THE TUSCAN OBSIDIAN SOURCE OF NORTHERN CALIFORNIA: ARCHAEOLOGICAL IMPLICATIONS AND GEOCHEMICAL VARIABILITY

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ABSTRACT

Prior to this study there had been no formal attempt to identify the full geographical extent and geochemical variability of the Tuscan obsidian source contained within the Tuscan Formation. Field investigations conducted by the author identified eight new glass sources within this northern California geological formation. Obsidian characterization of samples revealed significant geochemical differences between several of the locales, indicating that in addition to the known sources (Hughes 1983), there are two new identifiable geochemical groups. Archaeological implications of these source groups will be discussed in regards to the lithic procurement patterns of the prehistoric inhabitants who inhabited northcentral California.

INTRODUCTION

Despite the fact that California has been at the forefront of obsidian characterization studies from the very beginning, until the last 10 years, obsidian now known to originate from the Tuscan Formation was merely identified as "Source X". While trace and rare earth element analyses performed by Hughes and Hampel (Hughes 1983: 324) demonstrated that Tuscan obsidian localities were, in fact, the geographic counterparts for Jack's (1976:198) "Source X" distribution, to date, no formal attempt has been made to characterize the full geographical extent and geochemical variability of obsidian sources contained within this formation.

The early research conducted by Jack (1976) and Hughes and Hampel (1983) provided archaeologists with a rough understanding of the distribution of obsidian artifacts that originated from this geological source. Viewed from a geologist's perspective, a source attribution was considered to be sufficient provided there is a correlation between the trace element composition of an artifact and the composition of a provenienced obsidian source.

While this viewpoint may provide an acceptable starting point for the archaeologist concerned with lithic production systems, in order to fully understand the attributes of lithic sources that are likely to have been important to prehistoric stoneworkers, it is necessary to first examine the raw material variation which may be present within a specific "source" from a regional perspective. As Basgall (1989:111) so succinctly points out, "Especially critical is an ability to track the spatio-temporal dimensions of stone tool use across large regions". But this cannot be done with precision unless we have the ability to recognize intra-source variations with some accuracy. With these perspectives in mind, this study had as its principal objective the gathering of relevant data regarding the archaeological, geographical, petrological, and geochemical variability of artifact-quality glass derived from the Tuscan obsidian source located in northern California.

Proceedings of the Society for California Archaeology, 1995, Vol. 8, pp. 13-32.

THE TUSCAN FORMATION

The Tuscan Formation is situated within the southernmost portion of the Cascade Range in northcentral California. Although the Pliocene Tuscan Formation is thought to span a relatively small segment of geologic time, research has revealed that it is discontinuously exposed throughout an area of approximately 2000 square miles along the east side of the northern Sacramento Valley (Figure 1). Originating largely from a belt of isolated eruptive centers in the southernmost Cascade Range, the Tuscan Formation consists principally of tuff breccias formed by lahars, or volcanic mudflows, in beds ranging from 40 to 100 feet thick. The entire eastern accumulation reaches 1000 feet in thickness (Anderson 1933: 223). Erosion of the formation has resulted in the removal of the finer materials, leaving behind a surface concentration of the larger blocks to form the broad stony plains so characteristic of the foothill region east of Red Bluff and Redding.

While there was much speculation on the source of origin of the Tuscan Formation, no one was to write of it until Anderson and Russell observed that "... the source of the Tuscan formation must have been old volcanoes in the vicinity of Lassen Peak or farther east" (1939:231). Subsequent work examining the difference in the prevalent rock type among the blocks suggested to Lydon (1961) that there must be different sources for the breccias of the southern and northern areas. Because of these differences in rock type, Lydon (1961:463-466) believes that three major and at least four lesser source areas provided laharic debris to the Tuscan Formation.

Major contributions are thought to have come from two Pliocene composite volcanoes, Mount Yana, which is centered a few miles southwest of Butt Mountain and Lake Almanor, and Mount Maidu, which was once centered over the town of Mineral. The laharic deposits of Mount Yana are continuous with those of the main part of the Tuscan Formation and clearly form one of its principal sources (Lydon 1968:463). Although the relationship of the Tuscan Formation to the remnants of Mount Maidu is less clear than in the case of Mount Yana, research has shown that "... at least the earlier phases of activity of Mount Maidu itself must have contributed substantial debris to the Tuscan Formation" (Lydon 1968: 465).

Subordinate volumes originating from an area of indefinite structure situated north of Latour Butte constitute another major source for the Tuscan Formation (Lydon 1968). It is in this area that more than 1000 feet of Tuscan Formation deposit consisting chiefly of interbedded flows of andesite, beds of tuff breccia, and welded tuffs is clearly exposed. Unfortunately, the immediate source area of this deposit lies just to the east where it is covered by later volcanic flows, so that nothing can be said of the mechanisms of formation and emplacement (Lydon 1968:465).

Minor sources include an obscure area near Hatchet Mountain Pass, which may turn out to be the most significant source area for this study. Scattered outcrops of andesitic tuff breccia and associated thick accumulations of dacitic ash-flow pumice tuffs, some of which are welded, have been observed here (Lydon 1968:465). As observed at Latour Butte, thick successions of the latest Pliocene and early Pleistocene andesitic flows have obscured the details of the origin of the Tuscan Formation at this locality (Lydon 1968). Of interest to note is the fact that most of the previously reported sources of artifact-quality Tuscan obsidian can be found within this region.

Other minor and/or possible sources of the Tuscan Formation include tuff-breccia dikes south and southeast of Inskip Hill along State Highway 36 and possibly the Campbell Mound north of Chico. Although the morphology of the Campbell Mound suggests some sort of dome-like feature, whether it represents upwarping beds above a shallow intrusion, a primary laharic vent, or a source of secondarily mobilized tuff breccia cannot be stated with certainty at the present time (Lydon 1968).

"Source X"

Prior to this study, four individual exposures

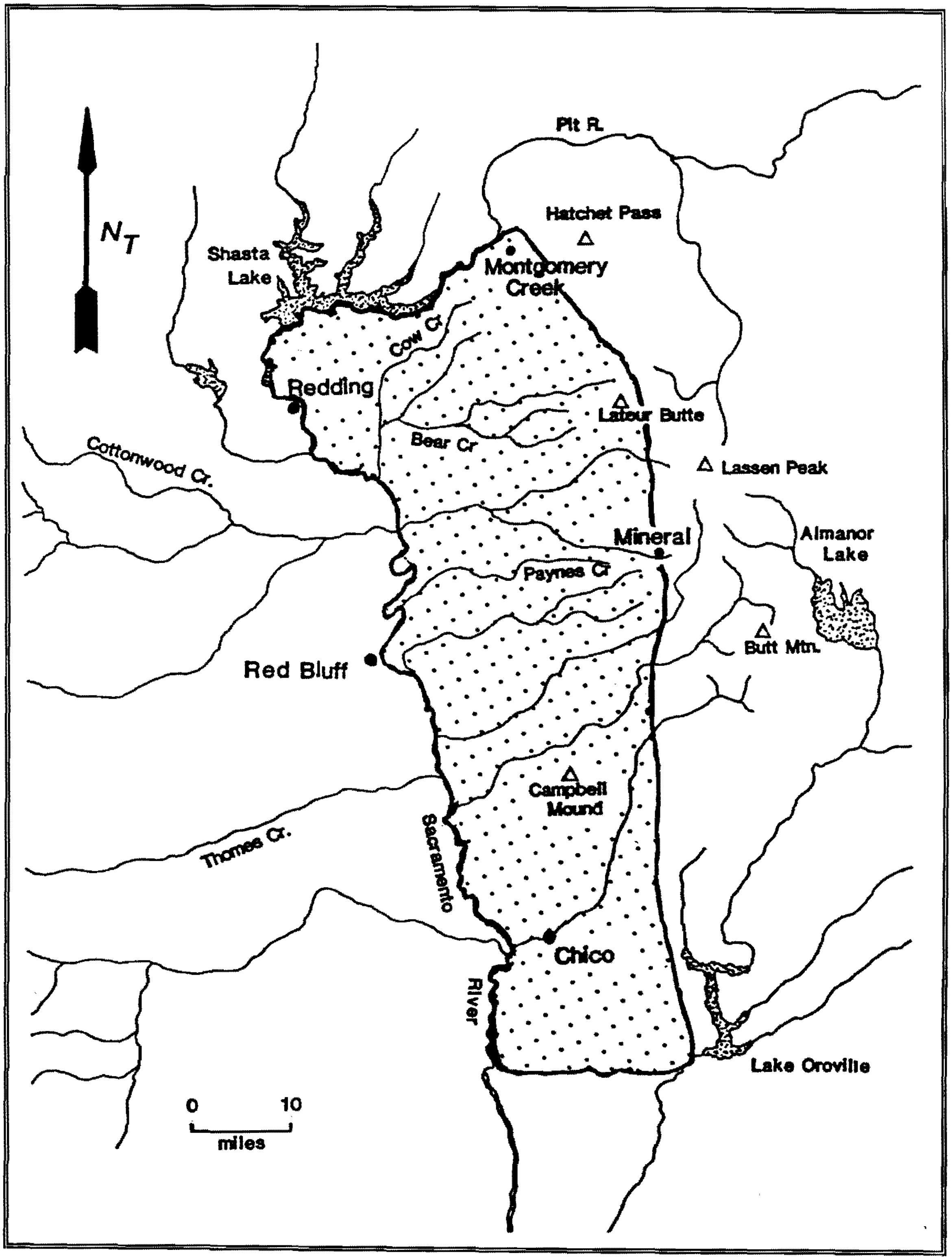

Figure 1. The study area.

of obsidian falling within the geographical confines of the Tuscan Formation within the study area had been located and summarily described by Hughes (1983:322-324). Within this particular geographic area, Hughes determined that it was possible to recognize similarities in their trace element chemistry which allowed all four exposures to be grouped into one chemical type (Hughes 1983:294). The names of the chemical types analyzed by Hughes are Backbone Ridge, Cow Creek, Oat Creek, and Buzzard Roost (Figure 2).

Determining the location of the primary source of the obsidian nodules in the Tuscan Formation has some importance for archaeology. The Tuscan Formation occupies an area which encompasses the traditional territories of at least three different ethnographic groups, the Wintu, the Yana, and the Maidu. If these sources of obsidian were controlled by certain prehistoric groups during the later periods, then the location of the source becomes an important determinant in the reconstruction of prehistoric exchange, interaction, territory, or procurement range. As pointed out by Shackley (1992:324), "It is not enough to discover, describe, and chemically analyze a glass source if the extent of the secondary deposits are not understood within the context of the region".

Unfortunately, the nature of the Tuscan Formation creates a special problem for archaeologists who are attempting to analyze the lithic production systems in this region. Research has revealed that the formation consists principally of tuff breccias formed by lahars, or volcanic mudflows. These volatile lahars spread over a large region during the Pliocene and the remnants of this formation today are discontinuously exposed throughout an area of approximately 2000 square miles along the east side of the northern Sacramento Valley. In other words, the depositional processes associated with these lahars indicate that artifact-quality glass may occur throughout the formation. Moreover, given the complex and incomplete geological history of the region, it will be difficult to predict where individual outcrops or localities of obsidian will occur, and to interpret how and where one source area relates to another source area.

Evidence to date indicates that volcanic activity associated with the formation of Tuscan lahars proceeded in point of time from south to north with at least three major and four lesser source areas providing the laharic debris to the Tuscan Formation (Lydon 1961:463-466). Furthermore, it appears that rather than a single enormous episodic mudflow event, a number of lahars of nearly identical consistency were deposited over a period of years. Therefore, it is possible that each of these original lahar source areas might have produced a chemically distinct obsidian source depending upon the location of the volcanic vents and the period of time in which the eruptive event occurred.

Although some obsidian sources in the Tuscan Formation, such as the Backbone Ridge area, are well known to local archaeologists, only summary documentation for these locales exists (Hughes 1983). Since it was clear that detailed documentation and additional petrological and geochemical analyses of the artifact-quality obsidian present at these "known" locales could provide additional information regarding the Tuscan obsidians, the decision was made to include the previously known source locales of Tuscan obsidian noted by Hughes (1983) and others as part of this study's sample collection (Al Farber, personal communication 1992; Richard Jenkins, personal communication 1991; Ritter 1992; Elaine Sundahl, personal communication 1990).

The strategy for locating "unknown" sources followed a general pattern based on geological and topographical information. Although regional geological maps were initially consulted to ascertain the location of exposed deposits of the Tuscan Formation, the best sources of information for locating obsidian were archaeologists, foresters, and local residents. It was also found that since the Tuscan Formation has been highly eroded in many places, nodules from the exposed ridgetops would be released into the sediment load of nearby drainages, in which case an examination of the

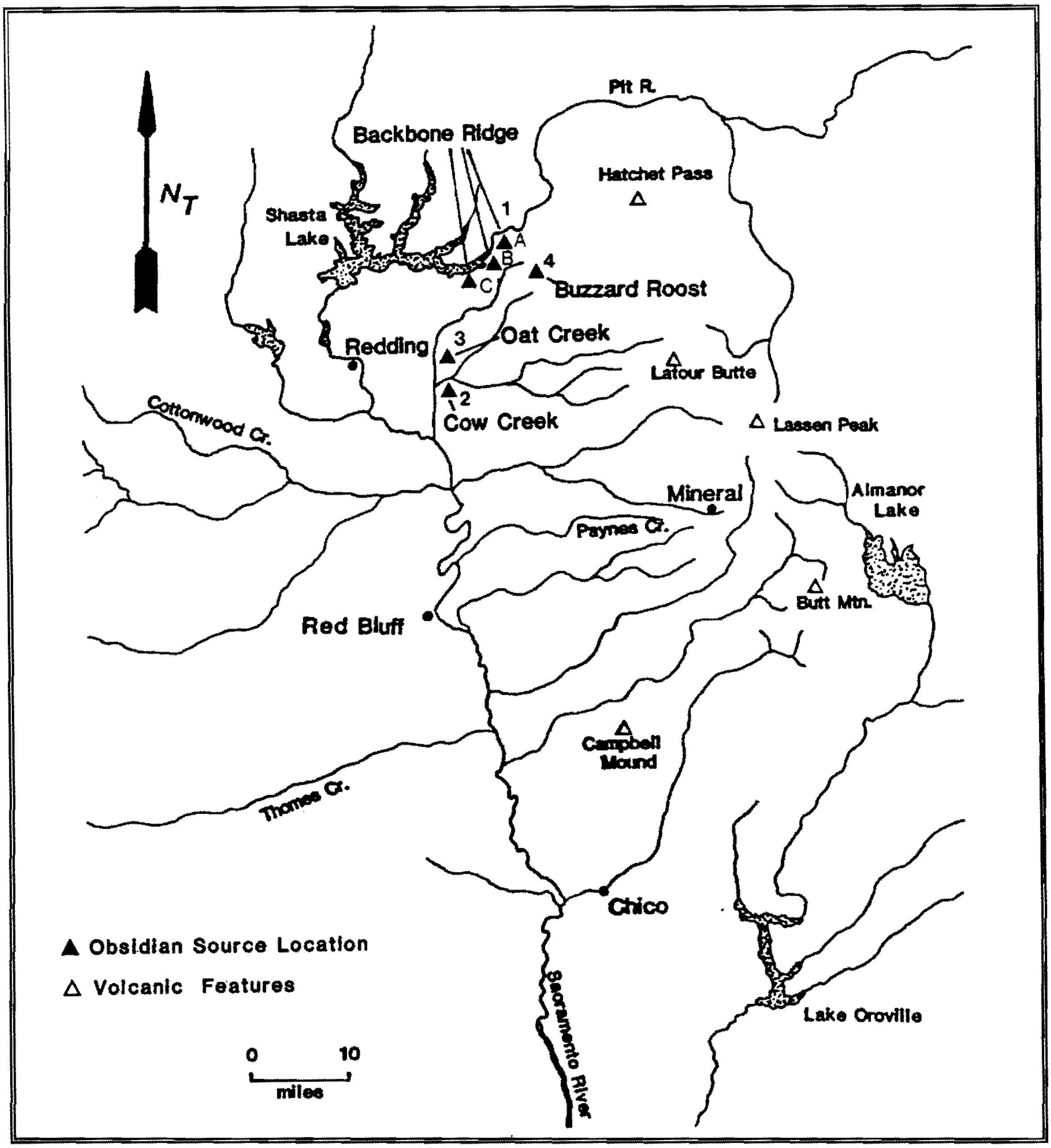

Figure 2. Tuscan Obsidian Source Localities. Source: Hughes, R.H., 1983, <u>Exploring Diachronic Variability in Obsidian Procurement Patterns in Northeast California and Southcentral Oregon: Geochemical Characterization of Obsidian Sources and Projectile Points in Energy Dispersive X-Ray Fluorescence</u>. Unpublished Ph.D. dissertation, Department of Anthropology, University of California, Davis. Adapted.

stream channels proved useful in locating additional source locales.

RESULTS

As a result of this survey, eight previously unidentified artifact-quality glass sources were found within the Tuscan Formation (Figure 3). They include the Paynes and Inks Creek source locales, the Paradise Ridge 1 and 2 source locales, the Oat/Swede Creek locale, the Dry Creek Tributary locale, the Woodman Hill Ridge locale, and the Sugar Pine Ridge locale. Previous x-ray fluorescence studies conducted by Jack and Hughes indicated that within-source trace element variability for the Tuscan source group was minor in comparison with other obsidian sources. However, since the source locales were found to occur in widely dispersed areas, the decision was made to reexamine the data to investigate whether geochemical variability might exist among the various collection loci.

The trace and rare earth element analysis of the obsidian specimens were performed in the Department of Geology and Geophysics, University of California, Berkeley, using a Spectrace 440 (United Scientific Corporation) energy dispersive x-ray fluorescence (EDXRF) spectrometer. Fifteen specimens were blindly selected from each source sample locality for EDXRF analysis. All specimens were first fractured with a rockhammer using bipolar reduction in order to obtain a relatively flat and fresh surface. The specimens were analyzed whole and were not reduced into pellets or fused disks. Before placing them in the EDXRF unit, the specimens were initially washed in tap water and then rinsed with distilled water and air-dried.

Table 1 presents the selected minor, trace and rare earth element measurements determined for obsidian samples from each sampling locus. Minor, trace and rare earth element data exhibited in Table 1 are reported in parts per million (ppm), a quantitative measure by weight. The raw measurements for this data reduction can be found in Hamusek-McGann (1993). Since quantitative values for the element barium (Ba) have proven extremely useful for distinguishing between some chemically similar obsidians (e.g., Kelly Mountain vs. certain Medicine Lake Highlands obsidians), Ba concentrations were measured on 5 specimens from each sample group except for the Paradise Ridge 2 and Backbone Ridge 4 sources.

Three separate discriminant analyses were executed on the entire set of specimens from the 15 obsidian source locales. The first analysis employed untransformed trace element concentrations for the nine best measured elements with each source locale being considered as geochemically distinct. The results of this analysis indicated that difficulties arise in attempting to assign group membership if all 15 groups are considered to be separate and distinct sources. The percent of "grouped" cases correctly classified was weak (50.65%) when each locus was considered to be a separate source.

For the second analysis, each source locale was divided into six main source groups (e.g., Inks Creek [INK]; Paynes Creek [PYC]; Philips Road [PHR]; Paradise Ridge 1 [PR1]; Paradise Ridge 2 [PR2]; and remaining loci grouped as one) using the same combination of elements. The use of six main source groups produced a correct classification rate of only 69.7%.

In the third discriminant analysis, each sampling locale was placed into three prime source groups on the basis of the geographic proximity among the various sampling locales and the central tendency data derived from the descriptive analysis. In other words, geographically proximate source locales which exhibited similar group means and ranges were arranged into one of the three prime source groups if their elemental means were within two standard deviations. Thus, Prime Group 1 included both the Paradise Ridge sources (PR1 and PR2), while Prime Group 3 included the Inks and Paynes Creek sources (INK and PYC). Prime Group 2 included those areas previously characterized by Richard Hughes as Tuscan obsidian, in addition to the remaining sample localities

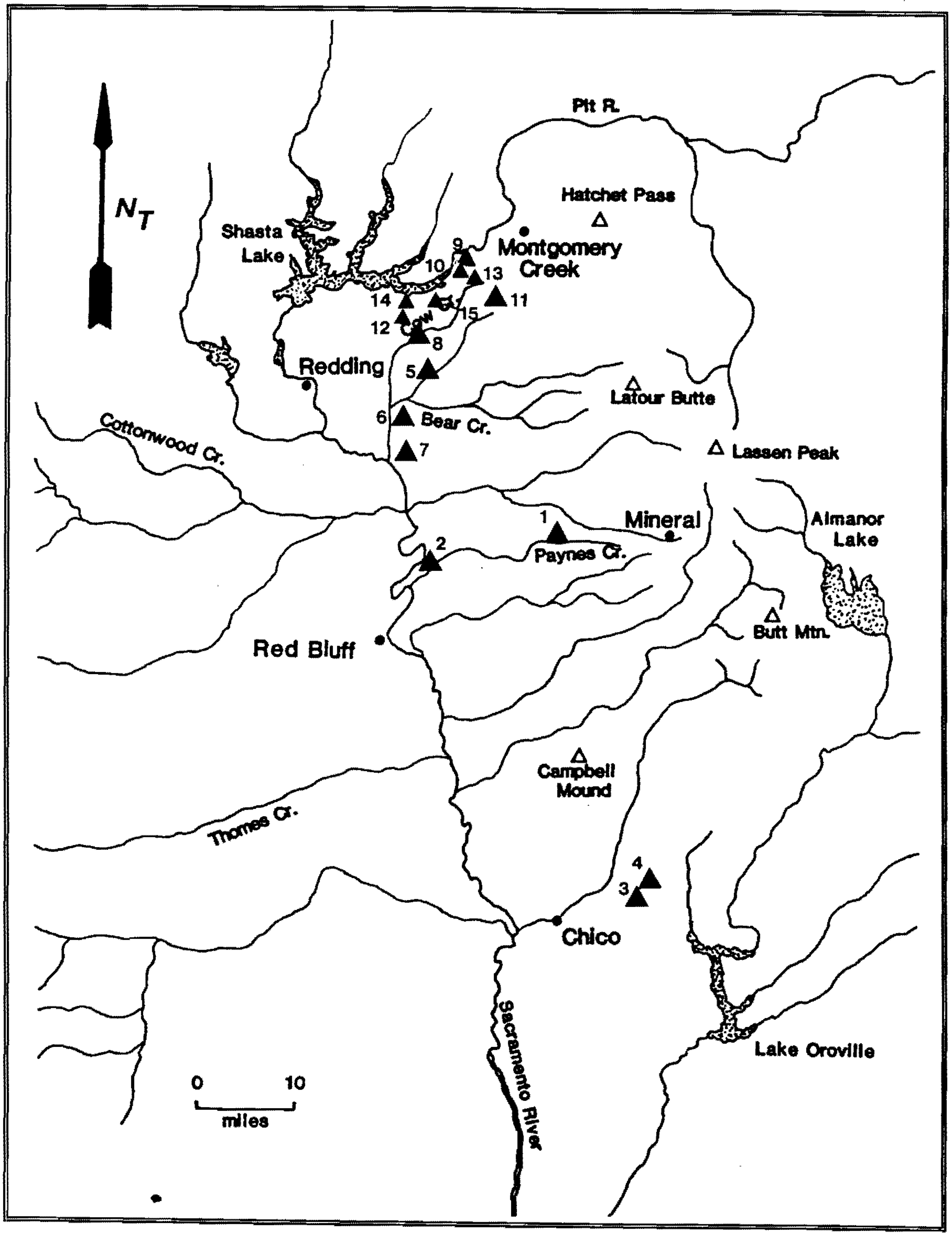

Figure 3. Sampling Locales of Tuscan Obsidian Sources.

TABLE 1

Measures of Central Tendency and Dispersion for the Minor, Trace and Rare Earth Element Data of Tuscan Obsidians from the Study Area

Element[1]	Mean	1st Standard Deviation	Minimum	Maximum
Paynes Creek (PYC) n=15[2]				
Ti	7381.831	702.479	6349.3	8974.75
Mn	1113.578	101.876	975.3	1337.254
Fe	52102.245	4116.074	46020.15	61298.92
Zn	105.149	8.177	89.131	116.255
Ga	18.509	2.091	13.149	21.361
Rb	44.304	3.339	38.611	50.366
Sr	353.254	17.945	324.033	381.931
Y	38.780	2.709	33.839	44.463
Zr	190.423	9.432	173.609	207.093
Nb	4.270	1.944	0.695	9.312
Ba	808.59	23.97	733.99	841.75
Inks Creek (INK) n=15[2]				
Ti	8982.609	1160.638	7174.37	11213.2
Mn	1134.119	121.876	971.353	1385.115
Fe	60994.107	7299.596	47083.48	73296.37
Zn	110.926	10.434	95.538	127.971
Ga	19.754	3.392	13.133	25.241
Rb	44.645	3.419	40.465	50.135
Sr	361.390	20.065	331.657	394.393
Y	36.762	2.643	33.259	42.167
Zr	177.065	14.069	161.928	210.523
Nb	5.809	2.653	1.383	9.96
Ba	607.70	147.87	422.39	792.70
Paradise Ridge 1 (PR1) n=15[2]				
Ti	752.032	132.121	588.916	1101.93
Mn	363.614	34.780	294.335	426.572
Fe	8122.612	724.434	7001.917	10032.4
Zn	49.521	15.095	27.777	83.596
Ga	13.306	2.467	9.279	19.392
Rb	109.838	7.119	95.701	118.358
Sr	65.048	4.029	57.581	71.557
Y	16.234	2.739	9.96	21.431
Zr	92.481	5.778	78.509	101.226
Nb	9.786	2.259	6.93	15.545
Ba	532.66	116.29	408.37	679.04

Table 1
(continued)

Element[1]	Mean	1st Standard Deviation	Minimum	Maximum
Paradise Ridge 2 (PR2) n=12				
Ti	832.397	153.572	706.187	1074.26
Mn	353.466	34.496	303.379	401.041
Fe	8192.209	641.778	7617.157	9311.278
Zn	32.363	4.608	25.344	38.584
Ga	15.475	2.414	12.403	19.53
Rb	114.899	5.804	101.741	123.957
Sr	70.049	3.155	65.095	74.484
Y	18.562	1.009	16.784	20.064
Zr	108.906	15.404	95.4	136.237
Nb	11.551	1.341	9.805	12.935
Oat/Swede Creek (OSC) n=15[2]				
Ti	502.544	72.783	318.271	613.935
Mn	600.112	40.063	553.429	668.909
Fe	8071.731	307.221	7549.109	8636.214
Zn	45.635	5.852	37.821	54.234
Ga	16.519	2.077	14.514	19.905
Rb	94.311	2.879	88.379	98.778
Sr	100.870	3.097	96.516	106.666
Y	16.763	1.152	15.178	19.104
Zr	74.429	5.326	67.902	84.035
Nb	6.716	2.317	3.095	10.761
Ba	1445.60	239.63	1142.94	1679.09
Dry Creek Tributary (DCT) n=15[2]				
Ti	520.186	117.324	384.307	762.659
Mn	586.863	48.213	489.14	689.439
Fe	8010.257	498.764	7214.455	9210.893
Zn	48.065	6.617	37.182	61.307
Ga	15.685	1.958	13.468	20.343
Rb	93.790	5.210	83.73	104.857
Sr	97.973	8.209	77.759	108.878
Y	17.346	1.082	16.011	19.986
Zr	72.200	6.923	64.715	93.445
Nb	6.520	2.318	2.647	10.955
Ba	1361.84	239.17	982.21	1649.60

Table 1
(continued)

Element[1]	Mean	1st Standard Deviation	Minimum	Maximum
Cow Creek Tributary (CCT) n=15[2]				
Ti	508.099	64.562	426.865	661.362
Mn	581.954	47.471	453.824	667.238
Fe	8041.896	181.144	7730.915	8424.475
Zn	44.682	6.193	37.083	61.964
Ga	15.534	1.300	13.424	18.283
Rb	92.068	4.862	79.983	99.022
Sr	99.992	3.647	88.19	104.654
Y	17.973	1.392	15.996	20.466
Zr	71.196	2.722	67.7	77.946
Nb	7.291	1.991	3.406	10.581
Ba	1658.53	67.96	1533.65	1735.68
Forest Camp Ridge (FCR) n=15[2]				
Ti	535.377	117.591	398.691	831.695
Mn	591.519	39.788	519.719	642.008
Fe	8006.444	590.673	7213.338	9311.156
Zn	44.088	2.061	40.388	46.694
Ga	16.361	1.697	13.269	18.765
Rb	93.947	4.059	88.884	100.004
Sr	85.650	5.008	76.447	90.069
Y	18.204	1.332	16.109	21.473
Zr	68.418	4.174	61.49	74.329
Nb	6.005	2.283	1.515	9.737
Ba	1600.03	68.35	1503.62	1693.06
Sugar Pine Ridge (SPR) n=15[2]				
Ti	503.601	89.766	390.359	659.79
Mn	605.337	64.975	507.29	745.796
Fe	8016.431	511.676	7266.17	8928.029
Zn	44.909	5.981	35.076	53.93
Ga	16.048	3.081	11.806	22.616
Rb	95.028	5.123	85.963	103.586
Sr	87.151	5.479	75.546	95.439
Y	17.853	1.267	16.062	20.707
Zr	68.651	3.851	61.609	74.856
Nb	6.846	1.783	3.766	9.833
Ba	1585.54	192.28	1247.19	1747.65

Table 1
(continued)

Element[1]	Mean	1st Standard Deviation	Minimum	Maximum
Philips Road (PHR) n=15[2]				
Ti	514.799	87.389	396.436	747.014
Mn	603.876	71.359	492.128	757.485
Fe	8068.148	596.582	7243.308	9256.168
Zn	42.189	4.869	35.812	48.59
Ga	16.166	2.101	13.49	19.965
Rb	94.996	6.792	78.007	104.501
Sr	91.803	11.282	73.562	110.255
Y	17.934	1.707	14.92	20.341
Zr	71.894	3.576	64.303	77.125
Nb	6.858	2.556	0.512	10.581
Ba	1632.32	97.91	1173.21	1672.02
Woodman Hill Ridge (WHR) n=15[2]				
Ti	462.834	59.353	362.75	569.824
Mn	586.529	49.634	496.311	666.494
Fe	7788.723	349.884	7004.509	8536.751
Zn	41.730	5.790	33.737	52.337
Ga	14.228	2.320	10.678	19.47
Rb	94.156	4.309	83.727	100.516
Sr	85.969	3.434	79.631	91.178
Y	17.855	1.280	16.496	20.821
Zr	70.551	4.197	65.033	77.399
Nb	7.189	2.375	1.987	10.614
Ba	1636.45	79.41	1521.17	1728.24
Backbone Ridge - Seaman Gulch 1 (BR1) n=21[2]				
Ti	519.988	115.034	348.593	880.259
Mn	597.714	71.676	485.188	738.803
Fe	7854.086	743.663	6788.019	10228.47
Zn	45.627	5.980	38.256	63.688
Ga	15.467	2.550	11.609	22.984
Rb	94.436	6.628	84.86	109.806
Sr	80.718	13.435	44.126	102.031
Y	16.581	1.342	14.167	19.7
Zr	67.911	4.592	58.997	76.648
Nb	6.96	1.740	3.317	10.351
Ba	1507.14	179.83	1173.21	1672.02

Table 1
(continued)

Element[1]	Mean	1st Standard Deviation	Minimum	Maximum
Backbone Ridge 2 - Section 26 (BR2) n=15[2]				
Ti	513.223	91.761	348.444	661.018
Mn	604.876	51.196	508.716	706.82
Fe	7914.555	459.143	6740.901	8632.924
Zn	44.524	4.729	38.956	51.205
Ga	16.773	1.844	13.98	20.211
Rb	96.161	5.370	86.831	104.033
Sr	84.310	12.496	42.738	97.407
Y	18.067	2.106	13.8	21.844
Zr	72.449	5.299	65.133	83.704
Nb	6.767	2.530	1.599	10.926
Ba	1559.87	71.24	1444.43	1624.36
Backbone Ridge 3 - Seaman Gulch 2 (BR3) n=15[2]				
Ti	483.214	73.411	378.259	618.052
Mn	592.709	48.117	533.701	696.34
Fe	7789.276	413.693	7175.562	8774.826
Zn	43.199	4.679	33.09	51.004
Ga	15.737	2.317	11.165	19.058
Rb	94.462	5.120	87.155	108.169
Sr	87.531	6.769	73.667	98.806
Y	18.137	1.507	15.688	20.974
Zr	71.275	5.363	65.595	83.222
Nb	7.003	2.047	3.713	10.451
Ba	1624.39	97.17	1562.02	1793.47
Backbone Ridge 4 - Quarry Workshop (BR4) n=15				
Ti	553.191	69.837	382.587	670.97
Mn	589.746	47.072	498.695	674.244
Fe	8088.206	477.719	7152.916	8793.566
Zn	46.220	6.546	36.807	63.458
Ga	15.908	1.543	13.212	18.39
Rb	92.837	6.527	82.884	102.963
Sr	89.864	9.266	72.802	109.106
Y	18.126	1.974	14.267	20.644
Zr	69.065	5.142	60.075	78.401
Nb	6.219	1.688	2.448	8.859
Ba	1513.52	91.65	1394.24	1666.89

[1] Ti=titanium, Mn=manganese, Fe=iron, Zn=zinc, Ga=gallium, Rb=rubidium, Sr=strontium, Y=yttrium, Zr=zirconium, Nb=niobium, Ba=barium. [2] Barium n=5.

(Backbone Ridge, Sugar Pine Ridge, Forest Camp Ridge, Cow Creek Tributary, Dry Creek Tributary, Oat/Swede Creek, Phillips Road Ridge and Woodman Hill Ridge.

The results of this analysis were much stronger with the percent of "grouped" cases correctly classified equaling 100%. Although this high percentage of success was achieved by using eight elements as variables (Ti, Mn, Fe, Zn, Rb, Sr, Y, and Zr), the results were only slightly less robust (99.57% correctly classified "grouped" cases) with the use of a select group of variables (Rb, Sr, Y, Zr, and Nb).

To test the significance of these finds, a one-way analysis of variance (ANOVA) was performed on the nine best measured elements (Ti, Mn, Fe, Zn, Rb, Sr, Y, Zr, and Nb) from each sampling locus. Basically, analysis of variance is concerned with comparing two different estimates of variation which together can be used to calculate the variance of the assumed normally distributed parent population from which the samples have been drawn. As can be seen in Table 2, the results of the analysis of variance showed significant departure from randomness ($\underline{p} < .05$) with the $\underline{F}$ value of all nine elements exceeding the critical value, thus indicating that the three prime group sampling localities contained obsidians of statistically significantly different geochemical types.

Table 2
Results of Analysis of Variance by Element for Three Prime Groups. Critical Value for $\underline{F}_{4,10}$ = 3.48 at .05 Significance Level

Element	F value	Sig of F
Ti	3662.109	.000
Mn	1244.666	.000
Fe	4283.376	.000
Zn	883.232	.000
Rb	125.300	.000
Sr	5722.819	.000
Y	43.580	.000
Zr	1684.644	.000
Nb	7.193	.000

The results of these analyses can be seen in Figure 4, which plots the concentration of Zr against Mn. While significant contrasts can be seen with many of the other elements also (Sr vs. Zr; Sr vs. Rb; Sr vs. Mn; Zr vs. Rb), these two elements help draw the clearest contrasts between the three prime source groups. Each symbol represents one individual specimen which was sampled from the locus specified on Figure 4. The ellipses express the 95% confidence limits for Zr and Mn for each source (see Hughes 1988 for discussion of probability ellipses). It is clear from this figure that the Inks Creek and Paynes Creek glasses contain higher concentrations of both Zr and Mn than the Paradise Ridge 1 and 2 source group and the other prime source groups examined. Moreover, the Inks and Payne Creeks obsidian group is more variable in Zr and Mn composition.

Similar separations of these three prime source groups are illustrated when plots are made between the element concentrations of Zr against Rb, Sr against Rb (Figure 5), and Sr against Zr (Figure 6).

The essential information imparted in Figures 4 through 6 is that three different geochemical types of obsidian can be recognized on the basis of Zr vs. Mn contrasts. These distinctive groups of obsidian were named according to prominent geographic features, or proximity to them. The Paynes Creek geochemical type consists of obsidian collected from the Inks and Paynes Creek source locales, while the Paradise Ridge geochemical type consists of obsidian collected from the Paradise Ridge 1 and 2 source locales. The third geochemical type consists of the remaining source locales, namely the Backbone Ridge groups, Cow, Oat/Swede, and Dry Creeks, Forest Camp Ridge, Philips Road, Woodman Hill, and Sugar Pine Ridge.

Attempts to distinguish between the various sampling localities contained in Prime Group 2 (BR1, BR2, BR3, BR4, SPR, FCR, CCT, DCT, OSC, PRR, WHR) with discriminant analyses functions proved to be difficult despite apparent

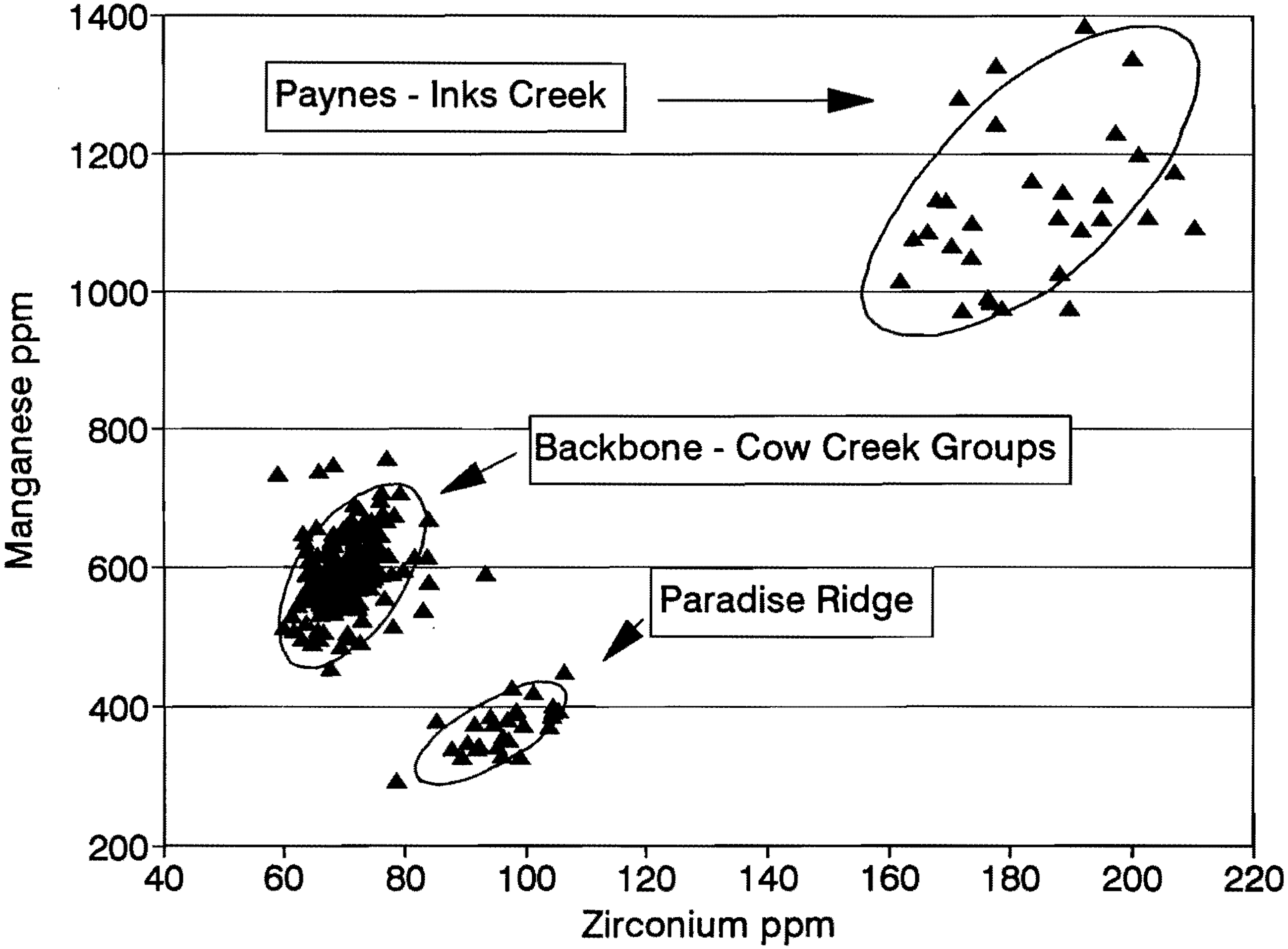

Figure 4. Zirconium (Zr) versus Manganese (Mn) Concentration Plot for Tuscan Obsidian Sources

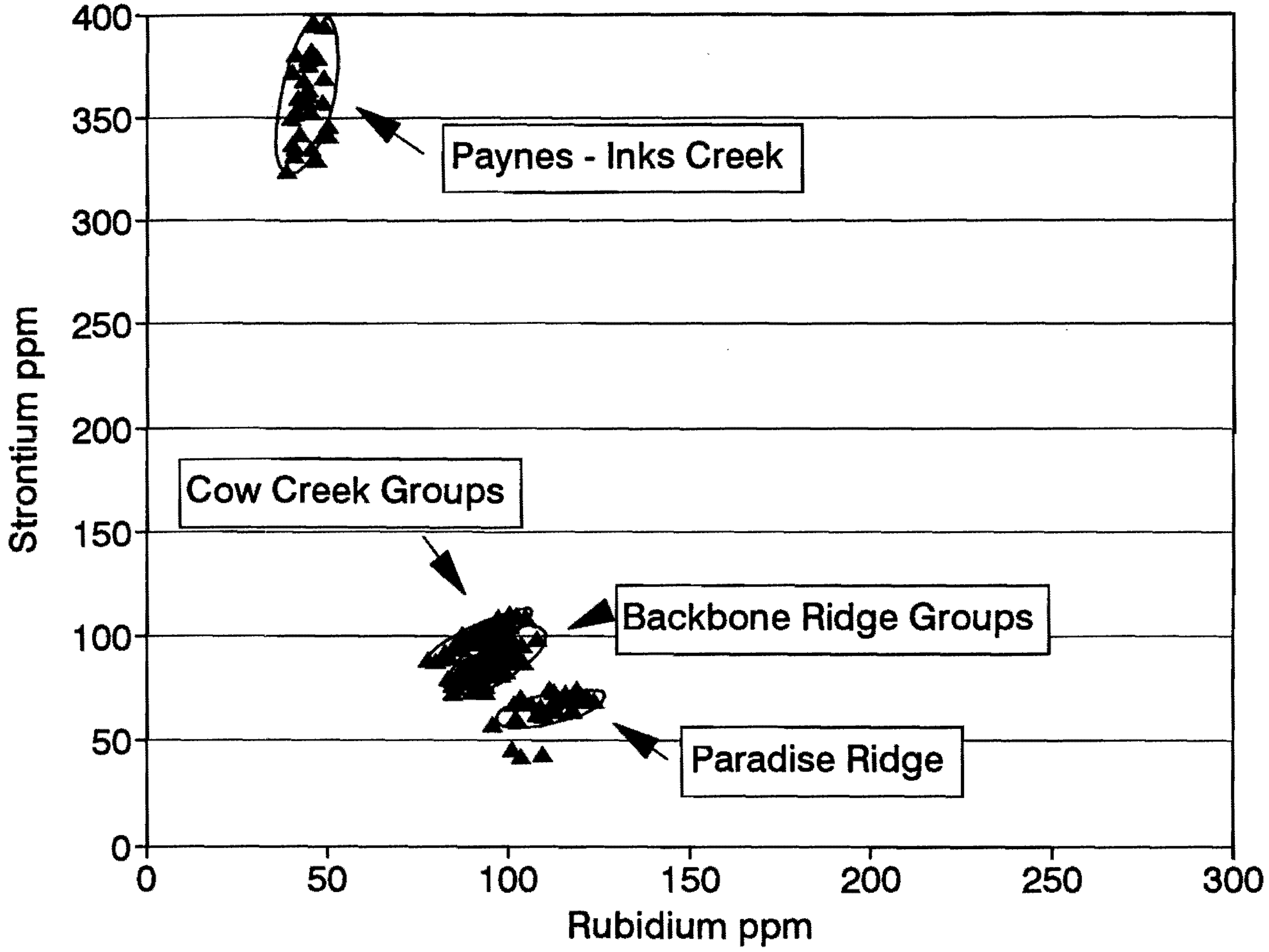

Figure 5. Rubidium (Rb) versus Strontium (Sr) Concentration Plot for Tuscan Obsidian Sources

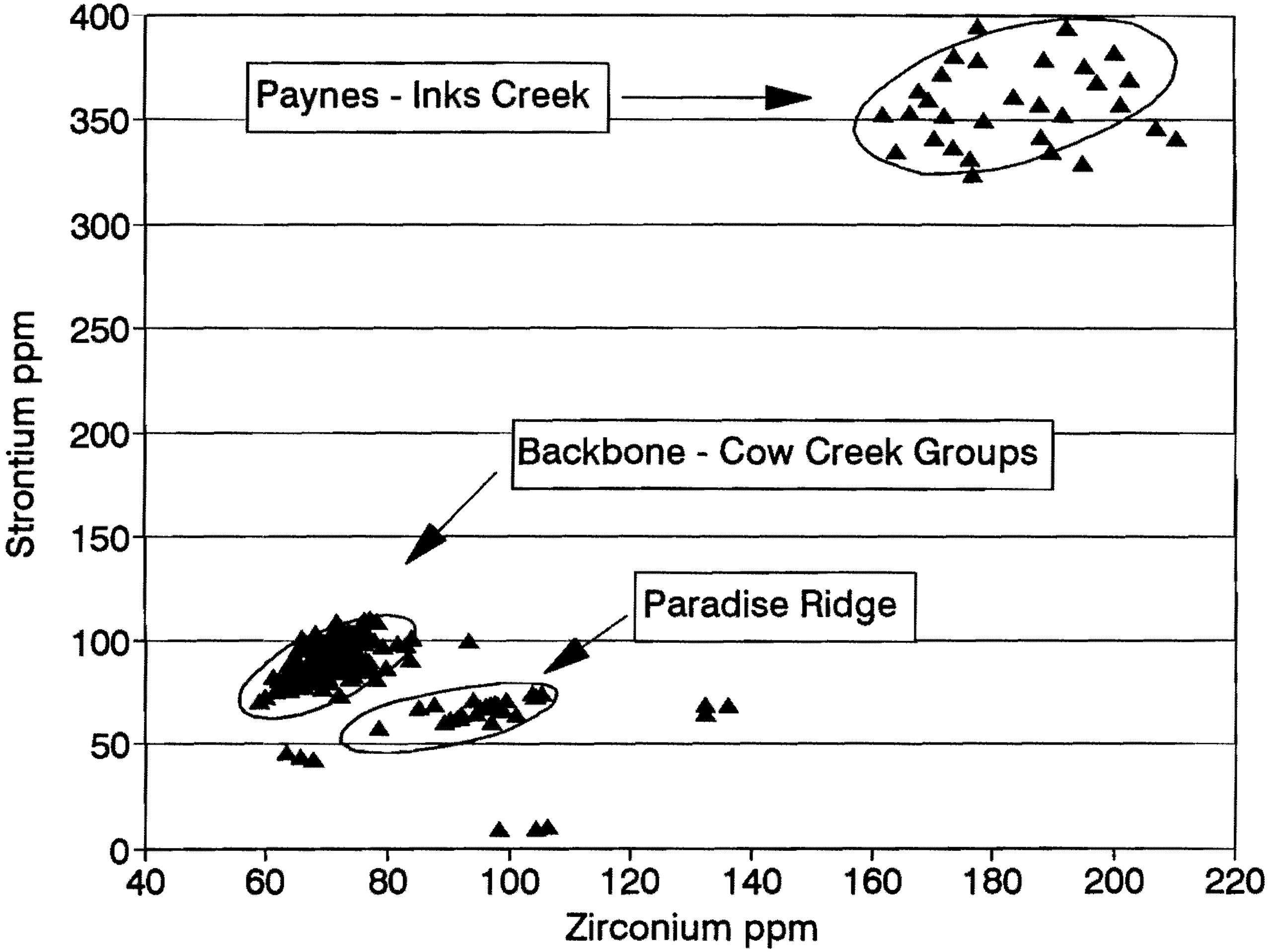

Figure 6. Zirconium (Zr) versus Strontium (Sr) Concentration Plot for Tuscan Obsidian Sources

differences which were observed in the ratio of group means with the elements Rb and Sr. However, a Two-Tailed T-Test performed on the Prime Group 2 sources indicate that at the 95% confidence level the Backbone Ridge source groups can be distinguished from the Cow Creek source groups on the basis of the ratioed values of Sr and Rb. This bimodal distribution in the Sr and Rb ratio is illustrated in Figure 7 as two separate clusters contained within the larger ellipse which is classified as the Prime Group 2 sources (see Hughes 1988 and Shackley 1990 for a discussion of this process).

These data suggest that while it is possible to have some overlap between these source subgroups at the extreme high and low ranges of the elemental values for Rb and Sr, statistically significant differences are present between these groups. Rather than occurring as random events, the differences observed in the ratios between Sr and Rb for the Cow Creek and Backbone Ridge glass appear to form a pattern, especially in regards to the Sr ppm values.

Although the obsidians from these various sources may be separated on the basis of their trace element concentration, attempts to visually source Tuscan obsidians are met with difficulties. The Paynes and Inks Creek materials as a group are distinctive, being vitrophyric and non-vitreous and as a result of this the glass from these sources is unpredictable during knapping and is of poor quality. However, the remaining sources are very similar megascopically with the degree of variability in each source being great. In other words, highly vitreous material can and frequently occurs within the same locale along with dull gray, opaque materials. Dense black opaque, mahogany or red and black flow-banded and transparent obsidian are also commonly encountered at all of these source locales except for the Paynes and Ink Creek loci.

Unfortunately, for some years there has been a general perception by areal researchers that compared to other obsidians, Tuscan obsidian is of lesser value since it is found primarily as small waterworn nodules (e.g., Chase-Dunn 1992). It has also been suggested that the nature of the Tuscan obsidian required that different methods of lithic reduction be used such as bipolar, during the manufacture of stone tools from this material. Because of these reasons, Tuscan obsidian was seen as less desirable by archaeologists than obsidian from the Medicine Lake Highlands and this led to a supposedly limited temporal and areal distribution of Tuscan obsidian in the archaeological record.

While all of the sources explored here can yield obsidian usable in producing bifacial tools and other artifacts, some of the glasses are much better suited to knapping than others. The Backbone Ridge and Cow Creek source localities contain some of the largest nodules observed and are excellent raw materials. A large majority of the Tuscan nodules approach the size category of boulders and could be easily manufactured into a variety of tool forms. As a combined group, the Tuscan obsidians are easy to control during direct freehand percussion or bipolar reduction. Also pressure flakes remove easily and predictably from all of these materials. On the other hand, knapping experiments indicate the Inks and Paynes Creek glass is not as predictable during lithic reduction and frequently "crumbles" during bipolar and/or freehand percussion reduction and essentially destroys or wastes the core. However, despite these apparent drawbacks, once a suitable nodule is reduced, the softness of the glass allows for ease in pressure-flaking.

While knapping and use qualities of a particular stone operate as important elements in raw material selection practices, there are other variables which may be equally important. As noted by Bamforth (1992), the distribution of source areas in space and the accessibility of stone at the source are two such aspects which undoubtedly were important determinants in hunter-gatherer lithic procurement strategies. Overall, the density of raw material at each of these source locales in most cases averaged at least 60 specimens per 2 m^2 area. Raw material is most abundant at the northern source areas with more than 300 nodules occurring within a 1 m^2 area.

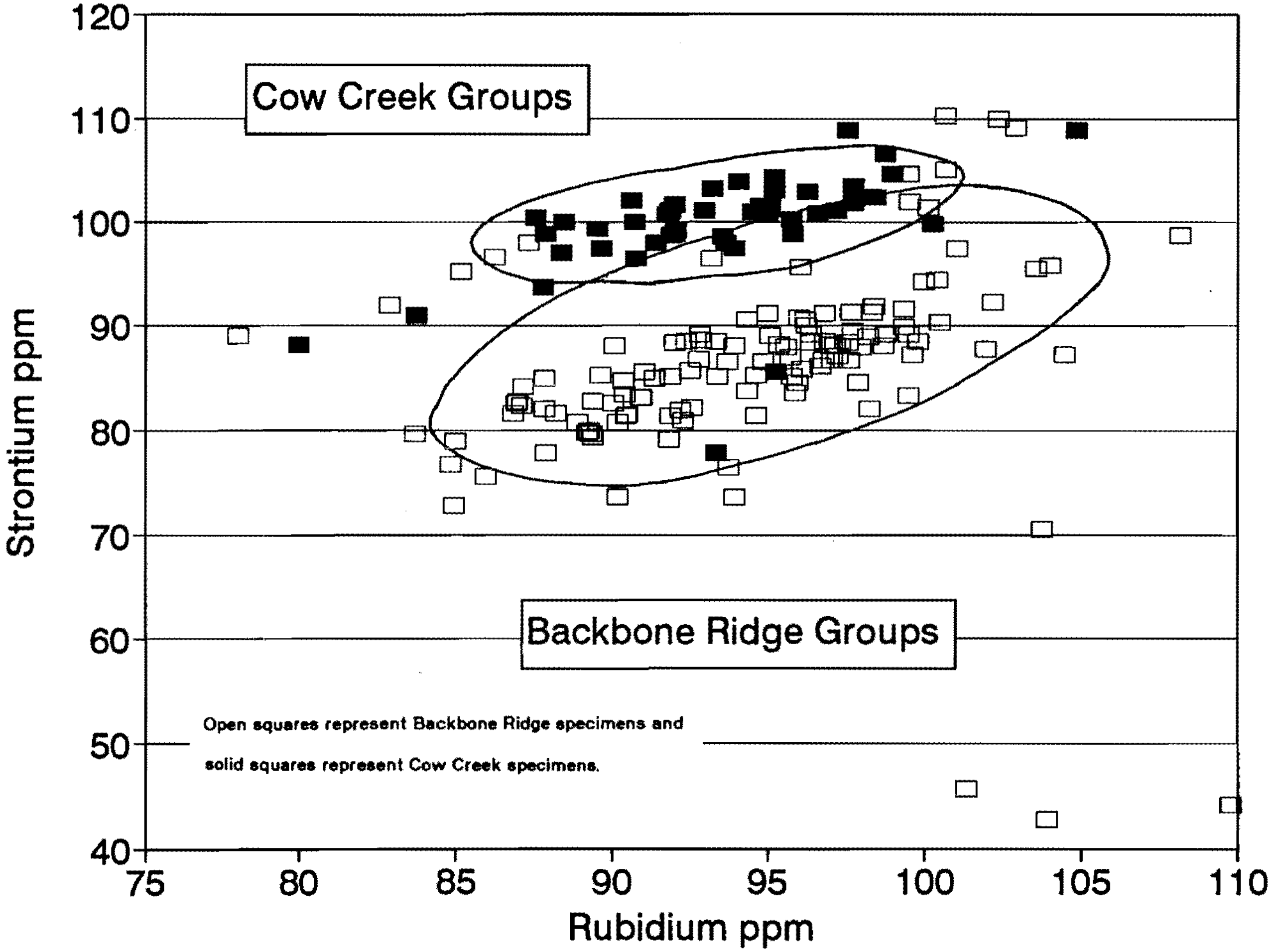

Figure 7. Rubidium (Rb) versus Strontium (Sr) Concentration Plot for the Backbone Ridge and Cow Creek Tuscan Obsidian Sources.

While it was not possible to identify each potential Tuscan obsidian source locality in the study area, clearly there is enough information to indicate that sources of artifact-quality glass in the region are widely distributed and abundant. At all of the source areas examined stone occurs mainly on the surface, providing easy access. Quite clearly, Tuscan obsidian was easy to extract and readily accessible to aboriginal groups traveling or living within the study area since "quarrying" Tuscan obsidian refers primarily to picking it up off the ground.

With this information in hand, the question then becomes whether the geochemical differences seen within the various source groups carry any archaeological significance. An examination of the geochemical trace element data from numerous archaeological investigations indicates that the spatial and temporal distribution of Tuscan obsidian encompasses an extended period of time over a broad-ranging area. Therefore, by examining the relationship between the nature and distribution of lithic sources in a region a better understanding of northeastern California prehistory can be achieved (see Hamusek-McGann 1993 for further discussions regarding these issues).

In addition, by identifying and locating the source of all the obsidian and other lithic specimens represented in an assemblage or set of assemblages, we can begin to outline a geographic range for raw material procurement and use regardless of how the material was obtained. It is only when this initial step is completed that we can begin to truly address the problem of tactics, whether the raw material was obtained directly or indirectly. Detailed knowledge of raw material locations from a regional perspective, the accessibility of raw material at the source locality, and the knapping quality of the specific lithic resource all have the potential to expand our understanding of the interaction between lithic procurement strategies and other aspects of prehistoric human behavior.

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