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SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM PREHISTORIC SITES ON THE SOUTHERN PARK PLATEAU, NORTHEAST NEW MEXICO

by

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INTRODUCTION

The following report documents a geochemical analysis of 53 obsidian artifacts from a number of sites on the Park Plateau in northeastern New Mexico. While the assemblage is dominated by obsidian from the Jemez Mountains in northern New Mexico, there is one specimen that appears to be from one of the sources in the Yellowstone Volcanic Field in western Wyoming and eastern Idaho. In addition to a discussion of the results, a short summary of the silicic petrology in the Jemez Mountains is included relevant to archaeological obsidian and attendant recent field studies.

ANALYSIS AND INSTRUMENTAL CONDITIONS

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, 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 WinTraceTM 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), thorium (Th) using Lα line, rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb). Weight percent iron ($Fe2O3^{T}$)

can be derived by multiplying ppm estimates by 1.4297(10-4). 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 Southwest obsidian is available in Shackley (1988, 1990, 1992, 1995; 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, Cu, Zn, and Ga were measured, but these are rarely useful in discriminating glass sources 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, and is included in Table 1. Source assignment was made by comparison to regional source standards at Berkeley (see Shackley 1995, 2002, 2005).

SILICIC VOLCANISM IN THE JEMEZ MOUNTAINS

Due to its proximity and relationship to the Rio Grande Rift System, potential uranium ore, geothermal possibilities, an active magma chamber, and a number of other geological issues, the Jemez Mountains and the Toledo and Valles Calderas particularly have been the subject of intensive structural and petrological study particularly since the 1970s (Bailey et al. 1969; Gardner et al. 1986; Heiken et al. 1986; Ross et al. 1961; Self et al. 1986; Smith et al. 1970; Figure 1 here). Half of the 1986 *Journal of Geophysical Research*, volume 91, was devoted to the then current research on the Jemez Mountains. More accessible for archaeologists, the geology of which is mainly derived from the above, is Baugh and Nelson's (1987) article on the relationship between northern New Mexico archaeological obsidian sources and procurement on the southern Plains.

Due to continuing tectonic stress along the Rio Grande, a lineament down into the mantle has produced a great amount of mafic volcanism during the last 13 million years (Self et al. 1986). Earlier eruptive events during the Tertiary more likely related to the complex interaction of the Basin and Range and Colorado Plateau provinces produced bimodal andesite-rhyolite fields, of which the Paliza Canyon (Keres Group) and probably the Polvadera Group is a part (Smith et al. 1970). While both these appear to have produced artifact quality obsidian, the nodule sizes are relatively small due to hydration and devitrification over time (see Hughes and Smith 1993; Shackley 1990, 1998a). Later, during rifting along the lineament and other processes not well understood, first the Toledo Caldera (ca. 1.45 Ma) and then the Valles Caldera (1.12 Ma) collapsed causing the ring eruptive events that were dominated by crustally derived silicic volcanisim and dome formation (Self et al. 1986). The Cerro Toledo Rhyolite and Valles Grande Member obsidians are grouped within the Tewa Group due to their similar magmatic origins. The slight difference in trace element chemistry is probably due to evolution of the magma through time from the Cerro Toledo event to the Valle Grande events (see Hildreth 1981; Mahood and Stimac 1990; Shackley 1998b; see Figure 1 here). This evolutionary process has recently been documented in the Mount Taylor field (Shackley 1998b). Given the relatively recent events in the Tewa Group, nodule size is large and hydration and devitrification minimal, yielding the best natural glass media for tool production in the Jemez Mountains.

Recent study of the secondary depositional context of these sources and their relationship to the Rio Grande Rift have indicated that only two of the major sources enter that stream system (Church 2000; Shackley 2005). Cerro Toledo Rhyolite erodes from the domes in the Sierra de Toledo along the northeast scarp of the caldera, and in much greater quantity due to the ash flow tuff eruptive event associated with the Rabbit Mountain dome on the southeast margin of the caldera. This latter eruption created large quantities of glass that have continually eroded into the Rio Grande system (see Figure 1). Most likely the Cerro Toledo obsidian present in these sites was procured directly from the Rio Grande alluvium, or in the Puye Formation to the northeast of Santa Fe. El Rechuelos obsidian present on a number of minor domes northeast of the caldera, and slightly earlier than the caldera event, erodes north into the Rio Chama and ultimately into the Rio Grande.

Obsidian from the Valle Grande member, however, does not leave the caldera floor, although some small nodules have been recovered from the East Jemez River, but does not erode outside the caldera area (Shackley 2005). This is likely due to the recent event that occurred as a resurgence on the caldera floor. Importantly, this would indicate that Valle Grande obsidian must be procured from the caldera floor proper (i.e. at Cerro del Medio) either directly or through exchange with groups with direct access. The Cerro Toledo Rhyolite and El Rechuelos obsidian could also be procured in this way, but they are also available, albeit in smaller nodule sizes in local alluvium (i.e. the Puye Formation).

SUMMARY AND CONCLUSION

The dominance of El Rechuelos located on the north side of the Valles Caldera seems sensible given that it is the nearest source to Park Plateau, and is available as secondary deposits in the Chama River (Shackley 2005; Table 2 and Figure 3 here). Valle Grande obsidian, however is only available in the caldera proper, and so had to be originally procured in the caldera (Shackley 2002, 2005). One sample (25198), exhibits a trace element chemistry similar to Obsidian Cliff in Yellowstone, but the match is not as precise as I would like (Figure 2). The proximity is similar enough to the obsidian in that volcanic field, and different enough from Southwest obsidian sources to provisionally assign that artifact to Yellowstone. The others noted with question marks in Table 1 are those, mainly due to small sizes, are slightly outside the composition reported for those sources, but are almost certainly from those sources (see Davis et al. 1998).

The one sample you suspected was not obsidian is certainly not (7349), but does appear to be a glassy volcanic based on the trace element chemistry. A more complete analysis would be necessary to determine its composition relative to rock classification.

REFERENCES CITED

Bailey, R.A., R.L. Smith, and C.S. Ross
1969 Stratigraphic Nomenclature of Volcanic Rocks in the Jemez Mountains, New Mexico. *U.S. Geological Survey Bulletin* 1274-P:1-19.

Baugh, T.G., and F.W. Nelson, Jr.
1987 New Mexico Obsidian Sources and Exchange on the Southern Plains. *Journal of Field Archaeology* 14:313-329.

Church, T.
2000 Distribution and Sources of Obsidian in the Rio Grande Gravels of New Mexico. *Geoarchaeology* 15:649-678.

Davis, M.K., T.L. Jackson, M.S. Shackley, T. Teague, and J.H. Hampel

1998 Factors Affecting the Energy-Dispersive X-Ray Fluorescence (EDXRF) Analysis of Archaeological Obsidian. In *Archaeological Obsidian Studies: Method and Theory*, edited by M.S. Shackley, pp. 159-180. Advances in Archaeological and Museum Science 3. Springer/Plenum Press, New York.

Gardner, J.N, F. Goff, S. Garcia, and R.C. Hagan
1986 Stratigraphic Relations and Lithologic Variations in the Jemez Volcanic Field, New Mexico. *Journal of Geophysical Research* 91:1763-1778.

Glascock, Michael D.
1991 *Tables for Neutron Activation Analysis* (3rd edition). The University of Missouri Research Reactor Facility.

Glascock, M.D., and M.P. Anderson
1993 Geological Reference Materials for Standardization and Quality Assurance of Instrumental Neutron Activation Analysis. *Journal of Radioanalytical and Nuclear Chemistry* 174(2):229-242.

Glascock, M.D., R. Kunselman, and D. Wolfman
1998 Intrasource Chemical Differentiation of Obsidian in the Jemez Mountains and Taos Plateau, New Mexico. *Journal of Archaeological Science* 26:861-868.

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.

Heicken, G., F. Goff, J. Stix, S. Tamanyu, M. Shafiqullah, S. Garcia, and R. Hagan
1986 Intracaldera Volcanic Activity, Toledo Caldera and Embayment, Jemez Mountains, New Mexico. *Journal of Geophysical Research* 91:1799-1815.

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

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.

Nelson, Fred W., Jr.
1984 X-Ray Fluorescence Analysis of Some Western North American Obsidians. In *Obsidian Studies in the Great Basin*, edited by R.E. Hughes, pp. 21-62. Contributions of the University of California Archaeological Research Facility 45. Berkeley.

Ross, C.S., R.L. Smith, and R.A. Bailey
1961 Outline of the Geology of the Jemez Mountains, New Mexico. *Field Conference Guidebook, New Mexico Geological Society* 12:139-143.

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.

Self, S., F. Goff, J.N. Gardner, J.V. Wright, and W.M. Kite
1986 Explosive Rhyolitic Volcanism in the Jemez Mountains: Vent Locations, Caldera Development and Relation to Regional Structures. *Journal of Geophysical Research* 91:1779-1798.

Shackley, M. Steven
1988 Sources of Archaeological Obsidian in the Southwest: An Archaeological, Petrological, and Geochemical Study. *American Antiquity* 53(4):752-772.

1990 *Early Hunter-Gatherer Procurement Ranges in the Southwest: Evidence from Obsidian Geochemistry and Lithic Technology*. Ph.D. dissertation, Arizona State University, Tempe.

1992 The Upper Gila River Gravels as an Archaeological Obsidian Source Region: Implications for Models of Exchange and Interaction. *Geoarchaeology* 7(4):315-326.

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

1998a Chemical Variability and Secondary Depositional Processes: Lessons from the American Southwest. In *Archaeological Obsidian Studies: Method and Theory*, edited by M.S. Shackley, pp. 83-102. Advances in Archaeological and Museum Science 3. Plenum Press, New York.

1998b Geochemical Differentiation and Prehistoric Procurement of Obsidian in the Mount Taylor Volcanic Field, Northwest New Mexico. *Journal of Archaeological Science* 25:1073-1082.

2002 Source Provenance of Obsidian Artifacts and Silicic Rocks from Los Alamos National Laboratory. Report prepared for the Ecology Group, Los Alamos National Laboratory.

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

Smith, R.L., R.A. Bailey, and C.S. Ross
1970 Geologic Map of the Jemez Mountains, New Mexico. Miscellaneous Geological Investigations Map I-571. U.S. Geological Survey, Denver.

Table 1. Elemental concentrations for the archaeological specimens. All measurements in parts per million (ppm).

Sample	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Source
4467	1382	437	5883	149	11	13	68	44	El Rechuelos
5491	2890	452	5496	119	8	19	60	44	El Rechuelos?
6078	1277	462	5561	146	10	17	69	48	El Rechuelos
6263	1211	474	5954	160	10	21	76	36	El Rechuelos
6345	1028	520	5786	149	11	21	68	49	El Rechuelos
6407	1094	532	5924	156	13	20	70	60	El Rechuelos
6450	1248	558	5860	157	13	16	68	50	El Rechuelos
6464	1598	460	5873	141	5	9	67	37	El Rechuelos
6498	1647	559	7322	142	11	28	67	49	El Rechuelos
6610	1317	466	9624	154	13	39	142	59	Valle Grande Rhy
7004	1211	499	5936	150	10	16	73	47	El Rechuelos
7055	1215	465	6061	154	7	26	64	51	El Rechuelos
7060	966	454	5878	156	9	30	64	46	El Rechuelos
7278	1018	530	8137	187	5	61	163	101	Cerro Toledo Rhy
7296	1791	538	8416	164	15	53	142	94	Cerro Toledo Rhy
7349	3970	147	13911	60	78	13	364	45	not obsidian
7393	1141	535	5826	152	11	18	71	48	El Rechuelos
7940	1051	561	6491	170	5	19	70	52	El Rechuelos
8910	1685	420	7922	133	11	30	147	42	Valle Grande Rhy
16074	930	460	5528	145	9	17	70	49	El Rechuelos
16429	971	585	8895	192	5	64	171	106	Cerro Toledo Rhy
16871	900	459	8769	154	5	45	169	63	Valle Grande Rhy
16872	1427	456	6024	153	17	15	66	50	Valle Grande Rhy
17669	1419	442	8493	153	9	51	148	42	Valle Grande Rhy
18205	894	417	5246	137	11	17	63	41	El Rechuelos
18324	970	474	8216	139	10	46	156	57	Valle Grande Rhy
18332	830	481	7745	181	6	58	158	107	Cerro Toledo Rhy
18420	886	445	5568	148	9	23	68	50	El Rechuelos
18859	1032	494	5534	146	12	30	61	42	El Rechuelos
18881	847	395	8287	145	10	34	157	58	Valle Grande Rhy
19457	1305	525	9450	168	18	39	161	56	Valle Grande Rhy
19497	1179	439	8401	149	14	44	159	49	Valle Grande Rhy
20820	888	376	5069	131	11	12	70	34	El Rechuelos
21196	940	472	5419	142	11	16	64	56	El Rechuelos
21258	870	408	7779	142	10	36	159	48	Valle Grande Rhy
21379	917	424	5155	138	5	19	62	45	El Rechuelos
21739	2004	393	5313	124	18	15	51	30	El Rechuelos
21784	1243	682	9752	211	9	60	168	96	Cerro Toledo Rhy
21800	1114	425	8713	156	14	46	160	57	Valle Grande Rhy
21830	1142	488	8475	156	14	35	163	55	Valle Grande Rhy
21978	936	472	6014	152	10	21	77	44	El Rechuelos
22098	1083	579	8995	193	6	57	162	109	Cerro Toledo Rhy
22279	1283	505	5911	144	10	19	70	46	El Rechuelos
22873	1064	451	5215	129	7	27	64	54	El Rechuelos
23337	1433	434	5697	138	10	10	72	54	El Rechuelos

23363	1747	476	8197	132	14	39	143	37	Valle Grande Rhy
Sample	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Source
24861	936	447	6197	153	8	17	64	55	El Rechuelos
25198	1189	332	11109	205	19	72	244	61	Yellowstone Volc. Field?
26150	1091	433	5254	134	11	20	61	58	El Rechuelos
26173	952	411	5421	138	11	17	63	49	El Rechuelos
26709	1126	501	5842	153	12	19	68	40	El Rechuelos
26798	988	453	5001	123	8	15	55	45	El Rechuelos
26813	1300	426	7448	126	8	29	133	42	Valle Grande Rhy?
RGM-1-S1	1628	316	13313	150	115	20	224	0	standard
RGM-1-S1	1726	294	13246	152	115	20	220	11	standard
RGM-1-S1	1576	321	12899	151	107	21	226	8	standard

Table 2. Frequency distribution of obsidian source provenance.

		Frequency	Percent
Source	El Rechuelos	30	57.7
	El Rechuelos?	1	1.9
	Valle Grande Rhy	14	26.9
	Cerro Toledo Rhy	6	11.5
	Yellowstone Volc. Field?	1	1.9
	Total	52	100.0

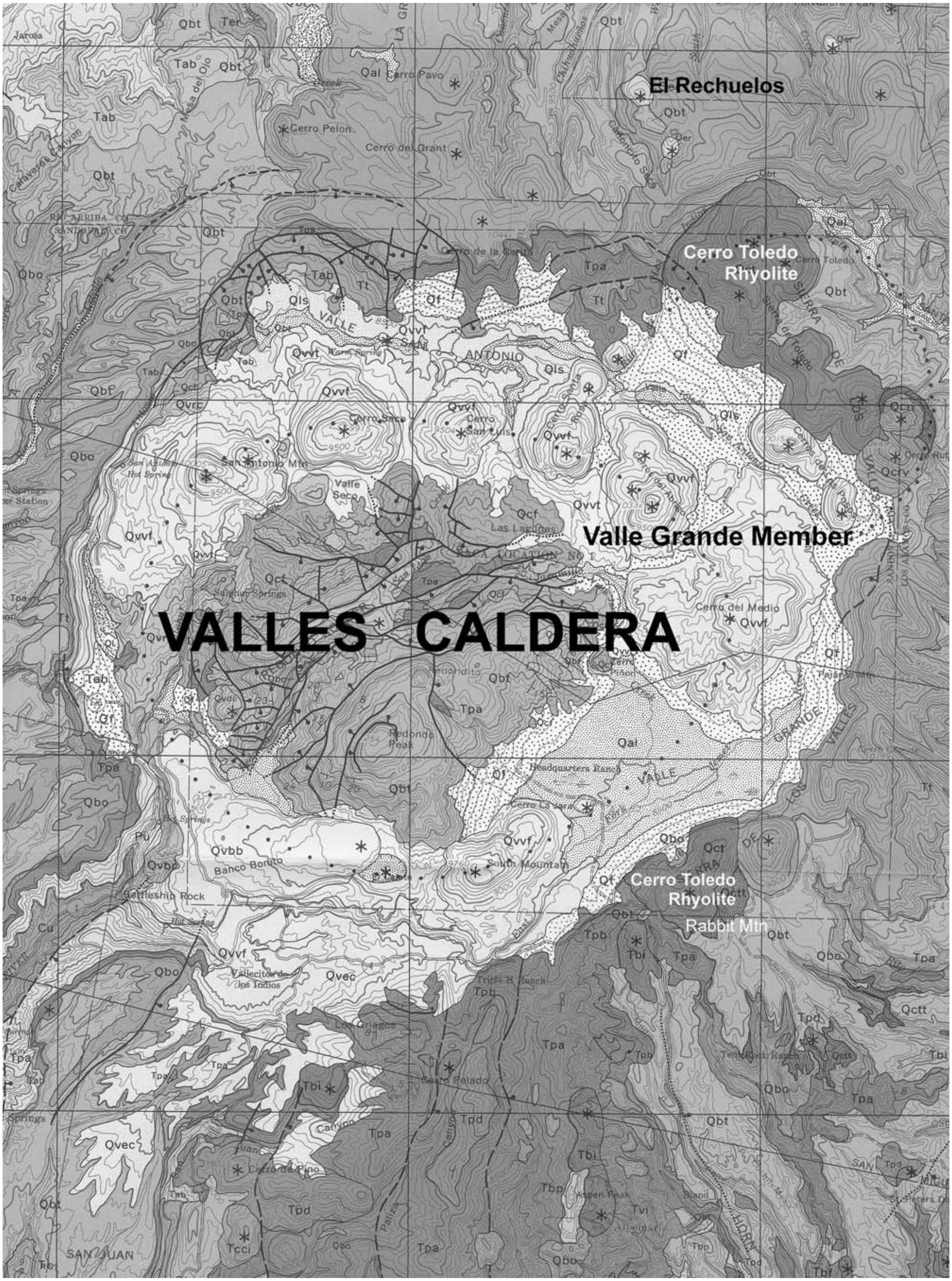

Figure 1. Topographical rendering of a portion of the Jemez Mountains, Valles Caldera, and relevant features. (from Baugh and Nelson 1987; Smith et al. 1970).

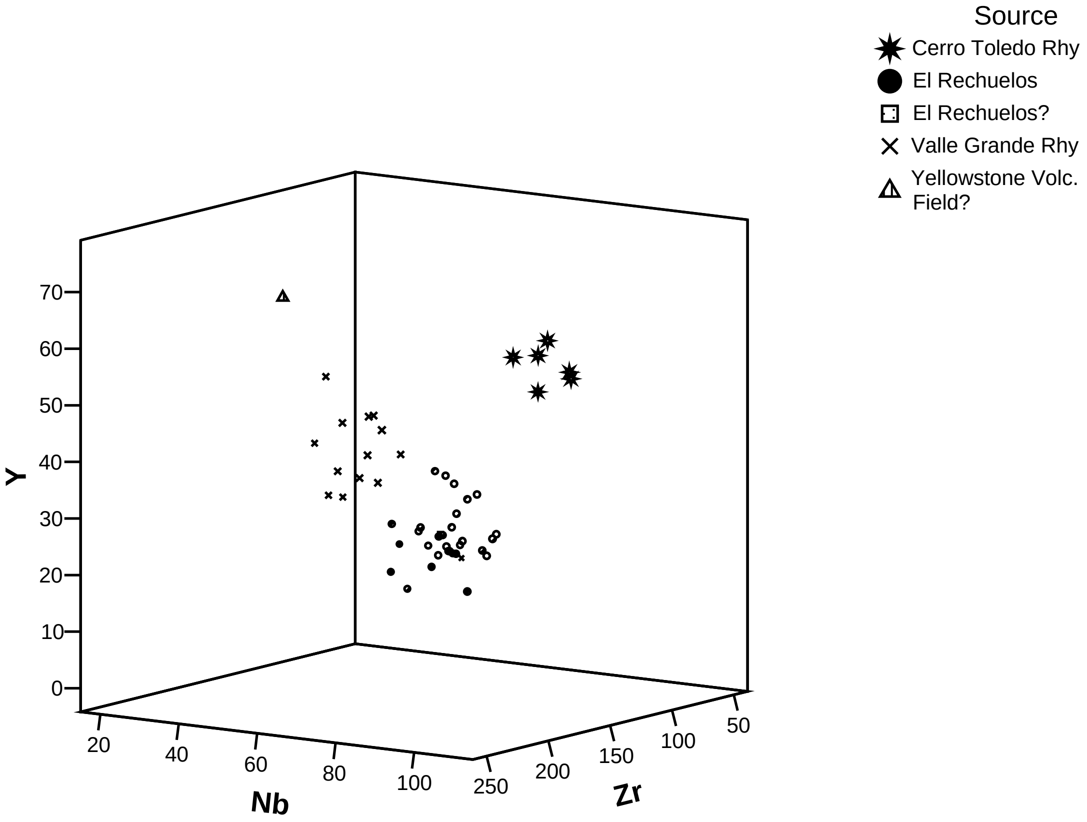

Figure 2. Y, Nb, Zr plot of archaeological samples from all sites.

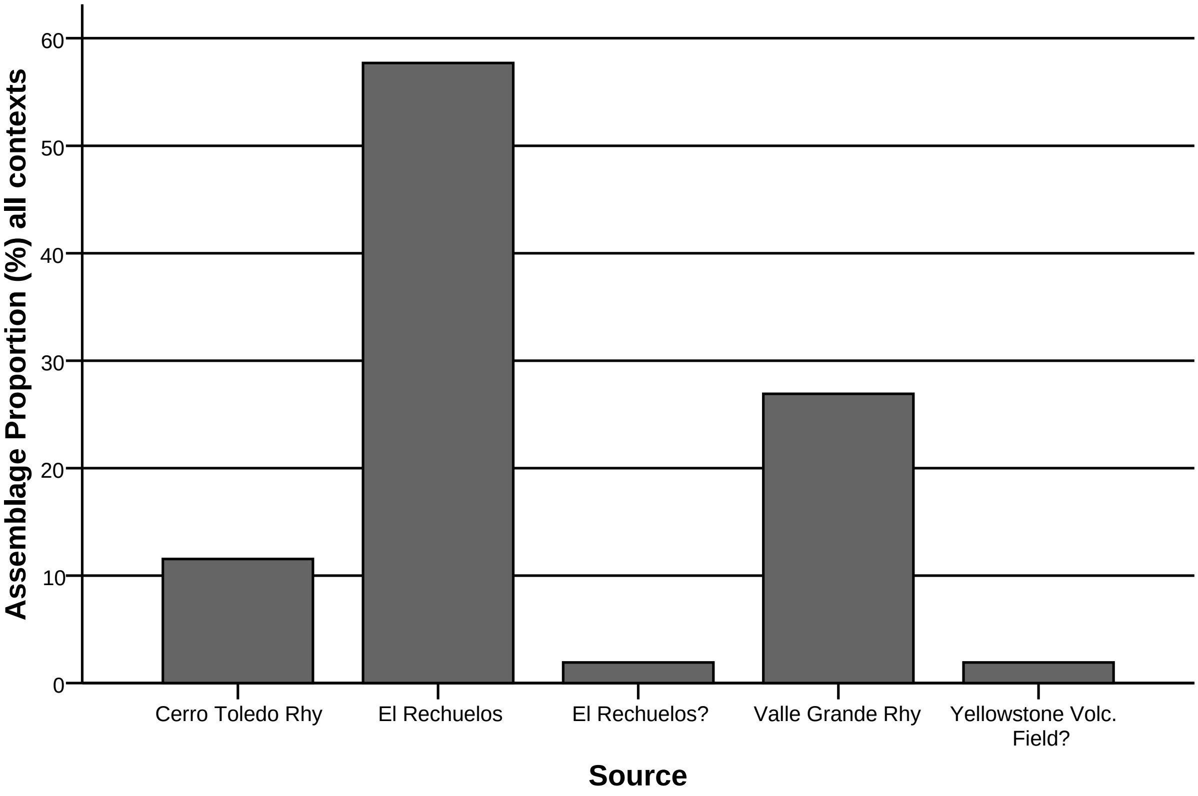

Figure 3. Frequency distribution of obsidian source provenance in LA 4624.