Title
SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM ARCHAEOLOGICAL SITES ON THE NAVAL WEAPONS STATION CHINA LAKE, INYO, KERN, AND SAN BERNARDINO COUNTIES, CALIFORNIA

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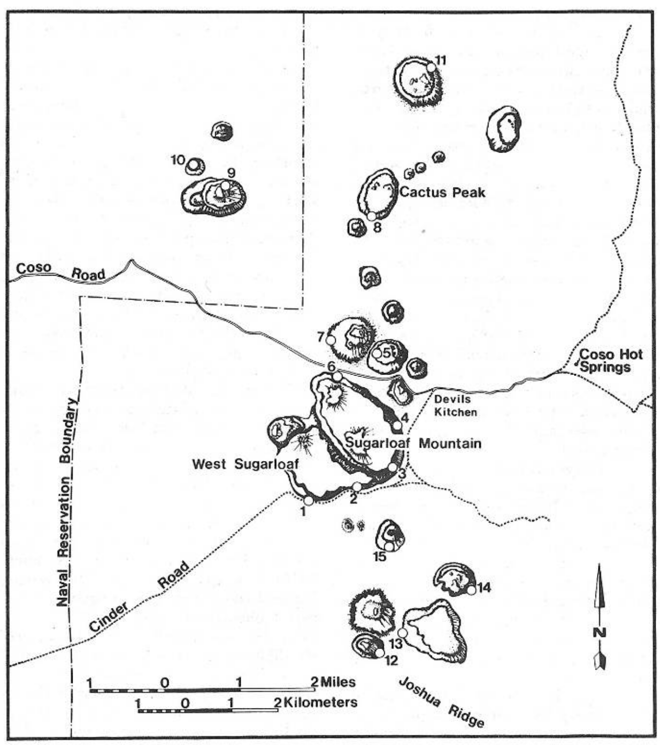

A portion of the Coso Volcanic Field with relevant rhyolite domes (from Bacon et al. 1981; Hughes 1988)

by

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INTRODUCTION

The analysis here of 185 artifacts, 183 obsidian, from a number of sites within the China Lake Naval Weapons Station indicates a relatively diverse provenance assemblage dominated by the West Sugarloaf dome obsidian as in previous studies (Shackley 2014, 2015a, 2015b, 2016).

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 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; Shackley 2011).

All analyses for this study were conducted on a ThermoScientific *Quant'X* EDXRF spectrometer, located at the University of California, Berkeley. 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 Ka-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. When barium (Ba) is analyzed in the High Zb condition, the Rh tube is operated at 50 kV and up to 1.0 mA, ratioed to the bremsstrahlung region (see Davis 2011; Shackley 2011). Further details concerning the petrological choice of these elements in Southwest obsidians is available in Shackley (1995, 2005; 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). RGM-1 a USGS obsidian standard from Glass Mountain, Medicine Lake Highlands is analyzed during each sample run of 20 to check stability of machine calibration (Table 1). Source assignments were made by comparison to Ericson and Glascock (2004) and Hughes (1988; see Table 1 and Figures 1 and

2here), as well as source standards for Sugarloaf, West Sugarloaf, and West Cactus Peak in this laboratory.

DISCUSSION

While the dominance of West Sugarloaf dome obsidian is typical in archaeological contexts in all time periods in the region, Sugarloaf, West Cactus Peak and Joshua Ridge obsidian does occur in smaller proportions (Ericson and Glascock 2004; Gilreath and Haarklau et al. 2005; Hildebrandt 1997; Hughes 1988; Shackley 2014, 2015; see Tables 1 and 2 here). In Figures 1 and 2 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. The 95% confidence ellipses also reflect this variability, not captured by earlier analyses nor those here at this lab.

The one "China Late Unknown A" has been assigned as such by Craig Skinner, and has been found in the region (Haarklau et al. 2005; Shackley and Skinner 2015). It's exact location is unknown, but certainly not from the dome complexes at Coso Volcanic Field.

REFERENCES CITED

Bacon, C.R., R. Macdonald, R.L. Smith, and P.A. Baedecker
1981 *Pleistocene High-Silica Rhyolites of the Coso Formation, Inyo County, California.* U.S. Geological Survey Bulletin 1527.

Davis, M.K., T.L. Jackson, M.S. Shackley, T. Teague, and J. Hampel
2011 Factors Affecting the Energy-Dispersive X-Ray Fluorescence (EDXRF) Analysis of Archaeological Obsidian. In *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology*, edited by M.S. Shackley, pp. 45-64. Springer, New York.

Ericson, J.E., and M.D. Glascock
2004 Subsource Characterization: Obsidian Utilization of Subsources of the Coso Volcanic Field, Coso Junction, California, USA. *Geoarchaeology* 19:779-805.

Gilreath, A.J., and W.R. Hildebrandt
1997 *Prehistoric Use of the Coso Volcanic Field.* Contributions of the University of California Archaeological Research Facility 56. Berkeley.

Govindaraju, K.
1994 1994 Compilation of Working Values and Sample Description for 383 Geostandards. *Geostandards Newsletter* 18 (special issue).

Hampel, Joachim H.
1984 Technical Considerations in X-ray Fluorescence Analysis of Obsidian. In *Obsidian Studies in the Great Basin*, edited by R.E. Hughes, pp. 21-25. Contributions of the University of California Archaeological Research Facility 45. Berkeley.

Haarklau, L., L. Johnson, and D.L. Wagner
2005 Fingerprints in the Great Basin: The Nellis Air Force Base Regional Obsidian Sourcing Study. U.S. Army Corps of Engineers, Fort Worth.

Hildreth, W.
1981 Gradients in Silicic Magma Chambers: Implications for Lithospheric Magmatism. *Journal of Geophysical Research* 86:10153-10192.

Hughes, Richard E.
1988 The Coso Volcanic Field Reexamined: Implications for Obsidian Sourcing and Hydration Dating Research. *Geoarchaeology* 3:253-265.

Hughes, Richard E., and Robert L. Smith
1993 Archaeology, Geology, and Geochemistry in Obsidian Provenance Studies. *In Scale on Archaeological and Geoscientific Perspectives*, edited by J.K. Stein and A.R. Linse, pp. 79-91. Geological Society of America Special Paper 283.

Mahood, Gail A., and James A. Stimac
1990 Trace-Element Partitioning in Pantellerites and Trachytes. *Geochemica et Cosmochimica Acta* 54:2257-2276.

McCarthy, J.J., and F.H. Schamber
1981 Least-Squares Fit with Digital Filter: A Status Report. In *Energy Dispersive X-ray Spectrometry*, edited by K.F.J. Heinrich, D.E. Newbury, R.L. Myklebust, and C.E. Fiori, pp. 273-296. National Bureau of Standards Special Publication 604, Washington, D.C.

Schamber, F.H.
1977 A Modification of the Linear Least-Squares Fitting Method which Provides Continuum Suppression. In *X-ray Fluorescence Analysis of Environmental Samples*, edited by T.G. Dzubay, pp. 241-257. Ann Arbor Science Publishers.

Shackley, M. Steven
1995 Sources of Archaeological Obsidian in the Greater American Southwest: An Update and Quantitative Analysis. *American Antiquity* 60(3):531-551.

2005 *Obsidian: Geology and Archaeology in the North American Southwest.* University of Arizona Press, Tucson.

2011 An Introduction to X-Ray Fluorescence (XRF) Analysis in Archaeology. In *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology*, edited by M.S. Shackley, pp. 7-44. Springer, New York.

2014 Source Provenance of Obsidian Artifacts from Five Sites on the Naval Weapons Station China Lake, Inyo, Kern, and San Bernardino Counties, California. Report prepared for Epsilon Systems Solutions, Ridgecrest, California.

2015a An Energy-Dispersive X-Ray Fluorescence Analysis of Obsidian Artifacts from Site Cs-Tl-01 on the Coles Sam Road Project, Naval Weapons Station China Lake, Inyo County, California. Report prepared for Epsilon Systems Solutions, Ridgecrest, California.

2015b Source Provenance of Obsidian Artifacts from Two Sites on the Naval Weapons Station China Lake, Inyo, Kern, and San Bernardino Counties, California. Report prepared for Epsilon Systems Solutions, Ridgecrest, California.

2016 Source Provenance Of Obsidian Artifacts from 25 Sites on the Naval Weapons Station China Lake, Inyo, Kern County, California. Report prepared for Epsilon Systems Solutions, Ridgecrest, California.

Shackley, M.S., and C. Skinner
2015 Source Provenance of Obsidian Paleoindian and Early Archaic Artifacts from the Great Basin. Report prepared for John Garret, Keller, Texas.

Table 1. Elemental concentrations and source assignments for the samples by site and USGS RGM-1 obsidian standard. All measurements in parts per million (ppm) or weight percent as noted.

Sample	Site	Ti ppm	Mn ppm	Fe %	Zn ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	Pb ppm	Th ppm	Source
2	35BA19	464	286	0.82	74	311	12	68	128	68	36	40	West Cactus Pk
5	35BA19	420	305	0.80	67	241	17	49	120	44	27	27	Sugarloaf
6	35BA19	644	295	0.96	65	265	15	52	155	45	31	31	West Sugarloaf
7	35BA19	532	275	0.82	60	255	18	54	139	46	29	33	West Sugarloaf
2A	35BA31	554	266	0.99	58	200	22	43	160	36	25	32	West Sugarloaf
2B	35BA31	471	303	0.85	58	255	15	52	136	47	30	31	West Sugarloaf
1	35BA31	410	300	0.83	57	263	17	53	142	54	25	33	West Sugarloaf
3	35BA31	453	297	0.86	65	256	20	57	139	48	30	36	West Sugarloaf
4	35BA31	446	292	0.91	84	271	20	52	144	46	34	30	West Sugarloaf
6	35BA31	517	280	0.86	54	260	15	55	139	47	30	38	West Sugarloaf
2A	35BA42	571	290	0.97	64	280	16	58	147	48	30	36	West Sugarloaf
2C	35BA42	604	307	0.98	66	270	22	54	144	50	35	48	West Sugarloaf
2B	35BA42	521	292	0.97	69	265	18	59	144	45	31	39	West Sugarloaf
2D	35BA42	485	295	0.90	71	268	14	54	146	46	31	39	West Sugarloaf
2G	35BA42	441	283	0.89	63	260	13	54	142	49	33	37	West Sugarloaf
2E	35BA42	629	338	1.13	79	303	18	62	153	46	39	43	West Sugarloaf
2H	35BA42	436	273	0.92	69	274	18	55	141	53	35	39	West Sugarloaf
2F	35BA42	442	307	0.99	82	348	12	73	128	74	42	40	West Cactus Pk
2I	35BA42	482	278	0.82	80	261	16	56	143	53	34	32	West Sugarloaf
2J	35BA42	527	286	0.91	71	264	17	55	143	51	29	39	West Sugarloaf
2	35BA44	567	264	0.96	66	210	17	43	160	31	23	30	West Sugarloaf
3	35BA44	435	284	0.93	63	269	19	58	143	48	31	37	West Sugarloaf
4	35BA44	487	280	0.82	59	258	19	55	148	53	28	39	West Sugarloaf
5	35BA44	487	275	0.92	73	261	18	54	137	50	28	30	West Sugarloaf
6	35BA44	498	411	0.53	45	100	85	15	49	14	23	15	China Lake Unk A
2A	35BA46	482	296	0.77	54	220	16	46	119	39	23	24	Sugarloaf
2B	35BA46	411	289	0.92	76	267	17	54	147	48	31	44	West Sugarloaf
2C	35BA46	494	266	0.86	65	255	16	53	136	50	31	36	West Sugarloaf
2E	35BA46	507	310	0.85	56	245	11	50	116	43	30	34	Sugarloaf
2F	35BA46	504	298	0.92	68	267	19	59	142	52	32	40	West Sugarloaf
2G	35BA46	444	259	0.72	53	218	17	45	114	40	27	31	Sugarloaf
2H	35BA46	551	252	0.68	52	213	12	45	104	39	26	25	Sugarloaf
2I	35BA46	392	314	0.93	82	278	14	56	145	49	30	29	West Sugarloaf
2J	35BA46	485	270	0.88	71	263	16	59	150	45	31	38	West Sugarloaf
2D	35BA46	537	276	0.93	74	264	19	54	145	47	32	44	West Sugarloaf
1A	35BA51	494	296	0.94	63	198	17	41	164	42	26	27	West Sugarloaf
1B	35BA51	481	292	0.89	59	263	14	52	143	48	30	35	West Sugarloaf
1C	35BA51	528	268	0.84	54	227	16	53	142	39	23	30	West Sugarloaf
1D	35BA51	465	317	0.93	76	270	16	49	140	44	29	33	West Sugarloaf
1E	35BA51	520	266	0.86	64	265	19	54	141	43	23	38	West Sugarloaf
1	35BA61	611	295	1.02	69	210	19	49	158	36	23	29	West Sugarloaf
6	35BA61	628	316	0.96	75	277	19	54	143	55	36	47	West Sugarloaf
10	35BA61	519	287	0.93	64	264	16	53	148	44	26	34	West Sugarloaf

11	35BA61	479	277	0.97	89	269	16	54	149	42	32	36	West Sugarloaf
Sample	**Site**	**Ti**	**Mn**	**Fe**	**Zn**	**Rb**	**Sr**	**Y**	**Zr**	**Nb**	**Pb**	**Th**	**Source**
14	35BA61	520	296	0.91	78	275	14	54	144	46	35	40	West Sugarloaf
7	35BA61	486	310	0.90	67	261	18	50	136	48	32	36	West Sugarloaf
9	35BA61	537	329	0.93	65	258	18	52	118	41	31	33	Sugarloaf
16A	35BA61	446	265	0.88	101	344	14	65	129	68	40	32	West Cactus Pk
16B	35BA61	455	304	0.87	63	264	19	53	139	46	31	41	West Sugarloaf
2	35BA67	533	300	0.94	77	267	17	59	147	48	31	37	West Sugarloaf
3	35BA67	438	287	0.80	62	237	11	44	114	43	30	24	Sugarloaf
4	35BA67	559	308	0.99	67	281	18	51	146	57	36	34	West Sugarloaf
5B	35BA67	427	286	0.83	63	252	19	50	143	44	29	30	West Sugarloaf
5A	35BA67	508	293	0.93	78	275	17	57	146	43	35	43	West Sugarloaf
7	35BA67	435	277	0.92	65	262	16	55	147	46	31	28	West Sugarloaf
6	35BA67	479	251	0.81	59	229	17	53	137	40	26	33	West Sugarloaf
8	35BA67	500	281	0.88	71	268	16	54	145	51	26	36	West Sugarloaf
10A	35BA67	668	304	0.91	64	249	17	54	147	51	28	35	West Sugarloaf
10B	35BA67	479	277	0.88	76	257	17	53	140	45	27	39	West Sugarloaf
2A	35BA68	505	300	0.91	61	262	19	51	148	52	28	32	West Sugarloaf
2B	35BA68	462	265	0.88	69	266	16	56	143	47	29	38	West Sugarloaf
2C	35BA68	511	259	0.83	60	244	15	55	143	45	25	30	West Sugarloaf
2D	35BA68	442	274	0.81	66	247	13	48	113	39	28	41	Sugarloaf
2E	35BA68	376	298	0.83	72	252	13	51	120	44	31	31	Sugarloaf
2G	35BA68	442	270	0.82	81	313	11	66	120	69	33	39	West Cactus Pk
2I	35BA68	327	271	0.77	71	231	9	50	117	42	28	36	Sugarloaf
2F	35BA68	505	300	0.90	72	269	17	54	142	48	32	46	West Sugarloaf
2J	35BA68	543	277	0.88	86	268	12	53	137	39	28	39	West Sugarloaf
2H	35BA68	443	270	0.91	81	272	15	55	143	45	29	37	West Sugarloaf
3A	35BA69	494	275	0.87	58	265	12	51	143	48	28	44	West Sugarloaf
3B	35BA69	407	265	0.80	54	254	14	55	141	46	26	35	West Sugarloaf
3C	35BA69	452	283	0.85	57	256	18	55	137	40	31	31	West Sugarloaf
3D	35BA69	457	273	0.84	57	256	15	56	135	44	28	40	West Sugarloaf
3E	35BA69	507	338	1.07	74	290	19	58	157	56	37	40	West Sugarloaf
3A	35BA72	582	281	0.89	59	254	17	52	146	38	29	29	West Sugarloaf
3B	35BA72	508	292	0.93	70	269	17	59	145	45	30	29	West Sugarloaf
3C	35BA72	535	288	0.93	71	271	14	58	141	50	27	27	West Sugarloaf
3D	35BA72	442	286	0.79	65	237	16	50	125	42	25	33	Sugarloaf
3E	35BA72	536	315	0.90	62	272	18	59	149	48	29	29	West Sugarloaf
8A	35BA78	1390	315	0.98	74	284	101	58	151	41	31	34	West Sugarloaf
8B	35BA78	658	320	0.88	68	254	19	50	113	45	30	38	Sugarloaf
9	35BA78	4062	547	3.78	85	90	487	25	309	20	16	14	not obsidian
12	35BA78	590	290	0.90	63	267	30	57	140	50	34	43	West Sugarloaf
14	35BA78	529	314	1.06	68	289	26	59	153	55	32	44	West Sugarloaf
10	35BA78	464	266	0.87	69	262	35	54	144	46	33	43	West Sugarloaf
11	35BA78	549	290	0.95	70	266	68	57	140	48	30	44	West Sugarloaf
13	35BA78	468	281	0.84	55	210	18	49	151	37	22	24	West Sugarloaf
7A	35BA78	454	283	0.88	66	258	41	57	143	51	27	42	West Sugarloaf
7B	35BA78	508	313	0.94	55	234	19	51	156	44	28	32	West Sugarloaf
7C	35BA78	603	277	0.91	61	189	476	44	156	36	27	27	not obsidian
2	INY6806	434	285	0.90	69	274	15	60	145	50	31	46	West Sugarloaf
5	INY6806	487	303	0.90	67	271	30	54	148	52	29	43	West Sugarloaf

3	INY6806	418	274	0.80	68	304	19	65	121	60	30	32	West Cactus Pk
Sample	**Site**	**Ti**	**Mn**	**Fe**	**Zn**	**Rb**	**Sr**	**Y**	**Zr**	**Nb**	**Pb**	**Th**	**Source**
7A	INY6806	487	277	0.86	57	261	20	51	140	44	29	37	West Sugarloaf
7B	INY6806	494	287	0.96	62	203	42	41	165	33	26	22	West Sugarloaf
90B	KER2144	519	266	0.86	79	252	17	52	141	49	28	31	West Sugarloaf
66	KER2144	579	283	0.93	59	197	18	42	161	38	23	21	West Sugarloaf
90C	KER2144	550	275	0.84	117	251	13	51	138	49	30	35	West Sugarloaf
90D	KER2144	546	290	0.90	83	277	17	59	145	44	34	43	West Sugarloaf
70A	KER2144	419	279	0.80	67	226	14	47	113	40	28	27	Sugarloaf
70B	KER2144	493	276	0.96	83	195	17	45	159	38	27	33	West Sugarloaf
73A	KER2144	492	284	0.89	70	265	14	57	141	48	31	40	West Sugarloaf
72A	KER2144	890	468	0.81	51	181	31	34	146	36	23	22	Joshua Ridge
73C	KER2144	499	269	0.77	72	229	12	47	107	43	25	32	Sugarloaf
70C	KER2144	504	284	0.88	73	257	12	50	141	49	27	25	West Sugarloaf
71	KER2144	463	287	0.80	103	233	13	41	119	45	31	23	Sugarloaf
72B	KER2144	461	304	0.87	86	258	15	52	123	40	31	31	Sugarloaf
80B	KER2144	488	261	0.89	73	272	17	58	143	48	29	29	West Sugarloaf
83	KER2144	478	290	0.90	72	263	19	58	145	49	31	32	West Sugarloaf
87	KER2144	594	295	0.90	92	251	17	50	139	49	34	43	
92	KER2144	505	290	0.92	110	259	15	58	145	48	28	38	West Sugarloaf
72C	KER2144	526	291	0.96	102	278	15	56	136	47	32	33	West Sugarloaf
77	KER2144	560	321	0.96	71	275	16	57	141	47	33	36	West Sugarloaf
90A	KER2144	573	285	0.88	67	262	16	52	142	46	33	47	West Sugarloaf
80A	KER2144	488	328	0.90	73	259	13	44	118	48	36	29	Sugarloaf
90C	KER2144	454	289	0.78	93	309	11	71	120	69	31	35	West Cactus Pk
73B	KER2144	498	292	0.93	85	267	16	55	138	46	30	45	West Sugarloaf
16B	KER5605	382	302	0.84	72	249	11	49	118	47	30	35	Sugarloaf
15B	KER5605	705	343	1.17	76	271	16	57	150	46	38	33	West Sugarloaf
16A	KER5605	1346	239	0.83	21	143	289	19	158	18	4	18	Joshua Ridge
15A	KER5605	430	287	0.84	63	259	17	57	139	45	33	38	West Sugarloaf
17	KER5605	456	284	0.73	60	225	15	49	116	41	27	31	Sugarloaf
15D	KER5605	513	300	0.95	66	239	20	43	161	43	25	33	West Sugarloaf
14D	KER5605	480	282	0.99	64	204	15	46	154	39	26	23	West Sugarloaf
14A	KER5605	483	268	0.95	60	224	19	51	161	40	28	30	West Sugarloaf
15C	KER5605	452	254	0.80	72	318	19	63	118	74	40	49	West Cactus Pk
14B	KER5605	539	288	0.92	71	225	22	50	151	38	25	33	West Sugarloaf
14C	KER5605	445	271	0.89	61	267	16	54	140	42	33	32	West Sugarloaf
5	KER9707	477	291	0.92	64	273	16	59	148	56	37	31	West Sugarloaf
2A	KER9707	449	288	0.80	61	231	12	49	114	42	33	32	Sugarloaf
1A	KER9707	537	276	0.87	56	267	18	60	143	49	36	44	West Sugarloaf
6A	KER9707	585	276	0.94	71	272	17	59	145	46	27	42	West Sugarloaf
4	KER9707	509	256	0.72	51	232	13	48	135	40	21	33	West Sugarloaf
1C	KER9707	438	258	0.79	51	245	11	47	134	49	27	28	West Sugarloaf
6C	KER9707	518	273	0.91	69	270	18	51	140	45	34	37	West Sugarloaf
1D	KER9707	421	314	0.98	75	285	15	59	145	56	37	43	West Sugarloaf
3	KER9707	499	272	0.86	68	245	17	50	142	42	33	27	West Sugarloaf
2B	KER9707	531	297	0.89	69	269	17	57	140	45	30	41	West Sugarloaf
1B	KER9707	474	297	0.98	68	257	16	54	144	49	30	31	West Sugarloaf
1E	KER9707	478	283	0.88	74	264	14	56	142	47	32	43	West Sugarloaf
1F	KER9707	512	306	0.91	77	263	15	56	142	47	26	22	West Sugarloaf

6B	KER9707	567	299	1.05	77	282	14	54	155	47	35	45	West Sugarloaf
Sample	**Site**	**Ti**	**Mn**	**Fe**	**Zn**	**Rb**	**Sr**	**Y**	**Zr**	**Nb**	**Pb**	**Th**	**Source**
41	KER10245	557	293	0.83	91	244	16	48	117	46	37	31	Sugarloaf
1C	SBR12342	516	285	0.86	66	257	12	59	141	43	28	34	West Sugarloaf
1B	SBR12342	533	339	1.01	68	288	20	50	138	47	34	39	West Sugarloaf
1E	SBR12342	555	288	0.88	78	264	15	55	138	45	30	32	West Sugarloaf
1D	SBR12342	547	307	0.92	68	232	22	52	155	43	30	38	West Sugarloaf
1F	SBR12342	574	265	0.87	55	210	27	44	160	41	25	30	West Sugarloaf
1G	SBR12342	478	280	0.83	69	241	12	46	120	41	27	31	Sugarloaf
1I	SBR12342	425	265	0.87	64	260	13	54	140	48	29	36	West Sugarloaf
1J	SBR12342	401	273	0.76	66	238	13	51	118	47	32	37	Sugarloaf
1H	SBR12342	514	293	0.79	60	231	15	52	113	41	25	32	Sugarloaf
1A	SBR12342	513	287	0.83	54	246	17	50	135	51	33	36	West Sugarloaf
1HX	SBR16690	449	298	0.89	76	267	16	53	137	46	31	34	West Sugarloaf
1BX	SBR16690	435	294	0.95	66	279	16	62	150	49	33	38	West Sugarloaf
1FX	SBR16690	553	292	0.96	74	282	17	58	145	49	32	41	West Sugarloaf
1AX	SBR16690	454	269	0.81	62	240	15	55	137	48	28	28	West Sugarloaf
1IX	SBR16690	427	285	0.92	79	269	14	57	145	55	31	35	West Sugarloaf
1DX	SBR16690	472	286	0.86	60	266	16	58	141	41	32	36	West Sugarloaf
1GX	SBR16690	356	271	0.89	69	268	16	55	146	44	35	36	West Sugarloaf
1JX	SBR16690	450	269	0.80	62	252	16	52	138	43	31	31	West Sugarloaf
2	SBR16690	523	280	0.93	103	269	17	56	138	49	23	34	West Sugarloaf
1E	SBR16690	415	260	0.83	71	256	19	54	129	44	33	43	West Sugarloaf
1C	SBR16690	490	290	0.91	70	275	14	58	137	48	31	41	West Sugarloaf
1B	SBR16992	501	299	0.88	62	268	14	52	135	43	27	35	West Sugarloaf
1D	SBR16992	545	309	0.98	70	276	15	58	144	53	36	47	West Sugarloaf
4	SBR16992	456	295	0.77	59	234	14	50	108	42	31	29	Sugarloaf
1H	SBR16992	465	277	0.86	71	264	16	53	137	45	31	33	West Sugarloaf
1I	SBR16992	489	288	0.83	58	241	12	46	120	41	29	36	Sugarloaf
1EX	SBR16992	457	299	0.88	62	250	12	51	120	49	34	41	Sugarloaf
1J	SBR16992	502	314	0.90	69	260	12	49	122	47	36	37	Sugarloaf
1F	SBR16992	566	264	0.81	58	257	13	52	137	51	26	28	West Sugarloaf
1G	SBR16992	456	299	0.92	79	272	16	57	139	52	28	39	West Sugarloaf
1CX	SBR16992	449	287	0.78	57	228	13	44	114	46	29	37	Sugarloaf
1A	SBR16992	410	295	0.79	57	237	16	47	114	44	28	50	Sugarloaf
7A	SBR28701	497	294	0.93	70	274	14	54	145	49	28	31	West Sugarloaf
7C	SBR28701	467	286	0.81	58	240	13	50	118	47	30	40	Sugarloaf
7F	SBR28701	573	305	0.98	76	246	24	54	152	47	29	39	West Sugarloaf
7G	SBR28701	495	273	0.92	75	270	18	55	144	48	31	36	West Sugarloaf
7H	SBR28701	537	315	0.98	70	237	16	46	153	43	26	39	West Sugarloaf
7I	SBR28701	573	274	0.96	92	250	16	58	148	44	33	44	West Sugarloaf
7B	SBR28701	566	293	0.89	59	238	20	50	156	48	28	36	West Sugarloaf
7D	SBR28701	596	267	0.90	61	215	16	47	147	37	28	31	West Sugarloaf
7E	SBR28701	420	282	0.90	73	257	18	55	141	43	35	38	West Sugarloaf
7J	SBR28701	614	304	1.06	85	229	18	44	158	43	29	30	West Sugarloaf
RGM1-S5		1384	300	1.30	42	143	104	25	218	11	18	16	
RGM1-S5		1607	327	1.29	37	147	102	24	215	8	19	17	
RGM1-S4		1465	304	1.31	36	151	110	26	215	10	20	14	

RGM1-S5	1457	311	1.30	34	147	103	21	215	10	21	17
RGM1-S5	1646	308	1.29	35	143	107	22	211	11	20	13

Table 2. Crosstabulation of source by archaeological site.

			Source				
			Joshua Ridge	Sugarloaf	West Cactus Pk	West Sugarloaf	Total
Site	35BA19	Count	0	1	1	2	4
		% within Site	0.0%	25.0%	25.0%	50.0%	100.0%
		% within Source	0.0%	3.2%	14.3%	1.4%	2.2%
		% of Total	0.0%	0.5%	0.5%	1.1%	2.2%
	35BA31	Count	0	0	0	6	6
		% within Site	0.0%	0.0%	0.0%	100.0%	100.0%
		% within Source	0.0%	0.0%	0.0%	4.2%	3.3%
		% of Total	0.0%	0.0%	0.0%	3.3%	3.3%
	35BA42	Count	0	0	1	9	10
		% within Site	0.0%	0.0%	10.0%	90.0%	100.0%
		% within Source	0.0%	0.0%	14.3%	6.3%	5.5%
		% of Total	0.0%	0.0%	0.5%	4.9%	5.5%
	35BA44	Count	0	0	0	4	4
		% within Site	0.0%	0.0%	0.0%	100.0%	100.0%
		% within Source	0.0%	0.0%	0.0%	2.8%	2.2%
		% of Total	0.0%	0.0%	0.0%	2.2%	2.2%
	35BA46	Count	0	4	0	6	10
		% within Site	0.0%	40.0%	0.0%	60.0%	100.0%
		% within Source	0.0%	12.9%	0.0%	4.2%	5.5%
		% of Total	0.0%	2.2%	0.0%	3.3%	5.5%
	35BA51	Count	0	0	0	5	5
		% within Site	0.0%	0.0%	0.0%	100.0%	100.0%
		% within Source	0.0%	0.0%	0.0%	3.5%	2.7%
		% of Total	0.0%	0.0%	0.0%	2.7%	2.7%
	35BA61	Count	0	1	1	7	9
		% within Site	0.0%	11.1%	11.1%	77.8%	100.0%
		% within Source	0.0%	3.2%	14.3%	4.9%	4.9%
		% of Total	0.0%	0.5%	0.5%	3.8%	4.9%
	35BA67	Count	0	1	0	9	10
		% within Site	0.0%	10.0%	0.0%	90.0%	100.0%
		% within Source	0.0%	3.2%	0.0%	6.3%	5.5%
		% of Total	0.0%	0.5%	0.0%	4.9%	5.5%
	35BA68	Count	0	3	1	6	10
		% within Site	0.0%	30.0%	10.0%	60.0%	100.0%
		% within Source	0.0%	9.7%	14.3%	4.2%	5.5%
		% of Total	0.0%	1.6%	0.5%	3.3%	5.5%
	35BA69	Count	0	0	0	5	5
		% within Site	0.0%	0.0%	0.0%	100.0%	100.0%
		% within Source	0.0%	0.0%	0.0%	3.5%	2.7%
		% of Total	0.0%	0.0%	0.0%	2.7%	2.7%
	35BA72	Count	0	1	0	4	5
		% within Site	0.0%	20.0%	0.0%	80.0%	100.0%
		% within Source	0.0%	3.2%	0.0%	2.8%	2.7%
		% of Total	0.0%	0.5%	0.0%	2.2%	2.7%
	35BA78	Count	0	1	0	8	9
		% within Site	0.0%	11.1%	0.0%	88.9%	100.0%
		% within Source	0.0%	3.2%	0.0%	5.6%	4.9%
		% of Total	0.0%	0.5%	0.0%	4.4%	4.9%
	INY6806	Count	0	0	1	4	5
		% within Site	0.0%	0.0%	20.0%	80.0%	100.0%
		% within Source	0.0%	0.0%	14.3%	2.8%	2.7%
		% of Total	0.0%	0.0%	0.5%	2.2%	2.7%
	KER10245	Count	0	1	0	0	1
		% within Site	0.0%	100.0%	0.0%	0.0%	100.0%
		% within Source	0.0%	3.2%	0.0%	0.0%	0.5%
		% of Total	0.0%	0.5%	0.0%	0.0%	0.5%
	KER2144	Count	1	5	1	15	22
		% within Site	4.5%	22.7%	4.5%	68.2%	100.0%
		% within Source	50.0%	16.1%	14.3%	10.6%	12.1%
		% of Total	0.5%	2.7%	0.5%	8.2%	12.1%
	KER5605	Count	1	2	1	7	11
		% within Site	9.1%	18.2%	9.1%	63.6%	100.0%
		% within Source	50.0%	6.5%	14.3%	4.9%	6.0%
		% of Total	0.5%	1.1%	0.5%	3.8%	6.0%
	KER9707	Count	0	1	0	13	14
		% within Site	0.0%	7.1%	0.0%	92.9%	100.0%
		% within Source	0.0%	3.2%	0.0%	9.2%	7.7%
		% of Total	0.0%	0.5%	0.0%	7.1%	7.7%
	SBR12342	Count	0	3	0	7	10
		% within Site	0.0%	30.0%	0.0%	70.0%	100.0%
		% within Source	0.0%	9.7%	0.0%	4.9%	5.5%
		% of Total	0.0%	1.6%	0.0%	3.8%	5.5%
	SBR16690	Count	0	0	0	11	11
		% within Site	0.0%	0.0%	0.0%	100.0%	100.0%
		% within Source	0.0%	0.0%	0.0%	7.7%	6.0%
		% of Total	0.0%	0.0%	0.0%	6.0%	6.0%
	SBR16992	Count	0	6	0	5	11
		% within Site	0.0%	54.5%	0.0%	45.5%	100.0%
		% within Source	0.0%	19.4%	0.0%	3.5%	6.0%
		% of Total	0.0%	3.3%	0.0%	2.7%	6.0%
	SBR28701	Count	0	1	0	9	10
		% within Site	0.0%	10.0%	0.0%	90.0%	100.0%
		% within Source	0.0%	3.2%	0.0%	6.3%	5.5%
		% of Total	0.0%	0.5%	0.0%	4.9%	5.5%
Total		Count	2	31	7	142	182
		% within Site	1.1%	17.0%	3.8%	78.0%	100.0%
		% within Source	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	1.1%	17.0%	3.8%	78.0%	100.0%

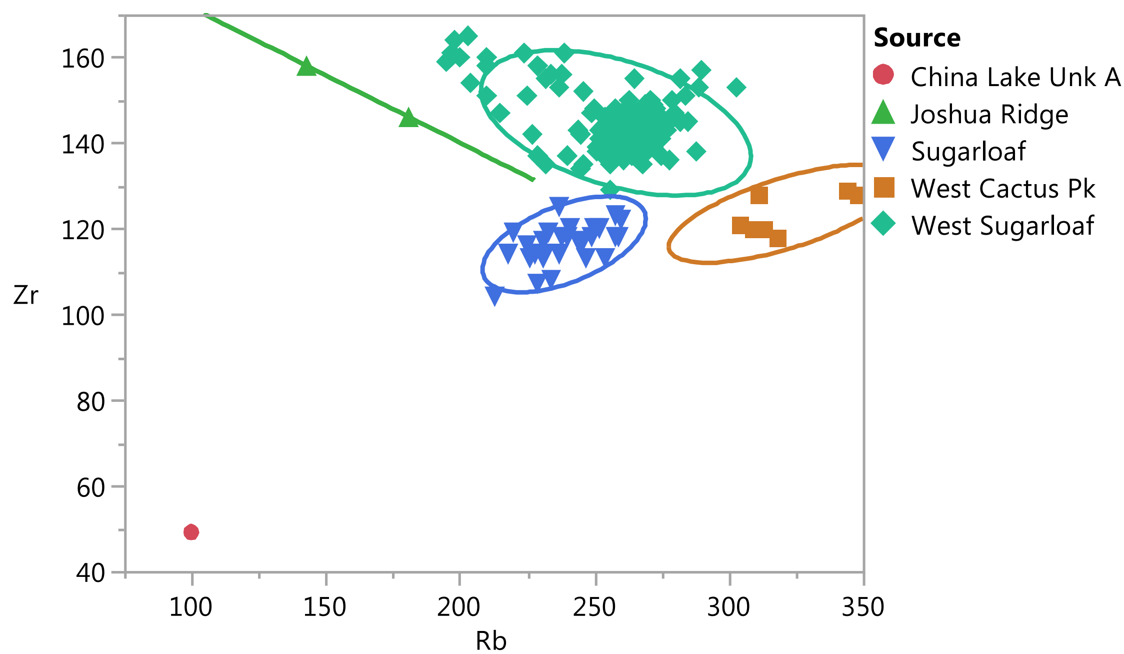

Figure 1. Bivariate plot of Rb/Zr concentrations for archaeological specimens from all sites (after Hughes 1988). Confidence ellipses are at 95%.

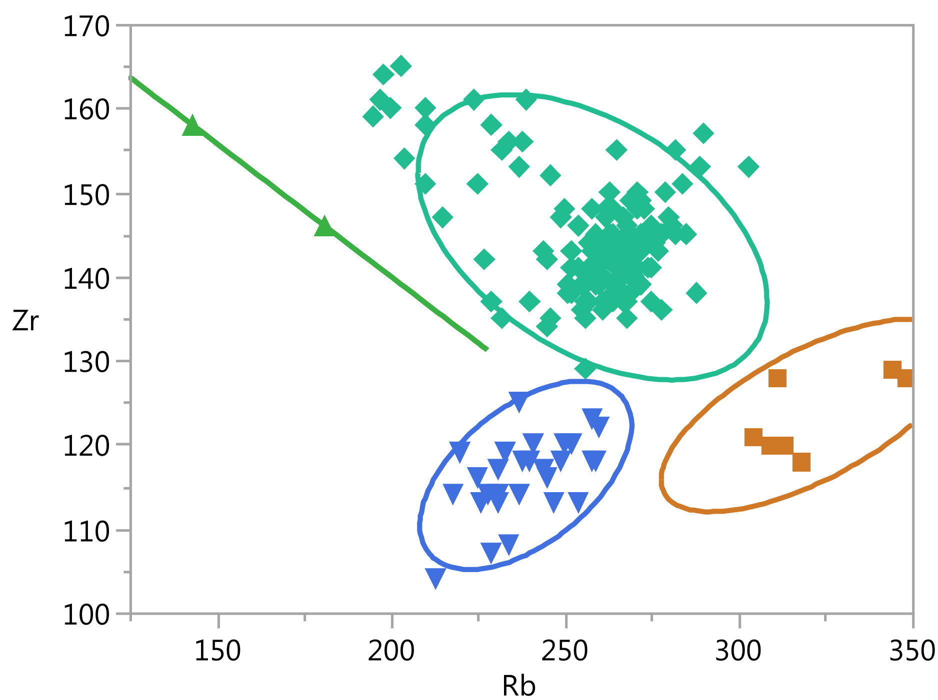

Figure 1. Bivariate plot of Rb/Zr concentrations for archaeological specimens from all sites, minus the unknown providing clarity (after Hughes 1988). Confidence ellipses are at 95%.