene was a dynamic time in eastern California prehistory: populations were on the rise, key technologies underwent significant transformations, and several important changes in how prehistoric hunter-gatherers used the landscape occurred. Two particularly noteworthy transitions that took place during this interval

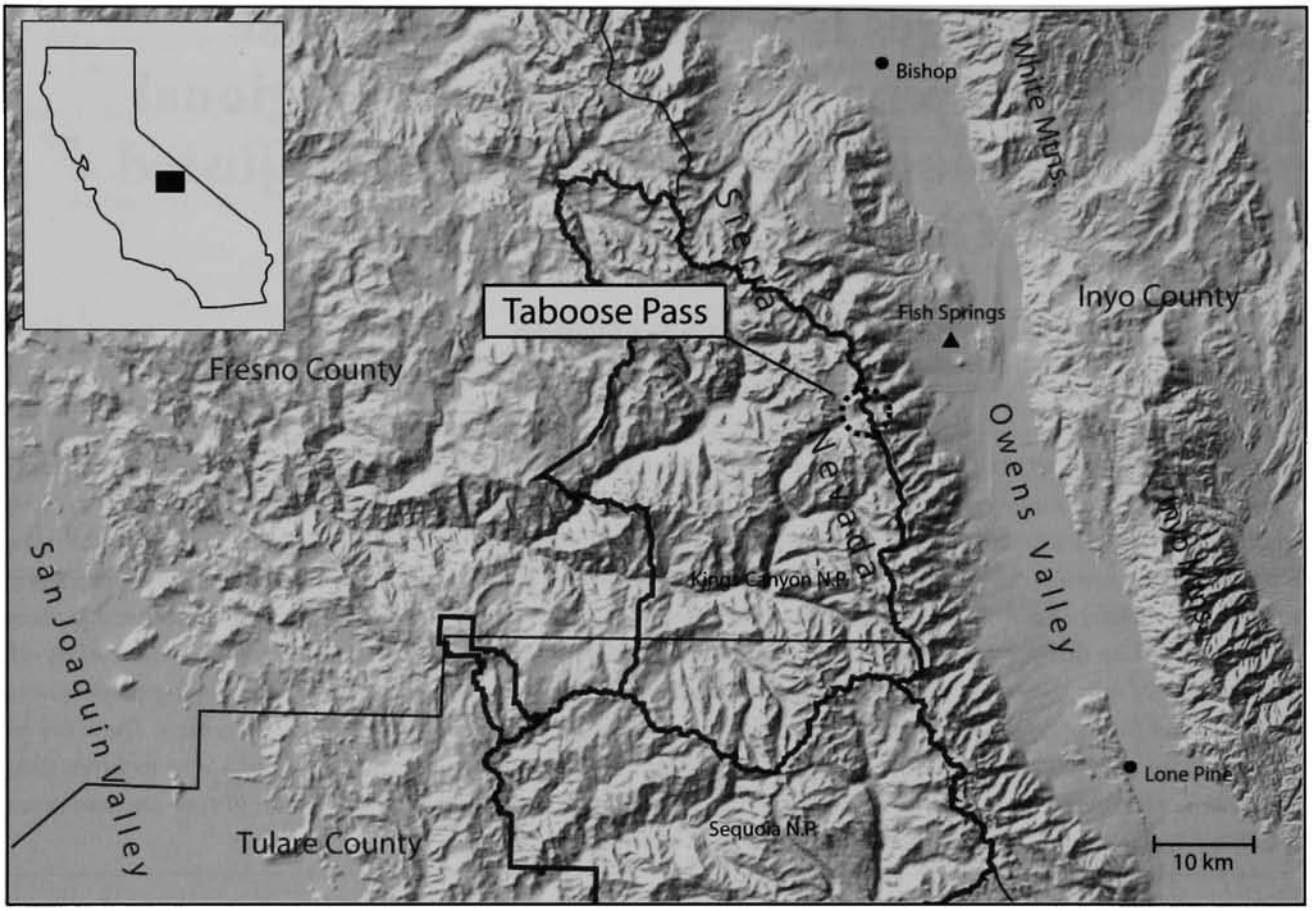

Figure 1. Project vicinity. Note location of Taboose Pass in relation to Fish Springs obsidian source.

were (1) the rise of logistically-organized subsistence-settlement systems after ca. 3,500 years before present (B.P.), accompanied by an unprecedented upsurge in obsidian use and an increasing exploitation of large game, and (2) the breakdown of logistical organization after ca. 1,350 B.P., marked by settlement shifts and an increasingly intensive use of resources.

These key transitions are manifested in the archaeological record of the western Great Basin in several ways. The rise of logistically-organized subsistence-settlement systems is evident in the types and locations of settlements on the landscape, with larger settlements located in prime lowland settings, contrasting sharply with peripheral special-purpose sites—such as seed-gathering camps and hunting camps—that are located in lowland scrub and alpine areas.

The Newberry period (ca. 3,500–1,350 B.P.) is noted for logistically-organized subsistence-settlement systems. Mobility patterns during this period are believed to have been structured around seasonal moves between lowland base camps, perhaps in a north-south orientation along the length of Owens Valley (Basgall 1989). From these base camps, logistical forays to satellite camps were made to hunt game or exploit specific vegetal resources as they became available (Basgall and McGuire 1988; Bettinger 1989, 1999; Delacorte 1990; Delacorte and McGuire 1993). Logistical organization was an important development because it allowed foragers to simultaneously exploit plant resources (in lowland settings) and animal resources (in upland settings) when and where they were abundant (Bettinger 1999; Zeanah 2000).

A major restructuring of land-use patterns occurred at the beginning of the Haiwee period (ca. 1,350–650 B.P.). Groups are thought to have made more intensive use of smaller foraging areas, and permanent or semi-permanent villages were established (Bettinger 1999). The atlatl and dart were replaced by the bow and arrow, milling equipment became more expedient in nature, and subsistence practices became more intensive and were concentrated in smaller areas. Increasingly formalized exchange relationships and territorial control may have also been initiated during this interval (Basgall and McGuire 1988; Bettinger 1989; Delacorte and McGuire 1993).

In the uplands, logistical hunting camps, an important component of pre-1,350 B.P. subsistence-settlement systems, decline in number and subsequently disappear from the archaeological record during this interval (Bettinger 1975; Bettinger 1978; Bettinger 1982; Delacorte 1990). The intensive exploitation of pinyon during this period is marked by the appearance of pinyon camps in the uplands (Bettinger 1976; Delacorte 1990). Also appearing in the highest elevations during this interval are alpine villages (Bettinger 1991; Delacorte 1990; Thomas 1982). Both pinyon camps and alpine villages are examples of a general shift in subsistence-settlement patterns, in which more intensive, residential use was made of a variety of environments that previously were uninhabited or used only temporarily (Bettinger 1999).

A parallel development in the archaeological record of this region that likely reflects the broad outlines of the aforementioned patterns is the steady rise and subsequent precipitous decline in obsidian production at eastern California quarries. The pattern evident at source locations studied thus far is characterized by markedly increased production between ca. 3,000 and 1,000 B.P., followed by a steep decline in production thereafter (Basgall 1983; Bouey and Basgall 1984; Gilreath and Hildebrandt 1997; Hall 1983; Jackson 1984; Singer and Ericson 1977). Although a variety of explanations for this pattern have been proposed, one current model explains increased toolstone use during the Newberry period as a necessary consequence of the technological demands of a spatially-expansive, logistically-organized settlement system (Bettinger 1999; Delacorte and McGuire 1993). Others see the pattern as more specifically related to increases in the exploitation of large game, perhaps over and above provisioning requirements (Hildebrandt and McGuire 2002). In either case, overall obsidian use-patterns add additional support to the idea that settlement strategies before and after ca. 1350 B.P. were distinct in the western Great Basin.

West of the Sierra crest, in California proper, less information is available about how human populations used the landscape throughout the late Holocene. Significant research has occurred at Yosemite National Park in the central Sierra Nevada (see Hull and Moratto 1999 for a review) and at a variety of locations in the southern Sierra Nevada (e.g., Goldberg and Skinner 1990; Jackson and Dietz 1984; McGuire 1981, 1995; McGuire and Garfinkel 1980; Moratto 1972, 1988; Moratto et al. 1988; Roper Wickstrom 1992). Unfortunately, a lack of depositional integrity and chronological controls remains a problem to be resolved over much of the region. It is also difficult to compare successive cultural changes that occurred in the Sierra Nevada to those in the Owens Valley, because divergent research interests have prompted researchers in each region to emphasize different aspects of the prehistoric record.

Available studies, however, suggest that between ca. 3,000 and 1,000 B.P., large, possibly year-round villages were located in the lower foothills (Moratto 1972; Moratto et al. 1988). As in the western Great Basin, lowland villages may have served as central locations from which logistically-organized forays for hunting and exploiting various plant resources originated. Between ca. 1,500 and 1,000 B.P., the use of large lowland villages appears to have waned, and a new pattern emerges with greater numbers of settlements at higher elevations (Cleland 1988; Moratto et al. 1978; Stevens 2002, 2003). This interval is poorly understood in the Sierra Nevada foothills, but it appears to represent either a regional depopulation or a change in settlement that produced less visible remains. Many earlier sites were apparently abandoned, and both the amount of obsidian from eastern sources and the numbers of marine shell beads and ornaments decreased, implying severed trade relations or a reduced demand for toolstone due to technological changes. Bow and arrow hunting replaced the use of the atlatl and dart during this interval, but evidence for other shifts in technology and subsistence practices are equivocal (Moratto 1972; Moratto et al. 1988). In Yosemite, a brief shift to a "forager" type settlement system (*sensu* Binford 1980) during the Tamarack phase (ca.1,450–750 B.P.) is suggested, bracketed by earlier and later phases characterized by a "collector" strategy (Hull 1989a, 1990; Hull et al. 1995; Hull and Moratto 1999). In either case, a clear settlement disruption is evident during this interval.

Although the details and exact timing of these cultural transitions on either side of the Sierra crest are still unknown, each undoubtedly had regionally significant effects on how hunter-gatherer groups used the wider landscape, specifically peripheral areas like the alpine Sierra Nevada. Because the study location at Taboose Pass is located both in the alpine zone and along a major travel route, it was anticipated that changes in settlement pattern as well as obsidian use would be apparent throughout the late Holocene, and that these changes would parallel those documented in core lowland areas of the Sierra Nevada foothills to the west and Owens Valley to the east.

OBSIDIAN HYDRATION DATING IN A HETEROGENEOUS LANDSCAPE

In order to explore regional land-use changes, it is necessary to accurately track both spatial and temporal patterns. Unfortunately, many archaeological sites in the southern Sierra Nevada lack suitable contexts for radiocarbon determinations and many time-sensitive artifacts are either uncommon (e.g., beads) or are poorly understood typologically (e.g., projectile points). In the western Great Basin, chronological indicators are better understood and obsidian hydration dating has proven a reliable and useful tool in elucidating regional land-use changes (Basgall 1989, 1990; Gilreath and Hildebrandt 1997; Richman and Basgall 1999). Due to the ubiquity of obsidian at prehistoric archaeological sites in the region, the present study also relied on obsidian hydration dating for chronological control.

The problem with applying this method over a larger region is that obsidian hydration rates are strongly affected by temperature, with cooler temperatures causing slower rates and warmer temperatures causing faster rates. Given that higher elevation settings are characterized by cooler temperatures, obsidian hydration data from lowland areas is not directly comparable to data from upland areas. This study compensated for this problem by converting raw micron readings to estimates of years B.P. using temperature-adjusted source-specific hydration rates. While this practice has been discouraged by some who feel that obsidian hydration dating should be treated as a relative rather than an absolute dating method, it was pursued here in order to allow temporal comparisons throughout an environmentally heterogeneous area.

Although it appears straightforward, using obsidian hydration as a relative dating method can be misleading. The common practice of arraying raw hydration readings in a histogram does not reflect reality, as any "peaks," "trends," or "gaps" that are observed do not correlate with any real-world dating scheme. Because hydration is a curvilinear process, the shape of any histogram will change after readings are converted to estimated dates, with earlier readings becoming more compressed than later readings. Raw hydration readings also do not allow comparisons between different temperature regimes. In either case, in addition to hydration, both time and temperature need to be taken into account if even relative comparisons are to be made.

Previous studies have established that several variables—including temperature, relative humidity, source variability, and intrinsic water content—affect the rate of obsidian hydration (Friedman and Long 1976; Friedman et al. 1994; Stevenson et al. 1993; Stevenson et al. 1998). The effect of time on the hydration process is well documented, and is generally understood to be best represented by a curvilinear function, with the rate of hydration changing over time and becoming slower as the hydrated layer forms. The effect of temperature on the hydration process is also well documented, with cooler temperatures slowing down the rate of hydration. This effect is illustrated in Figure 2, which shows that projectile points of similar age exhibit smaller hydration readings at lower temperatures. Hydration rates constructed for this study take into account the effects of temperature, time, and source material on the hydration process, but do not include adjustments for relative humidity or intrinsic water content.

To date, the most accurate hydration rates for eastern California obsidians have been formulated using data from low- to mid-elevation settings (Basgall 1990, 2000; Delacorte 1999; Hall and Jackson 1989). In order to apply these rates to artifacts recovered from a variety of temperature regimes, past researchers have advocated various corrections based on differences in Effective Hydration Temperature (EHT), derived from air temperature data (Basgall 1990; Tremaine 1993; Trembour and Friedman 1984). While this method has proven useful within a moderate range of temperature differences, the extreme range of elevations (from 915 to over 3660 m. [3,000–12,000 ft.]), and hence EHTs, involved in the present study required a different approach (see King 2004).

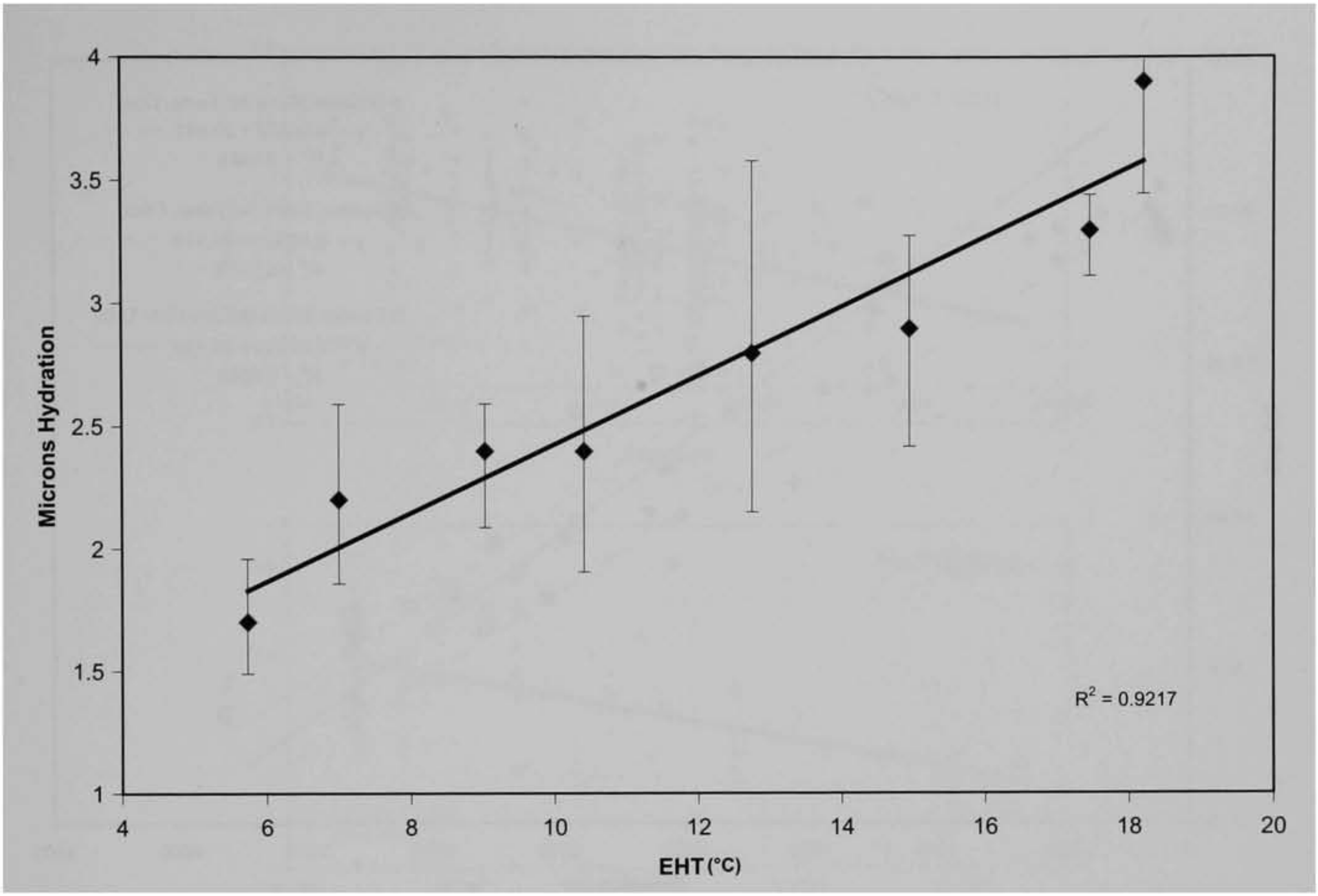

Figure 2. Plot of average hydration of 137 Rose Spring projectile points of Casa Diablo obsidian. Effective Hydration Temperature (EHT) versus hydration reading in microns. Data points represent mean values of several readings within equivalent temperature regimes (2-deg. C range). Vertical lines denote interquartile range. For data sources, see Stevens (2002).

Rather than constructing hydration rates based on data points from only lowland areas, the present study used projectile point data from a wide range of environments, including the floor of the Owens Valley, the middle elevations of the Coso Range and western slope of the southern Sierra Nevada, and high elevations along the crest of the southern Sierra Nevada.

Three temperature-dependent hydration rates were constructed for this study, one for each of the three most common obsidian sources in the southern Sierra Nevada: Casa Diablo, Fish Springs, and the Coso Volcanic Field. To construct hydration rates, weather station data from Fresno, Tulare, Inyo, and Mono counties were used to calculate EHTs (see Lee 1969) at a variety of elevations and environmental settings. Using these data, regression equations were constructed plotting EHT against elevation, thus allowing an estimated EHT to be calculated for any given location and elevation in the region. One equation was used for sites east of the Sierra crest, while a separate equation was used for sites west of the crest. The use of Lee's (1969) temperature integration equation to calculate EHT has been criticized by some because it is seen as less accurate at a microscale and less applicable to hydration studies than data derived from diffusion cells (Jones, et al. 1997; Ridings 1991, 1996; Stevenson et al. 1989). This criticism notwithstanding, when calculated EHTs are compared to diffusion cell data from the general region, the slope of the regression line does not differ significantly[1] (Figure 3). This suggests that the method provides comparable data at the regional scale of the current study. Additionally, air temperature data are readily available and can be applied to a wide variety of settings without the additional expense and time commitment of diffusion cell emplacement.

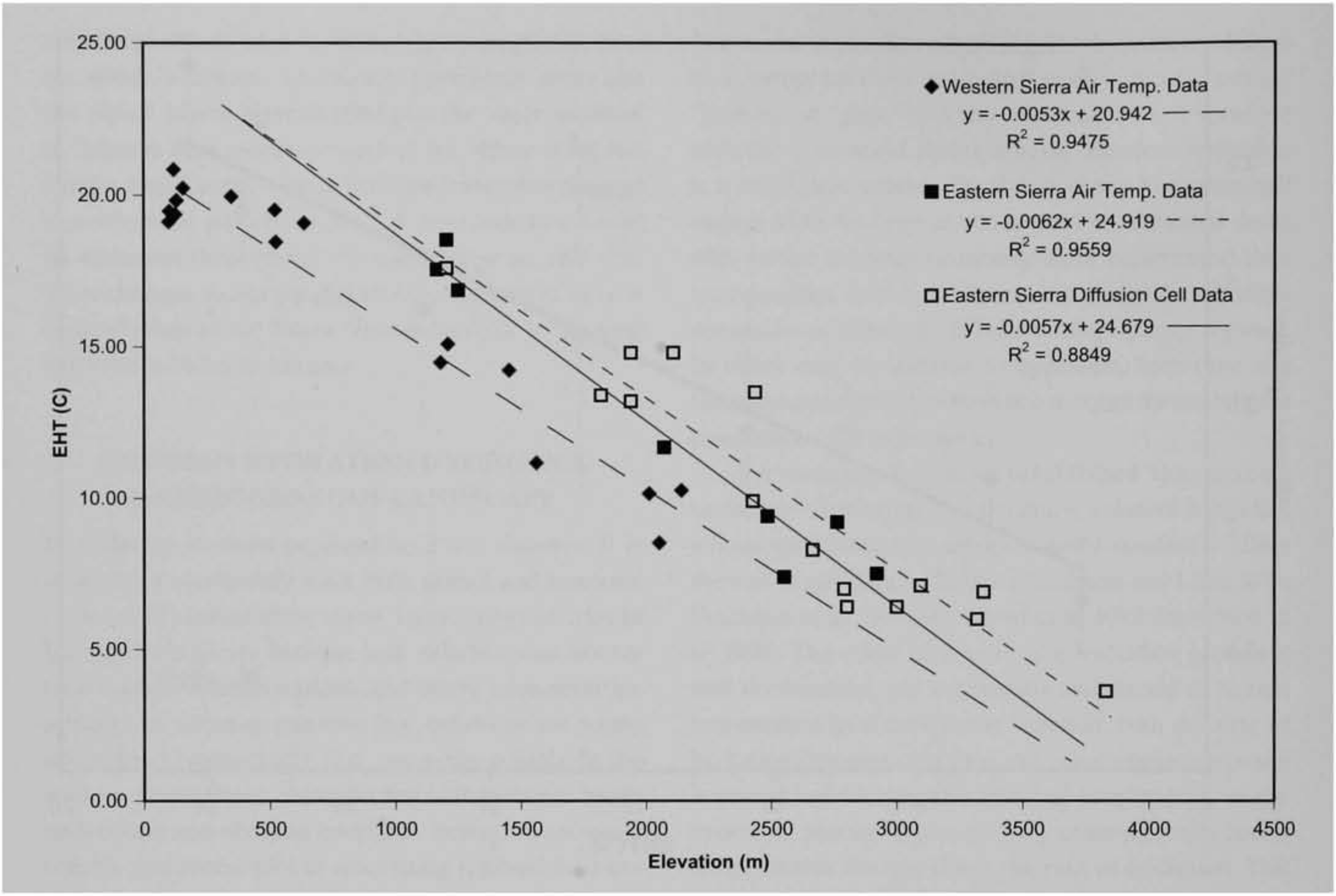

Figure 3. Comparison of Effective Hydration Temperature (EHT) estimations derived from diffusion cell data and regional air temperature data. Eastern Sierra diffusion cell data from Onken (1991).

Once EHT values were calculated for sites throughout the region, hydration readings from time-sensitive projectile point types were plotted against time-period midpoints. Elko, Rose Spring/Eastgate, and Desert series projectile points were used as markers for the Newberry (ca. 3,500–1,350 B.P.), Haiwee (ca. 1,350–650 B.P.)., and Marana (650 B.P.-historic contact) periods, respectively. Despite some uncertainty about the early end of the sequence (see Flenniken and Wilke 1989; Gilreath and Hildebrandt 1997), these projectile point types have proven worthwhile time markers throughout the Great Basin (Bettinger and Taylor 1974; Heizer and Hester 1978; Thomas 1981). The resulting hydration and time period midpoint values were graphed according to the method described by Hull (2001), where the natural log of the hydration squared divided by time in thousands of years ($\ln[x^2/t]$) is plotted against EHT (1/T) in degrees Kelvin (Figure 4). A total of 934 projectile points from the western Great Basin and Sierra Nevada were used to construct hydration rate equations for each of the three obsidian sources: 431 were from Casa Diablo, 366 were from Coso, and 137 were from Fish Springs.[2] This resulted in the following rate equations:

Casa Diablo:

$$x^2/\left[1.8735\cdot10^{14}e^{-8802.5(1/T)}\right]=t$$

Fish Springs:

$$x^2/\left[8.2694\cdot10^{11}e^{-7268.2(1/T)}\right]=t$$

Coso Volcanic Field:

$$x^2/\left[3.8799\cdot10^{14}e^{-8918.8(1/T)}\right]=t$$

where x=hydration in microns, e=base of natural logarithms (2.718), T=temperature in degrees Kelvin (°K=°C+273.16), and t= time in thousands of years. When

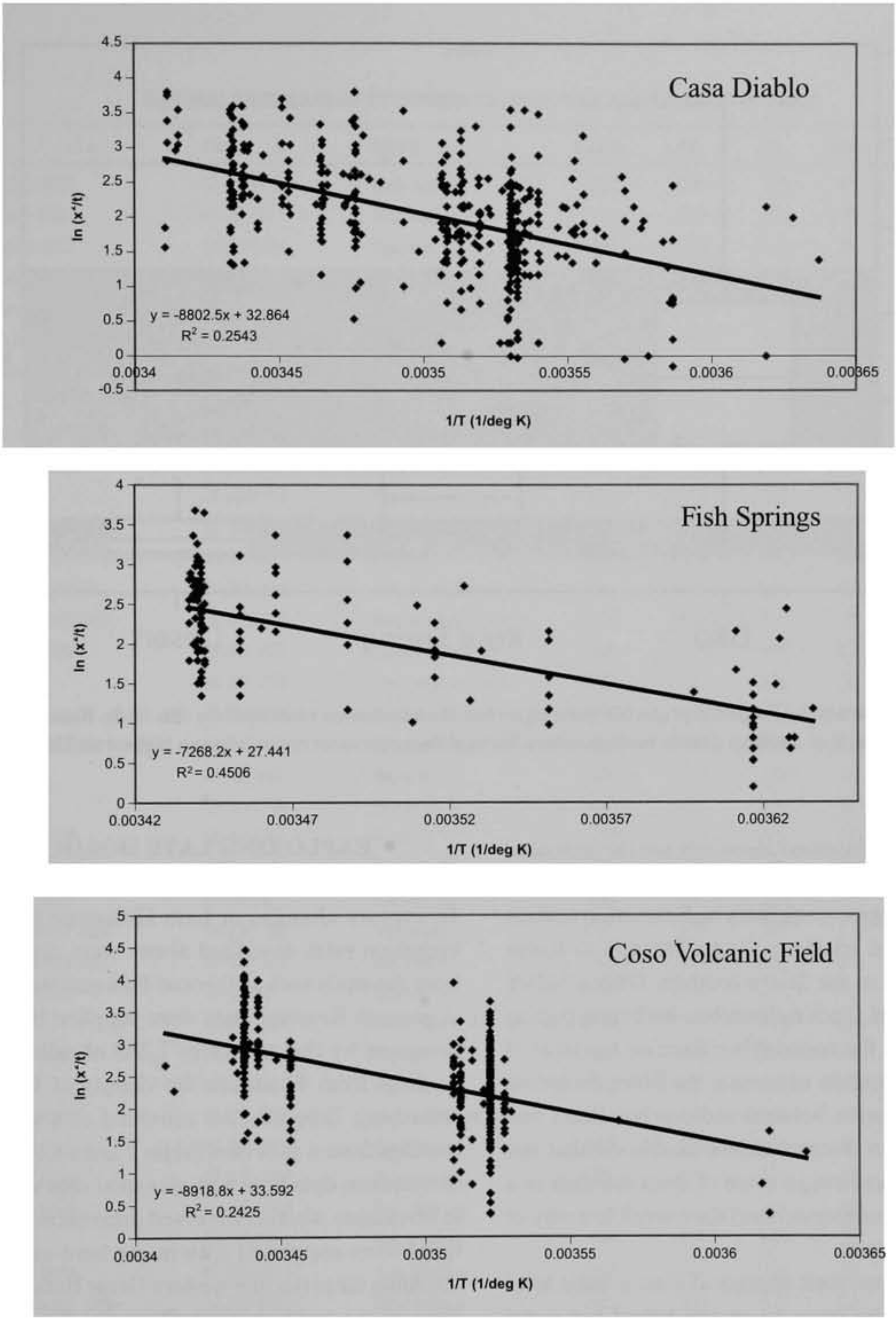

Figure 4. Regressions used to derive hydration rate equations. Despite low r-squared values, the probability value (P) associated with each is less than 0.0001.

these rates are applied to time-sensitive projectile points from across the region, most cluster within accepted ranges (Figure 5). Although this test remains somewhat circular, it suggests that derived dates may provide a reasonably accurate measure of time in a variety of environmental settings. A more independent measure of the accuracy of these rates is presented in Table 1, which shows 37 late Holocene obsidian hydration-radiocarbon date pairings

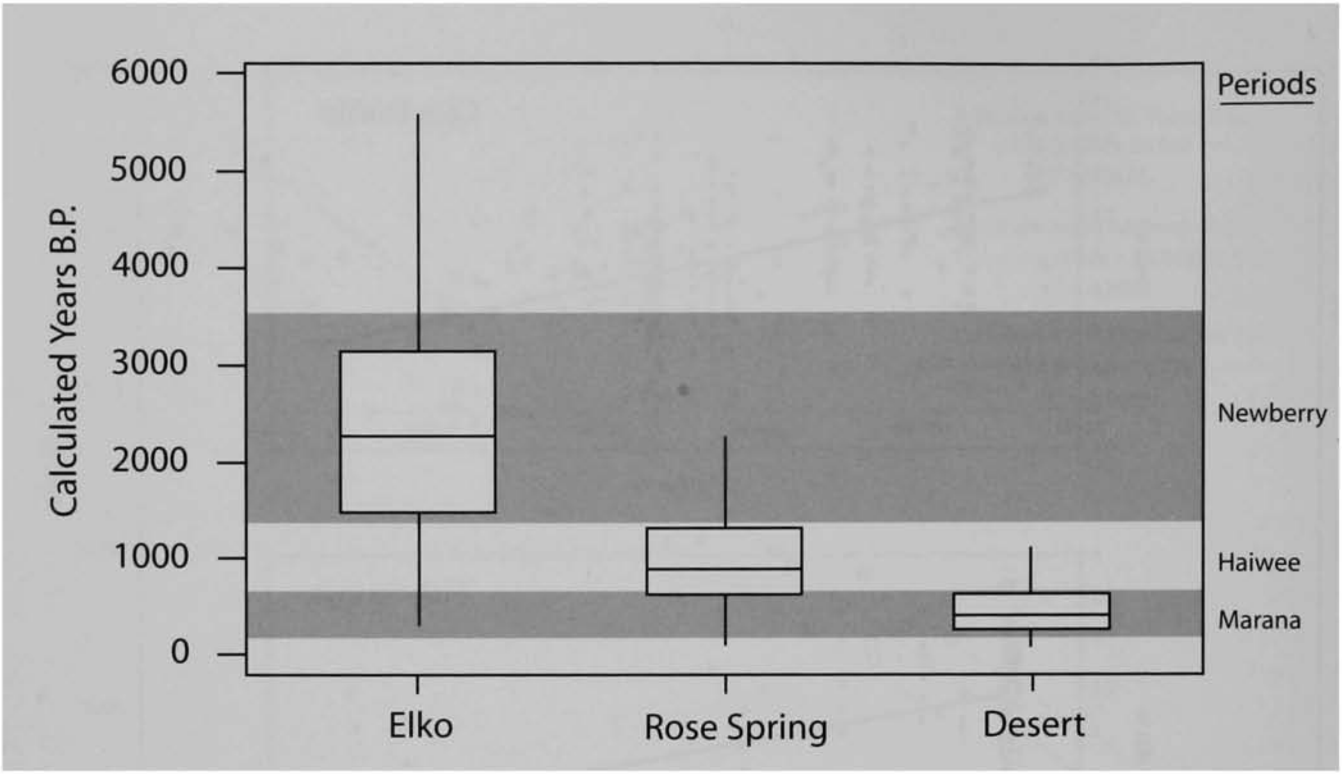

Figure 5. Age estimates of regional projectile point styles based on hydration rates used for this study. Boxes represent interquartile range. Box midlines denote median values. Vertical lines represent range between highest and lowest values.

from a variety of environmental settings, and the estimated dates calculated using obsidian hydration rates presented above. These examples range from high elevation settings in the central and southern Sierra Nevada to lower elevation settings in the Sierra foothills, Owens Valley, and Mojave Desert. Each radiocarbon-hydration pairing was selected from the regional literature on the basis of a qualitative evaluation of several variables, including strength of association between radiocarbon dates and obsidian hydration measurements, likelihood that the dated material represents an event of short duration or a single segregated component, and the overall integrity of the prehistoric deposit.

While the above tests suggest at least a basic level of accuracy for the rates given the broad temporal distinctions that this study is concerned with, those who apply these rates elsewhere should keep in mind that they are largely based on late Holocene data and are untested, and likely inaccurate beyond about 3,500 B.P. Beyond this date, projectile point typologies are less certain, the obsidian hydration process is less well understood, and calculated dates would represent unwise extrapolations.

EXPLORING LATE HOLOCENE LAND-USE CHANGES

To explore changes in Late Holocene land use, the hydration rates described above were applied to data from the study area at Taboose Pass and from the region in general. Regional data were supplied by a database compiled by the author of 1,288 obsidian hydration readings from 47 sites in the vicinity of Taboose Pass. Data from Taboose Pass consisted of a subset of 238 readings from 6 sites (see Tables 2 and 3). First, a sample of hydration data from high elevation sites was examined to investigate whether observed differences in alpine site types were correlated with major land-use changes in adjoining areas (i.e., the western Great Basin and western slope of the southern Sierra Nevada). Sites included in this sample were all within the Sierra Nevada, above 2,450 m. (8,000 ft.) in elevation, and ranged from the San Joaquin River drainage approximately 35 km. north of Taboose Pass, to the East Fork of the Kaweah River drainage approximately 70 km. to the south. Second, regional obsidian use was investigated by applying the Fish Springs hydration rate to a sample of artifacts and

Table 1.

REGIONAL RADIOCARBON-HYDRATION ASSOCIATIONS AND CALCULATED DATES

Reference	Site	Context	Elev(m)	EHT	Hyd.	Source	RCYBP	Calc. Age
Basgall and Delacorte 2002	CA-INY-5759	Poss. heart	1200	17.48	1.68	FS	40	247
Basgall and McGuire 1988	CA-INY-30	Structure 9	1150	17.79	2.30	CS	180	279
Basgall and Delacorte 2002	CA-INY-5364	Feature 8	1200	17.48	2.34	FS	250	479
Basgall and McGuire 1988	CA-INY-30	Structure 8	1150	17.79	2.43	CS	270	312
Basgall and McGuire 1988	CA-INY-30	Structure 10	1150	17.79	2.72	CS	360	391
Basgall and McGuire 1988	CA-INY-30	Structure 1	1150	17.79	3.22	CS	390	548
Basgall and McGuire 1988	CA-INY-30	Structure 5	1150	17.79	3.20	CS	410	541
Basgall and McGuire 1988	CA-INY-30	Structure 7	1150	17.79	2.85	CS	480	429
Hull 2001, Mundy and Hull 1988	CA-MRP-158	Ash/clay Feature	1207	14.54	1.97	CD	490	399
Basgall and Delacorte 2002	CA-INY-5397/H	Feature 1	1200	17.48	2.81	FS	660	691
Hull 2001, Hull 1989b	CA-MRP-199	Possible hearth	1768	11.57	1.86	CD	770	490
Basgall and Delacorte 2002	CA-INY-5763	Feature 2	1200	17.48	3.11	FS	820	846
Basgall and McGuire 1988	CA-INY-30	Feature 5*	1150	17.79	4.40	CS	860	1022
Giambastiani and Basgall 2000	CA-KER-2016	Burned rock feature	762	20.19	3.91	CS	890	628
Hull 2001, Mundy and Hull 1988	CA-MRP-158	Base of ash/clay feature	1207	14.54	2.75	CD	1050	780
Gilreath and Holanda 2000	CA-INY-1428	Component average*	1150	17.79	4.44	CS	1150	1041
Burke et al. 1995	CA-INY-4646	Component average*	1205	17.45	4.16	FS	1200	1519
Burke et al. 1995	CA-INY-4646	Component average*	1205	17.45	4.29	CD	1200	1398
Hull 2001, Hull et al. 1995	CA-TUO-166	Assoc. with upper tephra	2621	7.05	2.16	CD	1210	1089
McGuire 1981	CA-TUL-890	Hearth feature	1830	11.24	3.29	CS	1280	1157
Delacorte 1999	CA-INY-2750	Feature 6a	1150	17.79	4.03	CS	1330	858
Basgall and Delacorte 2002	CA-INY-5761	Feature 2*	1200	17.48	3.15	FS	1344	868
Delacorte and McGuire 1993	CA-INY-3806/H	Component average*	1150	17.79	4.40	CS	1355	1022
Basgall and McGuire 1988	CA-INY-30	Structure 11*	1150	17.79	5.23	CS	1410	1445
Hull 2001, Mundy and Hull 1988	CA-MRP-163	Ash feature	1207	14.54	2.91	CD	1420	875
Hull 2001, Mundy and Hull 1988	CA-MRP-163	Ash feature	1207	14.54	3.58	CD	1480	1324
Basgall and McGuire 1988	CA-INY-30	Structure 12*	1150	17.79	5.28	CS	1715	1472
Basgall 2001	CA-INY-1384	House Floor (F-4)	1250	17.17	4.78	CD	1740	1787
Basgall and McGuire 1988	CA-INY-30	Structure 14*	1150	17.79	5.43	CS	1765	1557
Basgall 2001	CA-INY-1384	Hearth (F-10)	1250	17.17	4.57	CD	1780	1634
Hull 2001, Hull et al. 1995	CA-TUO-166	Assoc. with lower tephra	2621	7.05	2.21	CD	1830	1139
Hull 2001, Montague 1994a	CA-TUO-2833	Hearth feature	2880	5.68	2.21	CD	1880	1330
Hull 2001, Montague 1994b	CA-TUO-2834	Poss. structure	2880	5.68	2.71	CD	2220	2008
Hull 2001, Montague 1994b	CA-TUO-2834	Poss. Structure	2880	5.68	2.28	CD	2250	1419
McGuire 1995	CA-FRE-61	Bulk flotation	146	20.17	5.94	CD	2360	2025
Hull 2001, Montague 1994b	CA-TUO-2834	Poss. Structure	2880	5.68	2.56	CD	2410	1782
Hull 2001, Hull and Moratto 1999	CA-TUO-2830	Wood charcoal	2870	5.73	3.24	CD	2660	2852

Note: Elev(m) = elevation in meters, EHT = Effective Hydration Temperature (calculated using equations shown in Figure 3), Hyd. = Average hydration reading from context, Source = Obsidian source (CD = Casa Diablo, FS = Fish Springs, CS = Coso Volcanic Field), RCYBP = Radiocarbon Years Before Present (uncalibrated), Calc. Age = Years BP value calculated using hydration rate equations developed for this study. *Average of two or more associated radiocarbon determinations.

Table 2.

ATTRIBUTES OF LIMITED-USE AND INTENSIVE-USE SITES

SITE	ELEV(m)	#	RR	RS	MID	BRM	GS	FAU	CER	STEA	PRJPT	BIF	FT
Intensive-Use Sites													
CA-FRE-3105[a]	3360	39	X	–	X	–	X	X	–	X	X	X	X
CA-FRE-3163[a]	3350	32	–	X	X	–	–	–	–	–	–	X	X
CA-FRE-3169[a]	3330	33	X	–	X	–	X	X	–	–	X	X	X
87A-32[b]	3243	10	–	–	–	X	X	–	–	–	–	X	–
CA-FRE-266[b]	3243	4	X	X	X	X	X	X	X	X	X	X	X
CA-TUL-103[b]	2926	5	–	–	X	–	–	X	X	–	–	–	–
CA-TUL-1253[b]	2658	9	–	–	X	X	X	–	–	–	–	–	–
CA-TUL-1252[b]	2609	9	–	–	–	X	–	–	–	–	–	X	–
CA-TUL-1250[b]	2591	7	–	–	–	X	–	–	X	–	–	–	–
CA-TUL-304[b]	2591	10	–	–	X	X	X	–	–	–	X	–	–
Limited-Use Sites													
CA-FRE-2162[b]	3536	11	–	–	–	–	–	–	–	–	–	X	–
CA-FRE-2164[b]	3536	9	–	–	–	–	–	–	–	–	–	X	–
CA-TUL-1263[b]	3511	5	–	–	–	–	–	–	–	–	–	X	–
CA-TUL-1264[b]	3487	14	–	–	–	–	–	–	–	–	–	X	–
CA-TUL-1265[b]	3475	12	–	–	–	–	–	–	–	–	X	X	–
CA-FRE-2168[b]	3426	16	–	–	–	–	–	–	–	–	–	X	–
CA-FRE-2169[b]	3426	29	–	–	–	–	–	–	–	–	X	X	–
CA-FRE-3165[a]	3360	47	–	–	–	–	–	–	–	–	–	–	X
CA-FRE-3102[a]	3335	45	–	–	–	–	X	–	–	–	–	X	X
CA-FRE-3160[a]	3320	42	–	–	–	–	–	–	–	–	X	X	X
CA-TUL-1242[b]	3316	5	–	–	–	–	–	–	–	–	–	–	X
CA-TUL-1240[b]	3310	13	–	–	–	–	–	–	–	–	X	X	X
CA-TUL-1239[b]	3304	8	–	–	–	–	–	–	–	–	–	X	–
CA-TUL-1241[b]	3304	5	–	–	–	–	–	–	–	–	–	X	–
88A-4[b]	3292	24	–	–	–	–	–	–	–	–	–	X	–
88A-5[b]	3243	17	–	–	–	–	–	–	–	–	X	–	–
CA-TUL-1231[b]	3219	9	–	–	–	–	–	–	–	–	–	X	–
CA-INY-3458[c]	2966	110	–	–	–	–	X	X	–	–	X	X	X
CA-TUL-1249[b]	2609	24	–	–	–	–	–	–	–	–	–	X	X
CA-TUL-1235[b]	2560	9	–	–	–	–	–	–	–	–	–	–	–
CA-INY-3448[d]	2475	10	–	–	–	–	–	–	–	–	X	–	X

Note: Elev = Elevation in meters, # = number of samples, RR = rock ring features, RS = rockshelter, MID = midden soil, BRM = bedrock mortars, GS = ground stone, FAU = faunal remains, CER = ceramics, STEA = steatite, PRJPT = projectile points, BIF = bifaces, FT = flake tools, X=present. [a]Sites at Taboose Pass, remainder of sites are in regional sample. Data from Stevens (2002), [b]Data from Roper Wickstrom 1992, [c]Data from Jackson and Jackson 1997, [d]Data from York 1988

debitage from three key areas defining an east-west swath across the Sierra Nevada. Further details pertaining to this second sample of hydration readings are discussed below and presented in Table 3.

Chronological patterning in the use of distinct site types was considered an important indicator of changing land-use practices. Based on a comparison of site attributes in the region, two general site types were defined: *limited-use* and *intensive-use*. Limited-use sites were composed of scatters of obsidian debitage of varying density with occasional flaked-stone tools such as projectile points and other tool types. Limited-use sites lacked signs of more intensive occupation, such as ground stone implements, midden soil, or structural remains. In contrast, intensive-

Table 3.

SITES IN FISH SPRINGS OBSIDIAN USE SAMPLE

SITE	REFERENCE	ELEV(m)	#
Fish Springs Source Vicinity			
CA-INY-3790	Wickstrom et al. 1994	1164	25
CA-INY-384	Wickstrom et al. 1994	1189	216
CA-INY-4547	Wickstrom et al. 1994	1219	28
CA-INY-4549/H	Wickstrom et al. 1994	1189	9
CA-INY-4550	Wickstrom et al. 1994	1164	191
Taboose Pass			
CA-FRE-3102	Stevens 2002	3353	22
CA-FRE-3160	Stevens 2002	3353	15
CA-FRE-3163	Stevens 2002	3353	9
CA-FRE-3165	Stevens 2002	3353	21
CA-FRE-3169	Stevens 2002	3353	5
Western Slope Southern Sierra Nevada			
CA-TUL-1198	Roper Wickstrom 1992	2000	19
CA-TUL-1227	Mundy 1991	2048	41
CA-TUL-1231	Roper Wickstrom 1992	3219	6
CA-TUL-1235	Roper Wickstrom 1992	2560	9
CA-TUL-1250	Roper Wickstrom 1992	2591	1
CA-TUL-1252	Roper Wickstrom 1992	2609	1
CA-TUL-1256	Roper Wickstrom 1992	2195	2
CA-TUL-1257	Roper Wickstrom 1992	2195	4
CA-TUL-1258	Roper Wickstrom 1992	2365	2
CA-TUL-24	Hale and Hull 1997	853	105
CA-TUL-28	Hale and Hull 1997	634	6
CA-TUL-304	Roper Wickstrom 1992	2591	1
CA-TUL-72	Jackson 1996	671	15

Note: Elev = Elevation in meters, # = number of samples

use sites were characterized by more diverse artifact inventories, often including both flaked and ground-stone implements, midden soil, and (in some cases) structural remains (Table 2). These two site types are necessarily defined rather generally because the available data do not allow for more detailed analysis of site constituents. For the purposes of this study, however, these general categories probably reflect the types of broadly divergent land-use practices being investigated.

Changes in regional obsidian use was seen as an additional prehistoric trend likely to be informative about land-use changes, because toolstone use and procurement practices are directly tied to fundamental aspects of hunter-gatherer behavior, including technological organization and mobility (Andrefsky 1994; Bamforth 1986; Kelly 1988; Parry and Kelly 1987). Obsidian from three separate areas was examined: (1) the Fish Springs source vicinity on the floor of the Owens Valley, (2) Taboose Pass on the Sierra crest, and (3) the western slope of the southern Sierra Nevada (see Table 3). Because no data from the Fish Springs source itself was obtainable, a sample of debitage and artifacts (n=469) likely to be related to quarrying activities (i.e., early biface thinning flakes, percussion flakes, early stage bifaces, and cores) was selected from five sites in the immediate vicinity of the source (i.e., <5 km). The sample from Taboose Pass included only decortication debitage (n=72), while the sample from the western slope of the Sierra Nevada included only debitage (n=212); available data did not permit further technological classification.

RESULTS

At Taboose Pass, limited-use and intensive-use sites clearly represent occupation during different temporal periods (Figure 6). Limited-use sites, characterized by dense scatters of Fish Springs obsidian, were most heavily used between about 3,000 and 2,000 B.P. After about 1,500 B.P., intensive-use sites, characterized by diverse artifact inventories, structural remains, and midden soil, were inhabited and earlier sites were little used. The earlier pattern is interpreted as related primarily to obsidian procurement and transport, based upon the location of Taboose Pass along a major east-west travel route and the general lack of projectile points at limited-use sites. Elsewhere, limited-use sites likely represent logistical hunting camps (see below). The subsequent late prehistoric pattern, on the other hand, is interpreted as reflecting extended stays at high elevation by small groups, possibly family units composed of men, women, and children.

Results of regional comparisons of obsidian hydration data show that this fundamental shift in the use of high-elevation areas late in prehistory was not confined to Taboose Pass. Based on the regional sample, limited-use sites were chiefly occupied between ca. 5,500 and 2,500 B.P. Intensive-use sites, on the other hand, witness a surge in occupation only after ca. 1,500 B.P. (Figure 6). Despite the fact that the data in the regional sample are not as numerous and show a wider dispersion of dates when compared to the Taboose Pass data, the same

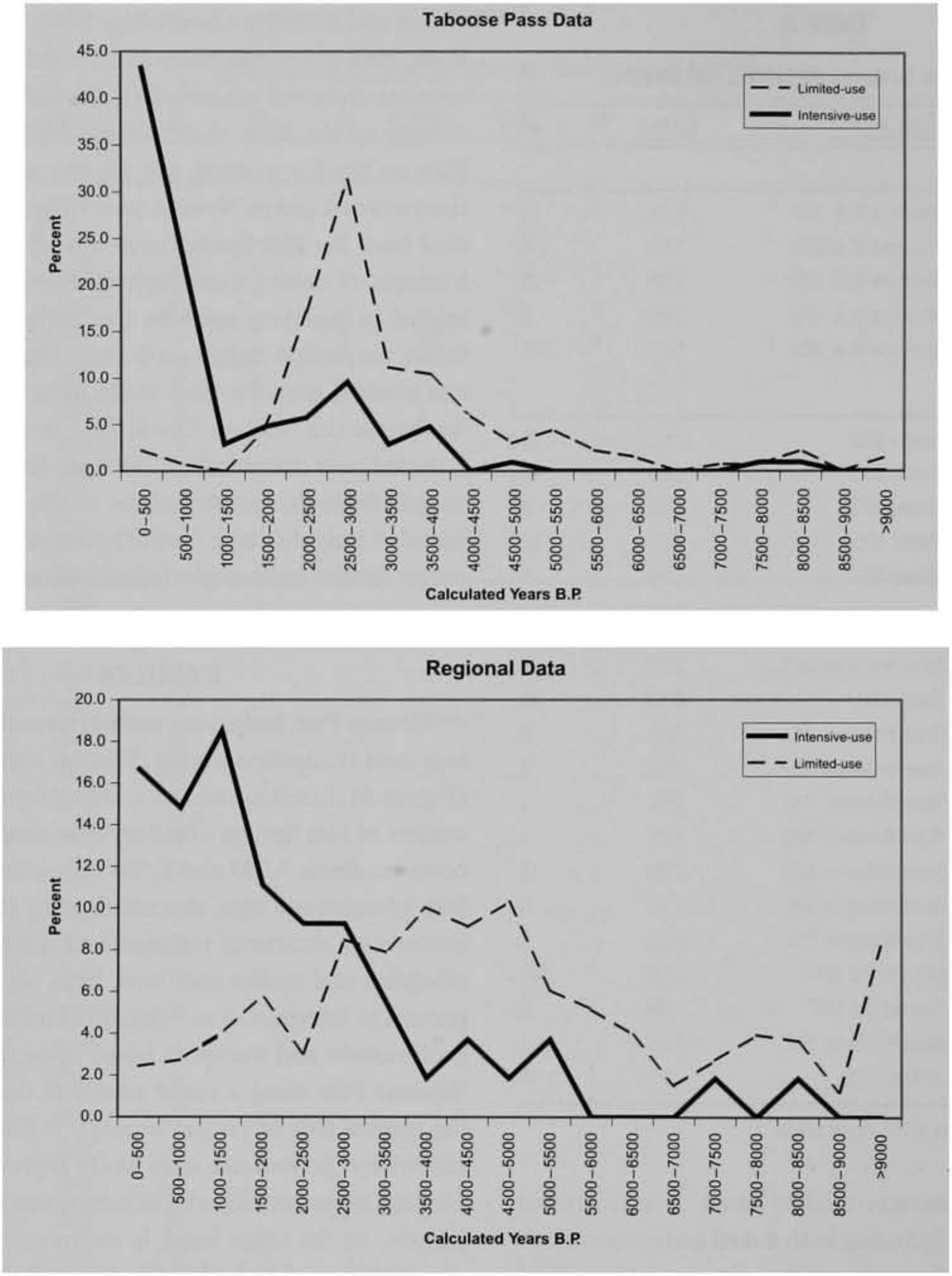

Figure 6. Temporal comparison of intensive-use and limited-use sites at Taboose Pass and in regional obsidian hydration sample.

overall trends in site use seem to be represented. Based on artifact assemblages and features, earlier sites (prior to ca. 1,500 B.P.) appear to be largely related to obsidian procurement and transport, or hunting forays most likely involving small groups of men. Later sites (after ca. 1,500 B.P.) suggest a more intensive use of higher elevation areas and longer stays by more diverse groups of people. It is interesting to note that many of the intensive-use sites found thus far, during surveys of both major travel routes and peripheral areas, are also located at key locations along travel corridors (Burge and Matthews 2000). These results are similar to developments in western Great Basin prehistory throughout the late Holocene (Bettinger 1991, 1999; Delacorte 1990).

The changing use of Fish Springs obsidian throughout the late Holocene parallels and complements the patterns discussed above. Data from near the Fish Springs source east of the Sierra Nevada indicate that this source was

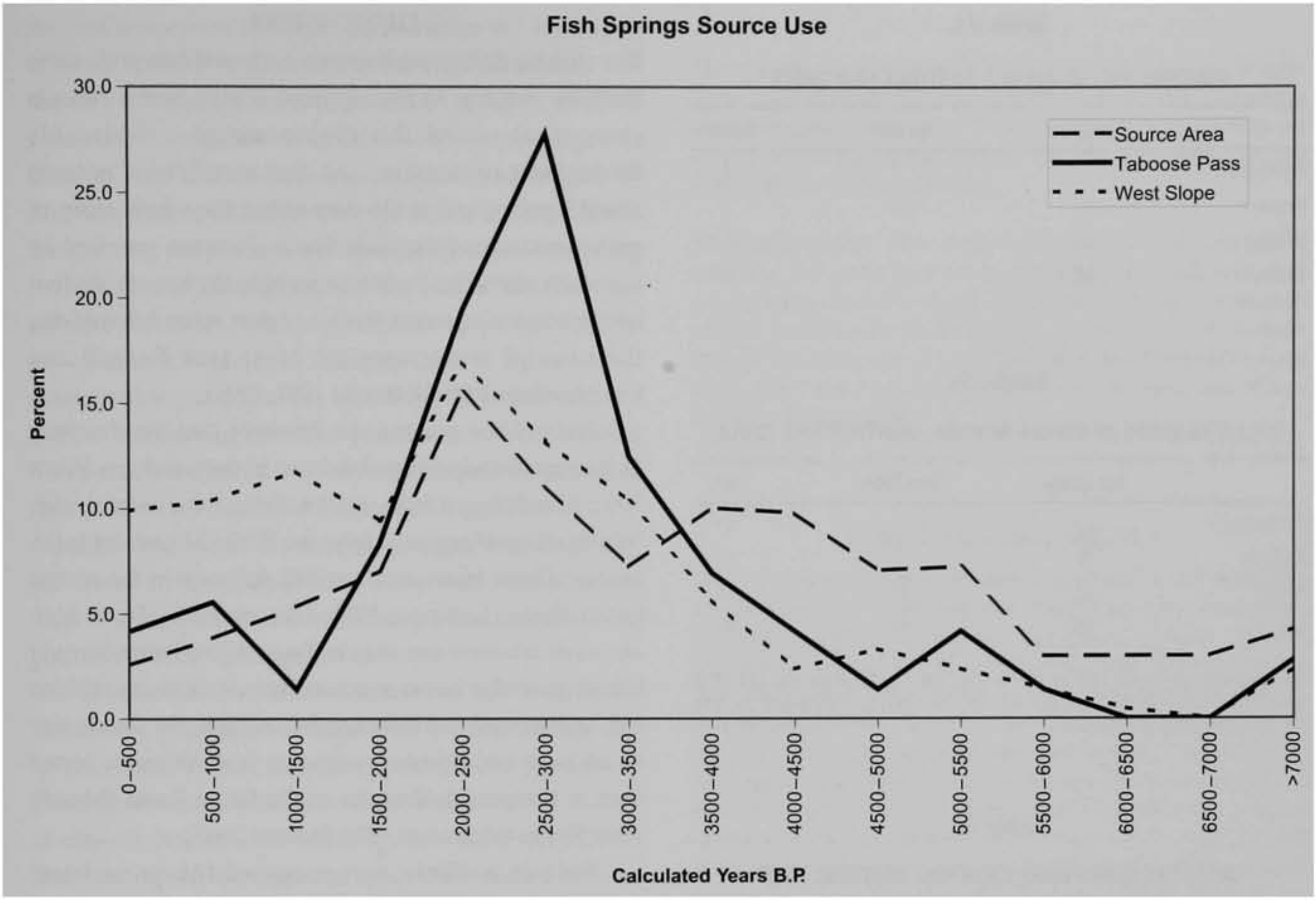

Figure 7. Fish Springs obsidian source use through time at three key geographic areas.

used throughout the Late Holocene, with a distinct surge between ca. 3,500 and 1,500 B.P. (Figure 7). This pattern is similar to quarry use histories at other eastern California obsidian sources (Basgall 1983; Bouey and Basgall 1984; Gilreath and Hildebrandt 1997; Hall 1983; Jackson 1984; Singer and Ericson 1977). Where the pattern diverges from other source locations (e.g., steady use between ca. 5,500 and 3,500 B.P.), the explanation may lie in the use of near-source occupation site data as a proxy for quarrying intensity instead of data from actual primary source locations. Unfortunately, it may be nearly impossible to correct this problem in future research as well, since the source itself is being quickly obliterated by mining activities. On the western slope of the southern Sierra Nevada, the use of Fish Springs obsidian also exhibits a surge between ca. 3,500 and 1,500 B.P., suggesting that much of the obsidian quarried at the Fish Springs source during this period ended up west of the crest. This interpretation is further supported by results from Taboose Pass, the most likely travel route from the Fish Springs source to western areas. At Taboose Pass, the peak in obsidian deposition also occurs between ca. 3,500 and 1,500 B.P.

Significantly, Fish Springs obsidian does not seem to have been in as much demand in areas east of the crest during the same time period. Data from sites in the central Owens Valley and on the western slope of the Sierra Nevada show that the use of Fish Springs obsidian in the former location diminishes between 3,500 and 1,350 B.P., while it increases substantially in the latter location (see Table 4). This suggests that much of the obsidian quarried from the Fish Springs source during the Newberry period was either directly accessed by westside groups, or was obtained from eastside groups who preferentially traded obsidian from the nearest source, but had access to higher-quality obsidian to the north and south.

Table 4a.

CENTRAL OWENS VALLEY: DEBITAGE AND TOOLS

	Fish Springs	Northern	Southern
Pre-Newberry	87	1	4
Newberry	55	29	7
Haiwee	70	13	5
Marana	80	2	5

Table 4b.

WESTERN SLOPE OF SIERRA NEVADA: DEBITAGE AND TOOLS

	Fish Springs	Casa Diablo	Coso
Pre-Newberry	41	12	47
Newberry	78	9	13
Haiwee	43	25	32
Marana	36	15	50

Note: Data from Hale and Hull 1997 (TUL-24); Jackson 1996 (TUL-72); Mundy 1991 (TUL-1227); Roper Wickstrom 1992 (TUL-1198, TUL-1231, TUL-1252, TUL-1256, TUL-1257, TUL-1258, TUL-304); only tool data used from TUL-24.

Table 4c.

WESTERN SLOPE SIERRA NEVADA: DEBITAGE ONLY

	Fish Springs	Casa Diablo	Coso
Pre-Newberry	80	0	20
Newberry	97	2	2
Haiwee	44	28	28
Marana	31	14	56

Note: Data from: Jackson 1996 (TUL-72); Mundy 1991 (TUL-1198); Roper Wickstrom 1992 (TUL-1198, TUL-1231, TUL-1250, TUL-1252, TUL-1252, TUL-1256, TUL-1257, TUL-304)

Note: Central Owens Valley data from Aberdeen-Blackrock project (Zeanah and Leigh 2002). The central Owens Valley data were obtained from chronostratigaphically secure contexts, while the Sierra Nevada data are based on chronological estimates using obsdian hydration data. Northern sources include Casa Diablo, Mono Glass Mountain, Mt. Hicks, and Queen). Southern source is Coso Volcanic Field. A total of 23 artifacts (6 pieces of debitage, 17 tools) from western slope sites was excluded from this analysis because they were not sourced to Fish Springs, Casa Diablo, or Coso. The largest share of these excluded artifacts (10 pieces) were sourced to Mono Glass Mountain/Mono Craters, while the remainder are unknowns, likely from eastern California sources (e.g., Saline Range).

Tables 4a–c: Percentages of Fish Springs obsidian relative to other obsidian sources in local assemblages.

DISCUSSION

The striking difference between early and late prehistoric land-use patterns in the alpine southern Sierra Nevada shows that use of this region varied considerably throughout prehistory, and that synchronic notions about hunting and trade do not tell the whole story of prehistoric use of the high Sierra. Patterns revealed by this study also offer further support to the hypothesis that late prehistoric groups in this region were intensifying their use of more marginal areas (see Basgall and Giambastiani 1995; Bettinger 1991, 1999).

It should be pointed out, however, that the character of late prehistoric alpine land use in the southern Sierra Nevada is different from that involving the extremely rich "alpine villages" reported from the White Mountains in the western Great Basin and from Mt. Jefferson in the central Great Basin (Bettinger 1991; Thomas 1982). Some high elevation intensive-use sites in the southern Sierra Nevada feature probable house structures (e.g., rock rings), midden soil, and ground and flaked stone artifacts, but the density of artifacts and other constituents is significantly lower than in comparable features in the Great Basin (Mundy 1988; Roper Wickstrom 1993; Stevens 2002).

Still, it is likely that many of the same basic conditions influencing groups to intensively exploit alpine environments in the White Mountains are relevant to similar late prehistoric residential use of the alpine Sierra Nevada. The advent of alpine villages in the White Mountains is seen by Bettinger (1991; 1994) as related, at least in part, to regional population growth and increased reliance on pinyon pine. In the southern Sierra Nevada, it is also important to consider how interregional travel and trade might have influenced prolonged stays at high elevation passes in late prehistory. Groups crossing the Sierra to maintain familial ties and exchange goods may have occasionally set up brief residential encampments along the way to exploit alpine plant and animal resources available during the summer months.

The earlier pattern, represented here by limited-use sites, is consistent with land-use patterns described for the Newberry period (3,500–1,350 B.P.) in the western Great Basin (Bettinger 1982; Canaday 1997; Delacorte 1990; Hildebrandt and McGuire 2002) in that the use of upland areas shows a focus on hunting, most likely of large game. Although chronological data pertaining to such limited-use sites along the southern Sierra crest are not numerous, the contrast between the long span of likely hunting-related sites in the regional sample and the shorter, notably more pronounced spike of obsidian procurement-related sites at Taboose Pass shows that two different, but related patterns are portrayed (Figure 6). The first pattern indicates that the use of the high Sierra for hunting purposes is an ancient tradition, spanning perhaps five millennia. At the tail end of this hunting-related pattern is the Late Archaic surge in obsidian procurement evident at Taboose Pass. It is likely that other major passes in the Sierra Nevada also show a similar increase in obsidian procurement-related sites. This pattern is distinct from alpine occupations described from the western Great Basin (Bettinger 1991), and probably relates to the unique geographic situation of the Sierra crest, which divides a populous, but obsidian-poor environment to the west from a less populous, but obsidian-rich environment to the east.

These contrasts between areas east and west of the Sierra crest underscore an important conclusion suggested by this study: namely, that the prehistories of the western Great Basin and California are interrelated, and treatments of either in isolation tell only a portion of the story. Given that the Sierra Nevada occupies the middle ground between these two prehistorically dynamic regions, further research in such high-elevation areas will undoubtedly contribute to our understanding of both regions.

On a final note (related to the methodology and future promise of obsidian hydration dating), it is important that continued effort be devoted to refinements of the method. The first generation of single-site or area-specific hydration rates has provided useful chronological control, but has also contributed to the insularity of Great Basin archaeology by making the westward geographic leap to California a departure from the comfort zone of dating accuracy. We should not be satisfied with available hydration rates, including those presented here, simply because they seem to be reasonably accurate. Instead, new methods of using obsidian hydration data should continue to be explored, with special attention given to developing methods that are accurate and consistent over a large and environmentally-diverse landscape. Only then can we begin the process of stitching together the patchwork of geographically-circumscribed academic and CRM projects to create a truly regional view of changing prehistoric land use.

NOTES

[1]Temperature regressions were compared using a multiple linear regression model, where the interaction of the two slopes was investigated using a *t*-test. The resulting probability value of 0.61 strongly suggests that the two lines do not interact; i.e., the slopes do not differ significantly.

[2]Projectile points were from both surface and subsurface contexts. No effort was made to account for differences in temperature related to depth of artifact recovery. For sources of data, see Stevens 2002. Additional sources of data include Basgall and Delacorte 2002, Hildebrandt and Ruby 1999, King et al. 2001, and unpublished data from Sequoia and Kings Canyon National parks.

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