LATE PREHISTORIC OBSIDIAN PRODUCTION AND EXCHANGE IN THE NORTH COAST RANGES, CALIFORNIA

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INTRODUCTION

This is a paper of three parts. The first part examines the geological distribution of obsidian in the North Coast Ranges. A number of obsidian quarries and other potential sources not previously reported are described and their trace-element geochemistry summarized. Secondly, I review the history and concept of obsidian artifact "sourcing" by archaeologists and geologists. Although the discussion relates specifically to North Coast Ranges obsidian, the example is appropriate to a much broader audience concerned with determining the original source of raw material for any lithic artifact. I offer a "cautionary tale" about how we come to "know" where obsidian was obtained by prehistoric people. A number of semantic conundrums arise and I make a recommendation for greater care in the use of terminology. Finally I discuss the selective exploitation of obsidian in the North Coast Ranges by late prehistoric populations. Although there are numerous obsidian sources in the region, not all were exploited for the manufacture of all types of chipped stone artifacts. For example, only certain obsidian types were used for projectile (arrow) points, while a broader inventory of obsidians was used for other artifact types. Available data strongly suggest that the production and distribution of certain obsidian artifacts was closely controlled by social elites.

OBSIDIAN SOURCES IN THE NORTH COAST RANGES

Obsidian in the North Coast Ranges originates in either the Sonoma Volcanics or the Clear Lake Volcanics (Figures 1 and 2). Obsidian fragments from the volcanic fields are also found as clasts in the gravels of younger alluvial deposits along the fringes of the volcanics. In the Sonoma Valley and in areas west and north of Santa Rosa, obsidian pebbles "apparently derived through erosion of obsidian in the upper member of the Sonoma Volcanics" are definitive of the Glen Ellen Formation (Fox 1983:11). Erosion of the Sonoma Volcanics and the Glen Ellen Formation has, in turn, resulted in the incorporation of obsidian pebbles into localized Quaternary alluvial and fluvial deposits.

Fox (1983:10) has divided the Sonoma Volcanics into two units, according to their age: "The lower member occupies most of the southern part of the volcanic field as it is exposed today. The member consists chiefly of silicic basalt, andesite, and dacite flows, with subordinate interlayered ash flows and rhyolite flows, and thus contrasts with the predominately tuffaceous rock of the younger part of the field to the north" (Figure 2). Rocks of the lower member of the Sonoma Volcanics date from 5.5 million years (m.y.) to >7.1 m.y., and the youngest dated material in the Sonoma Volcanics is assigned an age of ca. 2.9 m.y.

FIGURE 1
DISTRIBUTION OF SONOMA VOLCANICS AND OBSIDIAN LOCALITIES IN THE SOUTHERN NORTH COAST RANGES.

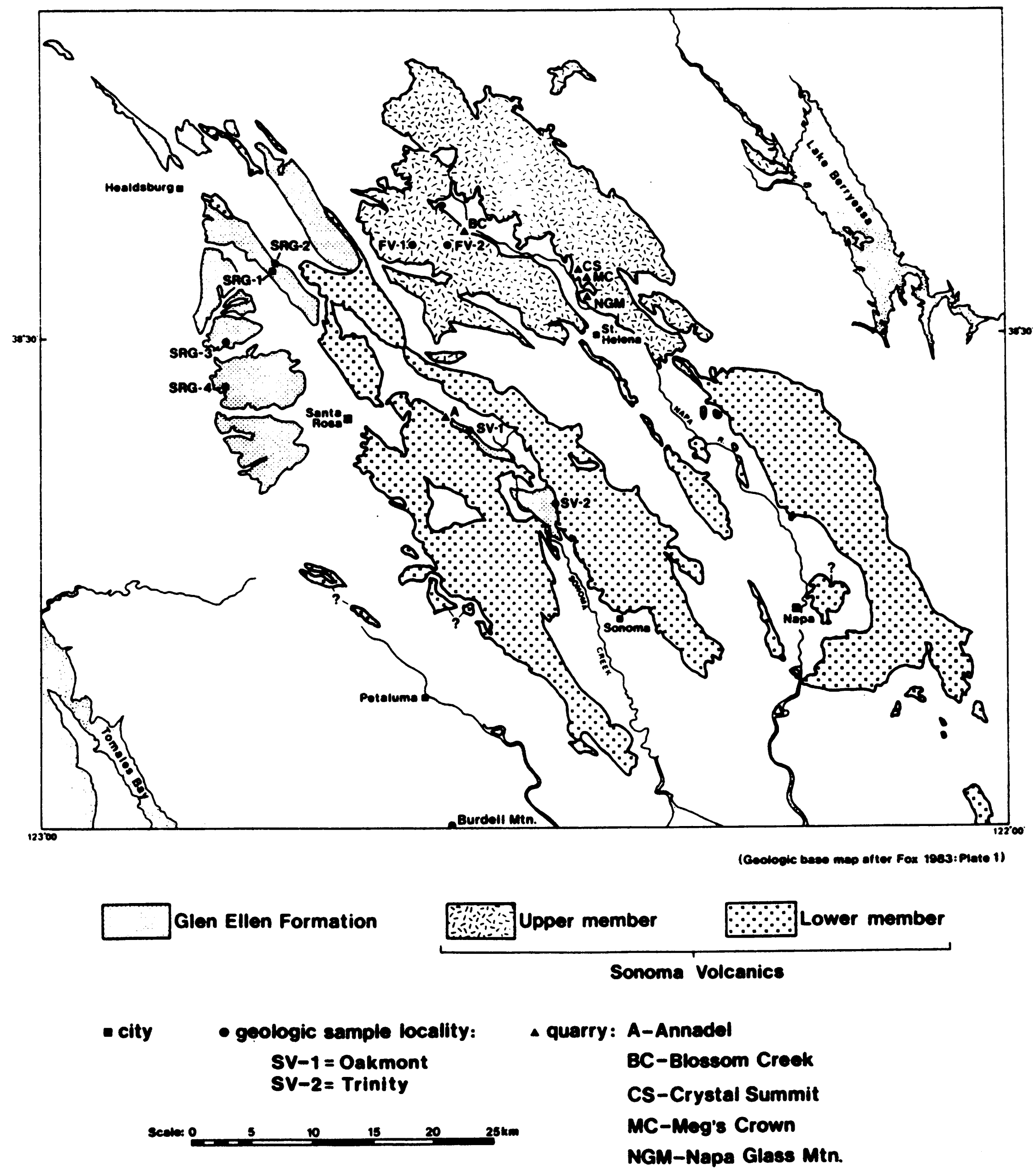
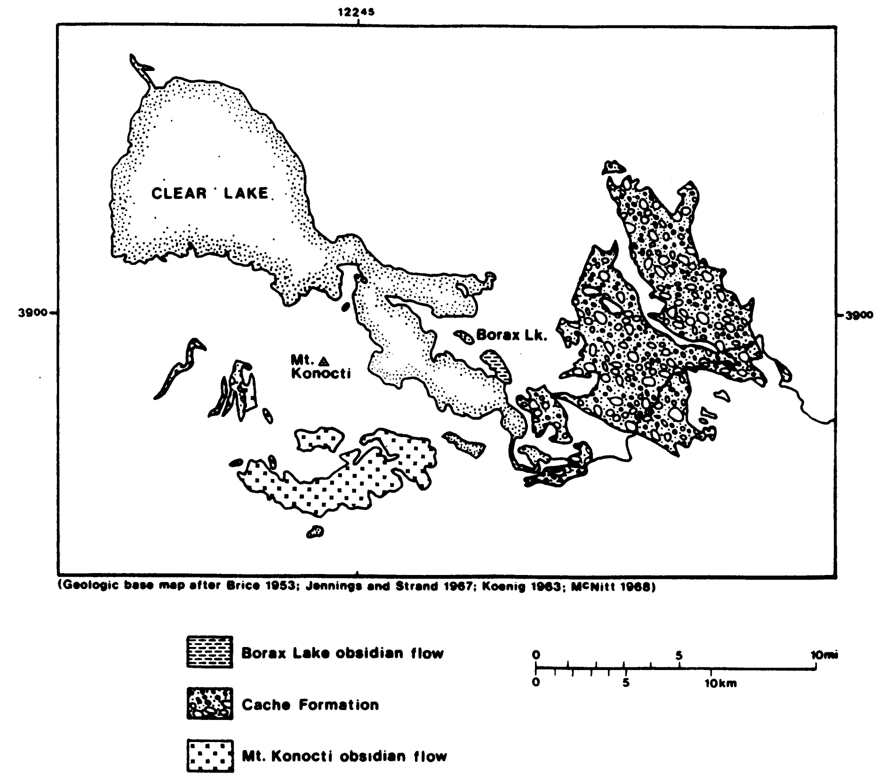


FIGURE 2
OBSIDIAN FLOWS IN THE CLEAR LAKE VOLCANICS



(Fox 1983:11; Mankinen 1972:2065). Obsidian occurs in association with rhyolitic rocks in both members of the Sonoma Volcanics.

Obsidians of the Clear Lake basin were produced during eruptions of the Clear Lake volcanics, and are largely confined to the basin itself. The Clear Lake Volcanics are much younger than the Sonoma Volcanics, generally dated as less than ca. 2 m.y. Obsidian flows of the Clear Lake Volcanics have been radiometrically dated, and range from ca. 1.01 m.y. to .088 m.y., the younger date being for the Borax Lake obsidian flow (Donnelly 1977:3-4; Donnelly-Nolan et al. 1981). Obsidian occurs as massive flows, domes and brecciated tuffs on the south side of Mt. Konocti (Brice 1953; McNitt 1968)). Borax Lake, on the east side of Clear Lake, was created when the small basin in which the lake is situated was sealed by an olivine dacite flow, which is capped by a rhyolite obsidian flow (Anderson 1936). Obsidian pebbles are a minor constituent of Cache Formation deposits southeast of Clear Lake (Brice 1953:33; Figure 2).

There is some confusion regarding the number and location of obsidian "quarries" in the North Coast Ranges. Heizer and Treganza (1944) examined the ethnographic and archaeological literature to determine the sources of various rocks and minerals (including obsidian) used by native Californians. Their inventory of obsidian quarries contains numerous errors, stemming in part from their identification of certain chert quarries as obsidian sources. Ball (1941) reports a number of obsidian sources in the study area but locational data are minimal. Efforts at correlating more recently discovered quarries in the Napa Valley region with Ball's inventory are stymied for lack of precise map data. Elsewhere (Jackson 1973; 1974) I have discussed the problems related to sorting out the lists of archaeologically reported obsidian sources in the region.

Other terminological and comparative problems arise. For example, Ericson's (1977:101) obsidian samples reportedly from "Napa Glass Mnt." were, in fact, collected not only from Glass Mountain itself, but also from "E. Dago Valley", "W. Dago Valley", and "Hill 450+". Obsidian collected by Ericson from Dago

Valley (ca. 1.4 kilometers north of Glass Mountain) would almost certainly have been material eroded from the source I call "Crystal Summit" (discussed below). The location of his "Hill 450+" is uncertain, as there are several hills near Glass Mountain with summit altitudes in excess of 450 feet. The point is not to denigrate Ericson's important efforts, but with increased resolution in our knowledge of the complexity of the geology (apart from the semantic problems discussed earlier), there is a need for explicit geographical mapping of sources with a concern for distinguishing among in situ versus redeposited obsidian.

Obsidian occurs throughout much of the Sonoma Volcanics field, for the most part, as very small pebbles ("Apache tears") unsuited for tool manufacture. I make no attempt to discuss these occurrences, except those for which I am aware that obsidian pebbles are of sufficient dimensions to possibly have been used in tool manufacture. I concentrate on obsidian in those areas where there is evidence for prehistoric quarrying. Likewise, I do not attempt to describe the geographical distribution of obsidian which occurs as float in stream channels. For example, obsidian is a constituent of gravels in the Napa River and in the streams which drain the area of the Mt. Konocti obsidian flow.

Burdell Mountain

A highly weathered obsidian crops out on the southwest slope of Burdell Mountain in Marin County (Figure 1). This obsidian consists of a black glassy matrix containing a nearly equal volume of crystalline inclusions, primarily feldspar. The obsidian is exposed over an area of approximately 20 square meters, with no evidence of quarrying. A recent excavation for a water tank adjacent the outcrop reveals isolated, nearly disintegrated obsidian masses to a depth of more than 3 meters, suggesting that the remains are the last vestiges of a small obsidian extrusion which has been nearly obliterated by weathering.

The obsidian and associated rhyolitic tuffs have not been recognized in published geologic mapping. The area of the obsidian and tuffs has been mapped as part of serpentine and marine sedimentary units of the Franciscan Complex (cf. Fox 1983; Koenig 1963; Sims et al. 1973). Fox (1983:Plate 1) maps Burdell Mountain basalts as part of the Tolay Volcanics (Morse and Bailey 1935) after Mankinen (1972) who reports a K-Ar age date for the basalts of Burdell Mountain of ca. 11.8 m.y. The stratigraphic position of the Burdell Mountain obsidian remains undefined but it is unlikely to be older than the basalts and is perhaps contemporary with the lower member of the Sonoma Volcanics.

Burdell Mountain obsidian is not suitable for tool manufacture, and has not been detected in archaeological collections. The obsidian is chemically unique (Figure 3), and its distinctive physical appearance would make it conspicuous in any collection of debitage or artifacts.

OBSIDIAN IN THE LOWER MEMBER OF THE SONOMA VOLCANICS

Obsidian occurs in both the upper and lower members of the Sonoma Volcanics. The best known obsidian in the lower member occurs in the vicinity of Annadel State Park in the upper Sonoma Valley. In addition to this archaeologically well known obsidian at least two other chemically discrete obsidian types are now recognized: Los Guilicos and Trinity.

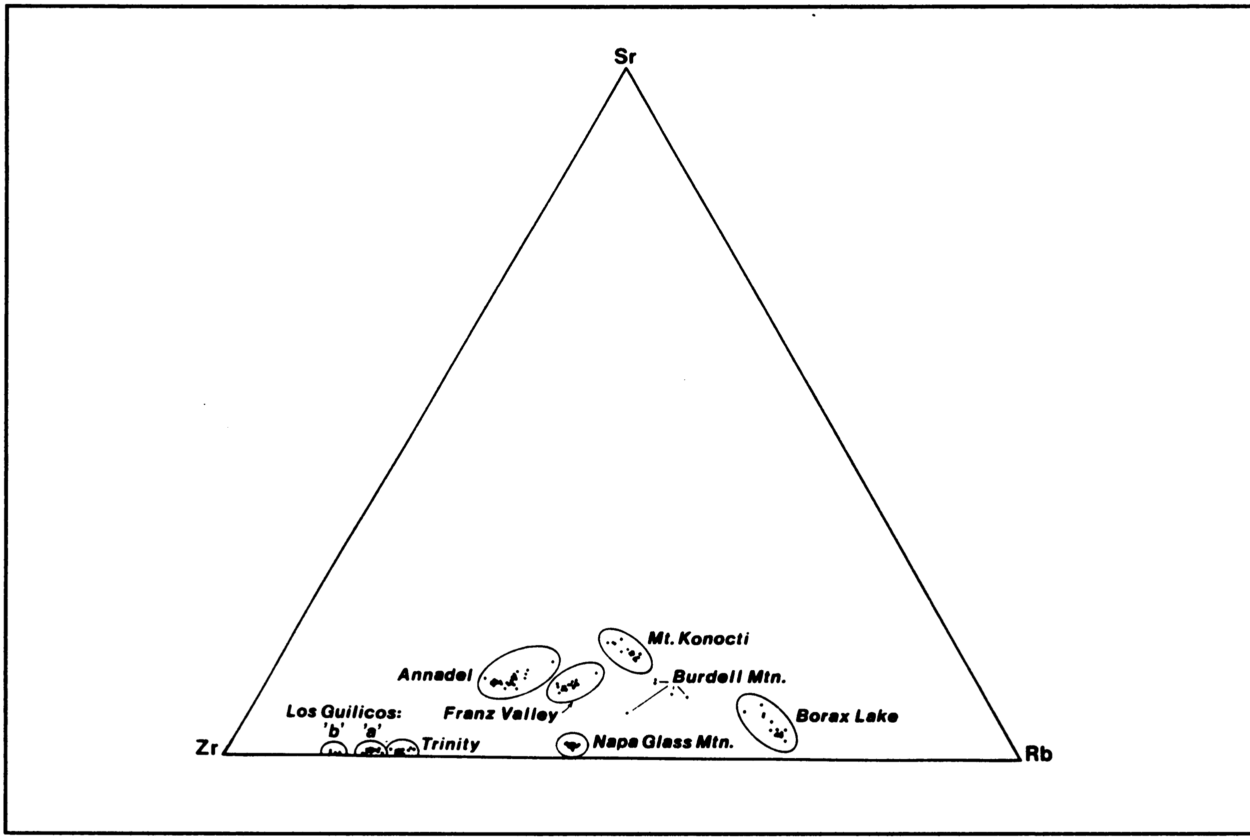
In the upper member of the Sonoma Volcanics we find the famous "Napa Glass Mountain" quarry and several other newly documented quarries which I call Blossom Creek, Crystal Summit, and Meg's Crown. These quarries all yield obsidian which is chemically and physically very similar, although slight chemical variability exists among them. In addition to these quarries, a chemically distinctive obsidian is found in tuffs of the upper member of the Sonoma Volcanics near Franz Valley. Other quarries are likely to exist.

Annadel

The Annadel obsidian quarry is located in what is now Annadel State Park in Sonoma County. The aboriginal quarry area is still covered with with vast amounts of obsidian flakes, partially completed tools, and rejected raw material. Heizer and Treganza (1944:304) cite a personal communication with L. L. Loud, pioneering California anthropologist, to the effect that quarry depressions excavated by the Indians were still visible ca. 1940. More recently Parkman (1983) indicates that some of these features remain. It is certainly true that distinct lithic reduction activity areas are still discernible at the site. Although the Annadel quarry has been explored by many archaeologists over the years, to my knowledge no comprehensive mapping of the quarry exists. A map of the main quarry area made by archaeology classes from Santa Rosa Junior college is on file at the Northwest Information Center, Sonoma State University.

Although obsidian is available in considerable volume at Annadel, the glass occurs ordinarily as relatively small pieces within a matrix of deeply weathered brecciated perlite (Higgins 1983:240). Obsidian pieces larger than fist-size are unusual in the quarry areas, although obsidian cobbles measuring as much as 30 centimeters in diameter can be found in

FIGURE 3
RELATIVE CONCENTRATION OF RB, SR, AND ZR IN NORTH COAST RANGES OBSIDIAN TYPES



nearby Santa Rosa Creek. Unmodified obsidian pieces are usually encrusted with a stubborn cortex which must be removed in the process of tool manufacture.

In its physical appearance Annadel obsidian tends to a matte or "greasy" luster, and the color is gray-black, often with distinctive banding, and a brownish tint. Occasionally one encounters Annadel obsidian of exceptional quality, exhibiting nearly vitreous luster, with a rather dense black color in reflected light. Rarely Annadel obsidian will have a reddish-brown color through thin edges when held before a strong light. The majority of Annadel obsidian is opaque. Origer (1982:194) has described Annadel obsidian as having a "dirty" color, and given the brownish tinge to the general grayish color often observed, this impression is appropriate. Origer's suggestion that Annadel obsidian is sometimes "greenish" is possibly in reference to obsidian which is recognized now as chemically distinct from the obsidian of the main Annadel quarry area and which I call Los Guilicos.

Annadel obsidian is also found in the Glen Ellen Formation, for example at the Oakmont collection locality (Figure 1: SV-1; Jackson 1986:53). It also occurs in more recent alluvial and fluvial deposits which incorporate material eroded from the Annadel quarry vicinity (e.g., along Santa Rosa Creek).

Los Guilicos

Two peralkaline obsidians (Los Gulicos A and B), distinguished by physical appearance and chemistry, are found in the southern portion of Annadel State Park, along the eastern slopes of Bennett Mountain, and as redeposited material in the Glen Ellen Formation on the west side of the Sonoma Valley. The in situ context of the obsidians is not yet established. The geographical distribution of the glasses would suggest that they are possibly eroding from the base of units mapped as "perlitic rhyolite" by Fox et al. (1973) in the Annadel State Park vicinity. Samples have been collected from Buick Meadow, Frey and Schulz Canyons and Glen Ellen Formation deposits at Oakmont (Figure 1).

Los Guilicos A is distinguished by its dull, greasy luster and typically gray to gray-green color. This obsidian generally lacks any inclusions. Pebbles of the glass I have observed rarely exceed 4 centimeters in greatest diameter. Los Guilicos A makes up the majority of the obsidian collected at the Oakmont sampling locality. Trace element chemistry of the obsidian is given in Jackson (1986:198, samples Oak2-Oak7, Oak11-Oak12, and Oak15-Oak18). To my knowledge there is no evidence that this material was actually quarried by aboriginal people. It is more likely that pebbles were collected off the ground if potentially useful pieces were encountered. Artifacts of this material have been found at CA-SON-455 and at sites in the Sonoma Valley.

Los Guilicos B is very similar in appearance to some Mt. Konocti obsidian, with a brilliant luster, numerous phenocrysts, and a black color in reflected light. Quite unlike Mt. Konocti glass, Los Guilicos B has a very definite green color when held before a strong light source. Pebbles of this material at the Oakmont collection locality rarely exceed 2 centimeters in greatest diameter. Trace element chemistry for Los Guilicos B samples from the Oakmont locality is given in Jackson (1986:198, samples Oak8, 9, 14, and 19).

I believe that Amaroli (1982; see Parkman 1983) was the first investigator to report the recovery of what I call Los Guilicos (generic) obsidian in an archaeological context. In his x-ray fluorescence analysis of obsidian from CA-SON-995, about 4 kilometers southeast of the main Annadel quarry area, Amaroli identified obsidians with what he perceived to be three distinct "trace element profiles." Unfortunately, Amaroli's analyses cannot be reproduced because he did not provide quantitative element concentration data, nor were his analyses calibrated against international rock standard values. Two of Amaroli's "trace element profiles" probably correspond to the typical Annadel obsidian chemical fingerprint, and the third to the chemical characteristics of what I call Los Guilicos, at least for the elements Rb, Sr, and Zr, which were the elements he employed.

Trinity

This obsidian has been found eroding from the base of rhyolitic flows on the east side of Sonoma Valley in the Calabazas Creek-Trinity Road area (Figure 1). Obsidian generally occurs at approximately the 400-foot elevation east of Highway 12. Trinity obsidian is a fine, dense black glass with minor inclusions. Phenocrysts (up to 3 mm long) sometimes appear elongated. In a few samples the glass has an almost metallic sheen. Banding is common, and luster ranges from a textured, greasy appearance, to vitreous. Light passing through thin shards reveals a predominately gray color with a distinctive gold-brown tint.

Trinity obsidian is found as rounded fragments up to ca. 15 centimeters in maximum diameter, although the vast majority of fragments are less than a third that size. The in situ obsidian occurs in a rhyolitic matrix, apparently the contact zone between units mapped by Fox et al. (1973) as rhyolitic flows ("Tsr") resting upon "andesitic to basaltic lava flows" ("Tsa"). This obsidian is also found in Glen Ellen Formation deposits in the west side of Sonoma Valley near Oakmont. This suggests that the geographical distribution of the obsidian extends north and south along the eastern edge of the Sonoma Valley from the collection locality.

Pebbles of Trinity obsidian from the base of the rhyolitic flow often exhibit a distinctive vesicular cortex typical of material rapidly chilled in a basal flow environment. Pebbles of Trinity obsidian in the Glen Ellen Formation are sufficiently rounded that this characteristic cortex is often obliterated.

While no clear evidence of aboriginal quarrying of Trinity obsidian has been found, neither has there been any concerted effort to locate any quarries of this glass. The area near the intersection of Trinity Road and Highway 12 remains, to my mind, the most likely area in which any such quarry might exist. Alternatively, it is possible that this material was simply scavenged from the landscape. Until we have a better understanding of the nature of the in situ occurrence of this glass we will not fully understand the methods of its procurement. Artifacts made of Trinity obsidian have been found at the collection locality and from CA-SON-120 approximately 1 km northwest of the Trinity Road locality.

OBSIDIAN IN THE UPPER MEMBER OF THE SONOMA VOLCANICS

Four major obsidian quarries are now known in the upper Napa Valley. For practical purposes these are indistinguishable in both physical (visual) and chemical (trace element) attributes. Unlike the foregoing discussion of obsidians in the lower members of the Sonoma Volcanics which focused on the unique physical and chemical properties of each obsidian, the following description is based on the differentiation of geographically discrete aboriginal quarries and their distribution within specific geologic map units.

Obsidian from the vicinity of Franz Valley, west of Napa Valley, is chemically unique among the obsidians from the upper member of the Sonoma Volcanics. Two localities where this material occurs have been sampled.

Glass Mountain

One of the best known sources of obsidian in central California is at Glass Mountain (often called "Napa Glass Mtn."), in the northern Napa Valley near the town of St. Helena (Figure 1). The mountain is dotted with quarry pits excavated by aboriginal miners. Heizer and Treganza (1944:304) estimated that "at least 100,000 cubic feet of obsidian flake refuse" blanket the slopes of the quarry area (cf. Heizer 1951:40, 42). This is probably a conservative estimate.

Glass Mountain obsidian is found in a matrix of tuff and perlite. Fox (personal communication 1984) believes that this locality represents a volcanic vent (cf. Fox et al. 1973). Obsidian from Glass Mountain is usually found as relatively small pieces throughout the ashy matrix, rarely exceeds 30 cm in maximum diameter, and most pieces are less than half that size. Much of the obsidian is encrusted with a rough cortex.

Obsidian from this source is typically very dense black, glossy to vitreous in luster, and opaque in all but the thinnest fragments. The glass is of a very high quality for knapping, and is generally free of inclusions and vesicles. Color of the obsidian varies and in addition to the common dense black, there are various shades of dark coffee brown, and, rarely, reddish brown. Flakes of Glass Mountain material which show a streaked, reddish-brown (rust) coloration when held before a strong light also occur. Another characteristic obsidian is a very fine glass, tending to a vitreous luster, more translucent, pale charcoal gray, and sometimes transparent in samples up to 3 mm thick.

Meg's Crown

Approximately 1.7 km NNE of the Glass Mountain quarry is an obsidian quarry area which I call Meg's Crown (Figure 1). Obsidian is exposed along the very steep south and east-facing slope of the narrow ridge which separates Dago Valley and Pratt Valley. The slopes of the hillsides are very densely covered by a mixed evergreen forest community liberally populated with poison oak. The lower southern and western slopes are planted in vineyards. No effort was made to map the extent or distribution of either the geology or cultural remains at this locality which is on private properties held by many owners.

Fox et al. (1973) map the area of Meg's Crown within a pumicitic ash-flow tuff unit. Much obsidian on the east slope of the ridge has been redistributed by landslides, and a bulldozer track cut to the summit of the hill has displaced large amounts of debitage and bifacially worked artifacts. Much worked material is found in the vineyards extending into Pratt Valley. I saw no evidence of quarry pits during my visits to the locality.

The obsidian at Meg's Crown is, in part, like the opaque, black obsidian so characteristic of Glass Mountain, but much more of the Meg's Crown material displays flow banding as gray swirls and sharp bands through the black glassy matrix. In thin sections the obsidian is primarily pale gray, with darker banding. The various opaque brown shadings known at Glass Mountain are apparently absent here. A small percentage of the glass is superb, flawless material with a very pale brown tint. This latter obsidian is transparent in sections up to 5 mm thick.

Crystal Summit

Approximately 2.4 km north of Glass Mountain and 1.4 km northwest of Meg's Crown is the Crystal Summit obsidian quarry (Figures 1 and 2). I thank Dr. John Rick, Stanford University, for bringing this locality to my attention. As with Meg's Crown, I have made no attempt to conduct a detailed mapping of the site, which is mostly wooded and covered with stands of poison oak.

The obsidian at Crystal Summit is exposed as small chunks and fragments generally less than 8 cm in greatest diameter, although larger pieces may occur. Fox et al. (1973) map this area in the same geologic unit as Glass Mountain. The obsidian apparently occurs in a rhyolitic tuff which caps a rhyolite flow. There is abundant evidence of aboriginal tool manufacture but no quarry pits were seen on my visit.

The obsidian at Crystal Summit is much like that at Meg's Crown and is characteristically banded. Unlike Meg's Crown and Glass Mountain a notable proportion of the Crystal Summit material has gas voids. I observed numerous preforms and other partially worked artifacts of obsidian with obvious defects of this sort. In many examples the defects were quite conspicuous and yet an effort had been made to complete a tool.

Blossom Creek

The Blossom Creek quarry is 3.8 km northwest of central Calistoga, in the upper Napa Valley (Figure 1). This locality was originally recorded as an archaeological site (CA-NAP-509) by Mrs. Yolanda Beard, although it was not initially recognized as a quarry. Suspicions that the site might be a quarry were first voiced to me by Thomas M. Origer, Sonoma State University, and his intuition was confirmed when we visited the site for a first-hand examination.

The geology of the Blossom Creek quarry is more complicated than that of the other Napa Valley sources.

Fox et al. (1973) include the area of the quarry in a unit mapped as Quaternary gravels. It is clear, however, that rhyolite tuffs occur in the quarry area and that obsidian is probably in situ in these tuffs. However, there are also redeposited gravels within the quarry area and obsidian is an important constituent of these gravels.

Franz Valley

Fox et al. (1973) map an extensive area surrounding Franz Valley as pumicitic ash-flow tuff. Obsidian in these tuffs is chemically and physically distinctive. Two localities in the Franz Valley area have been sampled. Obsidian at these localities occurs as rounded obsidian pebbles and cobbles in variable concentrations throughout the tuff deposits.

The FV-1 locality is on the east-facing slopes overlooking Franz Valley in the Devils Kitchen area. Obsidian fragments here are generally less than 3 cm in diameter, with a maximum surface density of approximately 15 per square meter. By contrast, at the FV-2 locality, on the Napa-Sonoma County line where it is crossed by Franz Valley School Road, obsidian pebbles litter the surface over an area in excess of 500 square meters at a density in excess of 100 pebbles per square meter. Most pebbles are less than 5 cm in diameter, however, pebbles in the 10-15 cm range are not uncommon, and cobbles up to 20 cm diameter have been collected. Despite the availability of raw material there is no evidence of tool manufacture at either of the Franz Valley localities. Projectile points made of Franz Valley obsidian have been found at CA-MRN-307 although those three projectile points are the only such artifacts from the southern North Coast Ranges demonstrated to be made of this obsidian (Jackson 1986).

Obsidian from the Franz Valley area is physically and chemically peculiar in some respects. Obsidian of a unique green-brown color with a vitreous luster accompanies the more common solid black and banded black with gray typical of Napa Valley sources. Obsidian of a solid "battleship gray" color with a matte luster is found at the FV-2 locality. Glass with mottled black and gray coloration also occurs. Franz Valley obsidian is chemically differentiated from Napa Valley obsidians by barium element concentrations in excess of 600 ppm (Jackson 1986).

GLEN ELLEN FORMATION NORTH AND WEST OF SANTA ROSA

I noted previously that obsidians from the Annadel, Los Guilicos and Trinity sources are found in Glen Ellen Formation deposits in the Sonoma Valley. As mapped by Fox (1983; cf. Gealey 1951) there is a series of exposures of Glen Ellen Formation deposits north and west of Santa Rosa. I have collected and chemically analyzed samples from four different locations in the Glen Ellen Formation near Santa Rosa (Figure 1). The sample localities are identified by the prefix "SRG."

Obsidian is ubiquitous in the general area around the SRG-1 and SRG-2 localities, but appears to diminish rapidly northward toward Healdsburg. Obsidian specimens at these two localities larger than 5 cm in diameter are rare. However, obsidian pebbles at SRG-1 and SRG-2 are consistently larger than those found at SRG-3 and SRG-4. Obsidian pebbles in Glen Ellen Formation deposits on the west side of the Santa Rosa valley tend to be quite small, rarely as much as 2.5 cm in maximum diameter. Although I have observed larger pebbles, they are invariably highly fractured and virtually disintegrate when one attempts to remove them from their conglomerate matrix. Travis (1952:22) estimates that obsidian makes up some 3% of the material in his "Pleistocene Gravel" unit in the Sebastopol quadrangle near Santa Rosa. This unit has been incorporated, for the most part, into the Glen Ellen Formation by Fox (1983).

Because there are no primary obsidian sources to the west of the Glen Ellen Formation in the Santa Rosa area, the obsidian in those deposits must have been derived from Sonoma Volcanics to the east. This assumption is supported by trace-element chemistry (Jackson 1986) which indicates that that the obsidian in the Glen Ellen Formation near Santa Rosa is of both Napa Valley and Franz Valley chemical types, with Napa Valley material in the majority.

At none of the collection localities is there any evidence of prehistoric quarrying. Given the typically small size of obsidian pebbles in the Glen Ellen Formation it seems unlikely that it would have been a regular source of raw material for aboriginal tool manufacture. However, archaeological collections of artifacts and debitage should be examined closely in order to detect the distinctive cortex which forms on these well-rolled pebbles. Recovery of debitage with such cortex will serve as an index to the extent to which such secondary sources were exploited, possibly for expedient tools.

TABLE 1
TRACE-ELEMENT CONCENTRATION VALUES FOR BURDELL MOUNTAIN OBSIDIAN AND OBSIDIAN FROM THE LOWER MEMBER OF SONOMA VOLCANICS

	Obsidian Source				
Trace-element	Burdell Mtn. (n=5)	Annadel (n=37)	Guilicos A (n=12)	Guilicos B (n=4)	Trinity (n=15)
Rb	159.2	135.8	173.9	146.2	147.1
Sr	29.6	50.3	7.7	2.8	3.6
Y	37.0	46.9	123.3	156.5	72.5
Zr	130.4	271.5	748.8	895.9	513.8
Nb	2.5	14.4	33.0	41.0	25.4
Ba	552.7	595.3	217.9	192.8	313.1
La	31.5	25.5	52.5	54.9	38.6
Ce	67.8	54.4	119.1	123.7	83.2

Notes: Mean values of Ba, La, and Ce for Annadel are for 19 samples; Burdell Mtn. element concentration values are extremely variable due to surface effects and values presented here are rough approximations.

OBSIDIAN IN THE CLEAR LAKE VOLCANICS

Two primary sources of obsidian in the Clear Lake area are Mt. Konocti and Borax Lake. These sources were of great importance to prehistoric people in the region and their economic significance would be difficult to overestimate. Like obsidian in the Sonoma Volcanics, we are not fully aware of all geographical occurrences of volcanic glass in the Clear Lake basin. Therefore we are not able to document with confidence the prehistoric extraction of this resource.

Mt. Konocti

A general description of the obsidian flow on the south side of Mt. Konocti has been given in the introduction to this section. Obsidian in the Mt. Konocti area is available over an area of more than 50 square kilometers (Figure 2), but to my knowledge there are no clearly defined aboriginal quarries per se. The obsidian is readily obtained without excavation. Blocks of obsidian more than 1 meter in greatest dimension have been observed.

The quality of Mt. Konocti obsidian is generally inferior to that of most of the obsidian from sources previously discussed because it contains numerous phenocrysts and tends to be quite brittle. Nevertheless the obsidian was widely employed for the manufacture of the full range of lithic artifact forms known for the region. Mt. Konocti glass ranges in color in reflected light from gray, to brown-black, to brick red-brown.

Borax Lake

The Borax Lake quarry is one of the most famous obsidian sources in California (cf. Heizer and Treganza 1944). This source yields a glass of variable quality, ranging from pumiceous material to a relatively dense glass. The glass ranges from a dark gray-black to a gray "frothy" appearance depending on the amount of gas voids in a given piece. The obsidian has a distinctive texture which also derives from the presence of gas voids in the glass. Obsidian pieces at the source have been observed up to 50 cm in greatest dimension.

TABLE 2
TRACE-ELEMENT CONCENTRATION VALUES FOR OBSIDIAN FROM THE UPPER MEMBER OF THE SONOMA VOLCANICS AND CLEAR LAKE VOLCANICS

	Obsidian Sources						
	Blossom	Crystal	Meg's	Napa Glass	Franz	Borax	Mount
Trace-	Creek	Summit	Crown	Mountain	Valley	Lake	Konocti
element	(n=41)	(n=20)	(n=20)	(n=37)	(n=30)	(n=19)	(n=19)
Rb	189.6	185.7	191.4	195.2	168.4	220.6	211.7
Sr	11.4	5.7	4.9	6.7	45.0	14.8	75.4
Y	44.2	42.8	44.4	46.2	37.7	45.6	38.8
Zr	238.4	224.0	225.2	240.8	235.1	94.4	203.6
Nb	13.7	13.5	14.4	14.3	13.2	15.1	14.5
Ba	471.2	440.7	426.4	414.7	619.8	34.3	626.0
La	28.6	29.8	31.9	31.8	30.0	22.6	30.9
Ce	62.8	64.5	65.4	64.2	63.4	50.8	64.8

Notes: Mean values of Ba, La, Ce for Blossom Creek are for 40 samples.

OBSIDIAN TRACE ELEMENT CHEMISTRY

There is a growing literature on the elemental chemistry of obsidian from the North Coast Ranges. For more comprehensive discussions I direct the interested reader to the following references: Anderson (1936: Borax Lake; Mt. Konocti); Bowman, et al. (1973: Borax Lake; Mt. Konocti); Ericson (1977: Annadel; Borax Lake; Mt. Konocti; Napa Glass Mtn.); Jackson (1986: Annadel; Blossom Creek; Borax Lake; Burdell Mtn.; Crystal Summit; Franz Valley; Los Guilicos; Meg's Crown; Konocti; Napa Glass Mtn.; Trinity). Tables 1 and 2 summarize trace element concentration values of obsidian from different sources, while Figure 3 is a ternary graph showing the separation achieved by Rb:Sr:Zr ratio of concentration values.

Obsidian "Sourcing" in the North Coast Ranges

Studies by Weaver and Stross (1965), Parks and Tieh (1966), Jack (1976), and Jack and Carmichael (1969) represent early efforts by North American chemists and geologists to demonstrate a correspondence between a geological "source" of obsidian and prehistoric obsidian artifacts. Such studies were developed in conjunction with geological studies of techniques to chemically "fingerprint" acid volcanic rocks. Not surprisingly, these geologists approached artifactual raw material source identification in much the same way they approached the general problem of geochemical characterization of other volcanic rocks. A "source" of raw material (e.g., obsidian) is described principally in terms of a geological map unit.

As non-anthropologists, these investigators were not necessarily oriented to the full anthropological implications of their research beyond the simple correlation of original geological source and end point of deposition for an artifact. Thus for example, the discovery of a projectile point of Casa Diablo obsidian in Contra Costa County signaled long-distance trade relations between coastal populations and groups living east of the Sierra Nevada summit. Implicit in these early studies was the assumption that obsidian artifacts were traded as finished items. There also was a lack of concern for discriminating artifacts from different time periods. However, some more anthropologically oriented topics of study, for example, discovering any correlations between "ethnic" groups and distributions of artifacts of obsidian from different sources (Jack 1976), are still of considerable interest to archaeologists.

For the geologist a source attribution is sufficient provided there is a correlation between the chemistry of an artifact and the chemistry of a provenienced obsidian. This is acceptable to the archaeologist as a starting point, but the demonstration of the location and means of resource extraction is mandatory if we are to understand a lithic production system. For the archaeologist and the geologist determining the "source" of lithic raw material exploited by prehistoric people should mean two different things. Geologically it is adequate simply to determine the presence of the material at specific geographical localities. While this is useful for the archaeologist, it is necessary that the term "source" actually relate to a locality where it can be explicitly demonstrated that the raw material was extracted or collected. Here the term "quarry" is appropriate where it can be demonstrated that lithic material was actually mined. "Quarry," however, is technically incorrect to describe a situation in which obsidian pebbles lying on the ground simply are collected. We might better term the latter a "lithic collection locality."

Determining the "source" of obsidian has taken on another meaning with regard to chemical characterization of volcanic glasses. In both geology and archaeology geochemical "sourcing" of obsidian means, in practice, to demonstrate a sufficiently close correspondence in elemental composition that an artifact of an "unknown" obsidian type can be correlated with a chemically described obsidian of known provenience. It is often the case that the chemistry of volcanic glasses is better known than their geographical distribution. It is, therefore, essential that archaeologists differentiate studies which match obsidian artifacts with chemically known obsidian types from studies which actually demonstrate the location from which the obsidian was obtained by prehistoric people.

Two examples make this point more explicitly. The "Napa Glass Mountain" obsidian source is one of the best known in the western United States. Obsidian found at Glass Mountain apparently is geochemically unique for a number of trace element concentrations, and prehistoric artifacts can be distinguished as being of Glass Mountain obsidian rather easily; we can make a correlation between the chemistry of the artifactual obsidian and that of obsidian from Glass Mountain. It has been assumed, by most archaeologists working in the region, that "Napa Glass Mountain" was the source of obsidian in the Napa Valley region and this was supported by the extensive evidence of prehistoric quarry activity at Glass Mountain.

It is now known that Glass Mountain is only one quarry area in the Napa Valley. The recent identification of the Blossom Creek, Crystal Summit, and Meg's Crown quarries in the upper Napa Valley demonstrates that equating obsidian chemical type with an (implied) quarry source of raw material can be misleading. Because the obsidian from these other quarries shows close similarities in chemical and physical attributes with Napa Glass Mountain obsidian their presence in the archaeological record went unrecognized. Obsidian artifacts formerly assigned as "Napa Glass Mountain" now must be attributed as "Napa Valley" since this geographical appellation encompasses all of the known, chemically undifferentiated, obsidian quarries in the area.

However, the upper Napa Valley quarries are not the only locations from which prehistoric people obtained obsidian of the generic Glass Mountain chemical type. Obsidian pebbles are found in Napa River gravels at least as far south as the city of Napa, and these pebbles were exploited as raw material for tools (Jackson 1978). Geochemically these pebbles are identical to Glass Mountain obsidian but they are found more than 30 km south of that quarry. There is no evidence to suggest that the pebbles were extracted from the river gravels by any means other than simple collection methods.

This latter example serves to emphasize the necessity of differentiating between lithic materials found in contexts of original deposition versus materials from contexts of secondary deposition. Quarries and collection localities can represent lithic extraction in either of these contexts. It is important archaeologically to be able to distinguish between the two potential sources of raw material. Technical studies of lithic debris from archaeological sites can very often distinguish raw material derived from different depositional contexts, as for example the difference between cortex on water-worn pebbles and obsidian found in ash tuffs or as massive flows (i.e., in the original depositional environment).

As generally employed, "sourcing" refers to the determination of the geochemical or physical characteristics of artifactual obsidian, and the comparison of these attributes with those of obsidians from known geological localities. I urge, however, that only if the physical or chemical attributes of an obsidian are unique to a specific quarry or collection locality should we claim to have determined the actual source of the raw material from which an artifact is made. Artifacts of glass from the Borax Lake quarry would meet these criteria because that source is both geographically discrete and chemically unique. Otherwise analyses of artifactual obsidian only provide a general provenience for the known geographical distribution of all chemically similar obsidian within a region. As I will discuss in the last part of this paper, a precise understanding of the geography of obsidian sources is a necessary condition of effective obsidian exchange studies.

STRUCTURE OF PREHISTORIC OBSIDIAN PRODUCTION AND EXCHANGE

In this section I offer some preliminary hypotheses based on extant data, conjure some speculative proposals, and open topics for future research. In an effort to place obsidian production and exchange in a broader social and economic context I present an abbreviated comparison of developments in obsidian projectile point and shell bead production ca. A.D. 1500 in west central California.

Selective Use of Obsidian Types

Of nine chemically distinct obsidians found in the North Coast Ranges there is archaeological evidence for the extensive use of only four types for the manufacture of arrow points: Annadel, Napa Valley, Borax Lake, and Mt. Konocti. Of a sample of approximately 2,000 projectile points only three of Franz Valley glass are demonstrated to be of another obsidian type. Glass quality is not a determining factor except when obsidian occurs as pebbles too small for point manufacture (Jackson 1986).

One implication of the evidence for selective use of obsidian types is that social or political means existed to restrict obsidian use by projectile point (or arrow) makers. Precisely how this might have operated is unclear. Another line of evidence, consistency in percentages of obsidian types represented at archaeological sites within a given tribelet territory and among sites representing multiple neighboring tribelets (Jackson 1986), suggests that some mechanism for management operated at local (village- or tribelet-specific) and regional (multi-tribelet) levels. Extrapolating from ethnography, we could conclude that the political and economic authority of village leaders was sufficient to exercise very explicit and pervasive control through the redistribution of resources. Also implied is a political unity and perhaps a class distinction among these social elites. Maintenance of that class and its authority may have been through the regulation of exchange in general, including the exchange of wealth items like clam disk beads (cf., e.g., Brumfiel and Earle 1987; Cohen 1983; Earle 1982; Kohl 1975; Pires-Ferreira and Flannery 1976).

As I have demonstrated (Jackson 1986), obsidian exchange can be linked to inter-group marriage patterns. But exchange commensurate with marriage is only one aspect of the regional exchange system. For example Wappo tribelets of the Napa Valley, who had no marriage ties with the Gualomi Pomo who controlled the Annadel obsidian quarry, were extremely successful in preventing the import of Annadel obsidian projectile points into the Napa Valley. By contrast, all Pomo tribelets which controlled obsidian sources also imported projectile points (and possibly some raw material) made of obsidian from sources outside their territories (Jackson 1986).

There is no demonstrably consistent correlation between geographical distribution of projectile points made of specific obsidian types and "ethnic" or "ethnolinguistic" groups per se. Obsidian point distributions reflect social and economic ties between tribelets, and regional exchange must be understood at this scale of social interaction (see Hughes and Bettinger 1984).

The importance of the exchange of obsidian projectile points is emphasized by the selective use of lithic materials for projectile points in general. Obsidian is not the only lithic material in the North Coast Ranges from which projectile points could be manufactured, but, in the southern North Coast Ranges, arrow points are made predominately of obsidian, even when alternate materials (e.g., chert) are available.

Bouey (1986:Appendix 4a) has demonstrated a preference for obsidian projectile points at sites in the Lake Sonoma area even though local chert quarries were mined and employed for other tool types, including arrow points. Artifact data from CA-MRN-471 are another example. A chert quarry is ca. 1.6 km away and chert occurs in the stream bed adjacent the site. Nevertheless, of 165 projectile points from the site only nine are of chert; the rest are made of either Annadel or Napa Valley obsidian. The closest Napa Valley quarry and the Annadel quarry are 48 km and 41 km north of CA-MRN-471, respectively.

It is not clear how obsidian use for other tool types corresponds with, or differs from, the selectivity demonstrated for arrow points. Functional considerations aside, there are preliminary data from which to argue that some obsidian types were restricted for local consumption and did not circulate generally in regional exchange systems. Trinity, Los Guilicos, and possibly Franz Valley obsidian are examples. It would seem prudent in future studies to recognize that obsidian type proportions may vary according to artifact type, and that this sort of variability may differ between regions or individual consumer groups.

Ethnographic accounts (e.g., Barrett 1952; McKern 1922) indicate that craft specialists, including arrow (point) makers, net makers, and bead makers were part of native societies and that these individuals were social elites. Craft specialization for obsidian projectile point manufacture is not clearly demonstrated in the central California archaeological record using the materialist criteria for identifying craft specialization advocated by, for example, Arnold (1984). However, several more indirect lines of evidence could support an argument for craft specialization in late prehistory.

There is evidence in the archaeological record for the distribution of shell and obsidian raw material as unfinished artifact forms. The exchange of raw material or partially completed items for both obsidian point and clam disk bead manufacture may have served to sustain the position of "craft specialist" in villages where inhabitants were without direct access to obsidian or shell raw material. You can't have an operational craft specialist if the individual has nothing upon which to practice his craft.

If artifacts were made only by specialists in tribelets which controlled sources of raw material, or within short distance of such groups, then there could be no production by specialists in outlying tribelets. I suggest that raw material and partially completed artifacts were traded among specialists to maintain them as social elites and to perpetuate the social relations of production. Whether specialists were independent of, attached to, or one-and-the-same-as the political leadership is another issue (see Brumfiel and Earle 1987:5-6 for an excellent summary discussion).

With regard to both obsidian projectile points and clam disk beads an interesting development occurred ca. A.D. 1500 in central California. Knappers began producing projectile points that were morphologically simpler; the serrations which characterize arrow points of the preceding several centuries were no longer made. Projectile points became somewhat smaller, were made from thin triangular flake blanks, and show progressively less invested knapping effort, especially in the latest prehistoric times. The basic form of arrow points in the southern North Coast Ranges after A.D. 1500 is a relatively uniform corner-notched or corner-removed shape which could be modified easily to accommodate the aesthetic/stylistic demands of a range of consumer societies.

Clam disk beads also represent a move toward simplification of production, but they also demarcate increased social complexity. The advent of these beads may signal development of a wealth item reserved for manipulation by social elites. Unlike Olivella shell beads which had become pervasive in a socially less differentiated economy, the principal role of clam disk beads was in maintaining status among elites engaged in inter- tribelet exchange (cf. Miller 1982; King 1971). Ethnographically bead makers were social elites (e.g., Barrett 1952; Gifford 1926; McKern 1922).

I suggest that elites controlled production of both clam disk beads and arrow points and maintained their control in the face of increased population growth, and resulting demand, by simplifying production (in the case of clam disk beads by instituting an entirely new form). Simplified forms allowed increased production with the same investment of labor, i.e., efficiency was increased. Standardization of point and bead forms allowed a greater latitude of materials to move in regional exchange systems without precluding local specialists from making finished artifacts which conformed to local stylistic considerations. In the example of clam disk beads, however, stylistic variation was minimized in consideration of the very extensive geographical distribution of these wealth items.

Volume of Production

Although there have been no serious efforts at quantifying the production of obsidian from North Coast Ranges sources, either in terms of volume of raw material extracted or artifact manufacture and consumption, it seems clear that the recent discovery of several major obsidian quarries should substantially increase whatever intuitive sense of production volume we may have. There are significant methodological problems inherent in attempts at measuring production volume. In most central California sites we lack the refined stratigraphy or relatively precise dating which are hallmarks of, for example, sites in the Southwest. Without precise temporal control, estimating obsidian volume in sites is extremely speculative. Nevertheless, even crude measures of production volume are an essential component of exchange studies which focus on aspects of the economy other than consumption (cf. Torrence 1986).

CONCLUSION

The recent discovery of several new obsidian quarries in the Napa Valley illustrates the difficulty of carrying out archaeological research concerning obsidian production in prehistory. Geologists, who have done extensive and detailed mapping of many areas of the United States, do not consistently differentiate obsidian from other rhyolitic or related rocks for mapping purposes. If they did, our job would be made considerably easier. But they don't, so a duplication of effort occurs each time an archaeologist searching for obsidian re-surveys an area mapped by geologists.

Survey in the rapidly developing urban and suburban areas of the North Coast Ranges is becoming increasingly difficult. The landscape is being steadily divided into smaller and smaller privately-held tracts, access to which is increasingly hard to gain. Efforts to systematically survey large-size areas with owners's permission are bogged down by attempts to obtain authorization to trespass. Yet if we cannot acquire a true sense of the geographical extent and intensity of prehistoric obsidian exploitation we cannot reasonably expect to understand this critical topic in archaeological exchange studies.

Exchange studies also require precision in the use of terminology. "Sourcing" obsidian by geochemical methods does not necessarily advise us of the quarry or collection locality for the raw material in the sense that we typically employ that term. As we come to recognize that prehistoric people may have obtained obsidian from <u>some</u> but <u>not all</u> localities on the landscape it behooves us to differentiate among these potential sources to understand how prehistoric populations created and exercised behavioral options.

We are only beginning to define the cultural context of prehistoric obsidian exchange in central California. At present there is tantalizing evidence to suggest that obsidian exchange took place within closely regulated redistribution systems. There was no monolithic "obsidian exchange system." Obsidian was only one commodity moving in regional systems, and obsidian in different forms very likely was distributed in very different ways.

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