Title
SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM CRYSTAL CAVE (39LA504) WESTERN SOUTH DAKOTA

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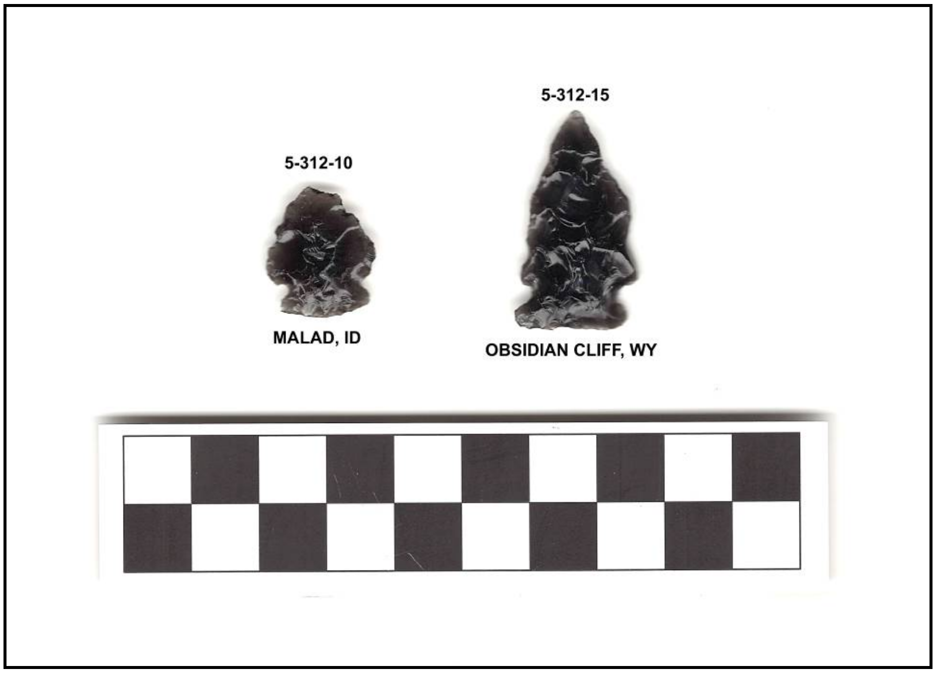

Two obsidian projectile points from Crystal Cave

by

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Report Prepared for

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INTRODUCTION

The results of the x-ray fluorescence analysis (XRF) here of 148 obsidian artifacts from Late Archaic contexts at Crystal Cave (39LA504), western South Dakota indicates procurement of three major prehistoric obsidian sources in western Wyoming (Obsidian Cliff) and eastern Idaho (Bear Gulch and Malad; see Tables 1 and 2 and Figures 1 and 2 here). These sources are common in Great Plains and Rocky Mountain sites (Hughes 2007; see discussion).

LABORATORY SAMPLING, ANALYSIS AND INSTRUMENTATION

The sample was 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 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 scandium (Sc). 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.

The analysis for 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 generally using an 8.8 mm tube collimator 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 and below detection limits. 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. 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 volcanic rocks is available in Shackley (1995, 2005; also Mahood and Stimac 1990; 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 (oceanic 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).

The data from the WinTrace™ software were translated directly into Excel for Windows software for manipulation and on into SPSS v.21 and JMP 4.1 for Windows for plotting. In order to evaluate these quantitative determinations, machine data were compared to measurements of known standards during each run. RGM-1 a USGS rhyolite (obsidian) standard was analyzed during each run of ≤20 samples. The USGS recommended values are included in Table 1. Trace element data exhibited in Table 1 is reported in parts per million (ppm), a quantitative measure by weight.

DISCUSSION

While the Obsidian Cliff source group in Yellowstone National Park and the Malad, Idaho source are well known in the archaeological literature, Bear Gulch, also known as Big Table Mountain in the Centennial Mountains of northeastern Idaho is less so (see http://www.sourcecatalog.com/id/source_id_bear_gulch.pdf; Henrickson 2008; Holmer 1997; Scheiber and Finley 2011; Willingham 1995; Figure 2 here). Bear Gulch is often recovered in association with Obsidian Cliff obsidian in Wyoming prehistoric contexts, and since South Dakota obsidian studies are rare, it is not clear whether this pattern holds in western South Dakota. This analysis suggests that it does.

Much of the obsidian debitage would be classified as secondary flakes with original cortex on the dorsal surfaces, suggesting that cores were transported to the site for further reduction. Additionally, the Zr versus Sr bivariate plot with 95% confidence ellipses exhibits very "tight" groups suggesting that these artifacts could be produced from single cores, keeping EDXRF precision in mind (Shackley 2011; Figure 1 here). All three of these sources are Quaternary sources producing large nodules (Henrickson 2008; Holmer 1997).

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Table 1. Elemental concentrations for the obsidian artifacts, USGS RGM-1 rhyolite standard, and USGS recommended values. All measurements in parts per million (ppm).

Sample	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Source
1-47	1200	283	9841	47	131	79	33	98	16	2055	Malad, ID
1-52	1159	250	9611	54	121	75	34	95	16	1692	Malad, ID
1-55	1130	245	9394	41	120	81	31	93	13	1931	Malad, ID
1-78	1043	249	9603	47	126	76	33	98	20	2125	Malad, ID
1-4	1045	298	9646	67	126	77	33	97	18	1970	Malad, ID
1-6	1174	291	9761	55	124	77	31	92	12	2008	Malad, ID
1-113	1129	268	10071	60	136	81	33	97	15	2018	Malad, ID
1-140	1089	264	9613	53	133	80	32	93	9	1930	Malad, ID
1-146	1152	275	9968	37	129	79	34	99	13	2058	Malad, ID
2-144	977	273	9322	50	111	70	32	89	17	2044	Malad, ID
2-147	1202	313	10103	68	135	84	30	95	18	1924	Malad, ID
2-153	1176	300	10291	85	134	78	32	100	16	1964	Malad, ID
2-159	1218	274	9871	74	125	74	32	92	16	1915	Malad, ID
2-160	1092	303	9691	92	121	82	33	93	15	2072	Malad, ID
2-163	1190	270	9885	41	131	81	34	100	11	2034	Malad, ID
2-179	1125	288	9574	47	125	78	38	95	19	2052	Malad, ID
2-182	1026	231	8925	36	117	74	39	90	12	2092	Malad, ID
2-192	1116	250	9836	61	129	83	36	93	8	1996	Malad, ID
3-206	1025	243	8917	44	117	70	34	89	19	1844	Malad, ID
3-227	1126	270	10008	69	126	78	35	96	15	2002	Malad, ID
3-229	1090	253	9372	39	118	77	31	97	11	2054	Malad, ID
3-254	1154	295	9910	44	131	79	31	94	11	1941	Malad, ID
3-256	1064	261	9073	52	120	75	31	94	9	1988	Malad, ID
3-266	1145	267	9851	57	130	77	37	97	16	2033	Malad, ID
3-268	1147	276	10127	66	132	82	30	91	19	1961	Malad, ID
3-269	1163	307	10290	42	132	87	35	97	21	1954	Malad, ID
3-280	1072	284	10008	56	133	85	33	101	16	2154	Malad, ID
3-359	782	246	10925	85	252	13	82	179	44	23	Obsidian Cliff, WY
4-286	1101	278	9402	58	124	71	33	99	20	2048	Malad, ID
4-288	1080	290	10106	92	130	77	33	99	11	1915	Malad, ID
4-293	1030	270	9419	46	126	73	34	95	15	1925	Malad, ID
4-294	1064	258	9247	48	124	74	33	88	17	2099	Malad, ID
4-296	1040	251	9239	38	122	75	32	96	17	2069	Malad, ID
4-298	1150	271	9849	74	125	77	33	95	18	1893	Malad, ID
4-300	1085	258	9103	42	120	75	31	96	16	1994	Malad, ID
4-303	1256	302	10499	91	139	81	38	94	18	1988	Malad, ID
4-307	1084	283	9705	70	132	76	32	98	7	2009	Malad, ID

Sample	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Source
5-312-10	1224	302	10359	52	137	81	35	95	12	2067	Malad, ID
5-312-15	826	259	11232	100	259	10	84	178	47	36	Obsidian Cliff, WY
5-314	866	262	11623	98	273	13	82	180	46	13	Obsidian Cliff, WY
5-327	808	254	10910	86	251	13	77	172	47	32	Obsidian Cliff, WY
5-333	875	238	11071	86	257	11	77	174	49	28	Obsidian Cliff, WY
5-342	843	247	11067	91	249	10	83	174	46	0	Obsidian Cliff, WY
5-345	884	252	11319	92	262	9	75	185	47	19	Obsidian Cliff, WY
5-372	860	251	11178	95	254	13	76	173	48	26	Obsidian Cliff, WY
5-389	968	286	11929	126	270	12	82	175	42	11	Obsidian Cliff, WY
5-409	959	268	11770	138	260	10	75	171	49	31	Obsidian Cliff, WY
6-413	914	262	11366	85	265	16	80	177	49	0	Obsidian Cliff, WY
6-426	761	217	10089	79	234	9	77	168	44	13	Obsidian Cliff, WY
6-430	879	264	11524	98	273	12	79	183	46	34	Obsidian Cliff, WY
6-435	901	306	11793	125	266	13	80	184	46	41	Obsidian Cliff, WY
6-437	974	277	11192	160	259	13	76	173	41	28	Obsidian Cliff, WY
6-444	978	267	11459	97	263	10	80	184	45	10	Obsidian Cliff, WY
6-450	959	256	11783	126	262	9	78	178	52	0	Obsidian Cliff, WY
6-452	910	264	11725	116	267	9	76	181	48	3	Obsidian Cliff, WY
6-484	1125	263	9845	62	126	82	34	94	14	2024	Malad, ID
7-494	1254	287	10723	45	133	82	35	97	12	1991	Malad, ID
7-500	867	241	10921	86	249	9	81	175	43	27	Obsidian Cliff, WY
7-506	965	281	12159	117	267	11	83	184	47	10	Obsidian Cliff, WY
7-508	881	255	11361	111	263	13	79	176	46	26	Obsidian Cliff, WY
7-512	923	246	11547	107	261	13	81	178	46	26	Obsidian Cliff, WY
7-517	863	278	11707	108	262	9	87	175	49	19	Obsidian Cliff, WY
7-523	834	248	10899	91	254	10	80	180	47	12	Obsidian Cliff, WY
7-538	845	261	11021	110	251	9	84	174	46	0	Obsidian Cliff, WY
7-546	816	220	9751	72	225	14	75	160	49	0	Obsidian Cliff, WY
8-498	869	287	11592	112	265	11	77	174	47	37	Obsidian Cliff, WY
8-546	1185	275	9818	67	126	81	35	95	17	2039	Malad, ID
8-552	1110	273	9830	60	127	83	31	97	21	2029	Malad, ID
8-574	1023	260	9031	89	120	78	33	92	11	1848	Malad, ID
8-576	1059	277	9693	56	124	80	33	95	18	1974	Malad, ID
8-585	1043	254	9319	50	124	78	32	95	16	2034	Malad, ID
8-599	1058	287	9916	39	128	79	34	101	16	2058	Malad, ID
8-606	1099	267	9591	55	126	78	34	95	9	2078	Malad, ID
8-612	1027	247	9598	51	126	78	35	99	17	2088	Malad, ID
9-1	1360	304	10756	58	137	81	30	103	15	1921	Malad, ID
9-2	1777	368	13864	74	193	53	44	300	61	920	Bear Gulch, ID
9-3	1510	313	12882	72	179	53	41	287	56	934	Bear Gulch, ID
9-4	1114	269	9746	53	129	78	33	97	17	1986	Malad, ID

9-5	1907	370	14464	73	201	53	39	304	56	881	Bear Gulch, ID
Sample	**Ti**	**Mn**	**Fe**	**Zn**	**Rb**	**Sr**	**Y**	**Zr**	**Nb**	**Ba**	**Source**
9-6	950	266	12214	142	268	11	82	179	48	0	Obsidian Cliff, WY
9-8	890	266	11036	84	252	14	73	172	47	15	Obsidian Cliff, WY
9-9	1231	263	10187	61	133	81	33	99	14	1989	Malad, ID
9-10	1184	283	9829	61	128	78	32	94	13	2009	Malad, ID
9-11	1785	384	13492	106	183	51	43	294	58	834	Bear Gulch, ID
9-12	923	254	12150	112	273	10	80	183	44	43	Obsidian Cliff, WY
9-13	1086	274	9597	44	125	76	32	91	14	1921	Malad, ID
9-14	871	278	10974	83	247	14	76	174	48	0	Obsidian Cliff, WY
9-15	1650	331	13157	99	182	54	43	288	62	867	Bear Gulch, ID
9-16	1054	255	8958	59	112	72	30	95	15	2041	Malad, ID
9-17	1224	280	10221	58	132	83	34	97	11	2029	Malad, ID
9-18	1770	331	13559	117	180	53	41	290	54	823	Bear Gulch, ID
9-19	1106	260	9668	52	126	79	36	101	12	2079	Malad, ID
9-20	880	330	11717	120	273	13	79	178	46	5	Obsidian Cliff, WY
9-21	1161	276	10214	73	139	83	32	96	18	1999	Malad, ID
9-22	1179	296	10527	131	141	83	38	102	18	1863	Malad, ID
9-23	1609	302	12681	59	181	53	46	302	59	977	Bear Gulch, ID
9-24	1076	256	8997	45	118	71	26	92	14	1963	Malad, ID
9-25	1222	275	10111	45	133	83	30	100	17	1954	Malad, ID
9-26	864	265	11415	114	263	12	78	184	45	26	Obsidian Cliff, WY
9-27	1365	225	9950	214	214	12	63	144	42	19	Obsidian Cliff, WY
9-28	1083	278	9861	40	126	78	28	90	15	1897	Malad, ID
9-29	1196	286	10407	44	133	80	36	98	16	2083	Malad, ID
9-30	933	285	11563	84	259	13	82	177	47	30	Obsidian Cliff, WY
9-31	1731	334	13903	127	194	56	49	300	60	754	Bear Gulch, ID
9-32	904	285	11921	144	267	9	79	174	42	0	Obsidian Cliff, WY
9-33	1060	253	9363	45	121	82	33	92	13	1891	Malad, ID
9-34	1259	322	10705	111	141	84	37	98	16	2003	Malad, ID
9-35	820	242	10848	93	249	13	74	174	46	25	Malad, ID
9-37	1127	260	9909	52	135	79	34	99	9	2016	Malad, ID
9-38	1132	306	10051	64	132	84	33	103	19	1978	Malad, ID
9-39	1745	336	13735	87	191	51	47	296	60	900	Bear Gulch, ID
9-40	1785	354	14131	104	193	52	46	302	59	834	Bear Gulch, ID
10-647	1624	326	12374	82	177	52	45	300	63	902	Bear Gulch, ID
10-654	1587	329	12942	64	179	52	44	300	61	899	Bear Gulch, ID
10-656	1420	303	11540	57	153	45	43	275	62	968	Bear Gulch, ID
10-657	1614	342	13674	81	194	54	43	304	56	986	Bear Gulch, ID
10-670	1630	351	13321	98	183	48	45	297	61	888	Bear Gulch, ID
10-674	1795	374	14102	65	187	49	45	307	57	965	Bear Gulch, ID
10-675	1769	330	13135	72	189	51	47	296	50	913	Bear Gulch, ID

10-693	1859	362	14747	95	199	55	48	305	57	877	Bear Gulch, ID
10-706	1564	358	13000	80	182	51	40	301	55	907	Bear Gulch, ID

Sample	**Ti**	**Mn**	**Fe**	**Zn**	**Rb**	**Sr**	**Y**	**Zr**	**Nb**	**Ba**	**Source**
11-783	1161	286	10021	39	128	76	33	97	16	2003	Malad, ID
11-792	1078	242	8992	44	117	70	33	94	11	2053	Malad, ID
11-795	1090	264	9522	50	125	74	32	95	12	2036	Malad, ID
11-799	1053	264	9697	39	125	76	27	96	15	1987	Malad, ID
11-806	1481	295	11844	75	168	46	41	279	56	840	Bear Gulch, ID
11-814	821	240	10992	96	254	11	77	169	44	2	Obsidian Cliff, WY
11-827	1119	260	9555	41	131	77	32	97	14	2073	Malad, ID
11-835	846	262	10916	81	254	11	72	177	49	0	Obsidian Cliff, WY
11-837	1309	317	10928	55	145	84	36	99	14	2068	Malad, ID
11-843	1146	249	9235	40	118	79	33	91	17	2027	Malad, ID
11-858	1085	252	9271	45	122	74	30	93	12	1853	Malad, ID
11-873	816	255	10995	84	243	10	70	176	50	7	Obsidian Cliff, WY
11-890	965	250	11081	91	249	11	77	176	53	41	Obsidian Cliff, WY
11-895	845	256	11178	96	250	15	74	175	41	27	Obsidian Cliff, WY
11-896	1052	248	9109	52	120	74	30	89	14	1948	Malad, ID
11-899	839	257	10831	100	251	9	74	171	45	34	Obsidian Cliff, WY
11-901	1025	273	9655	47	127	77	33	99	13	2018	Malad, ID
11-906	1086	253	9256	43	120	74	31	96	15	2010	Malad, ID
11-912	1045	345	9503	165	126	80	34	100	14	2032	Malad, ID
11-919	1186	302	10772	74	141	85	36	98	14	1906	Malad, ID
11-924	1925	360	14585	89	189	53	46	312	59	937	Bear Gulch, ID
11-925	846	263	11620	96	262	14	74	179	44	23	Obsidian Cliff, WY
11-946	856	267	11187	94	260	12	77	170	52	1	Obsidian Cliff, WY
11-957	1179	289	10403	57	135	78	32	96	21	1985	Malad, ID
11-970	1138	279	10096	79	138	82	34	96	17	2017	Malad, ID
11-976	903	247	11370	91	257	11	80	173	43	18	Obsidian Cliff, WY
11-981	1239	291	10351	42	134	80	37	99	12	1858	Malad, ID
RGM1-S5	1595	296	13210	44	146	107	24	221	3	727	standard
RGM1-S5	1509	286	13255	43	149	104	27	216	10	787	standard
RGM1-S5	1531	288	13066	40	147	106	27	219	10	719	standard
RGM1-S5	1543	285	13171	42	150	105	25	223	9	787	standard
RGM1-S5	1523	317	13132	39	151	105	25	225	9	731	standard
RGM1-S5	1528	293	13223	40	148	106	28	221	7	754	standard

Table 2. Crosstabulation of obsidian source by sample group.

			Source			
			Bear Gulch, ID	Malad, ID	Obsidian Cliff, WY	Total
Sample	1	Count	0	9	0	9
		% within Sample	0.0%	100.0%	0.0%	100.0%
		% within Source	0.0%	11.0%	0.0%	6.1%
		% of Total	0.0%	6.1%	0.0%	6.1%
	2	Count	0	9	0	9
		% within Sample	0.0%	100.0%	0.0%	100.0%
		% within Source	0.0%	11.0%	0.0%	6.1%
		% of Total	0.0%	6.1%	0.0%	6.1%
	3	Count	0	9	1	10
		% within Sample	0.0%	90.0%	10.0%	100.0%
		% within Source	0.0%	11.0%	2.2%	6.8%
		% of Total	0.0%	6.1%	0.7%	6.8%
	4	Count	0	9	0	9
		% within Sample	0.0%	100.0%	0.0%	100.0%
		% within Source	0.0%	11.0%	0.0%	6.1%
		% of Total	0.0%	6.1%	0.0%	6.1%
	5	Count	0	1	9	10
		% within Sample	0.0%	10.0%	90.0%	100.0%
		% within Source	0.0%	1.2%	20.0%	6.8%
		% of Total	0.0%	0.7%	6.1%	6.8%
	6	Count	0	1	8	9
		% within Sample	0.0%	11.1%	88.9%	100.0%
		% within Source	0.0%	1.2%	17.8%	6.1%
		% of Total	0.0%	0.7%	5.4%	6.1%
	7	Count	0	1	8	9
		% within Sample	0.0%	11.1%	88.9%	100.0%
		% within Source	0.0%	1.2%	17.8%	6.1%
		% of Total	0.0%	0.7%	5.4%	6.1%
	8	Count	0	8	1	9
		% within Sample	0.0%	88.9%	11.1%	100.0%
		% within Source	0.0%	9.8%	2.2%	6.1%
		% of Total	0.0%	5.4%	0.7%	6.1%
	9	Count	10	19	9	38
		% within Sample	26.3%	50.0%	23.7%	100.0%
		% within Source	47.6%	23.2%	20.0%	25.7%
		% of Total	6.8%	12.8%	6.1%	25.7%
	10	Count	9	0	0	9
		% within Sample	100.0%	0.0%	0.0%	100.0%
		% within Source	42.9%	0.0%	0.0%	6.1%
		% of Total	6.1%	0.0%	0.0%	6.1%
	11	Count	2	16	9	27
		% within Sample	7.4%	59.3%	33.3%	100.0%
		% within Source	9.5%	19.5%	20.0%	18.2%
		% of Total	1.4%	10.8%	6.1%	18.2%
Total		Count	21	82	45	148
		% within Sample	14.2%	55.4%	30.4%	100.0%
		% within Source	100.0%	100.0%	100.0%	100.0%
		% of Total	14.2%	55.4%	30.4%	100.0%

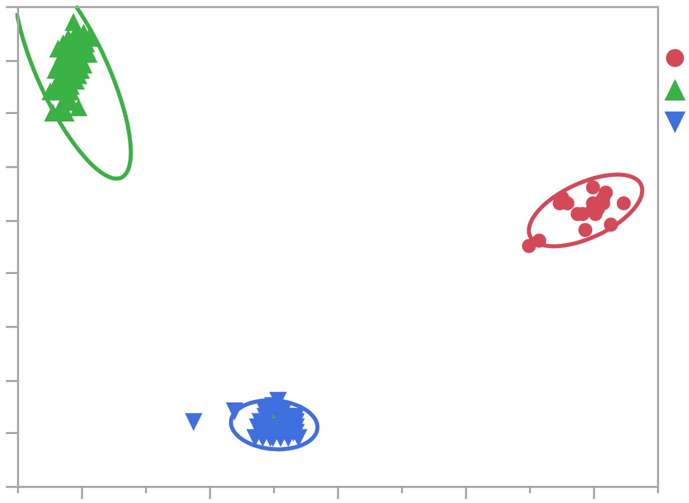

Figure 1. Zr versus Sr bivariate plot of all the artifacts. Confidence ellipses are at 95%.

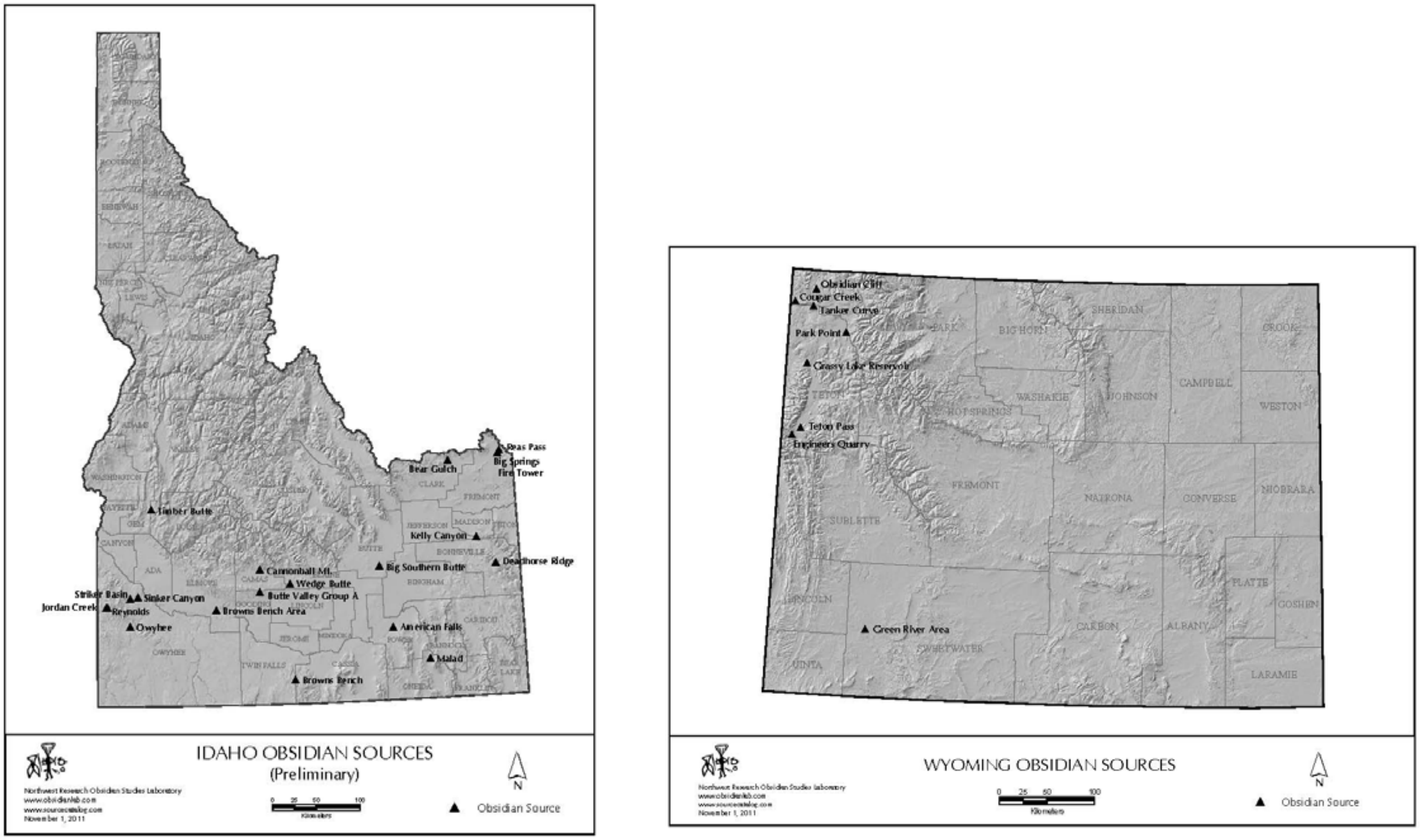

Figure 2. Location of sources of archaeological obsidian in Idaho and Wyoming (from http://www.sourcecatalog.com/index.html)