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SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM PREHISTORIC SITES IN KANSAS AND NEBRASKA

by

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INTRODUCTION

The analysis here of 149 samples from sites of various time periods in Kansas and Nebraska when viewed with the previous analysis from Kansas sites (n=38) comprises nearly 200 obsidian artifacts assigned to source from the region (see Shackley 2005a). While the majority of artifacts in these sites were produced from the two major sources in the Valles Caldera, Jemez Mountains, northern New Mexico, a few were produced from the Malad, Idaho source as in the original project (Shackley 2005a). Most importantly, three of the artifacts, one core fragment, and two blades, were produced from the Sierra de Pachuca source in Hidalgo, Mexico. While Pachuca obsidian does occur in North America, it is exceedingly rare, and the core fragment from 14SN4 may be the largest piece ever recovered north of Mexico (see Barker et al. 2002).

LABORATORY SAMPLING, ANALYSIS AND INSTRUMENTATION

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).

The trace element analyses were performed in the Archaeological XRF Laboratory, Department of Earth and Planetary Sciences, University of California, Berkeley, using a Spectrace/ThermoNoran^{TM} QuanX energy dispersive x-ray fluorescence spectrometer. The spectrometer is equipped with an air cooled Cu x-ray target with a 125 micron Be window, an x-ray generator that operates from 4-50 kV/0.02-2.0 mA at 0.02 increments, using an IBM PC based microprocessor and WinTrace^{TM} reduction software. The x-ray tube is operated at 30 kV, 0.14 mA, using a 0.05 mm (medium) Pd primary beam filter in an air path at 200 seconds

livetime to generate x-ray intensity Kα-line data for elements titanium (Ti), manganese (Mn), iron (as FeT), zinc (Zn), gallium (Ga), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb). Zinc and gallium are only reported for the basalt artifacts, since they are generally in low quantities in western North American obsidian. Trace element intensities were converted to concentration estimates by employing a least-squares calibration line 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 the high concentrations of iron and thus for all the other elements. Further details concerning the petrological choice of these elements in obsidian is available in Shackley (1995, 1998 and 2005; also Mahood and Stimac 1991; and Hughes and Smith 1993). Specific standards used for the best fit regression calibration for elements Ti through Nb include G-2 (basalt), AGV-1 (andesite), GSP-1, SY-2 (syenite), BHVO-1 (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), all US Geological Survey standards, BR-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). In addition to the reported values here, Ni, and Cu, were measured, but these are rarely useful in discriminating glass sources, are poorly measured with the Cu target, and are not generally reported.

The data from the WinTrace software were translated directly into Excel for Windows software for manipulation and on into SPSS for Windows for statistical analyses. In order to evaluate these quantitative determinations, machine data were compared to measurements of known standards during each run. RGM-1 is analyzed during each sample run for obsidian artifacts to check machine calibration (see Table 1). Compilation and

discussion of RGM-1 analyses are available at http://www.swxrflab.net/anlysis.htm. Source assignments were made with reference to the source standard library at Berkeley (Shackley 1995, 1998, 2005b), and published and unpublished data throughout the literature. A few samples could not be assigned to source and do not match any published source standard data from North America or Mexico. They are either from as yet unlocated and documented sources, or may be known, but not published.

DISCUSSION

The provenance of the obsidian artifacts dominated by Jemez Mountains sources is not surprising, and is rather typical of late period sites in the Plains (Baugh and Nelson 1987; Hawley and Hughes 1999; Hughes 1988; Hughes and Lees 1991; Hughes and Roper 1999; Tables 1 and 2, and Figures 1 and 2 here). The two major sources in the Sierra de los Valles is Valles Rhyolite, often called Cerro del Medio in the vernacular, and Cerro Toledo Rhyolite often called Obsidian Ridge in the vernacular (see Shackley 2005b). The two sources have very different eruptive and depositional histories that are important for prehistoric procurement.

The Cerro Toledo Rhyolite glass was erupted slightly earlier in a caldera collapse creating Plinian events around the east side of the Cerro Toledo caldera (Shackley 2005). Because of the large ash flow tuffs directed to the east and south, a large portion of the ash and rhyolite glass was ultimately eroded into the Rio Grande system, and now can be found as marekanites as far as Chihuahua (Church 2000; Shackley 2005b). It is generally impossible to determine whether raw material was procured from the primary domes in the Sierra de los Valles or in secondary contexts except by using a rough nodule size index. The slightly later Valle Grande caldera collapse that produced the Cerro del Medio and other domes producing Valles Rhyolite glass have not yet eroded outside the caldera, and so must have been originally procured in the caldera. For a distance as great as that between northern New Mexico and Kansas, this may not be an issue, but procurement in the late period in the Jemez Mountains

likely required some payment, that may not have been necessary in the secondary deposits of the Rio Grande.

Generally, Idaho and Wyoming sources tend be associated with Woodland and Archaic period sites in the Plains, but they also occur in later period sites, either as scavenged raw material from earlier contexts or through exchange relationships with the northwestern Plains (Hawley and Hughes 1999; Logan et al. 2001).

What is probably most interesting here is the presence of three artifacts produced from one of the domes in Sierra de Pachuca, in the state of Hidalgo, Mexico (Charlton 1969; Ponomarenko 2004; Spence and Parsons 1967). Two of the specimens are late stage polyhedral blades from 14MP1, and the other is a core fragment from 14SN4, which has no specific provenience. Sierra de Pachuca is one of the most widely exchanged obsidian sources in the Americas, and has been found from the Midwestern United States to at least Honduras in the south (Ponomarenko 2004). The finished polyhedral blades were certainly exchanged as finished items, while the core represents what appears to be exchange of raw material. The other recently reported blade from the Spiro Mounds, Oklahoma is a larger piece that appears to be an early stage production blade used as a scraper (Barker et al. 2002).

With this relatively large sample we can confidently say that, at least in the late prehistoric period, obsidian procurement in the Kansas/Nebraska region of the Plains was dominated by relationships with groups in the northern Rio Grande, probably the Tewa and Tiwa speakers such as those at Jemez, San Ildefonso, Santa Clara, and their prehistoric ancestors at Bandelier, Otowi, Pecos, and other sites in the northern Rio Grande.

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Table 1. Elemental concentrations for the obsidian archaeological specimens, and source standards. All measurements in parts per million (ppm).

Site/Sample	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Source
UKansas									
14RC2-S-04-04	908	425	8294	149	6	44	154	57	Valle Grande Rhy, NM
14SC1-S-03-05	979	405	8440	151	11	42	167	51	Valle Grande Rhy, NM
14SN3-NOCAT	889	542	9296	192	5	66	172	94	Cerro Toledo Rhy, NM
14SN4-NOCAT	1196	825	30131	206	17	103	1113	95	Sierra de Pachuca, Hidalgo
25CH1-13188-1	909	443	8684	152	16	40	160	54	Valle Grande Rhy, NM
25CH1-13188-2	959	433	8805	156	11	42	160	59	Valle Grande Rhy, NM
25CH1-13188-3	954	473	8598	147	7	40	152	56	Valle Grande Rhy, NM
25CH1-13188-4	878	407	8068	149	14	39	157	57	Valle Grande Rhy, NM
25CH1-13188-5	1033	437	8552	146	9	40	161	51	Valle Grande Rhy, NM
25CH1-14585	1009	438	8919	153	13	40	159	56	Valle Grande Rhy, NM
KSHS									
14CM406-172	917	597	9532	207	8	60	178	102	Cerro Toledo Rhy, NM
14CM406-1915	1074	531	8632	173	6	65	159	84	Cerro Toledo Rhy, NM
14CM406-219	924	616	9052	192	6	67	175	97	Cerro Toledo Rhy, NM
14CM406-2210	966	555	9521	197	10	61	177	103	Cerro Toledo Rhy, NM
14CM406-3548	969	584	9528	206	5	56	172	92	Cerro Toledo Rhy, NM
14CM406-3636	972	591	9247	199	7	62	179	96	Cerro Toledo Rhy, NM
14CM406-3959	850	607	9425	209	5	63	179	91	Cerro Toledo Rhy, NM
14CM406-4385	5387	585	9011	194	13	55	182	100	Cerro Toledo Rhy, NM
14CM406-5757	851	485	8475	192	11	65	170	98	Cerro Toledo Rhy, NM
14CM406-615	980	592	9166	196	8	66	176	101	Cerro Toledo Rhy, NM
14CM406-6479	887	543	8685	187	6	61	170	95	Cerro Toledo Rhy, NM
14CM406-6486	849	531	7961	181	9	61	157	82	Cerro Toledo Rhy, NM
14CM406-6523	941	566	8897	198	7	62	172	92	Cerro Toledo Rhy, NM
14CM406-7032	905	649	9658	209	5	59	179	96	Cerro Toledo Rhy, NM
14CM406-7132	985	586	8871	199	5	49	175	97	Cerro Toledo Rhy, NM
14CM406-7133	848	563	8561	195	5	62	169	103	Cerro Toledo Rhy, NM
14CM406-7456	923	523	8994	201	5	64	173	111	Cerro Toledo Rhy, NM
14CM406-7460	921	581	8810	18	8	67	173	98	Cerro Toledo Rhy, NM

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14CM406-7568	872	622	9507	211	9	62	181	101	Cerro Toledo Rhy, NM
14CM406-7814	991	581	10166	201	10	61	179	97	Cerro Toledo Rhy, NM
14CM406-7993	999	608	8869	190	5	63	164	92	Cerro Toledo Rhy, NM
14CM406-803	1049	616	9411	200	6	59	169	91	Cerro Toledo Rhy, NM
14CM406-8257	975	710	10258	216	5	66	186	99	Cerro Toledo Rhy, NM
14CM406-8599	836	541	8764	195	5	61	176	102	Cerro Toledo Rhy, NM
14CM406-8720-B	899	529	8531	188	7	62	165	94	Cerro Toledo Rhy, NM
14CM406-8720-B	874	599	8643	194	8	59	162	96	Cerro Toledo Rhy, NM
14CO3-130-1	1137	459	9876	162	7	42	157	57	Valle Grande Rhy, NM
14CO3-135-4	857	634	9679	209	5	65	167	97	Cerro Toledo Rhy, NM
14CO3-172-1	922	444	8885	159	5	39	151	62	Valle Grande Rhy, NM
14CO3-279-9	1005	514	10023	163	12	35	158	62	Valle Grande Rhy, NM
14CO3-307-1	949	452	8777	150	10	45	160	55	Valle Grande Rhy, NM
14CO3-410-2	1184	380	7506	122	10	41	145	51	Valle Grande Rhy, NM
14CO3-44-1	900	400	8631	152	14	47	157	57	Valle Grande Rhy, NM
14MP1-979	1038	494	9258	189	8	55	157	89	Cerro Toledo Rhy, NM
14MP1-995	1063	423	8742	149	13	41	157	56	Valle Grande Rhy, NM
14MP408-1033-4	910	441	8372	150	6	36	159	55	Valle Grande Rhy, NM
14MP408-2040	957	439	8567	148	10	44	164	57	Valle Grande Rhy, NM
14MP408-2202-1	925	440	9189	161	13	37	173	58	Valle Grande Rhy, NM
Site/Sample	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Source
14MP408-2630-1	876	624	9216	205	7	64	178	99	Cerro Toledo Rhy, NM
14MP408-2975-1	1008	543	9321	157	8	37	147	49	Valle Grande Rhy, NM
14MP408-2988-1	938	434	8440	157	7	37	165	52	Valle Grande Rhy, NM
14MP408-3051	1071	547	9924	173	10	35	164	50	Valle Grande Rhy, NM
14MP408-548-4	1027	503	8692	152	11	41	154	45	Valle Grande Rhy, NM
14MP408-548-4-1	898	479	8924	155	15	41	165	55	Valle Grande Rhy, NM
14MP408-945-1	1026	487	8923	149	10	37	163	49	Valle Grande Rhy, NM
14OS365-SURF	989	257	7939	127	77	28	84	13	Malad, ID
14RC301-1673	1001	444	8895	155	10	39	164	55	Valle Grande Rhy, NM
14RC301-1674	940	449	9201	172	17	52	160	53	Valle Grande Rhy, NM

14RC301-2099	951	452	8613	142	8	42	156	57	Valle Grande Rhy, NM
14RC301-2100	1023	449	8902	157	10	44	168	53	Valle Grande Rhy, NM
14RC301-2550	960	480	8488	146	9	37	149	36	Valle Grande Rhy, NM
14RC301-2551	971	424	8966	156	11	42	173	56	Valle Grande Rhy, NM
14RC301-2552	1059	619	9257	192	8	61	159	98	Cerro Toledo Rhy, NM
14RC301-517	898	362	7881	139	8	41	145	54	Valle Grande Rhy, NM
14RC301-518	1237	365	10379	150	16	44	165	46	Valle Grande Rhy, NM
14RC301-519	967	270	8010	123	73	28	87	21	Malad, ID
14RC301-520	969	417	8426	151	9	37	161	55	Valle Grande Rhy, NM
14RC301-572	943	523	8804	194	8	60	161	93	Cerro Toledo Rhy, NM
14RC3-587	955	441	8684	158	8	40	162	56	Valle Grande Rhy, NM
14RC3-588	1011	437	8674	156	16	40	164	63	Valle Grande Rhy, NM
14RC5-10	879	515	8269	176	7	62	169	99	Cerro Toledo Rhy, NM
14RC5-116	982	435	8311	148	10	41	156	50	Valle Grande Rhy, NM
14RC5-1-7	872	387	7823	142	10	44	160	54	Valle Grande Rhy, NM
14RC5-187	869	461	9082	159	12	47	166	54	Valle Grande Rhy, NM
14RC8-11869	1051	545	9725	167	16	46	163	53	Valle Grande Rhy, NM
14RC8-12448	924	534	8420	192	6	57	155	80	Cerro Toledo Rhy, NM
14RC8-12723	1083	489	9881	171	6	44	166	53	Valle Grande Rhy, NM
14RC8-13757	1111	472	8690	152	10	39	150	62	Valle Grande Rhy, NM
14RC8-13758	864	445	8971	153	5	46	153	45	Valle Grande Rhy, NM
14RC8-144492	825	530	7906	188	5	58	153	93	Cerro Toledo Rhy, NM
14RC8-24791	878	394	8879	153	8	44	165	61	Valle Grande Rhy, NM
14RC8-31009	926	413	7936	144	10	37	152	48	Valle Grande Rhy, NM
14RC8-52655	838	561	8900	200	9	70	173	91	Cerro Toledo Rhy, NM
14RC8-52656	872	526	8977	161	10	37	164	55	Valle Grande Rhy, NM
14RC8-54268	900	405	7932	138	10	39	149	43	Valle Grande Rhy, NM
14RC8-6145	22100	527	7935	187	9	62	168	95	Cerro Toledo Rhy, NM
14RC8-6152	989	423	8380	153	9	43	153	60	Valle Grande Rhy, NM
14RC8-6305	851	533	8380	186	7	62	165	94	Cerro Toledo Rhy, NM
14RC8-7987	871	557	8551	192	5	65	164	91	Cerro Toledo Rhy, NM

14RC8-7988	951	570	9078	197	9	62	175	99	Cerro Toledo Rhy, NM
14RC9-569-79	1032	494	9005	163	8	39	158	51	Valle Grande Rhy, NM
14RC9-586-171	1044	437	9216	160	9	44	165	56	Valle Grande Rhy, NM
14RC9-674	903	404	8669	161	12	38	164	57	Valle Grande Rhy, NM
14RC9-696-93	890	418	8425	149	13	43	162	57	Valle Grande Rhy, NM
14RC9-699-151	953	461	9316	167	13	44	159	53	Valle Grande Rhy, NM
14SC1-10498	931	498	8616	192	5	63	167	95	Cerro Toledo Rhy, NM
14SC1-14914	22466	592	9115	205	5	62	175	94	Cerro Toledo Rhy, NM
14SC1-16699	926	437	8341	144	12	40	155	56	Valle Grande Rhy, NM
14SC1-16942	894	547	8526	195	6	60	167	101	Cerro Toledo Rhy, NM
14SC1-20764	945	574	8686	196	6	60	172	103	Cerro Toledo Rhy, NM
14SC1-20977	973	486	9418	156	14	45	157	61	Valle Grande Rhy, NM
Site/Sample	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Source
14SC1-22075	884	437	8426	146	12	39	166	59	Valle Grande Rhy, NM
14SC1-23675	961	535	9196	157	6	41	170	56	Valle Grande Rhy, NM
14SC1-25274	915	574	8677	192	7	69	171	98	Cerro Toledo Rhy, NM
14SC1-26590	881	592	8665	202	8	61	177	97	Cerro Toledo Rhy, NM
14SC1-27658	989	411	8597	154	13	44	163	56	Valle Grande Rhy, NM
14SC1-43130	1592	499	9651	168	14	48	168	53	Valle Grande Rhy, NM
14SC1-5200	884	588	9217	201	8	71	170	94	Cerro Toledo Rhy, NM
14SC1-8184	936	443	8488	149	13	40	157	54	Valle Grande Rhy, NM
14SC1-9755	1003	457	8607	151	9	38	164	54	Valle Grande Rhy, NM
Kansas Anthro Assn.									
14A307-148	1039	435	8457	148	12	37	163	55	Valle Grande Rhy, NM
14A307-5694	800	479	8464	172	8	61	160	78	Cerro Toledo Rhy, NM
14BA401-291	867	594	8883	193	8	63	177	89	Cerro Toledo Rhy, NM
14BA401-375	915	573	8902	200	10	71	171	97	Cerro Toledo Rhy, NM
14BA401-507	876	528	8826	180	11	47	148	82	Cerro Toledo Rhy, NM
14BA401-548	823	576	8594	190	5	66	169	102	Cerro Toledo Rhy, NM
14BA401-549	771	567	8934	199	5	61	173	93	Cerro Toledo Rhy, NM
14BA406-4	1000	407	8680	153	8	42	155	49	Valle Grande Rhy, NM
14CO1-217-34	1282	399	8045	14	11	33	140	38	Valle Grande Rhy, NM

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14CO1509-13-9	919	630	8981	189	10	66	161	98	Cerro Toledo Rhy, NM
14CO332-26-3	1006	425	8912	154	12	46	165	55	Valle Grande Rhy, NM
14CO385-93-1	886	459	8626	140	7	40	159	44	Valle Grande Rhy, NM
14CO501-707-1	981	472	8706	143	6	43	156	50	Valle Grande Rhy, NM
14CO501-805	944	444	8652	158	15	49	154	53	Valle Grande Rhy, NM
14CS375-WS4	920	276	8946	246	11	59	144	55	unknown
14MD306-66-4	1148	461	7512	203	48	16	115	27	unknown
14MD306-975*	1155	430	8849	150	14	33	148	54	Valle Grande Rhy, NM
14MD310-0	895	370	7603	129	14	30	142	47	Valle Grande Rhy, NM
14MP1-1995	1427	1270	18844	211	23	116	948	104	Sierra de Pachuca, Hidalgo
14MP1-1996	1426	1151	17506	198	14	110	915	92	Sierra de Pachuca, Hidalgo
14MP1-1998	951	521	8572	177	8	57	167	96	Cerro Toledo Rhy, NM
14MP1-1999	928	576	9154	194	8	68	174	98	Cerro Toledo Rhy, NM
14MP1-3957	1578	309	10958	141	79	31	197	4	unknown
14OT5-760	839	286	7542	115	67	21	85	15	Malad, ID
14PA307-103	790	381	7045	119	12	38	136	45	unknown
14PA307-433	1067	473	9033	159	10	42	165	48	Valle Grande Rhy, NM
14PA307-5034	863	484	8373	186	6	59	170	92	Cerro Toledo Rhy, NM
14PA307-550	944	437	8318	149	9	43	162	48	Valle Grande Rhy, NM
14PA307-551	1033	468	9660	162	10	44	166	50	Valle Grande Rhy, NM
14RC2-257	945	441	8933	158	11	37	167	57	Valle Grande Rhy, NM
14RC2-267	954	442	8673	152	14	37	155	57	Valle Grande Rhy, NM
14RC2H-237A	947	491	9226	161	11	37	166	55	Valle Grande Rhy, NM
14RC2H-237B	941	482	9297	168	8	43	168	50	Valle Grande Rhy, NM
14SC1-10084	1007	322	6691	113	5	32	131	58	unknown
14SC1-5201	1002	553	8594	187	5	54	157	91	Cerro Toledo Rhy, NM
14SC1-6586	951	465	8907	158	13	45	171	53	Valle Grande Rhy, NM
14TO305-556	956	628	9674	210	5	61	180	105	Cerro Toledo Rhy, NM
14TO305-557	860	570	8186	174	11	56	162	90	Cerro Toledo Rhy, NM
14TO305-558	1058	558	8978	198	7	61	166	102	Cerro Toledo Rhy, NM
RGM1-S1	1454	285	1311	14	10	25	220	8	standard

			7	4	9				
RGM1-S1	1574	322	1333	14	11	22	219	10	standard
			2	8	1				
RGM1-S1	1533	331	1296	14	10	20	222	11	standard
			4	3	8				
RGM1-S1	1625	332	1308	14	10	25	210	6	standard
			5	3	8				
Site/Sample	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Source
RGM1-S1	1433	300	1319	14	11	20	209	7	standard
			9	5	0				
RGM1-S1	1492	308	1333	14	11	28	215	4	standard
			3	7	2				
RGM1-S1	1576	314	1315	14	10	19	219	12	standard
			4	7	7				
RGM1-S1	1593	325	1334	14	11	20	219	3	standard
			0	6	2				
RGM1-S1	1588	307	1332	14	11	28	223	9	standard
			3	8	5				

Table 2. Crosstabulation of site by source for the analysis.

Count

		Source					
		Cerro Toledo Rhy, NM	Valle Grande Rhy, NM	Malad, ID	Sierra de Pachuca, Hidalgo	unknown	Total
Site	14A307	1	1	0	0	0	2
	14BA401	5	0	0	0	0	5
	14BA406	26	1	0	0	0	27
	14CO1	0	1	0	0	0	1
	14CO1509	1	0	0	0	0	1
	14CO3	1	6	0	0	0	7
	14CO332	0	1	0	0	0	1
	14CO385	0	1	0	0	0	1
	14CO501	0	2	0	0	0	2
	14CS375	0	0	0	0	1	1
	14MD306	0	1	0	0	1	2
	14MD310	0	1	0	0	0	1
	14MP1	3	1	0	2	1	7
	14MP408	1	9	0	0	0	10
	14OS365	0	0	1	0	0	1
	14OT5	0	0	1	0	0	1
	14PA307	1	3	0	0	1	5
	14RC2	0	3	0	0	0	3
	14RC2H	0	2	0	0	0	2
	14RC3	0	2	0	0	0	2
	14RC301	2	9	1	0	0	12
	14RC5	1	3	0	0	0	4
	14RC8	7	9	0	0	0	16
	14RC9	0	5	0	0	0	5
	14SC1	8	10	0	0	1	19
	14SN3	1	0	0	0	0	1
	14SN4	0	0	0	1	0	1
	14TO305	3	0	0	0	0	3
	25CH1	0	6	0	0	0	6
Total		61	77	3	3	5	149

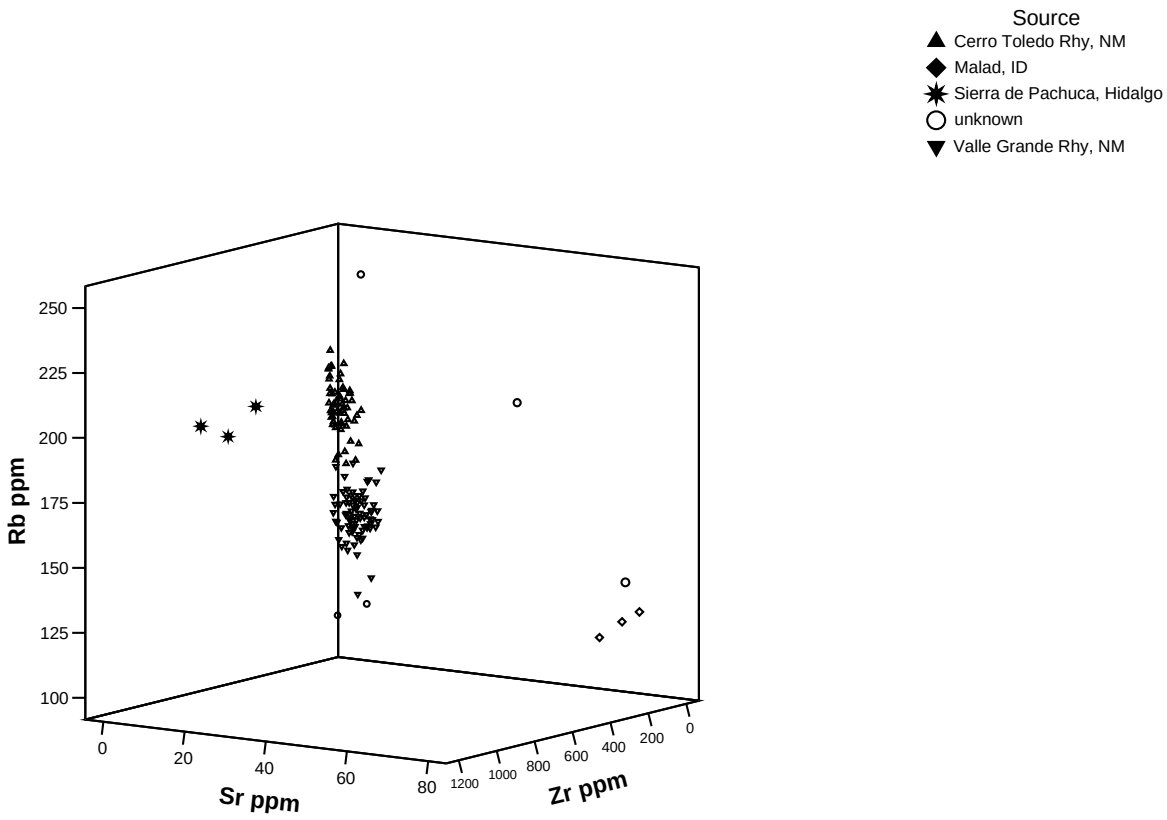

Figure 1. Rb, Sr, Zr three-dimensional plot of elemental concentrations for obsidian archaeological samples from all sites.

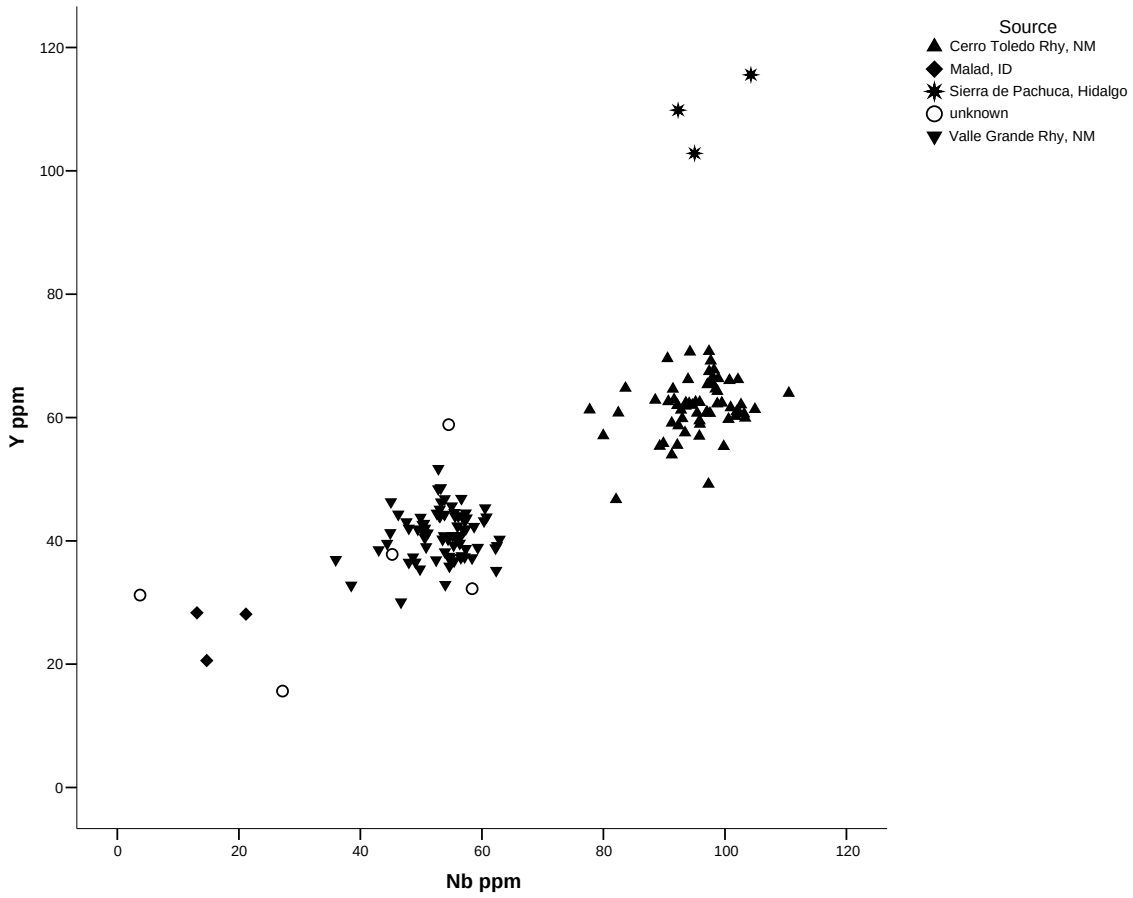

Figure 2. Y versus Nb biplot of archaeological samples more effectively separating the Jemez Mountains sources.