Title
SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM EIGHT SITES ON THE NAVAL WEAPONS STATION CHINA LAKE, INYOCOUNTY, CALIFORNIA

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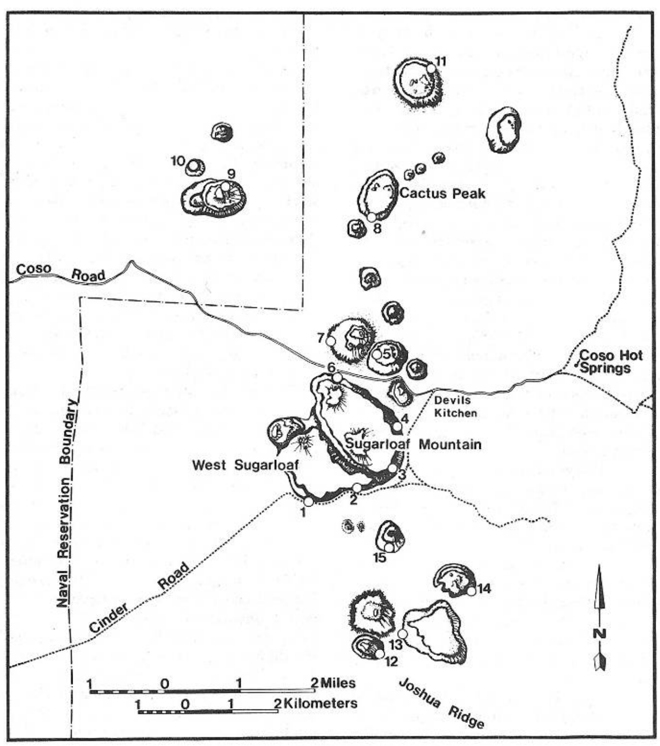

A portion of the Coso Volcanic Field with relevant rhyolite domes (from Bacon et al. 1981; Hughes 1988)

by

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INTRODUCTION

The analysis here of 132 artifacts from eight sites in Inyo County within the China Lake Naval Weapons Station indicates a relatively diverse provenance assemblage dominated by West Sugarloaf dome obsidian in the Coso Volcanic Field, as in all the previous studies by this laboratory, and all the artifacts were produced entirely from Coso Volcanic Field sources, Sugarloaf, West Sugarloaf, and West Cactus Peak domes (see discussion below). No sources outside the Coso field were present.

LABORATORY SAMPLING, ANALYSIS AND INSTRUMENTATION

All archaeological samples are analyzed whole. The results presented here 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 (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; Shackley 2011).

All analyses for this study were conducted on a ThermoScientific *Quant'X* EDXRF spectrometer, located at the Geoarchaeological XRF Laboratory, Albuquerque, New Mexico. It is equipped with a thermoelectrically Peltier cooled solid-state Si(Li) X-ray detector, with a 50 kV, 50 W, ultra-high-flux end window bremsstrahlung, Rh target X-ray tube and a 76 µm (3 mil) beryllium (Be) window (air cooled), that runs on a power supply operating 4-50 kV/0.02-1.0 mA at 0.02 increments. The spectrometer is equipped with a 200 l min^{-1} Edwards vacuum pump, allowing for the analysis of lower-atomic-weight elements between sodium (Na) and titanium (Ti). Data acquisition is accomplished with a pulse processor and an analogue-to-digital converter. Elemental composition is identified with digital filter background removal, least squares empirical peak deconvolution, gross peak intensities and net peak intensities above background.

For the analysis of mid Zb condition elements Ti-Nb, Pb, Th, the x-ray tube is operated at 30 kV, using a 0.05 mm (medium) Pd primary beam filter in an air path at 100 seconds livetime to generate x-ray intensity $K\alpha_1$-line data for elements titanium (Ti), manganese (Mn), iron (as $Fe_2O_3^T$), cobalt (Co), nickel (Ni), copper, (Cu), zinc, (Zn), gallium (Ga), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), niobium (Nb), lead (Pb), and thorium (Th). Not all these elements are reported since their values in many volcanic rocks are very low. Trace element intensities were converted to concentration estimates by employing a linear calibration line ratioed to the Compton scatter established for each element from the analysis of international rock standards certified by the National Institute of Standards and Technology (NIST), the US. Geological Survey (USGS), Canadian Centre for Mineral and Energy Technology, and the Centre de Recherches Pétrographiques et Géochimiques in France (Govindaraju 1994). Line fitting is linear (XML) for all elements but Fe where a derivative fitting is used to improve the fit for iron and thus for all the other elements. Further details concerning the petrological choice of these elements in Southwest obsidians is available in Shackley (1995, 2005, 2019; Shackley et al. 2018; also Mahood and Stimac 1991; and Hughes and Smith 1993). Nineteen specific pressed powder standards are used for the best fit regression calibration for elements Ti-Nb, Pb, Th, and Ba, include G-2 (basalt), AGV-2 (andesite), GSP-2 (granodiorite), SY-2 (syenite), BHVO-2 (hawaiite), STM-1 (syenite), QLO-1 (quartz latite), RGM-1 (obsidian), W-2 (diabase), BIR-1 (basalt), SDC-1 (mica schist), TLM-1 (tonalite), SCO-1 (shale), NOD-A-1 and NOD-P-1 (manganese) all US Geological Survey standards, NIST-278 (obsidian), U.S. National Institute of Standards and Technology, BE-N (basalt) from the Centre de Recherches Pétrographiques et Géochimiques in France, and JR-1 and JR-2 (obsidian) from the Geological Survey of Japan (Govindaraju 1994). Ba was not acquired for this study since it is in very small proportions in Coso Volcanic Field obsidian and not useful in source assignment (Ericson and Glascock 2004;

Hughes 1988). RGM-1 a USGS rhyolite (obsidian) standard from Glass Mountain, Medicine Lake Highlands northern California is analyzed during each sample run of ≤19 to check the stability of machine calibration (Table 1). Source assignments were made by comparison to Ericson and Glascock (2004), Hughes (1988), Nelson and Tingey (1997), Skinner (2005) and source standards in the laboratory (see Table 2 and Figure 1 here).

DISCUSSION

While the dominance of West Sugarloaf dome obsidian is typical in archaeological contexts in all time periods in the region, Sugarloaf and West Cactus Peak obsidian does occur in smaller proportions (Ericson and Glascock 2004; Gilreath and Hildebrandt 1997; Hughes 1988; see Tables 2 and 3 here). In Figure 1 it is apparent that the distribution of the West Sugarloaf rubidium composition is somewhat greater than Hughes (1988) early analysis, but similar in other elements to the Ericson and Glascock (2004) study and generally within the 90% confidence ellipse for the source using laboratory source standards. Since the original study, I have analyzed source standards from Sugarloaf, West Cactus Peak, and West Sugarloaf on loan from Craig Skinner. The analyses between the laboratories is close enough that no changes in source assignment are evident (see Craig et al. 2007; Poupeau et al. 2010 for inter-laboratory experiments).

The dominance of Coso Volcanic Field obsidian in these sites, and the lack of other non-Coso sources is sensible given that the quality of the obsidian for toolstone production is a good as any on Earth, particularly West Sugarloaf (c.f. Gilreath and Hildebrandt 1997). The Coso sources, particularly West Sugarloaf have been recovered throughout much of southern California into northern Baja California, and well into the Great Basin (Gilreath and Hildebrandt 1997). A recent extensive study of obsidian procurement in southern Alta California and northern Baja California found Coso sources common in Archaic through Late Prehistoric sites in that region, although dominated by Obsidian Butte after the eruption of the dome complex around 2200 bp. (Schmitt et al. 2019; Shackley 2019; see also Panich et al. 2017).

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Table 1. Recommended values for USGS RGM-1 obsidian standard and mean and central tendency data from this study. ± = 1st standard deviation.

SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Pb	Th
RGM-1 (Govindaraju 1994)	1600	279	12998	149	108	25	219	8.9	24	15.1
RGM-1 (USGS recommended)[1]	1619±120	279±50	13010±210	150±8	110±10	25[2]	220±20	8.9±0.6	24±3	15±1.3
RGM-1, pressed powder standard (this study, n=6)	1505±83	306±10	13708±44	147±2	107±2	25±2	220±2	6±2.6	20±2.3	16±3

[1] Ti, Mn, Fe calculated to ppm from wt. percent from USGS data.
[2] information value

Table 2. Elemental concentrations and source assignments for the archaeological specimens. All measurements in parts per million (ppm).

Cat #	Site	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Pb	Th	Source
2A	INY-5654/H	594	311	12064	253	14	45	125	48	32	34	Sugarloaf
2B	INY-5654/H	567	275	12074	264	15	54	145	48	34	45	W Sugarloaf
3	INY-5654/H	632	337	13147	308	22	56	159	48	38	34	W Sugarloaf
4A	INY-5654/H	445	314	11952	247	15	49	114	46	33	29	Sugarloaf
4B	INY-5654/H	410	304	11864	245	10	53	123	43	35	31	Sugarloaf
4C	INY-5654/H	649	290	12411	258	19	53	148	47	34	35	W Sugarloaf
5A	INY-5654/H	450	278	11828	245	17	52	152	46	32	35	W Sugarloaf
5B	INY-5654/H	606	283	12302	280	18	53	146	50	35	41	W Sugarloaf
6A	INY-5654/H	604	289	11563	233	17	52	122	42	25	30	Sugarloaf
6B	INY-5654/H	535	319	12395	264	22	51	157	44	27	26	W Sugarloaf
20A	INY-5654/H	446	283	12023	266	14	63	145	48	32	35	W Sugarloaf
23B	INY-5654/H	526	287	12054	281	16	58	142	57	34	41	W Sugarloaf
24A	INY-5654/H	505	284	11855	215	22	46	156	39	21	34	W Sugarloaf
21A	INY-5654/H	506	286	11901	226	20	49	155	45	26	29	W Sugarloaf
21B	INY-5654/H	476	308	12191	284	19	60	146	51	31	33	W Sugarloaf

Cat #	Site	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Pb	Th	Source
21C	INY-5654/H	524	278	11740	222	19	47	153	45	28	30	W Sugarloaf
23A	INY-5654/H	576	315	12186	277	18	54	149	44	32	37	W Sugarloaf
28A	INY-5654/H	456	282	11911	263	16	51	139	41	32	30	W Sugarloaf
28B	INY-5654/H	601	295	11806	231	11	49	120	45	30	25	Sugarloaf
29	INY-5654/H	414	282	11288	241	14	47	110	41	34	35	Sugarloaf
30A	INY-5654/H	425	292	11466	250	13	48	122	40	29	38	Sugarloaf
30B	INY-5654/H	491	293	12077	288	18	52	148	48	32	41	W Sugarloaf
30C	INY-5654/H	461	276	11340	234	12	46	110	35	27	28	Sugarloaf
31A	INY-5654/H	377	288	11261	239	17	47	124	44	27	23	Sugarloaf
31B	INY-5654/H	445	290	11734	263	18	57	141	46	30	38	W Sugarloaf
31C	INY-5654/H	462	290	11841	263	15	49	138	49	31	43	W Sugarloaf
32A	INY-5654/H	416	351	11979	256	9	51	121	49	35	32	Sugarloaf
32B	INY-5654/H	318	282	11327	233	15	50	117	43	28	41	Sugarloaf
32C	INY-5654/H	516	320	12206	265	17	49	149	48	37	37	W Sugarloaf
4A	INY-5655	562	344	12310	270	18	50	121	44	31	37	Sugarloaf
5	INY-5655	542	323	12757	310	9	57	144	53	39	47	W Sugarloaf
6	INY-5655	846	293	12108	268	17	56	136	52	29	34	W Sugarloaf
7A	INY-5655	445	259	11182	292	13	64	120	73	31	34	W Cactus Pk
7B	INY-5655	516	315	11899	263	11	52	117	46	30	33	Sugarloaf
8	INY-5655	613	298	11965	327	10	73	129	67	42	41	W Cactus Pk
9A	INY-5655	574	272	11724	256	20	55	139	43	29	28	W Sugarloaf
9B	INY-5655	439	316	11761	254	13	47	120	40	37	27	Sugarloaf
9C	INY-5655	439	286	11759	320	10	62	123	65	37	42	W Cactus Pk
10	INY-5655	454	276	11362	235	12	46	118	41	28	40	Sugarloaf
11A	INY-5655	460	288	11520	237	11	47	113	49	29	35	Sugarloaf
11B	INY-5655	542	300	11453	240	14	49	116	43	25	29	Sugarloaf
11C	INY-5655	510	294	11926	267	15	55	143	51	37	38	W Sugarloaf
12	INY-5655	466	294	11495	238	17	46	116	43	34	33	Sugarloaf
13	INY-5655	491	282	11809	251	18	55	132	44	29	43	W Sugarloaf
14A	INY-5655	439	279	11591	251	12	45	115	44	34	32	Sugarloaf
14B	INY-5655	621	286	12135	273	11	56	138	40	30	33	W Sugarloaf
14C	INY-5655	431	309	11438	237	10	50	117	43	34	35	Sugarloaf
15A	INY-5655	532	288	11924	262	18	58	148	43	31	35	W Sugarloaf
16A	INY-5655	758	323	12771	280	16	50	139	49	35	35	W Sugarloaf

Cat #	Site	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Pb	Th	Source
17A	INY-5655	519	298	12026	273	15	54	142	46	34	45	W Sugarloaf
7A	INY-7012	558	279	12040	270	15	51	144	49	28	34	W Sugarloaf
7B	INY-7012	555	325	12009	247	15	49	117	42	34	35	Sugarloaf
8A	INY-7012	455	323	12007	243	14	44	120	43	34	25	Sugarloaf
9A	INY-7012	560	291	11600	234	16	42	110	45	30	33	Sugarloaf
12A	INY-7012	537	307	12009	335	12	72	123	68	37	46	W Cactus Pk
12B	INY-7012	689	303	12182	229	18	44	152	39	27	29	W Sugarloaf
13A	INY-7012	449	309	12161	341	12	69	125	68	44	45	W Cactus Pk
13B	INY-7012	452	273	11746	324	9	63	124	69	46	44	W Cactus Pk
25A	INY-7012	443	306	11617	240	16	50	113	49	33	39	Sugarloaf
25B	INY-7012	440	284	11534	237	13	51	113	48	31	31	Sugarloaf
26A	INY-7012	402	294	11674	249	10	47	115	48	36	44	Sugarloaf
26B	INY-7012	415	293	11441	243	14	54	119	43	29	38	Sugarloaf
26C	INY-7012	439	316	11851	253	12	50	116	45	36	43	Sugarloaf
28A	INY-7012	496	277	11432	240	11	45	121	42	25	25	Sugarloaf
28B	INY-7012	371	295	11426	239	12	49	117	44	31	34	Sugarloaf
28C	INY-7012	474	295	11570	244	17	51	125	42	31	36	Sugarloaf
9A	INY-7024	528	292	11850	252	18	52	146	48	30	30	W Sugarloaf
10A	INY-7024	582	297	12270	279	17	55	146	45	32	46	W Sugarloaf
11A	INY-7024	585	295	12336	261	12	58	146	46	31	42	W Sugarloaf
11B	INY-7024	540	299	12404	248	18	48	157	44	28	33	W Sugarloaf
12A	INY-7024	717	299	11874	267	15	59	136	41	37	48	W Sugarloaf
15A	INY-7024	521	286	12163	271	17	56	145	46	32	33	W Sugarloaf
14B	INY-7024	486	294	12065	275	14	58	139	53	34	38	W Sugarloaf
15C	INY-7024	502	305	12180	283	13	58	146	50	33	44	W Sugarloaf
16A	INY-7024	335	283	11660	265	14	57	146	50	30	34	W Sugarloaf
16B	INY-7024	465	270	11543	253	16	59	142	43	25	36	W Sugarloaf
16C	INY-7024	516	290	11841	272	17	53	146	56	34	39	W Sugarloaf
17A	INY-7024	505	311	12210	285	11	60	139	52	32	39	W Sugarloaf
17B	INY-7024	557	293	12073	278	12	56	143	45	31	31	W Sugarloaf
18A	INY-7024	513	277	12080	289	16	56	147	51	29	34	W Sugarloaf
18B	INY-7024	473	297	12367	301	20	64	149	48	35	49	W Sugarloaf
19A	INY-7024	519	294	11820	278	15	54	142	49	27	34	W Sugarloaf
20A	INY-7024	503	290	11917	267	15	60	138	46	31	42	W Sugarloaf

Cat #	Site	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Pb	Th	Source
20B	INY-7024	532	308	12686	302	13	54	152	48	36	37	W Sugarloaf
21A	INY-7024	433	302	11999	278	15	62	150	52	33	37	W Sugarloaf
21B	INY-7024	509	267	11852	267	17	59	138	45	35	34	W Sugarloaf
21C	INY-7024	518	265	12114	283	15	56	147	46	35	37	W Sugarloaf
22A	INY-7024	458	292	12043	277	17	54	140	50	31	26	W Sugarloaf
22B	INY-7024	563	327	12736	297	17	57	142	45	41	45	W Sugarloaf
28A	INY-7024	565	322	12391	288	20	56	147	49	35	37	W Sugarloaf
29A	INY-7024	511	291	11915	269	16	58	142	49	26	40	W Sugarloaf
29B	INY-7024	573	298	11807	258	14	55	133	46	33	35	W Sugarloaf
30A	INY-7024	556	285	12033	275	16	53	140	47	31	38	W Sugarloaf
30B	INY-7024	524	296	12276	283	15	56	142	52	35	38	W Sugarloaf
31A	INY-7024	532	296	12032	261	15	54	138	48	31	33	W Sugarloaf
2A	RP4-RF-03	515	301	12487	277	11	50	146	43	34	40	W Sugarloaf
3A	RP4-RF-03	463	292	12019	264	16	57	147	50	33	35	W Sugarloaf
3B	RP4-RF-03	573	297	12381	257	19	50	145	51	31	40	W Sugarloaf
4A	RP4-RF-03	481	292	11941	234	20	49	156	40	27	29	W Sugarloaf
4B	RP4-RF-03	622	298	11895	208	30	45	151	39	25	32	W Sugarloaf
4C	RP4-RF-03	513	297	12092	231	18	46	155	39	32	37	W Sugarloaf
5A	RP4-RF-03	537	286	12052	224	21	51	165	38	27	36	W Sugarloaf
5B	RP4-RF-03	649	307	12322	243	22	43	160	42	26	35	W Sugarloaf
3A	RP4-SH-03	615	287	12510	325	9	65	126	64	37	37	W Cactus Pk
3B	RP4-SH-03	437	298	12236	351	17	72	122	69	45	35	W Cactus Pk
5	RP4-SH-03	433	296	11937	337	12	71	137	73	41	42	W Cactus Pk
5A	RP4-SH-03	593	290	12605	253	21	53	154	42	28	25	W Sugarloaf
5B	RP4-SH-03	626	293	12702	219	20	42	155	36	26	25	W Sugarloaf
8	RP4-SH-03	575	305	12316	287	15	54	142	48	30	37	W Sugarloaf
9A	RP4-SH-03	505	286	11923	268	15	59	144	51	31	35	W Sugarloaf
9B	RP4-SH-03	568	287	11982	264	17	60	139	39	34	42	W Sugarloaf
11A	RP4-SH-03	623	327	12551	273	20	53	147	49	32	32	W Sugarloaf
12	RP4-SH-03	629	316	11691	241	16	44	109	45	39	43	Sugarloaf
6A	RP4-RF-05/H	611	306	12195	282	19	65	145	42	34	33	W Sugarloaf
6B	RP4-RF-05/H	686	317	12077	249	16	46	122	36	34	36	Sugarloaf
7A	RP4-RF-05/H	495	299	12206	289	15	47	143	50	34	49	W Sugarloaf
10A	RP4-RF-05/H	575	275	11744	268	18	55	141	48	35	36	W Sugarloaf

Cat #	Site	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Pb	Th	Source
10B	RP4-RF-05/H	534	267	11946	266	17	57	142	45	33	43	W Sugarloaf
12A	RP4-RF-05/H	598	334	12556	298	15	58	144	53	35	41	W Sugarloaf
12B	RP4-RF-05/H	514	309	12324	294	17	58	141	48	31	38	W Sugarloaf
13A	RP4-RF-05/H	573	301	12474	277	19	51	153	42	29	44	W Sugarloaf
13B	RP4-RF-05/H	668	294	12195	275	17	57	144	44	31	39	W Sugarloaf
14A	RP4-RF-05/H	493	291	12124	284	14	54	147	51	33	41	W Sugarloaf
14B	RP4-RF-05/H	544	293	12462	281	18	56	146	50	42	40	W Sugarloaf
16	RP4-RF-05/H	579	321	12812	307	17	60	153	51	38	42	W Sugarloaf
2A	RP4-SH-05	640	323	12465	271	18	60	146	49	31	35	W Sugarloaf
2B	RP4-SH-05	411	296	11599	258	15	53	137	48	32	32	W Sugarloaf
3A	RP4-SH-05	418	281	11793	333	10	68	127	64	39	45	W Cactus Pk
3B	RP4-SH-05	754	312	12673	306	18	55	151	47	34	23	W Sugarloaf
4A	RP4-SH-05	631	319	12459	297	15	51	142	52	35	38	W Sugarloaf
4B	RP4-SH-05	573	311	12338	282	20	55	137	51	33	42	W Sugarloaf
5	RP4-SH-05	505	321	12355	297	15	62	140	49	32	39	W Sugarloaf

Table 2. Crosstabulation of source by archaeological site.

			Source			
			W Sugarloaf	Sugarloaf	W Cactus Pk	Total
Site	INY-5654/H	Count	18	11	0	29
		% within Site	62.1%	37.9%	0.0%	100.0%
		% within Source	20.2%	33.3%	0.0%	22.0%
		% of Total	13.6%	8.3%	0.0%	22.0%
	INY-5655	Count	9	9	3	21
		% within Site	42.9%	42.9%	14.3%	100.0%
		% within Source	10.1%	27.3%	30.0%	15.9%
		% of Total	6.8%	6.8%	2.3%	15.9%
	INY-7012	Count	2	11	3	16
		% within Site	12.5%	68.8%	18.8%	100.0%
		% within Source	2.2%	33.3%	30.0%	12.1%
		% of Total	1.5%	8.3%	2.3%	12.1%
	INY-7024	Count	29	0	0	29
		% within Site	100.0%	0.0%	0.0%	100.0%
		% within Source	32.6%	0.0%	0.0%	22.0%
		% of Total	22.0%	0.0%	0.0%	22.0%
	RP4-RF-03	Count	8	0	0	8
		% within Site	100.0%	0.0%	0.0%	100.0%
		% within Source	9.0%	0.0%	0.0%	6.1%
		% of Total	6.1%	0.0%	0.0%	6.1%
	RP4-RF-05/H	Count	11	1	0	12
		% within Site	91.7%	8.3%	0.0%	100.0%
		% within Source	12.4%	3.0%	0.0%	9.1%
		% of Total	8.3%	0.8%	0.0%	9.1%
	RP4-SH-03	Count	6	1	3	10
		% within Site	60.0%	10.0%	30.0%	100.0%
		% within Source	6.7%	3.0%	30.0%	7.6%
		% of Total	4.5%	0.8%	2.3%	7.6%
	RP4-SH-05	Count	6	0	1	7
		% within Site	85.7%	0.0%	14.3%	100.0%
		% within Source	6.7%	0.0%	10.0%	5.3%
		% of Total	4.5%	0.0%	0.8%	5.3%
Total		Count	89	33	10	132
		% within Site	67.4%	25.0%	7.6%	100.0%
		% within Source	100.0%	100.0%	100.0%	100.0%
		% of Total	67.4%	25.0%	7.6%	100.0%

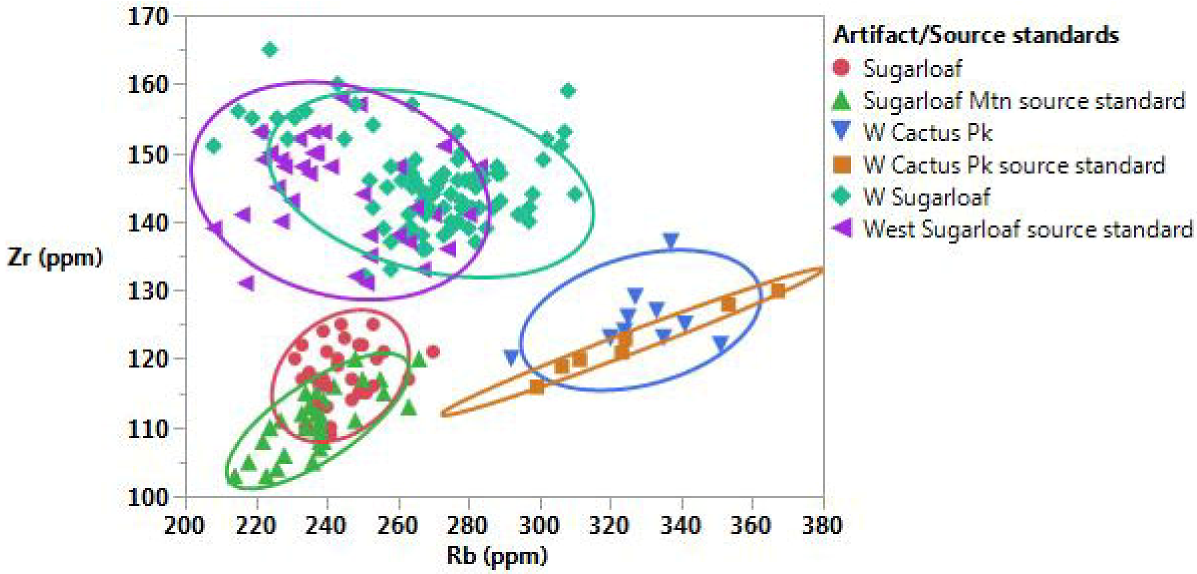

Figure 1. Rb/Zr bivariate plot of the archaeological specimens and Coso volcanic field source standards at this laboratory (after Hughes 1988). Confidence ellipses at 90%. See discussion above.