Title
Sources of Obsidion at Pueblo Grande: an Energy Dispersive X-ray Fluorescence (EDXRF) Analysis

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SOURCES OF OBSIDIAN AT PUEBLO GRANDE: AN ENERGY DISPERSIVE X-RAY FLUORESCENCE (EDXRF) ANALYSIS

by

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INTRODUCTION

Insight into the procurement of obsidian during all periods of Hohokam occupation in Arizona is, at best, in a very preliminary form. The geochemical analysis here of 220 obsidian artifacts from Pueblo Grande is a great step toward the understanding of Hohokam obsidian procurement. This report is focused on the geochemistry of obsidian and patterns of obsidian procurement at the *site locus proper*, irrespective of temporal and spatial variability, addressed elsewhere.

Based on a preliminary analysis of obsidian artifacts from some other Classic period Hohokam contexts I have argued that Northern Arizona obsidian was not a common feature in late Hohokam sites (Shackley 1988, 1989). This analysis indicates that this is not the case. This sample exhibited a substantial proportion (25.9%) of obsidian from Government Mountain and Partridge Creek in north central Arizona. Indeed, the obsidian assemblage from Pueblo Grande is quite diverse, exhibiting glass from seven known and three unknown sources. One of the unknowns is probably derived from Superior, but the small size prohibited a confident assignment. The source provenience of the material does not conform to the Law of Monotonic Decrement and merits discussion (see Shackley 1990).

ANALYSIS AND INSTRUMENTATION

Unlike the earlier study of Southwestern obsidians (Shackley 1988, 1990), these data are generated under different analytical conditions. These results are quantitative in that they are derived from "filtered" intensity values ratioed to the appropriate x-ray continuum regions through a least squares fitting formula rather than plotting the proportions of the net intensities in a ternary system (McCarthy and Schamber 1981; Schamber 1977). Or more essentially, these data through the analysis of international rock standards, allow for inter-instrument comparison with a predictable degree of certainty (Hampel 1984).

The trace element analyses 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 spectrometer. The spectrometer is equipped with a Rh x-ray tube, a 50 kV x-ray generator, with a Tracor X-ray (Spectrace) TX 6100 x-ray analyzer using an IBM PC based microprocessor and Tracor reduction software. The x-ray tube was operated at 30 kV, .20 mA, using a .127 mm Rh primary beam filter in an air path at 250 seconds livetime to generate x-ray intensity data for elements lead (Pb), thorium (Th), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb). Trace element intensities were converted to concentration estimates by employing a least-squares calibration line established for each element from the analysis of up to 26 international rock standards certified by the U.S. Bureau of Standards, the U.S. Geological Survey, Canadian Centre for Mineral and Energy Technology, and the Centre de Recherches Pétrographiques et Géochimiques in France (Govindaraju 1989). Further details concerning the petrological choice of these elements in Southwestern obsidians is available in Shackley (1988, 1990).

In order to evaluate these quantitative determinations, machine data were compared to measurements of known standards. Table 1 shows a comparison between values recommended for two international rock standards, one rhyolite (RGM-1) and one obsidian

(NBS-278). One of these standards is analyzed during each sample run to insure machine calibration. The results shown in Table 1 indicate that the machine accuracy is quite high, and other instruments with comparable precision should yield comparable results.

Trace element data exhibited in Tables 1 and 2 are reported in parts per million (ppm), a quantitative measure by weight. Source probability is based on a comparison with 1-sigma levels of variability. Although Pb and Th ppm concentrations were reported, they generally are not used as diagnostic indicators given their general lack of inter-source variability. Table 2 exhibits the trace element concentrations for the 220 samples. Figures 1 through 4 exhibit concentration plots of five incompatible elements (Rb, Sr, Y, Zr, Nb) used in determining the source provenience. Since this analysis, titanium (Ti) has been found to be an important discriminating element between Superior and Vulture which are most easily discriminated here with Rb, Sr, and Zr (see Figures 1 through 3). Megascopic attributes are also sometimes a secondary attribute useful in discriminating between these two sources (Shackley 1988, 1990). Superior (Picketpost Mountain) is uniformly almost transparent in thin flakes and bifaces while Vulture is more opaque and often banded or cloudy.

Six samples (63-66, 87, and 175) could not be assigned to known sources. The cluster of four (63-66) comprised three unmodified marekanite nodules and one bipolar flake from a single provenience unit, Feature 1006. These apparently represent a single group probably from one knapper's tool kit. The nodules are small marekanites rather typical of the mid-Tertiary glass sources in the Sonoran Desert (Shackley 1988, 1990). Obsidian from this source has not appeared in other known contexts. Three other samples from this feature were derived from the Vulture source in the northwestern Sonoran Desert approximately 95 km west-northwest of the site. It is *theoretically* possible that these unknown specimens are chemical outliers in the Vulture source group, but this is very unlikely (see Shackley 1990). The other unknown was also recovered from a feature that also contained Vulture obsidian (Feature 1694). XRF sample number 175 was a very small side-notched projectile point that is nearly clear glass and appears similar to Superior obsidian, but its small size may have caused an erroneous reading. It is possible that the unknown source provenience nodules were procured from a spatially small source somewhere in the Sonoran Desert, although recent research has not detected the presence of this source in southeastern or western Arizona (Shackley 1992, 1991).

SPATIAL AND CULTURAL INFERENCES

Treating the site as a single component locus of obsidian procurement, a number of inferences and observations can be made. One of the first and basic observations directed toward provenience analyses is the determination of distance and direction to sources. A primary measure is the Law of Monotonic Decrement that states that in circumstances of uniform loss or deposition, artifacts produced from a given source material will occur in monotonically decreasing proportions as the effective distance from the source increases (Renfrew 1977). The term *effective* distance is an important one, but in the Sonoran Desert environment it is not as important as in some other environments.

Table 3 and Figure 5 exhibit the frequency distribution, distance to source, direction, and region of procurement for the Pueblo Grande data. As expected, a vast majority of the material was procured from relatively close sources (Sauceda Mountains - 30.5%, and Vulture - 26.8%). The nearest source, Superior, only contributed 10%. This can be seen graphically in Figure 6, a regression scattergram of the proportions plotted against linear distance. If the Law of Monotonic Decrement were operating perfectly we would see a perfect negative linear relationship ($r^2=1.0$) between proportion and distance. As you can see this is not the case, where $r^2=.22$, standard error of the estimate=11.88, significant at .291, reflecting the large scatter of data points.

One broken obsidian projectile point recovered from Feature 958 in a Soho phase contexts was produced from glass procured from the newly discovered Tank Mountain source in east central Yuma County, Arizona 160 km west-southwest (Shackley 1991). This is unusual in Gila-Salt Hohokam contexts, but was also noted in Classic period context at Grand Canal (Shackley 1989). this is a considerable distance to the west, nearly to the Colorado River, although Sedentary period ceramics have been found at the source (Shackley 1991).

CONCLUSION AND SUMMARY

Table 2 exhibits the distance and direction to the sources detected in the analysis. Material was procured from many sources in all cardinal directions and environments from the Sonoran Desert (Sauceda Mts, Vulture, Superior, Los Vidrios, Tank Mts), to piñon-juniper woodlands (Partridge Creek), to yellow pine forest-grassland (Government Mountain). During the Archaic period, these upland environments were important resource areas exploited in the late summer and fall. The Hohokam procurement of obsidian in these environments could be the result of similar logistic forays into these environments, or a result of interaction and exchange. The relatively small proportion of glass material from the nearest source Superior (Picketpost Mtn) only 80 km distant is probably the effect of source control by Salado groups. The relatively high proportion of glass from the Government Mountain source in northern Arizona may be an effect of differential exchange/contact with groups to the north. Most of the Sonoran Desert sources can certainly be said to be within Classic period Hohokam "range", discussed elsewhere. Los Vidrios material, for example, is located along the Sonoita River in northern Sonora on the route to the Gulf of California and could have been procured incidental to (or embedded within) shell procurement expeditions or exchanged *with* shell material from groups to the south.

The diversity of sources in the obsidian assemblage at Pueblo Grande is certainly provocative. In many ways it is always easier to determine the source provenience of archaeological material than to explain how it arrived in its final depositional context (Ward 1977). That is beyond the limit of the goal of this analysis.

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Table 1. X-ray fluorescence concentrations for selected trace elements of two international rock standards. ± values represent first standard deviation computations for the group of measurements. All values are in parts per million (ppm) as reported in Govindaraju (1989) and this study. RGM-1 is a U.S. Geological Survey rhyolite (obsidian) rock standard, and NBS-278 is a National Bureau of Standards obsidian standard.

SAMPLE	Pb	Th	Rb	Sr	Y	Zr	Nb	Ba
RGM-1 (Govindaraju 1989)	24	15.1	149	108	25	219	8.9	807
RGM-1 (this study)	23±2.6	14±2.4	150±3.4	105±1.7	26±0.9	218±5	9.5±1.1	844±48.86
NBS-278 (Govindaraju 1989)	16.4	12.4	127.5	63.5	41	295	n.r.	1140
NBS-278 (this study)	19.1±0.9	14±2.2	126±1.9	62±2.3	40±2.2	280±3.6	14±1.4	n.a.

Table 2. X-ray fluorescence concentrations for obsidian artifacts from Pueblo Grande. All values are in parts per million (ppm).

SAMPLE	Pb	Th	Rb	Sr	Y	Zr	Nb	SOURCE
1	35.498	9.472	113.239	80.33	18.596	75.529	43.581	GOVT MTN
2	25.429	19.78	155.709	67.019	32.435	190.536	19.529	SAUCEDA MTS
3	24.797	20.137	150.14	66.485	31.744	184.081	19.151	SAUCEDA MTS
4	37.288	4.724	106.227	72.968	18.985	71.845	35.052	GOVT MTN
5	26.704	31.063	171.918	70.249	34.371	192.282	19.129	SAUCEDA MTS
6	32.151	32.033	176.857	71.897	32.201	195.918	20.61	SAUCEDA MTS
7	24.173	23.714	157.783	70.614	34.878	190.768	15.446	SAUCEDA MTS
8	24.586	38.531	152.276	73.202	26.886	176.299	13.662	SAUCEDA MTS
9	30.156	24.725	135.542	67.368	34.125	172.487	17.129	SAUCEDA MTS
10	23.313	13.05	140.337	60.309	29.13	174.1	15.788	SAUCEDA MTS
11	27.004	5.356	96.95	72.195	19.348	68.191	36.864	GOVT MTN
12	18.225	25.479	146.913	64.225	32.9	180.189	19.239	SAUCEDA MTS
13	27.576	11.144	160.1	68.636	37.104	188.262	17.645	SAUCEDA MTS
14	28.981	10.597	115.351	17.427	24.14	79.416	23.685	SUPERIOR
15	24.113	21.455	154.508	70.166	30.921	183.727	17.932	SAUCEDA MTS
16	29.362	28.701	173.059	77.963	30.381	202.322	14.753	SAUCEDA MTS
17	44.556	39.275	227.306	4.104	33.01	71.666	36.593	PARTRIDGE CR
18	34.364	30.275	231.29	16.769	37.373	101.866	19.43	PARTRIDGE CR
19	31.261	14.032	100.229	74.515	16.513	64.877	37.392	GOVT MTN
20	15.928	21.752	159.416	70.083	32.323	191.826	19.689	SAUCEDA MTS
21	28.398	24.512	152.722	68.507	33.963	182.655	18.73	SAUCEDA MTS
22	23.521	22.304	136.622	63.304	27.168	177.866	18.988	SAUCEDA MTS
23	26.006	14.131	135.249	37.448	14.634	104.673	15.561	VULTURE
24	24.501	22.706	165.059	67.649	34.657	202.006	19.493	SAUCEDA MTS
25	21.022	26.194	152.068	70.401	29.968	193.575	19.311	SAUCEDA MTS
26	27.058	33.764	163.494	75.257	32.173	200.636	20.325	SAUCEDA MTS
27	29.181	36.818	254.121	6.81	70.012	219.606	29.942	LOS VIDRIOS
28	25.233	27.597	239.973	9.526	70.045	218.659	27.239	LOS VIDRIOS
29	31.178	14.289	109.911	73.404	17.787	72.327	39.291	GOVT MTN
30	24.793	19.948	151.994	69.866	33.767	194.198	18.638	SAUCEDA MTS
31	26.952	26.115	229.625	10.905	69.613	213.386	25.263	LOS VIDRIOS
32	20.467	17.597	149.33	69.731	32.573	187.48	18.043	SAUCEDA MTS
33	19.987	19.169	158.973	72.448	31.443	190.643	16.429	SAUCEDA MTS
34	25.174	22.658	163.603	71.775	32.425	194.361	17.498	SAUCEDA MTS
35	35.34	7.867	109.59	77.908	21.368	73.896	38.389	GOVT MTN
36	22.336	29.143	216.552	8.464	61.532	200.202	24.206	LOS VIDRIOS
37	24.274	18.165	138.623	35.473	16.909	122.342	15.845	VULTURE
38	31.072	15.424	101.864	68.689	18.397	69.621	39.877	GOVT MTN
39	24.775	20.257	159.131	66.897	31.771	191.168	16.94	SAUCEDA MTS
40	24.172	20.249	151.825	71.412	34.34	189.28	22.886	SAUCEDA MTS
41	28.562	13.091	97.656	69.312	15.103	68.837	38.901	GOVT MTN
42	32.501	17.035	102.563	75.48	13.679	62.637	34.197	GOVT MTN
43	25.053	30.927	153.039	73.022	33.583	180.592	18.974	SAUCEDA MTS
44	54.164	21.088	142.239	68.251	25.172	173.884	18.235	SAUCEDA MTS
45	36.591	17.135	99.119	66.787	15.142	61.123	29.711	GOVT MTN
46	42.103	34.98	223.342	12.865	36.999	70.323	38.447	PARTRIDGE CR
47	42.248	26.283	215.512	20.86	36.115	80.227	42.756	PARTRIDGE CR
48	23.881	17.387	133.812	38.81	16.979	104.99	21.869	VULTURE
49	27.105	18.912	128.979	34.616	18.902	117.086	17.362	VULTURE

SAMPLE	Pb	Th	Rb	Sr	Y	Zr	Nb	SOURCE
50	23.794	9.051	124.5	35.249	17.335	117.816	15.903	VULTURE
51	40.885	14.588	138.204	36.27	24.709	123.3	20.322	VULTURE
52	33.774	13.222	137.621	68.87	22.685	169.887	11.687	SAUCEDA MTS
53	35.64	23.492	144.738	40.641	16.394	117.197	16.915	VULTURE
54	20.101	20.408	132.81	37.618	17.505	123.37	20.134	VULTURE
55	23.698	5.416	126.233	33.898	19.799	114.364	18.456	VULTURE
56	32.367	8.688	100.757	74.172	16.141	69.637	38.081	GOVT MTN
57	33.389	11.04	107.852	73.338	17.565	68.945	38.54	GOVT MTN
58	34.89	15.412	103.837	74.477	21.945	67.351	35.509	GOVT MTN
59	28.386	10.673	103.887	73.21	18.129	69.36	36.933	GOVT MTN
60	23.354	18.679	127.412	45.962	17.698	115.1	17.424	VULTURE
61	25.331	11.76	131.399	33.101	16.814	118.394	19.612	VULTURE
62	20.673	9.597	131.546	34.049	20.913	118.97	16.524	VULTURE
63	26.199	18.382	168.098	9.08	39.199	255.639	24.876	UNKNOWNA
64	23.838	22.103	156.141	9.477	36.516	239.572	25.759	UNKNOWNA
65	25.266	21.322	171.231	11.653	35.593	255.689	26.29	UNKNOWNA
66	27.104	17.847	140.449	11.868	33.407	226.703	25.05	UNKNOWNA
67	35.181	15.224	114.503	77.389	18.882	69.917	38.306	SAUCEDA MTS
68	22.909	22.46	158.825	73.388	37.023	195.455	19.606	SAUCEDA MTS
69	26.991	18.455	151.01	69.572	33.132	177.759	17.133	SAUCEDA MTS
70	30.747	8.001	103.962	73.847	22.758	67.256	36.625	GOVT MTN
71	36.443	21.723	91.222	59.077	20.136	63.586	39.971	GOVT MTN
72	21.459	28.016	164.105	64.522	34.368	201.919	21.164	SAUCEDA MTS
73	23.271	15.622	127.813	4.596	25.855	87.916	24.283	SUPERIOR
74	36.059	15.79	97.037	61.826	15.969	61.193	37.823	GOVT MTN
75	21.004	19.693	162.549	67.658	34.371	198.837	20.294	SAUCEDA MTS
76	37.705	14.313	108.51	21.921	22.838	102.164	16.761	SUPERIOR
77	33.55	34.549	224.908	4.887	36.412	88.223	21.041	PARTRIDGE CR
78	26.584	29.505	227.023	-6.66	70.896	207.564	22.818	LOS VIDRIOR
79	33.654	25.725	172.018	63.674	35.991	182.021	23.904	SAUCEDA MTS
80	32.339	24.479	176.823	63.665	35.447	191.323	21.24	SAUCEDA MTS
81	27.855	8.235	134.808	34.279	21.953	113.419	13.415	VULTURE
82	26.829	8.134	137.204	24.604	17.787	120.402	17.258	VULTURE
83	30.451	15.506	139.387	26.405	22.536	119.057	18.375	VULTURE
84	61.713	11.471	140.54	26.236	21.081	123.867	18.243	VULTURE
85	26.916	25.301	140.834	25.149	21.962	115.286	21.994	VULTURE
86	34.487	25.496	148.91	55.009	26.544	169.783	17.02	VULTURE
87	26.441	3.621	81.054	41.339	32.278	105.398	7.728	UNKNOWNB
88	32.303	34.927	162.47	63.592	34.281	169.889	18.248	VULTURE
89	33.367	16.683	108.561	62.262	16.727	66.047	44.888	GOVT MTN
90	39.821	18.452	96.965	62.478	18.769	59.813	42.799	GOVT MTN
91	36.627	10.671	117.922	25.813	17.064	95.097	10.366	SUPERIOR
92	32.468	14.231	113.955	73.773	21.128	74.677	45.922	GOVT MTN
93	24.678	11.11	132.326	26.842	15.676	115.533	12.532	VULTURE
94	28.817	28.842	164.108	61.133	37.624	190.624	18.486	SAUCEDA MTS
95	30.135	25.759	177.394	64.909	35.284	191.506	22.279	SAUCEDA MTS
96	35.562	26.824	142.079	31.83	26.463	111.811	24.421	SUPERIOR
97	35.799	18.703	97.469	14.347	16.54	72.967	4.045	SUPERIOR
98	32.649	14.57	134.632	27.684	13.73	114.685	21.088	VULTURE
99	36.048	0	110.642	3.662	32.399	70.073	18.925	SUPERIOR
100	28.574	18.858	95.666	1.274	24.678	67.524	16.804	SUPERIOR
101	28.287	17.519	130.878	24.412	20.354	116.921	17.83	VULTURE
102	27.62	16.723	163.041	64.325	24.091	170.539	14.812	SAUCEDA MTS

URL

SAMPLE	Pb	Th	Rb	Sr	Y	Zr	Nb	SOURCE
103	31.377	0	98.54	16.711	20.303	89.434	8.878	SUPERIOR
104	26.274	26.04	161.509	67.344	30.977	194.594	19.959	SAUCEDA MTS
105	29.797	15.142	125.928	22.411	23.82	107.266	23.439	SUPERIOR
106	46.632	31.974	209.768	-5.433	37.689	60.918	33.378	PARTRIDGE CR
107	38.677	23.358	198.175	5.99	33.082	56.988	26.809	PARTRIDGE CR
108	36.402	12.379	110.086	67.126	20.243	68.249	45.41	GOVT MTN
109	39.963	18.492	165.672	36.775	15.368	124.698	16.9	VULTURE
110	27.745	8.334	136.78	29.184	23.133	111.306	14.861	VULTURE
111	32.787	3.122	100.274	5.27	28.178	75.027	21.045	SUPERIOR
112	27.674	18.592	140.874	28.457	22.269	121.461	23.956	VULTURE
113	38.753	20.243	114.264	73.505	26.268	74.494	45.586	GOVT MTN
114	32.232	18.109	149.723	22.606	19.923	120.278	17.264	VULTURE
115	41.024	19.983	116.596	73.795	23.298	67.18	42.769	GOVT MTN
116	28.817	21.739	173.887	72.636	37.891	217.639	21.014	SAUCEDA MTS
117	22.767	15.797	149.279	26.216	23.035	120.009	17.88	VULTURE
118	27.791	10.416	152.737	24.98	26.418	125.038	22.816	VULTURE
119	32.569	15.104	107.714	67.67	18.805	71.73	43.706	GOVT MTN
120	39.467	10.308	115.68	69.149	15.611	74.587	49.337	GOVT MTN
121	36.808	9.284	116.02	71.293	26.078	76.279	48.453	GOVT MTN
122	28.756	15.058	129.642	12.189	17.534	78.34	27.903	SUPERIOR
123	27.189	9.194	132.555	30.907	19.694	116.69	17.357	VULTURE
124	26.746	9.34	142.457	4.985	34.174	56.271	25.698	SUPERIOR
125	41.145	15.515	116.555	75.733	19.02	75.19	49.381	GOVT MTN
126	23.101	26.56	158.482	59.604	32.494	194.853	21.198	SAUCEDA MTS
127	25.773	32.67	254.137	-2.674	74.086	218.306	27.409	LOS VIDRIOS
128	33.23	16.498	111.394	66.081	21.079	71.215	41.539	GOVT MTN
129	27.78	28.688	238.232	-1.888	72.115	210.898	26.389	LOS VIDRIOS
130	23.965	28.112	168.813	66.532	36.097	196.295	18.738	SAUCEDA MTS
131	33.435	8.502	105.153	68.399	21.516	64.801	45.442	GOVT MTN
132	35.631	21.013	117.015	72.963	29.26	68.27	47.099	GOVT MTN
133	33.85	19.536	138.281	28.377	22.807	119.862	19.052	VULTURE
134	29.055	21.621	158.337	28.403	21.372	125.592	20.68	VULTURE
135	36.666	13.601	102.777	69.073	17.748	76.609	49.699	GOVT MTN MTN
136	29.983	13.35	138.621	30.173	20.267	123.121	18.547	VULTURE
137	22.534	18.15	137.108	32.72	20.586	132.378	17.364	VULTURE
138	29.736	8.243	129.113	27.141	19.439	122.749	17.963	VULTURE
139	22.722	17.349	153.17	63.487	34.292	190.855	19.147	SAUCEDA MTS
140	31.456	20.697	127.364	22.618	14.809	123.156	9.235	VULTURE
141	33.58	15.534	122.934	34.524	22.915	135.702	24.23	VULTURE
142	29.964	3.213	121.706	28.245	17.153	118.542	17.081	VULTURE
143	24.664	18.263	163.81	68.197	34.975	200.588	25.622	SAUCEDA MTS
144	36.928	10.845	101.67	68.335	22.135	80.776	51.985	GOVT MTN MTN
145	23.845	16.976	122.366	28.986	21.933	123.004	21.312	VULTURE
146	24.513	1.307	128.15	25.861	22.94	122.999	19.24	VULTURE
147	28.134	14.207	120.456	30.858	22.007	115.286	18.178	VULTURE
148	22.062	17.149	139.129	60.397	31.827	175.632	13.964	SAUCEDA MTS
149	35.142	30.888	153.126	58.215	23.536	186.932	17.874	SAUCEDA MTS
150	21.71	31.095	146.694	64.717	30.96	185.233	19.567	SAUCEDA MTS
151	28.116	9.813	101.627	69.355	25.303	80.558	47.029	GOVT MTN MTN
152	22.084	23.427	129.319	29.044	18.803	122.553	23.704	VULTURE
153	30.879	21.416	140.189	35.04	21.397	129.465	22.918	VULTURE
154	22.345	10.403	125.143	34.654	14.239	122.976	22.746	VULTURE
155	27.05	9.98	132.823	34.478	22.917	126.053	16.547	VULTURE

SAMPLE	Pb	Th	Rb	Sr	Y	Zr	Nb	SOURCE
156	30.454	12.227	137.926	128.892	18.247	106.394	11.831	TANK MTS
157	25.409	19.839	126.037	35.545	18.218	99.794	18.984	VULTURE
158	29.445	8.432	108.727	12.308	27.742	88.945	24.253	SUPERIOR
159	21.36	15.362	136.881	33.141	22.848	128.524	21.587	VULTURE
160	18.455	23.211	150.385	63.563	34.447	195.553	18.391	SAUCEDA MTS
161	30.333	11.735	108.718	72.415	25.614	82.409	56.477	GOVT MTN MTN
162	21.233	14.635	112.138	13.727	23.528	84.055	27.982	SUPERIOR
163	24.445	15.954	110.446	6.263	18.96	82.672	12.897	SUPERIOR
164	23.427	6.612	124.489	35.077	16.579	115.19	15.541	VULTURE
165	23.937	12.804	138.724	66.541	27.905	169.949	12.717	SAUCEDA MTS
166	22.623	9.553	105.34	17.819	25.191	77.196	17.097	SUPERIOR
167	35.292	11.381	104.33	68.718	18.708	67.647	52.72	GOVT MTN MTN
168	23.027	15.443	149.424	64.739	32.999	179.17	21.68	SAUCEDA MTS
169	19.628	22.991	155.927	94.316	27.908	174.457	13.682	SAUCEDA MTS
170	20.76	9.168	105.883	10.073	22.645	87.256	27.052	SUPERIOR
171	27.231	27.936	160.953	66.656	26.204	200.814	20.917	SAUCEDA MTS
172	42.305	8.274	118.945	78.352	22.36	89.826	47.684	GOVT MTN
173	34.853	14.135	104.012	69.805	17.156	89.65	43.878	GOVT MTN
174	34.956	10.943	98.605	67.721	20.538	89.372	47.185	GOVT MTN
175	41.655	0	55.111	5.37	14.509	52.832	11.241	UNKNOWN (very small, prob. Superior)
176	30.601	10.627	97.361	68.935	24.266	89.753	49.905	GOVT MTN
177	26.108	24.178	148.391	67.178	30.549	197.063	23.042	SAUCEDA MTS
178	34.346	17.123	88.736	63.215	21.217	77.35	50.989	GOVT MTN
179	22.976	23.688	150.689	71.652	30.419	200.858	23.095	SAUCEDA MTS
180	23.578	19.539	148.892	68.629	32.096	202.434	23.382	SAUCEDA MTS
181	32.07	11.521	99.702	72.283	22.064	91.665	42.044	GOVT MTN
182	35.893	9.822	92.767	67.112	24.317	87.981	44.445	GOVT MTN
183	25.697	19.636	116.939	49.164	26.081	158.104	22.604	SAUCEDA MTS
184	43.182	38.44	238.785	4.204	44.954	106.049	56.112	PARTRIDGE CR
185	18.864	20.786	146.418	67.662	30.607	197.337	25.576	SAUCEDA MTS
186	25.182	34.448	151.336	65.883	36.946	194.021	23.496	SAUCEDA MTS
187	29.935	17.827	108.257	75.517	22.128	94.495	53.675	GOVT MTN
188	22.058	17.367	138.467	62.049	30.507	194.318	15.034	SAUCEDA MTS
189	24.94	25.37	168.004	69.806	37.446	208.882	26.024	SAUCEDA MTS
190	33.581	11.512	107.76	77.371	21.301	92.356	55.384	GOVT MTN
192	32.141	19.5	102.888	75.489	22.045	87.737	52.372	GOVT MTN
193	25.139	17.11	135.573	34.997	20.453	140.689	25.394	VULTURE
194	32.792	35.422	246.342	17.018	35.136	122.487	24.038	PARTRIDGE CR
195	23.745	9.383	122.742	34.594	18.988	132.472	17.332	VULTURE
196	19.605	20.079	155.381	67.793	32.96	204.638	20.998	SAUCEDA MTS
197	20.914	25.711	154.624	65.014	33.132	201.277	25.849	SAUCEDA MTS
198	23.685	14.261	137.407	36.537	24.401	136.881	24.752	VULTURE
199	25.534	15.556	126.765	34.394	19.006	132.352	17.506	VULTURE
200	25.218	18.441	144.861	70.492	31.983	200.466	24.953	SAUCEDA MTS
201	29.034	31.136	124.015	38.373	16.758	122.214	20.387	VULTURE
202	27.318	19.223	123.14	30.434	19.438	128.554	24.75	VULTURE
203	19.487	18.592	100.851	15.407	18.847	96.203	33.826	SUPERIOR
204	22.117	16.853	133.058	35.882	19.371	141.079	23.638	VULTURE
205	27.035	13.33	129.366	36.947	23.876	134.847	19.72	VULTURE
206	25.034	17.926	118.211	15.961	23.536	105.557	26.509	SUPERIOR
207	33.57	6.328	101.658	74.511	22.877	89.323	44.869	GOVT MTN
210	26.621	16.203	141.467	40.186	17.553	132.667	21.574	VULTURE
211	27.688	14.568	124.363	31.919	15.529	125.323	24.404	VULTURE

URL

SAMPLE	Pb	Th	Rb	Sr	Y	Zr	Nb	SOURCE
213	21.536	12.586	112.316	15.071	25.186	102.731	26.397	SUPERIOR
214	23.353	21.655	153.408	67.283	30.961	196.095	18.339	SAUCEDA MTS
216	35.129	15.448	107.701	77.009	18.376	89.701	54.585	GOVT MTN
217	19.872	15.951	140.176	64.843	29.122	186.601	16.093	SAUCEDA MTS
218	20.355	24.147	161.029	75.025	33.946	213.902	22.928	SAUCEDA MTS
219	30.567	15.633	138.024	37.312	19.446	139.163	19.734	VULTURE
220	22.917	20.567	151.968	66.732	31.23	201.671	23.986	SAUCEDA MTS
221	31.363	25.229	168.902	73.886	37.16	210.9	22.818	SAUCEDA MTS
222	31.452	29.914	257.808	7.351	72.701	241.139	33.335	LOS VIDRIOS
223	26.821	17.644	132.928	35.979	20.86	135.4	23.837	VULTURE
224	39.269	14.587	113.631	78.272	22.541	95.856	54.959	GOVT MTN
225	22.992	11.375	106.482	35.257	22.633	100.901	29.426	SUPERIOR

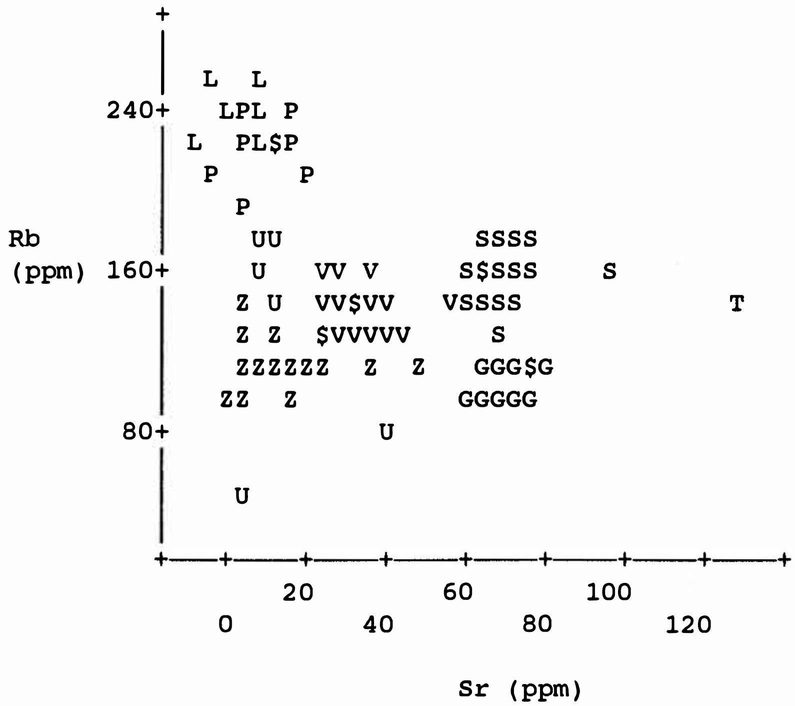
Figure 1. Sr versus Zr concentration plot for analyzed obsidian artifacts.

```
           +
           |        T
           |
           |
           |
        95+                     S
           |
 Sr        | GG$GGGG            SSSSSSSSS
 (ppm)     | GGGGGG            $SSSSSSS
           |  G                VS  SS
      47.5+          V       S
           |       $$ VVVVVV
           |      Z   $VVVV
           |   ZZPZZ $Z $
           |$  PZZ$                L  LLU  $ U
         0+  Z$   Z   P              L L
           | P                       L
           ++-----+-----+-----+-----+-----+-----+-----+--+
              82.5      137.5     192.5     247.5
           55        110       165       220

                            Zr (ppm)
```

Legend: G= Government Mtn.; L=Los Vidrios; P=Partridge Creek; S=Sauceda Mts; U=unknown; Z=Superior (Picketpost Mtn); $=multiple occurrences

Figure 2. Rb versus Sr concentration plot for analyzed obsidian artifacts.



Legend: G= Government Mtn.; L=Los Vidrios; P=Partridge Creek; S=Sauceda Mts; U=unknown; Z=Superior (Picketpost Mtn); $=multiple occurrences

URL

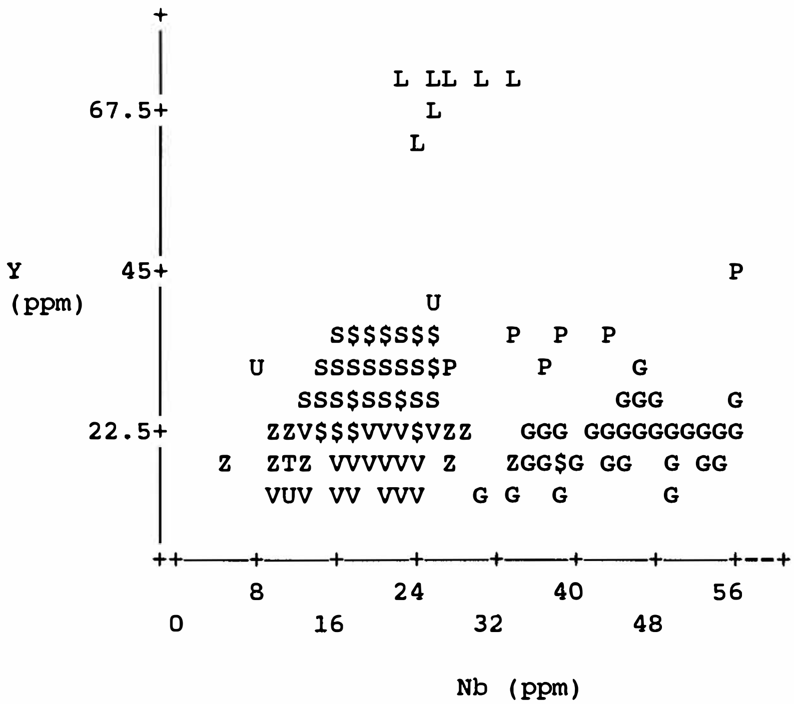
Figure 3. Rb versus Zr concentration plot for analyzed obsidian artifacts.

```
         +
         |
         |                              L   L
      240+         P  P              L L
         |   P  P  P            L LL
         | P   P
         |P
Rb       |                       S SSSS S     U
(ppm) 160+             V       $SSSSSS S    U
         |Z         T$VVVVV    $SSSSSS   U
         |    Z Z VVZVVVVVV    S
         |  G$$$$$ZZ        S
         | G$$$G$$
       80+         U
         |
         |U
         |
         ++----+----+----+----+----+----+----+--+
            82.5    137.5     192.5     247.5
         55       110       165       220

                            Zr (ppm)
```

Legend: G= Government Mtn.; L=Los Vidrios; P=Partridge Creek; S=Sauceda Mts; U=unknown; Z=Superior (Picketpost Mtn); $=multiple occurrences

Figure 4. Y versus Nb concentration plot for analyzed obsidian artifacts.



Legend: G= Government Mtn.; L=Los Vidrios; P=Partridge Creek; S=Sauceda Mts; U=unknown; Z=Superior (Picketpost Mtn); $=multiple occurrences

Table 3. Frequency distribution of obsidian source provenience, distance to source, direction and region of origin.

Source	Frequency	Percent	Distance[1] to Source(km)	Direction	Region
SAUCEDA MTS	67	30.5	110	SW	NW Sonoran
VULTURE	59	26.8	95	WNW	NW Sonoran
GOVERNMENT MTN	48	21.8	210	N	Colo. Plateau
SUPERIOR	22	10.0	80	ESE	NE Sonoran
LOS VIDRIOS	8	3.6	205	SSW	Cent. Sonoran
PARTRIDGE CR	9	4.1	225	NNW	NW C. Plateau
TANK MTS	1	.5	160	WSW	NW Sonoran
UNKNOWN	1	.5	n/a	n/a	
UNKNOWN A	4	1.8	n/a	n/a	
UNKNOWN B	1	.5	n/a	n/a	
	-------	-------			
TOTAL	220	100.0			

1 Straight line distance.

Figure 5. Frequency and proportional histogram of obsidian source provenience.

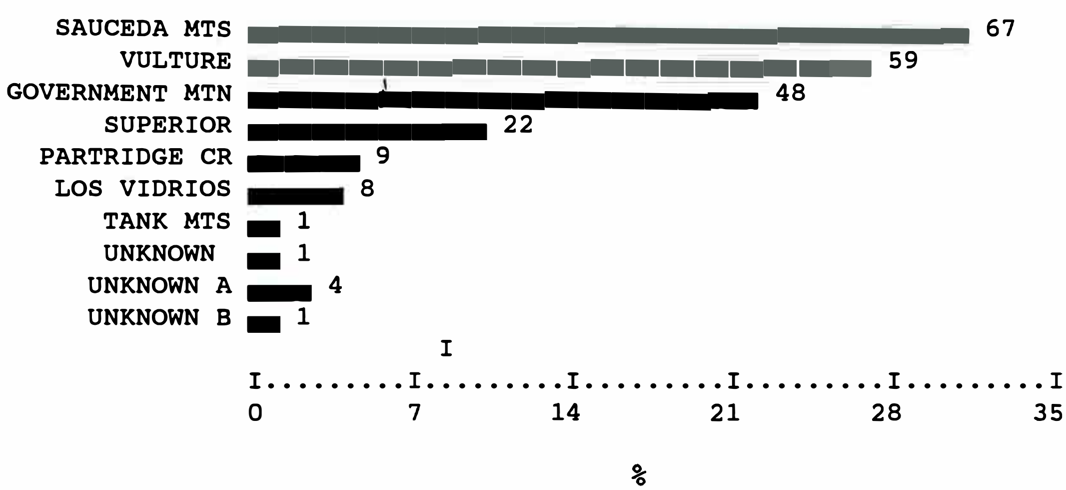
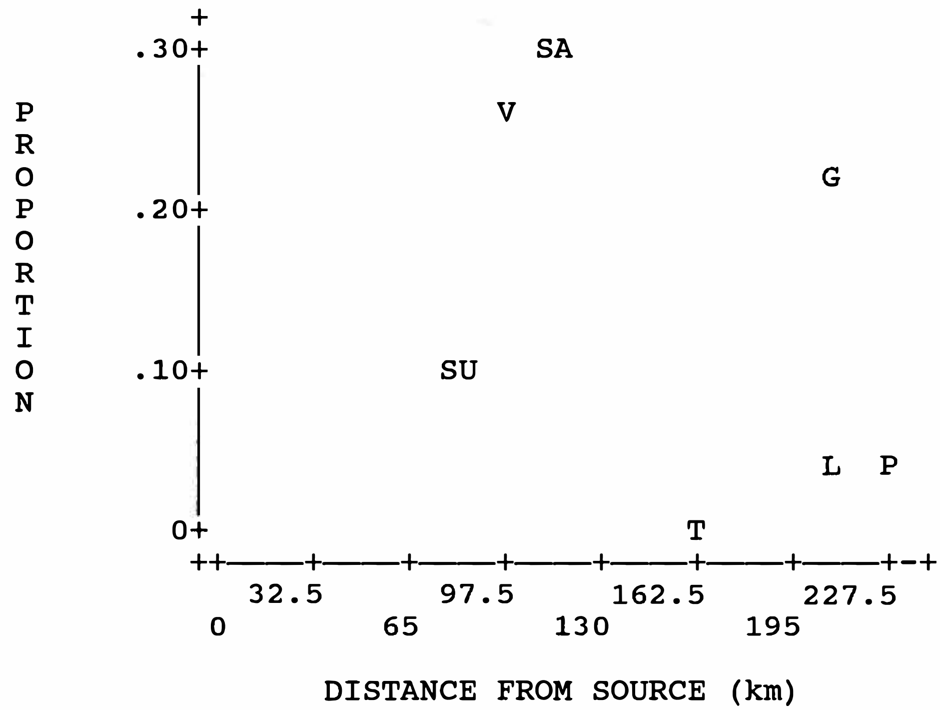


Table 2. X-ray fluorescence concentrations for obsidian artifacts from Pueblo Grande. All values are in parts per million (ppm).

SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Source
1G1M385	1358.5	358.0	11136.0	177.0	76.926	35.377	210.1	25.5	Sauceda Mts
1CSTL1A577	1149.1	301.3	8566.6	141.8	41.302	17.314	124.8	15.6	Vulture
1J1Z313	1437.8	314.5	10727.4	163.7	78.945	34.438	199.0	21.6	Sauceda Mts
1G1MI90	410.0	504.8	10024.5	116.4	83.752	21.212	80.5	55.2	Govt Mtn
1G1Y203	1312.1	322.5	10544.6	155.7	68.643	34.285	189.3	25.2	Sauceda Mts
1G1232	868.1	487.8	7838.7	120.3	19.988	23.467	92.9	33.8	Superior
1J1Z321	1109.3	458.2	8441.7	103.3	35.294	17.724	94.9	29.5	Superior
92.2.2	1106.3	403.4	9529.3	164.8	47.242	22.646	150.5	27.4	Vulture
92.25	462.3	490.7	9972.8	109.7	76.884	17.287	78.3	52.2	Govt Mtn
92.2.1	937.0	455.6	7811.5	124.0	20.794	17.951	87.7	26.1	Superior
92.30.1	994.2	424.0	7611.8	119.5	17.012	20.375	88.9	28.0	Superior
92.22	951.2	342.1	8853.3	141.7	42.678	17.803	129.9	24.1	Vulture
92.30.4	797.8	464.9	6449.9	108.843	19.515	20.52	88.4	29.5	Superior
90.30.3	313.6	459.1	10832.5	421.161	6.039	85.094	177.6	259.1	RS Hill/Sitgreaves
92.30.2	659.1	312.0	8673.4	225.694	16.86	31.594	109.3	23.3	Partridge Cr
92.29.1	676.1	333.2	9038.1	243.007	22.587	34.662	109.1	24.7	Partridge Cr
92.2.5	853.8	392.0	7920.0	140.128	41.295	17.491	126.9	17.3	Vulture
92.2.3	840.8	411.9	8119.1	148.574	40.292	15.788	133.7	25.6	Vulture
92.2.4	1169.8	357.7	10470.8	167.236	78.792	32.008	205.0	21.6	Sauceda Mts

Figure 6. Regression scatterplot of assemblage proportion and distance to source for obsidian artifacts recovered from Pueblo Grande.



Legend: G=Government Mt, L=Los Vidrios, P=Partridge Cr, SA=Sauceda Mts, SU=Superior (Picketpost Mt), T=Tank Mts, V=Vulture.