SPATIAL AND TEMPORAL PATTERNING OF OBSIDIAN MATERIALS IN THE GEYSERS REGION

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INTRODUCTION

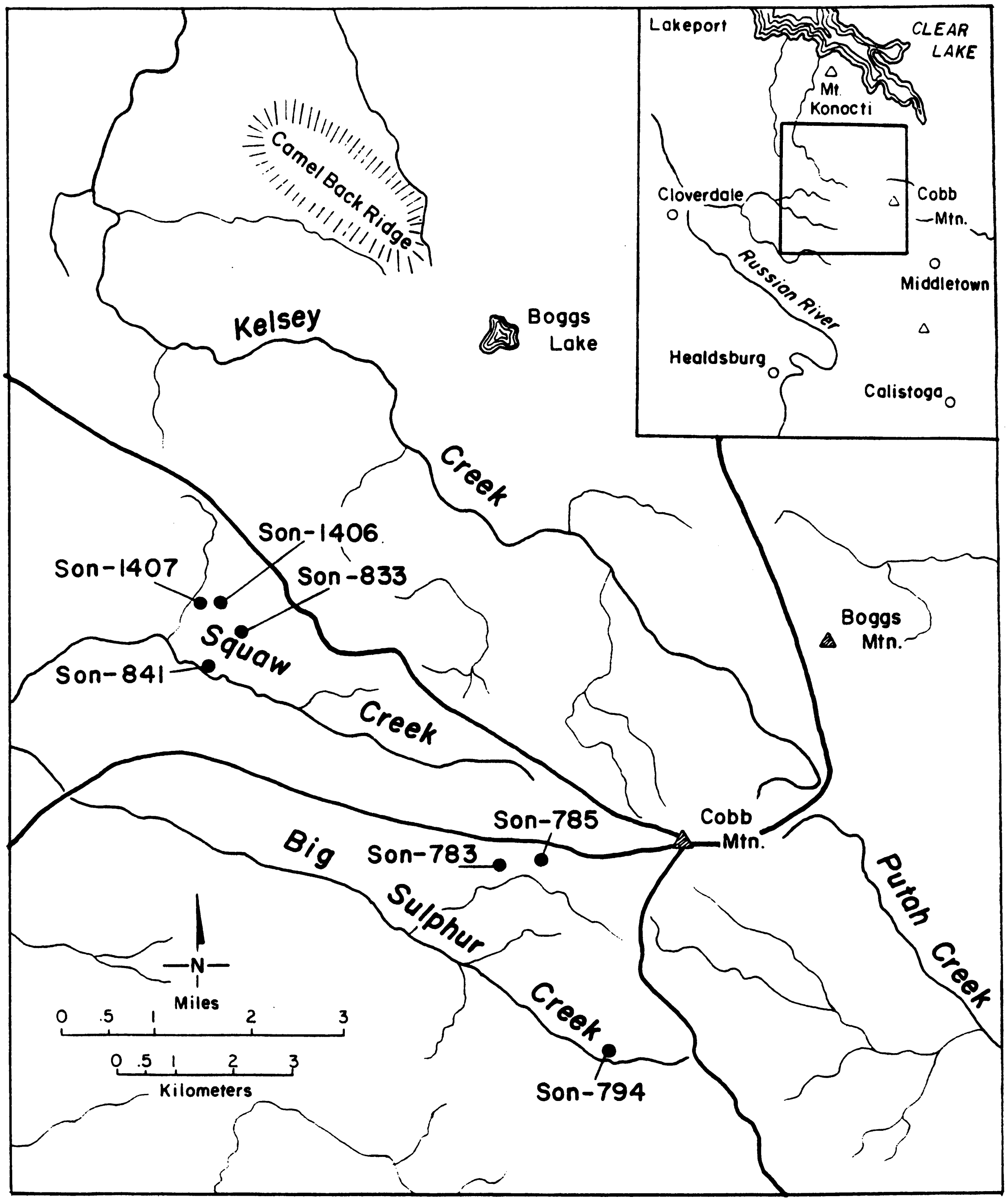
This paper focuses upon the archaeology of the geothermal region of northeastern Sonoma and adjoining portions of Lake and Mendocino counties, California, referred to here as the Geysers region, and draws from information and materials obtained over a period of 14 years during more than 100 separate archaeological field investigations implemented as a result of environmental protection regulations that helped guide the development of geothermal resources in the region (see Fredrickson 1985). While field work was an activity of cultural resource management, the integrative and synthetic work is an academic endeavor (cf. Lipe 1974). The present study further illustrates the contributions that small, often ephemeral, archaeological sites (in this example, ones located in a hinterland locality) can provide to the understanding of a region's prehistory (see Whalen 1986; Glassow 1985). Obsidian sourcing and hydration studies offer an indispensible key to such understanding when employed not only to obtain temporal control but also to gain estimates of interrelatedness, or relative social distance, between adjacent localities (Kay 1975; Wilmsen 1973).

THE STUDY AREA

Although the geothermal resource area within which the Geysers region is located is much larger, the area under study here consists of about 100 contiguous square miles in the Mayacmas Mountains within northeastern Sonoma and adjoining portions of Lake and Mendocino counties (Map 1). The approximate center of the area is about 75 air miles north of San Francisco, with Clear Lake located an additional 15 miles to the north. The study area trends roughly 20 miles in a northwesterly direction, with its widest portion of about 12 miles trending northeasterly through a central point formed at the joined corners of the three counties. The regions is comprised for the most part of the Mayacmas uplands, contrasting with the surrounding lowlands of Kelsey and Putah creeks, and the Russian River. Terrain is usually rugged, lacking broad valleys, with numerous slopes greater than 60 percent. Although slopes often rise steeply from stream bottoms, occasional narrow valleys and low rolling hills offer more gentle terrain.

For purposes of the present work, the study area has been stratified with respect to major stream drainages. To the north, wholly within Lake County, are the drainages of High Valley and Kelsey creeks, together referred to as the Kelsey Creek locality; in the central area totally in Sonoma County are Squaw Creek and the lower portion of Big Sulphur Creek, whose drainages are referred to here as the Squaw Creek locality; to the south, also totally in Sonoma County, is the upper portion of Big Sulphur Creek, referred to as the Big Sulphur Creek locality; to the west, in Lake County, is Putah Creek, whose lands are referred to as

MAP 1
MAP OF GEOTHERMAL STUDY AREA SHOWING MAJOR DRAINAGES AND ARCHAEOLOGICAL SITES



the Putah Creek locality.

The region is marked by a complex floral mosaic, consisting of various combinations of chaparral, cypress forest, grassland, oak woodland, Douglas fir-oak woodland, and yellow pine forest (Simons 1985). Although all these vegetation communities are present within each of the four localities, different localities are dominated by different plant associations, a circumstance that affects the relative frequency of different site types. Chaparral and cypress forest associations dominate much of the Kelsey Creek locality, while grassland and oak woodland cover a great deal of the Squaw Creek locality. Flake scatters, assumed to be associated with hunting, dominate Kelsey Creek, while sites with more extensive cultural deposits, assumed to be indicative of upland camps, are most common at Squaw Creek. In short, the study area forms a rugged upland backcountry, usually dominated by chaparral and yellow pine forest, as contrasted with the more gentle and generous terrain which surrounds the area. As already mentioned, the study area also contains geothermal resources, the development of which has prompted the archaeological work reported here.

Territories of four ethnographic Native American communities converge within the region, with Geysers Rock at the head of Squaw Creek forming the approximate point of convergence. An Eastern Pomo community with its major villages along the lower reaches of Kelsey Creek controlled the Kelsey Creek locality. A Southern Pomo community with its major village located on the Russian River near Cloverdale controlled the Squaw Creek portion. The upper Big Sulphur Creek portion was controlled by a Western Wappo community whose major village is believed to have been at the Geysers proper. The Putah Creek locality was controlled by the community at Middletown, consisting of either Lake Miwok or Northern Wappo, or both (Kroeber 1932: 366ff.; Merriam 1955: 43ff.).

THE DATA BASE

Systematic and intensive archaeological survey associated with geothermal resources development began in 1973 (e.g., Fredrickson 1973; Peak 1973). Since then, numerous surveys have generated more than 200 reports, letters, and environmental documents pertaining to archaeological resources. As a result of this work, more than 100 contiguous square miles have been surveyed and more than 340 prehistoric archaeological sites have been recorded. Of these, about 63 percent are flake scatters while about 37 percent are believed to have subsurface deposits. Because these evaluations are based primarily upon observable surface attributes and have only occasionally been tested by subsurface investigations, the actual numbers for each category are subject to change as subsurface data become available.

It was recognized during initial work in the geothermal region that obsidian flakes occurred at virtually all of the identified archaeological sites. Indeed, a significant majority of sites was marked by obsidian flakes alone, with even bifacially worked tools apparently absent (Fredrickson 1974: 13ff.). Limited subsurface investigation did little to change this perception (Fredrickson 1985: 29). Because geothermal development is land intensive, it was also recognized that impacts to archaeological resources, both anticipated and locationally unanticipated, could occur as a result of implementation of any one of the many different projects under development (Fredrickson 1974: 16ff.). Although each power plant utilizes only a few acres, it draws upon steam from wells contained within a leasehold averaging about 800 to 1000 acres in size. Considering that about 30 power plants are now operating, under construction, or in the permitting stages, a significantly large ground surface area is affected. Within each leasehold are about 10 to 15 steam wells required to furnish steam to operate the power plant, a complex network of pipelines to transport the steam, support roads, and power transmission lines. Add to this service centers, disposal areas, and other geothermal features, and the potential threat to archaeological resources through land disturbance activities becomes acute.

In view of these circumstances, an explicit plan that focused upon analysis of archaeological obsidian was initiated in 1973 to complement the archaeological surveys required by law (Fredrickson 1974: 29). Although preliminary analyses of obsidian data have been reported previously (e.g., Eisenman and Fredrickson 1980; Jackson 1974), a more thorough analysis was made possible during the preparation of an archaeological management plan for the geothermal area by Sonoma State University's Anthropological Studies center (Fredrickson 1985) under contract to the U.S. Bureau of Land Management (see acknowledgements).

ASSUMPTIONS

Our studies have attempted to control for two major variables, space and time. The spatial dimension has been controlled as described above through stratifying by major drainage. The temporal dimension has been controlled, though only to a limited extent because of cost constraints, through source-specific obsidian hydration studies. Because no satisfactory hydration rates have been developed for the obsidian sources under consideration, we have resisted the temptation to convert obsidian hydration readings into calendric dates. However, at this point in the research, source-specific hydration data reported in microns provide a satisfactory framework for relative dating.

The spatial stratification of the study area by major drainages (rather than vegetation or geomorphology) is not an arbitrary procedure. Territorial boundaries in ethnographic California were frequently at divides between watersheds. This was certainly the case within the present study area. To place this geomorphological variable within a larger context, we can see that in at least some cases the topographic features that marked the division between past sociopolitical units, i.e., ethnographic village-communities, even today mark the division between present day sociopolitical units, i.e., contemporary counties.

The study of boundary behavior is of special theoretical importance in the evolution of hunters and gatherers. Given the natural imbalance in both temporal and spatial occurrences of resources needed by humans, the presence of such boundaries is a sign that at least implicit agreements have been reached between neighbors to regulate resource use. It follows from this that there is at least implicit agreement to make reciprocal use of each other's resources, presumably through both formal and informal exchange networks, visits to the resource site, reciprocal gift giving, or other means by which goods unevenly distributed in nature become redistributed culturally. The shift from a condition without firm social and territorial boundaries to one with such boundaries (and vice versa), or any shift in boundary location, then, can be taken to mark a major shift in local sociopolitical organization.

The analytical division of the study area into four localities allows testing of hypotheses pertaining to social distance. Wilmsen (1973: 15) suggested that archaeological data could be used to measure social distance, or "social interaction intensity between groups occupying different territories," because archaeological data can be both quantified and denoted by spatial coordinates. Following Wilmsen, Kay (1975), in a study of interrelatedness among central Missouri Hopewell settlements, suggested that "social distance between peoples is reflected in the degree of similarity between artifacts commonly found." In the present study, I assume that interrelatedness, or social distance, can be estimated on the basis of patterning of obsidian tools and debitage, stratified by source. I also assume that the extent of interrelatedness between two communities is inversely proportional to the extent of fall off (the term applied to the decline in material from one locality as compared with an adjoining one) between the communities. For example, if a series of commodities are more or less equally distributed within two communities, then fall-off is low by definition and interrelatedness is assumed to be high.

Several simple assumptions, none of which is necessarily true, have been made in drawing inferences from the distributional data. First, the principle of least effort is assumed. For example Borax Lake obsidian is assumed to have entered the region from the northeast, where its parent source is located, rather than by a more round about route from the south. Second, it is assumed that materials will move from the locality with a greater quantity into a locality with a lesser quantity. Third, materials will move from one locality into an immediately adjoining locality, rather than from one locality into another that is one step or more removed (such as from Squaw Creek into Putah Creek).

Because the local obsidian sources occur at four different locations separated by as few as nine and as many as 40 miles, it may be that obsidian from each source moves into the region by means of a different set of social transactions and possibly along a different route. Similarities in the distribution of the different sources within each pair of localities is then assumed to be reflective of social interaction between these localities. Similarly, obsidian in different forms (e.g., trade blanks, finished projectile points) may enter a locality as a result of various and sometimes contrasting types of social interaction. Although some points were imported into the several localities as finished objects, it is also likely that other points and bifacially worked tools were manufactured within their find locality.

The argument here is that close social interrelatedness is indicated when there are similarities in proportions of different obsidians, by source and form, at contiguous sites, and that similar social behavioral patterns contributed to the similarities in obsidian distribution. Relative social distance among adjoining localities, then, can be estimated by observing differences and similarities in the patterning of obsidian materials.

There is evidence that the form in which the obsidian occurs is important, since different forms may enter a locality in different ways (see Hughes and Bettinger 1984). However, in the present study we control only for flakes and bifacially worked tools. Other variables such as flake characteristics (a function of technological processes) and point type (whether manufactured locally or imported ready-made) may also prove to have significance with respect to the processes that affect the movement of obsidian in space.

Empirical evidence gained from obsidian studies within the study area supported the preliminary finding that archaeological sites within any one locality are more similar to one another with respect to the distribution of obsidian by source and form than they are to sites in adjoining localities (Eisenman and Fredrickson 1980). The data assembled here support findings that within the study area: (1) each locality has its own distinctive patterning of obsidian distributions, (2) there is more connectedness between some pairs of localities than between others, and (3) the movement of the different obsidians between communities can be reconstructed from fall-off patterns.

STUDY FINDINGS

The obsidian sample which constitutes the basis for findings reported here consists of 1265 flakes and 269 points and other bifacially worked tools obtained from 154 archaeological sites located within the study area. Although identification of geological sources for the obsidian was carried out largely using macroscopic criteria, i.e., visually observable characteristics that distinguish one parent source from another, geologic sources for about 22 percent of the sample have been determined by x-ray fluorescence (XRF). Two additional data sets were employed in the temporal analysis presented here. One includes source specific hydration measurements from an additional 223 specimens (including both flaked tools and débitage) obtained from excavations at four sites within the Squaw Creek locality (Peak and Associates 1985; Farber 1987); the other includes hydration measurements from 46 specimens (including only flakes) obtained from excavations at three sites within the Big Sulphur Creek locality. None of these 269 specimens are included in the major sample of flakes and points described above.

The following topics are discussed below: (1) distribution of obsidian by source within each of the four localities, controlling for differences between flakes and bifacially worked tools, but not distinguishing further among variables such as flake characteristics, flake tools, and tool form; and (2) possible routes of entry for obsidian from each of the four represented sources into each of the four localities, as inferred from the patterning of fall-off.

Obsidian Source Distributions

The present study area is within each reach of the four principal North Coast Ranges obsidian sources. Mt. Konocti obsidian occurs within the Kelsey Creek locality at an outcrop about six miles north of Geysers Rock, Borax Lake obsidian is available about 15 miles to the northeast, and Annadel and Napa Valley obsidians occur about 27 miles to the south. There are no natural barriers, such as large rivers or exceptionally difficult terrain, between the source localities and the present study area.

If the principal of least effort were applied to the distribution of obsidian without regard to other selection factors, one would predict abundant Mt. Konocti obsidian, somewhat lesser amounts of Borax Lake materials, and about equal but small quantities of Napa and Annadel (cf. Ericson 1977). These expectations were not met. Most noteworthy of several findings is the over-representation of Napa Valley obsidian in the Big Sulphur Creek locality and of Borax Lake obsidian at Putah Creek, and the under-representation of Annadel obsidian.

Jackson (1974) was the first to recognize that Napa Valley obsidian within the Big Sulphur Creek locality was over-represented with respect to the distance-decay (fall-off) hypothesis, and subsequent studies have confirmed and added to this initial observation (Eisenman and Fredrickson 1980; Fredrickson 1985). These findings are supported by data presented in Tables 1-4. Table 1 presents the distribution of obsidian flakes by source and major drainage within the study area; Table 2 depicts this distribution through a histogram. Table 3 shows the distribution of obsidian points and bifaces by the same variables; Table 4 depicts the point/biface distribution through a histogram. Implications of the data provided in the tables are discussed below, incorporating information obtained from obsidian hydration studies.

The spatial distribution of 1265 obsidian flakes whose sources have been determined is shown in Tables 1 and 2. The distribution generally follows that predicted by the distance-decay hypothesis in that numbers become less as distance from source increases. However, significant differences in fall-off rates occur between localities. The amount of Mt. Konocti obsidian in the tested flakes falls off dramatically (from about 85- to 52%) across the border from the Kelsey Creek and Squaw Creek localities into either the Big Sulphur Creek or Putah Creek localities. Conversely, both Borax Lake and Napa fall off significantly in the reverse direction (from about 23% Borax Lake at Big Sulphur to 9% at Squaw Creek and from 19.4% Napa at Big Sulphur to 5% at Squaw Creek). Annadel is noteworthy by its virtual absence (less than 0.1%; only 5 of more than 1200 flakes in the total sample) in all localities.

Also important are the close similarities in the frequencies of the different obsidian sources within the Kelsey Creek and Squaw Creek localities, as well as within the Big Sulphur and Putah Creek localities. If the guiding assumptions of this study are correct, the obsidian distributions within any pair of localities are

TABLE 1

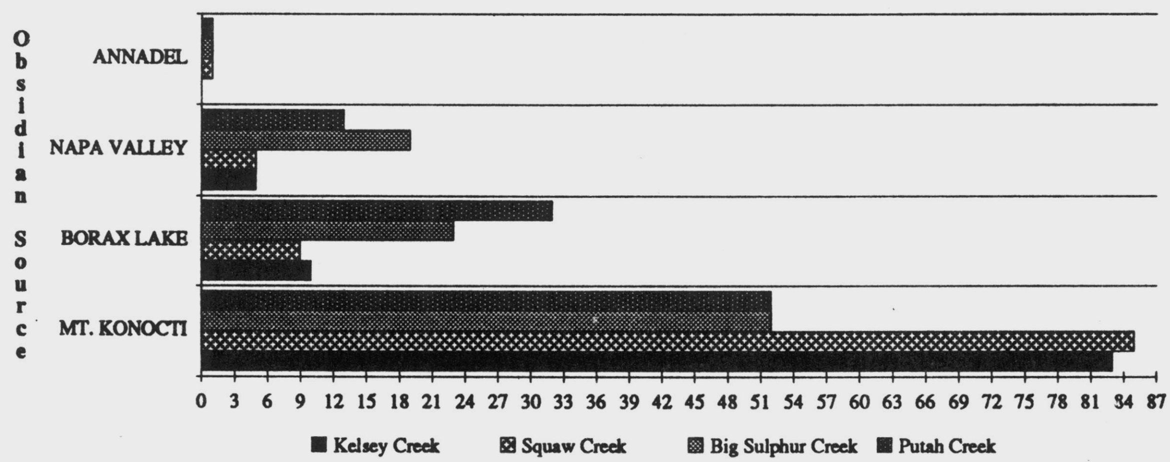
DISTRIBUTION OF OBSIDIAN FLAKES BY SOURCE AND MAJOR DRAINAGE WITHIN THE GEOTHERMAL REGION OF LAKE AND SONOMA COUNTIES

	Mt. Konocti	Borax Lake	Napa Valley	Annadel	Unknown	Totals
Kelsey Creek	349/83%	43/10%	23/ 5%	0	8/2%	423
Squaw Creek	430/85%	44/ 9%	27/ 5%	3/1%	4/1%	508
Big Sulphur Creek	99/52%	45/23%	37/19%	1/1%	10/5%	192
Putah Creek	58/52%	36/32%	15/13%	1/1%	2/2%	112
totals	936/76%	168/14%	102/8%	5/<.1%	24/2%	1235

1. Number/Percent
2. Chi Square calculated only for Mt.Konocti, Borax Lake, and Napa Valley sources.
3. Number = 1206.
4. Chi Square = 128.714.
5. Probability of Chance = 0.0000.

TABLE 2

HISTOGRAM OF OBSIDIAN FLAKES BY SOURCE AND MAJOR DRAINAGE WITHIN THE GEOTHERMAL REGION OF LAKE AND SONOMA COUNTIES



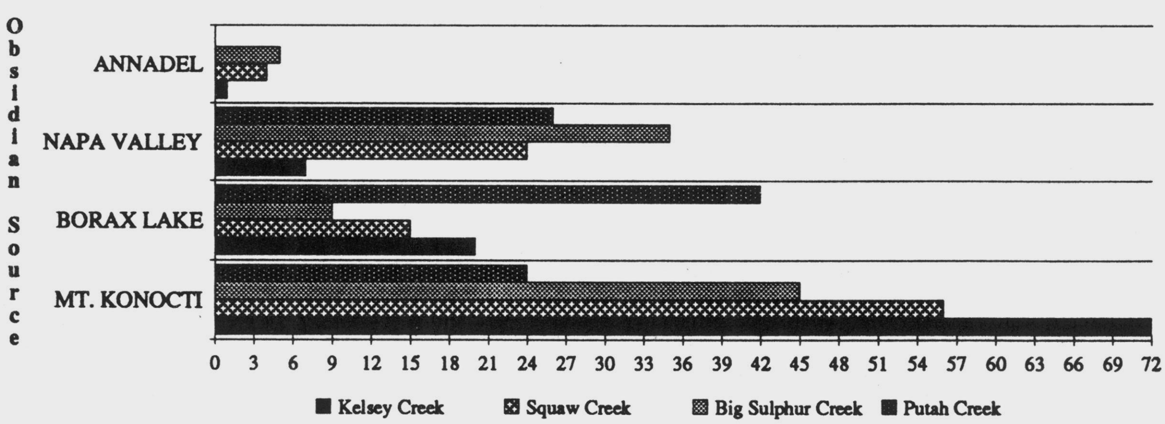
1. Bar graphs depict percentage of each source within each locality. 2. Histogram generated from data in Table 1.

TABLE 3
DISTRIBUTION OF OBSIDIAN BIFACES BY SOURCE AND MAJOR DRAINAGE WITHIN THE GEOTHERMAL REGION OF LAKE AND SONOMA COUNTIES

	Mt. Konocti	Borax Lake	Napa Valley	Annadel	Unknown	totals
Kelsey Creek	63/72%	18/20%	6/ 7%	1/1%	0	88
Squaw Creek	44/56%	12/15%	19/24%	3/4%	0	78
Big Sulphur Crk	29/45%	6/ 9%	23/35%	3/5%	4/6%	65
Putah Creek	9/24%	16/42%	10/26%	0	3/8%	38
totals	145/54%	52/19%	58/22%	7/3%	7/3%	269

1. Number/Percent
2. Chi Square calculated only for Mt. Konocti, Borax Lake and Napa valley sources.
3. Number = 255
4. Chi Square = 42.4277
5. Probability of Chance = 0.0000

TABLE 4
HISTOGRAM OF OBSIDIAN POINTS AND BIFACES BY SOURCE AND MAJOR DRAINAGE WITHIN THE GEOTHERMAL REGION OF LAKE AND SONOMA COUNTIES



1. Bar graphs depict percentage of each source within each locality. 2. Histogram generated from data in Table 3.

reflective of social interaction between these localities. Thus, the Kelsey Creek and Squaw Creek localities form an interaction unit and the Big Sulphur and Putah Creek localities form an interaction unit. It can be inferred, then, that there is greater social distance between the two units than between the subsets of each unit.

The findings of the present study also show significant differences between the distribution of obsidian points and bifaces by source when compared to the distribution of flakes (see Hughes and Bettinger 1984). Tables 3 and 4 depict the spatial distribution, again without reference to chronology, of 269 points and bifaces, similarly stratified by locality and source. Although the distributional patterns for points and bifaces differ from those of flakes, they complement rather than contradict one another. In the main it is likely that the point distributions differ from flake distributions because the point distributions are influenced by the movement of particular point forms as well as by raw materials. Table 4 illustrates well the concept of fall-off between contiguous localities, showing that the use of Mt. Konocti obsidian for points and bifaces declines dramatically from one locality to another, presumably as effective distance from source increases.

The figures for points and bifaces clearly show that Mt. Konocti obsidian, as expected, dominates the Kelsey Creek drainage (72%), but it falls-off markedly in the Squaw Creek drainage (56%); the close similarities observed with flakes is not repeated. Mt. Konocti falls-off again and ceases to be a majority (45%) within the Big Sulphur Creek drainage, where Napa Valley is significantly represented in the assemblage (35%). Putah Creek differs even more, with Borax Lake dominating this assemblage (42%) while Mt. Konocti, with outcrops located no more than seven miles away, constitutes only a small proportion (24%).

To this point, relatively little data exist regarding the time depth of these patterns. Table 5 presents hydration readings from 223 specimens (including both flakes and points/bifaces) obtained from four sites tested by excavation within the Squaw Creek locality (Peak and Associates 1985; Farber 1987). Table 6 contains reading from 46 specimens (including flakes only) from three sites tested by excavation in the Big Sulphur Creek locality. Because it is not yet possible to correlate hydration readings from different sources with equivalent chronological ages, we must be cautious in asserting that one source appeared in the region earlier than others: in addition the present hydration sample is too limited to allow many reliable generalizations.

The heavy bias of the Squaw Creek hydration sample in favor of points and bifaces and the Big Sulphur Creek bias in favor of flakes can be accounted for to some extent not only by the sampling methods of the investigators but also by differences in each series of sites that were investigated. The Squaw Creek sites had depth up to a meter or more and contained flaked stone artifacts and milling tools and were likely to have been seasonally occupied camps. On the other hand, two of the Big Sulphur Creek sites were sparse flake scatters with little depth and few if any bifacially worked tools; the third was equivalent to those at Squaw Creek in representing a seasonally utilized camp. These differences are reflected in the tables in that 67% of the Squaw Creek sample and none of the Big Sulphur Creek sample is made up of points and bifaces. It is likely that the non-Mt. Konocti obsidian at Squaw Creek represents projectile points that were imported into the locality as finished tools. The sparse flake scatter context of the Big Sulphur Creek specimens also suggests that the non-Mt. Konocti obsidian there represents repair and maintenance flakes rather than manufacturing debris.

Although Borax Lake obsidian in the Big Sulphur Creek sample has substantially greater hydration readings than the other two sources, we must be cautious in assigning that source temporal priority. Several lines of contextual evidence elsewhere in the North Coast Ranges suggest that the hydration rate for Borax Lake obsidian is somewhat more rapid than the rates of either Mt. Konocti or Napa. The data in Tables 5 and 6 suggest that despite Mt. Konocti's probable dominance during all time periods, both Borax Lake and Napa Valley obsidian appear to have been utilized in both localities at a substantially early date. However, data presented in Table 1 indicate that both Borax Lake and Napa Valley obsidian were quantitatively more important in the Big Sulphur Creek locality as compared with the Squaw Creek locality. Annadel obsidian appears to have been brought into the region only during the late period and then only in extremely small quantities.

Movement of Obsidian into the Geothermal Region

Tables 7-10 present reconstructions of the movement of obsidian from the four local sources into and within the geothermal region employing data on flake distributions for one set of reconstructions and on points and bifaces for a second set. The arrows in the tables indicate what are reconstructed to be the most likely routes of movement. Although it is presently not possible to separate the data on imported points and bifaces from locally manufactured specimens, distributional differences suggest that imported objects at times had entry routes different from those of the raw

TABLE 5
DISTRIBUTION OF OBSIDIAN HYDRATION READINGS FROM FOUR SITES WITHIN THE SQUAW CREEK LOCALITY

Microns	Mt. Konocti	Borax Lake	Napa Valley	Annadel
0.0-1.0	-	-	-	-
1.1-1.3	1	-	1	1
1.4-1.6	8	1	1	-
1.7-1.9	14	1	2	1
2.0-2.2	16	2	3	-
2.3-2.5	23	2	5	1
2.6-2.8	29	1	5	-
2.9-3.1	19	1	1	-
3.2-3.4	17	-	-	-
3.5-3.7	11	-	-	-
3.8-4.0	5	1	1	-
4.1-4.3	11	2	-	-
4.4-4.6	9	1	1	-
4.7-4.9	4	-	-	-
5.0-5.2	7	1	-	-
5.3-5.5	1	1	-	-
5.6-5.8	1	-	-	-
5.9-6.1	2	1	-	-
6.2-6.4	-	-	-	-
6.5-6.7	1	-	-	-
6.8-7.0	-	1	-	-
7.1-7.3	1	1	-	-
7.4-7.6	1	-	-	-
7.7-7.9	1	-	-	-
8.0-8.2	-	-	-	-
8.3-8.5	-	-	-	-
8.6-8.8	-	-	1	-
totals	182	17	21	3

1. Data from Farber 1985, Peak and Associates 1987.
2. Specimens from both surface and subsurface of Son-833, -841, -1406, -1407.
3. (Points-bifaces)/(cores-flake tools-flakes-shatter) as follows: Mt. Konocti, 11/71; Borax Lake, 16/1; Napa Valley, 20/1; Annadel, 2/1.

TABLE 6
DISTRIBUTION OF OBSIDIAN HYDRATION READINGS FROM THREE SITES WITHIN THE BIG SULPHUR CREEK LOCALITY

microns	Mt. Konocti	Borax Lake	Napa Valley
0.0-1.0	-	-	-
1.1-1.3	4	-	-
1.4-1.6	1	1	1
1.7-1.9	-	-	-
2.0-2.2	2	-	-
2.3-2.5	2	-	-
2.6-2.8	1	-	-
2.9-3.1	-	-	-
3.2-3.4	2	-	3
3.5-3.7	2	-	4
3.8-4.0	2	3	-
4.1-4.3	1	-	1
4.4-4.6	-	1	-
4.7-4.9	-	-	-
5.0-5.2	1	-	-
5.3-5.5	-	1	2
5.6-5.8	-	1	-
5.9-6.1	-	5	-
6.2-6.4	-	1	-
6.5-6.7	-	-	-
6.8-7.0	-	2	-
7.1-7.3	-	-	-
7.4-7.6	-	-	-
7.7-7.9	-	-	-
8.0-8.2	-	1	-
8.3-8.5	-	-	-
8.6-8.8	-	1	-
totals	18	17	11

1. Data from files of the Obsidian Laboratory, Sonoma State University.
2. Specimens from both surface and subsurface of Son-783, -785, -794.
3. Specimens include flakes and chunks only.
4. No Annadel specimens were identified at these sites.

materials. The distributional data suggest the following reconstructions.

Mt. Konocti obsidian, assumed to derive from the source within the Kelsey Creek locality, appears to have been moved freely into Squaw Creek and less freely into Putah Creek. Certainly the number of Mt. Konocti points found in the Putah Creek locality is less than expected considering its proximity to the source. From Squaw Creek, Mt. Konocti obsidian was then moved into Big Sulphur Creek where the raw material may have moved freely between Big Sulphur and Putah. Points and bifaces, however, were more likely to have moved from Big Sulphur into Putah than the reverse.

Borax Lake obsidian was transported from its source separately into both the Kelsey Creek and Putah Creek localities. If obsidian were moved between these two localities, it would have been more likely from Putah into Kelsey than the reverse. Although Big Sulphur may have received finished tools from both Squaw and Putah, raw material would have been moved from Big Sulphur into Squaw, as well as from Kelsey into Squaw.

Napa Valley obsidian was moved from its source separately into both Big Sulphur and Putah; if there was movement between the two localities, it was more likely from Big Sulphur into Putah than the reverse. From Big Sulphur, this obsidian was moved into Squaw and subsequently into Kelsey. Kelsey may also have received Napa Valley obsidian from Putah.

Annadel obsidian may have entered the region through Big Sulphur Creek and from there to Kelsey creek by way of Squaw Creek; it may also have entered Squaw Creek independently of Big Sulphur.

TABLE 7
RECONSTRUCTED MOVEMENTS OF OBSIDIAN BETWEEN KELSEY AND SQUAW LOCALITIES BY SOURCE AND FORM

	Kelsey Creek..................Squaw Creek
MT. KONOCTI OBS:	
Flakes	>>————————————>>
Points/Bifaces	>>————————————>>
BORAX LAKE OBS:	
Flakes	<<————————————>>
Points/Bifaces	>>————————————>>
NAPA VALLEY OBS:	
Flakes	<<————————————>>
Points/Bifaces	<<————————————<<
ANNADEL OBS:	
Flakes	?
Points/Bifaces	<<————————————<<

1. Arrows, e.g., >>————>>, indicate direction of movement.
2. Table based on data from Tables 1 through 4.

TABLE 8
RECONSTRUCTED MOVEMENT OF OBSIDIAN BETWEEN KELSEY AND PUTAH LOCALITIES BY SOURCE AND FORM

	Kelsey Creek.....................Putah Creek
MT. KONOCTI OBS:	
Flakes	>>————————————>>
Points/Bifaces	>>————————————>>
BORAX LAKE OBS:	
Flakes	<<————————————<<
Points/Bifaces	<<————————————<<
NAPA VALLEY OBS:	
Flakes	<<————————————<<
Points/Bifaces	<<————————————<<
ANNADEL OBS:	
Flakes	?
Points/Bifaces	?

1. Arrows, e.g., >>———>>, indicate direction of movement.
2. Table based on data from Tables 1 though 4.

CONCLUSIONS

The findings to date prompt the hypothesis that a portion of the boundary between the spheres of influence for Mt. Konocti and Borax Lake obsidian, and possibly Napa Valley as well, resides within the present study area. Minimally, however, it can be stated with regard to routine obsidian use that there was little social distance between the Kelsey Creek and Squaw Creek drainages over an extended period of time. Greater social distance during this time span existed between these two localities as a unit and the Big Sulphur and Putah Creek drainages as a unit.

Insofar as the distribution of obsidian monitors social relationships, it appears that during all time periods the Annadel source locality was more removed in social distance from the study area than was the Napa Valley despite the fact that both sources are about equidistant over similar terrain from the study area. This may be related to the fact that Wappo communities controlled both Big Sulphur Creek (and possibly Putah Creek) and the Napa Valley obsidian sources. Although these communities were politically separate from one another, intermarriage may have facilitated the movement of obsidian from its source to the study area (see Jackson 1986; Jackson [this volume]).

It is evident that raw material, from whatever source, was moved with relative freedom between the Kelsey and Squaw localities and between the Big Sulphur and Putah localities. However, the distribution of points and bifaces shows no such symmetry, with their fall-off patterns suggesting more controlled movement between adjoining localities.

The obsidian fall-off patterns outlined above are proportional to the extent of social distance between adjoining localities. This suggestion forms a hypothesis for which implications may be developed that can be tested by data sets that are independent of obsidian

TABLE 9

RECONSTRUCTED MOVEMENT OF OBSIDIAN BETWEEN SQUAW AND BIG SULPHUR LOCALITIES BY SOURCE AND FORM

	Squaw Creek..................Big Sulphur Ck
MT. KONOCTI OBS:	
Flakes	>>————————————>>
Points/Bifaces	>>————————————>>
BORAX LAKE OBS:	
Flakes	<<————————————<<
Points/Bifaces	>>————————————>>
NAPA VALLEY OBS:	
Flakes	<<————————————<<
Points/Bifaces	<<————————————<<
ANNADEL OBS:	
Flakes	?
Points/Bifaces	<<————————————<<

1. Arrows, e.g., >>————>>, indicate direction of movement.
2. Tables based on data from Tables 1 and 4.

sourcing data. For example, when we infer that the Kelsey and Squaw localities have less social distance between them than between either the Big Sulphur or Putah localities, we can test the inference, now as an hypothesis, by the implication that other artifact forms will also fall-off at the same juncture. Successful testing of the hypothesis may then prompt us to seek a higher level of explanation as to why such social distance is found between some localities and not between others.

Overall, the findings outlined here are consistent with observations made by Hughes and Bettinger (1984) regarding the influence of prehistoric sociocultural systems on the distribution of obsidian. They have suggested that obsidian is not only a utilitarian commodity, it is also a socioceremonial one. They also suggested that the village-community (rather than the ethnolinguistic unit) would be the social unit responsible for obsidian distribution and use, and consequently the one most likely to be reflected in archaeological obsidian distributions. In the present study, although the ethnographic inhabitants of each of the territories under consideration had a different ethnolinguistic affiliation, each also constituted a separate village-community. Finally, at the current level of understanding, we can concur with Hughes and Bettinger (1984) that obsidian study provides "a potentially powerful tool for the investigation of prehistoric sociocultural systems."

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TABLE 10
RECONSTRUCTED MOVEMENT OF OBSIDIAN BETWEEN BIG SULPHUR AND PUTAH LOCALITIES BY SOURCE AND FORM

	Putah Creek....................Big Sulphur Ck
MT. KONOCTI OBS:	
Flakes	<<————————————>>
Points/Bifaces	<<————————————<<
BORAX LAKE OBS:	
Flakes	>>————————————>>
Points/Bifaces	>>————————————>>
NAPA VALLEY OBS:	
Flakes	<<————————————<<
Points/Bifaces	<<————————————<<
ANNADEL OBS:	
Flakes	?
Points/Bifaces	?

1. Arrows, e.g., >>————>>, indicate direction of movement.
2. Tables based on data from Tables 1 and 4.

Thomas Jackson, who carried out XRF trace element analyses on obsidian specimens that allowed their attribution to specific parent sources, as well as serving as tests for visual sourcing, i.e., the identification of parent sources on the basis of macroscopic characteristics. The assistance of Jan Keswick in carrying out visual sourcing is also acknowledged. Acknowledgement is due Thomas Origer, who performed the obsidian hydration work reported here, who supervised visual sourcing efforts, and who, over the years, participated in much of the field work upon which the present study is based. The hydration readings for the obsidian sample reported by Peak and Associates (1985) and Farber (1987), cited in this paper, were made by R.J. Jackson; XRF source identifications for about half of these specimens were made by Paul D. Bouey; XRF sourcing for the remaining half was conducted by Richard E. Hughes. Other researchers whose work contributed directly to the present study include Lynn Eisenman, Mark Hale, John Hayes, Thomas Kaufman, Pat Mikkelsen, James Quinn, Nelson Thompson, and Kim Tremaine. Archaeological consultants and consulting firms whose field work contributed to this study include Peak and Associates, Archaeological Resource Services, Archaeological Services, Professor Delbert True, Pacific Bioarchaeology Laboratory, and Sonoma State University's Anthropological Studies Center. Archaeological reports and site records generated through their studies are on file with the Northwest Information Center of the California Archaeological Inventory at Sonoma State University, Rohnert Park, CA 94928.

REFERENCES CITED

Eisenman, L., and D.A. Fredrickson 1980. Temporal seriation of Native American sites at the Geysers. Paper presented at annual meeting, Society for California Archaeology, Redding, California.

Ericson, J.E. 1977. Prehistoric exchange systems in California: the results of obsidian dating and tracing. Unpublished Ph.D. dissertation, Department of Anthropology, University of California, Los Angeles.

Farber, A. (with contributions by H.L. Crew and A.S. Peak) 1987. Archaeological investigations in the Mayacmas Mountains: Volume II. CA-SON-833 and CA-SON-841. Report prepared for GEO Operator Corporation, Santa Rosa, California. Copy on file with Northwest Information Center, Sonoma State University, Rohnert Park, California.

Fredrickson, D.A. 1973. The archaeological impact evaluation of five drill sites and the subdrainage containing them, near Geysers Resort, Sonoma County, California. Prepared for Ecoview Environmental Consultants, Walnut Creek, California. Copy on file with Northwest Information Center, Sonoma State University, Rohnert Park, California.

____ 1974. Archaeological resources and geothermal development at The Geysers, Sonoma County, California. Prepared for Ecoview Environmental Consultants, Walnut Creek, California. Copy on file with Northwest Information Center, Sonoma State University, Rohnert Park, California.

____ 1985. Cultural resources management for northern California's Geysers geothermal region (prehistoric archaeology). Prepared for U.S. Department of the Interior, Bureau of Land Management, Ukiah District Office, Ukiah, California. Copy on file with Northwest Information Center, Sonoma State University, Rohnert Park, California.

Glassow, M.A. 1985. The significance of small sites to California archaeology. **Journal of California and Great Basin Anthropology** 7(1):58-66.

Hughes, R.E. and R.L. Bettinger 1984. Obsidian and prehistoric sociocultural systems in California. IN: Exploring the limits: frontiers and boundaries in prehistory, edited by S.P. De Atley and F.J. Findlow. **British Archaeological Reports, International Series** 223:153-172.

Jackson, T.L. 1974. The economics of obsidian in central California prehistory: applications of x-ray fluorescence spectrography in archaeology. Unpublished M.A. thesis, Department of Anthropology, San Francisco State University, San Francisco.

____ 1986. Late prehistoric obsidian exchange in central California. Unpublished Ph.D. dissertation, Department of Anthropology, Stanford University.

Kay, M. 1975. Social distance among central Missouri Hopewell settlements: a first approximation. **American Antiquity** 40(1):64-71.

Kroeber, A.L. 1932 . The Patwin and their neighbors. **University of California Publications in American Archaeology and Ethnology** 29(4).

Lipe, W.D. 1974. A conservation model for American archaeology. **The Kiva** 39:213-245.

Merriam, C. H. 1955. **Studies of California Indians.** University of California Press, Berkeley.

Peak, A.S. 1973. An archaeological survey and reconnaissance of the Signal Oil Project, Middletown California. Prepared for Environmental Assessment Engineering. Copy on file with Northwest Information Center, Sonoma State University, Rohnert Park, California.

Peak and Associates, Inc. 1985. Archaeological investigations in the Mayacmas Mountains: Volume I. CA-SON-1406 and CA-SON-1407, Sonoma County, California. Report prepared for GEO Operator Corporation, Santa Rosa, California. Copy on file with Northwest Information Center, Sonoma State University, Rohnert Park, California.

Simons, D.D. 1985. Environmental setting. IN: Cultural resources management plan for northern California's Geysers geothermal region (prehistoric archaeology), by David A. Fredrickson, pp. 10-20. Prepared for U.S. Department of the Interior, Bureau of Land Management, Ukiah District Office, Ukiah, California.

Whalen, M.E. 1986. Small-site analysis in the Hueco Bolson of western Texas. **Journal of Field Archaeology** 13(1):69-81.

Wilmsen, E.N. 1973. Interaction, spacing behavior, and the organization of hunting bands. **Journal of Anthropological Research** 29(1):1-31.