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SOURCE PROVENANCE OF ARCHAEOLOGICAL OBSIDIAN FROM PREHISTORIC SITES IN THE GALLINA REGION NORTHWEST NEW MEXICO

by

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INTRODUCTION

The following report documents a geochemical analysis of 62 obsidian bifaces and pieces of debitage from a number of sites in the Gallina region of northwest New Mexico (see Hibben 1938; Green 1956; Mackey and Green 1979; Turner et al. 1993). All of the obsidian artifacts were produced from one of the sources in the El Rechuelos Rhyolite of the Polvadera Group in the north Jemez Mountains or the Valle Grande Member of the Tewa Group in the Valles Caldera in Jemez Mountains (Figure 1). No Cerro Toledo Rhyolite glass was present in the assemblage, probably reflecting raw material availability in the Jemez Mountains to the inhabitants in the Gallina region. This analysis is the largest yet in this part of northwestern New Mexico, and can serve as a baseline study for future work in the region.

LABORATORY SAMPLING, ANALYSIS AND INSTRUMENTATION

All samples were analyzed whole with little or no formal preparation. 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 Department of Geology and Geophysics, University of California, Berkeley, using a Spectrace™ 400 (United Scientific Corporation) energy dispersive x-ray fluorescence spectrometer. The spectrometer is equipped with a Rh x-ray tube, a 50 kV x-ray generator, with a Tracor X-ray (Spectrace™) TX 6100 x-ray analyzer using an IBM PC based microprocessor and Tracor reduction software. The x-ray tube was operated at 30 kV, 0.20 mA, using a 0.127 mm Rh primary beam filter in a vacuum path at 250 seconds livetime to generate x-ray intensity Kα-line data for elements titanium (Ti), manganese (Mn), iron (as Fe^T), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb). Weight percent iron ($Fe_2O_3^T$) 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). Further details concerning the petrological choice of these elements in Southwest obsidians 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 and SY-2 (syenite), BHVO-1 (hawaiite), STM-1 (syenite), QLM-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, and BR-N (basalt) from the Centre de Recherches Pétrographiques et Géochimiques in France (Govindaraju 1994). In addition to the reported values here Ni, Cu, Zn, Th, and Ga were measured, but these are not consistently useful in discriminating glass sources and are not generally reported. These data are available on disk by request.

The approximate practical detection limits of the elements of interest that include error imposed by inter-element interference are as follows: Ti 23 ppm; Mn 40 ppm; Fe 10 ppm; Pb 8 ppm; Rb 5 ppm; Sr 3.5 ppm; Y 7 ppm; Zr 7 ppm; Nb 8 ppm; Ba 20 ppm; La 20 ppm; Ce 20 ppm. These are the smallest amounts that can be quantitatively measured, defined as a signal which is six standard deviation units above background (6Σ).

The data from the Tracor 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. Table 1 shows a comparison between values recommended for three international obsidian and rhyolite rock standards, RGM-1, NBS(SRM)-278, and JR-2. One of these standards is analyzed during each sample run to check machine calibration. The results shown in Table 1 indicate that the machine accuracy is quite high, particularly for the mid-Z elements, and other instruments with comparable precision should yield comparable results. Further information on the laboratory instrumentation can be found on the World Wide Web at: http://obsidian.pahma.berkeley.edu/. Trace element data exhibited in Tables 1 and 2 are reported in parts per million (ppm), a quantitative measure by weight. Source assignment was made by comparison to source standards here at Berkeley, and published and unpublished references in Baugh and Nelson (1987), Nelson (1984), and Glascock et al. (1999). The data reported in Glascock et al. (1999) are, in some cases, sample splits also analyzed at Berkeley. Statistical agreement between these labs is quite high and discussed in Shackley (1998a; see also Davis et al. 1998).

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; Goff et al. 1990; 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, 1998b). 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 crustal derived silicic volcanism 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 1998c; see Figure 2 here). This evolutionary process has recently been documented in the Mount Taylor field to the southwest and along the same lineament (Shackley 1998c). 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.

SUMMARY AND CONCLUSION

In the assemblage overall, the distribution of the two sources, El Rechuelos and Valle Grande is essentially equal (Table 3; Figures 2 and 3). In all the sites with sample sizes under 10, this distribution holds, although the sample sizes are really too small to derive confident conclusions on an intra-site level. At Largo-Leeson 2, with a sample size of 18, 72.2% of the artifacts were produced from obsidian procured from Valle Grande sources. Given the relatively small sample size at this site, however, it is possible that the distribution is due to sampling error, and larger samples would indicate a more equal distribution of the two sources.

The secondary distribution of source material in the Jemez Mountain region is, as yet, unknown and is currently being investigated by this laboratory. It is quite possible that all or part of the raw material used in the production of artifacts in this assemblage was procured from secondary deposits on the northwest side of the Jemez Mountains where equal proportions of El Rechuelos and Valle Grande glass is available. Both seem to be equally good media for tool production, and so selection may not have been an issue.

None of the sources to the south such as Mount Taylor, Red Hill or Mule Creek are present in this assemblage suggesting that the procurement of raw material was essentially to the east. Nodule sizes of these two obsidians are relatively large and the quality is high, so there may not have been a need to procure obsidian from sources at a greater distance. Indeed, the absence of Cerro Toledo obsidian which erodes generally to the west of the caldera and not present in this collection argues for rather expedient procurement. Mount Taylor sources (Grants Ridge and Horace Mesa) which are essentially equidistant from these sites as the Jemez sources, also not present in this collection, argues for interaction with groups to the east of the Gallina region rather than the south; or simply ready or desired access to the region to the east (Shackley 1998c). Recent analyses of obsidian from the Pecos Pueblo area indicated a more even distribution of Jemez Mountains sources, probably due to the availability of all these sources as secondary deposits in the Rio Grande (Shackley 1998d; White 1999).

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Table 1. X-ray fluorescence concentrations for selected trace elements of three international rock standards. ± values represent first standard deviation computations for the group of measurements. All values are in parts per million (ppm) as reported in Govindaraju (1994) and this study. RGM-1 is a U.S. Geological Survey rhyolite standard, NBS (SRM)-278 is a National Institute of Standards and Technology obsidian standard, and JR-2 is a Geological Survey of Japan rhyolite standard. Fe^T can be converted to $Fe_2O_3^T$ with a multiplier of 1.4297^{10-4} (see also Glascock 1991).

SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba
RGM-1 (Govindaraju 1994)	1600	279	12998	149	108	25	219	8.9	807
RGM-1 (Glascock and Anderson 1993)	1800±200	323±7	12400±300	145±3	120±10	n.r.[a]	150±7	n.r.	826±31
RGM-1 (this study)	1516±58	259±19	13991±143	152±3	108±2	24±1	226±4	10±1	806±12
SRM-278 (Govindaraju 1994)	1469	402	14256	127.5	63.5	39	290	18	1140[b]
SRM-278 (Glascock and Anderson 1993)	1460±270	428±8	14200±300	128±4	61±15	n.r.	208±20	n.r.	891±39
SRM-278 (this study)	1376±96	372±17	15229±399	129±2	68±2	42±2	290±3	17±2	1090±38
JR-2 (Govindaraju 1994)[b]	540	852	6015	297	8	51.3[b]	97.2[b]	19.2	39
JR-2 (this study)	343±51	680±17	7358±65	300±5	10±1	49±3	94±2	16±2	34±6

[a] n.r. = no report; n.m.=not measured

[b] values proposed not recommended

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

SITE	SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Source
Largo-Leeson 1	56-2-25	948.4	388.7	10017.5	161.6	7.6	43.1	170.0	55.3	Valle Grande
Largo-Leeson 1	56-2-58	945.9	430.3	11203.1	169.1	4.0	46.9	169.1	55.8	Valle Grande
Largo-Leeson 1	53-2-7	907.1	405.9	7368.4	163.3	5.3	27.4	67.4	43.4	El Rechuelos
Largo-Leeson 1	56-2-54	930.7	418.2	7702.0	166.9	7.9	21.7	71.5	44.9	El Rechuelos
Largo-Leeson 1	56-2-24	954.8	413.4	8001.4	162.1	6.2	25.1	73.8	48.1	El Rechuelos
Largo-Leeson 1	58-2-80	1046.6	356.6	11126.8	170.5	6.8	52.1	173.6	54.3	Valle Grande
Largo-Leeson 1	56-2-83	911.1	365.4	10245.3	167.1	5.0	44.6	165.4	54.2	Valle Grande
Largo-Leeson 1	56-2-81	874.1	381.5	7236.8	158.0	4.9	25.8	70.0	48.0	El Rechuelos
Largo-Leeson 1	80-44-23	1293.1	377.6	9121.9	160.3	13.5	27.8	77.0	45.2	El Rechuelos
Largo-Leeson 1	57-6-443	1089.2	425.5	11896.9	172.0	7.6	47.4	174.7	59.4	Valle Grande
Largo-Leeson 2	55-17-90	868.3	395.4	7085.8	156.6	5.6	20.3	68.1	46.9	El Rechuelos
Largo-Leeson 2	57-6-438	822.6	327.6	9191.5	144.1	4.0	38.8	157.8	49.4	Valle Grande
Largo-Leeson 2	55-17-98	1093.8	457.0	11211.2	203.7	13.2	47.1	174.1	57.7	Valle Grande
Largo-Leeson 2	55-17-100	1134.0	339.3	10316.2	169.9	4.1	40.8	144.7	43.4	Valle Grande
Largo-Leeson 2	55-17-99	986.1	403.5	10622.6	174.5	6.5	48.1	171.8	56.9	Valle Grande
Largo-Leeson 2	55-17-95	26983.8	319.3	9370.4	153.7	6.5	39.4	157.3	66.1	Valle Grande
Largo-Leeson 2	55-17-97	1008.7	302.4	9931.3	159.9	4.9	45.6	161.1	49.6	Valle Grande
Largo-Leeson 2	55-17-115	939.6	332.7	9747.6	153.9	7.6	42.0	152.8	46.5	Valle Grande
Largo-Leeson 2	55-17-116	832.9	366.3	6929.8	152.3	6.6	23.0	68.1	49.0	El Rechuelos
Largo-Leeson 2	55-17-80	1321.6	381.7	7392.9	165.2	6.4	23.2	71.5	50.2	El Rechuelos
Largo-Leeson 2	57-6-436	894.2	383.8	7384.3	157.7	5.4	24.6	72.8	47.2	El Rechuelos
Largo-Leeson 2	55-17-165	816.2	415.4	7336.3	163.1	6.9	21.1	74.2	49.9	El Rechuelos
Largo-Leeson 2	55-17-82	1220.8	356.1	10144.7	161.7	6.9	41.6	162.4	56.2	Valle Grande
Largo-Leeson 2	55-17-28	1069.2	445.0	11742.6	189.6	4.1	46.6	190.5	57.2	Valle Grande
Largo-Leeson 2	57-6-434	967.5	387.0	10995.7	173.9	5.0	46.0	177.2	53.5	Valle Grande
Largo-Leeson 2	55-17-54	2012.0	377.8	10148.7	165.8	4.3	47.5	164.9	54.6	Valle Grande
Largo-Leeson 2	55-17-145	964.8	508.8	12432.6	196.5	8.3	46.3	188.4	58.7	Valle Grande
Largo-Leeson 2	55-17-144	819.7	390.5	10715.8	170.2	7.1	45.3	178.5	57.5	Valle Grande
Burriones	55-17-5	960.2	412.0	11035.7	169.9	3.6	44.5	177.5	55.0	Valle Grande
Carricito Comm	49-8-48	959.0	419.4	10673.8	177.9	1.9	43.8	179.1	54.7	Valle Grande
Carricito Comm	49-8-47	1452.7	435.2	7749.8	168.6	6.2	26.5	75.2	48.3	El Rechuelos
Carricito Comm	49-8-46	803.7	384.4	7345.9	160.8	6.6	26.2	72.7	51.6	El Rechuelos
Carricito Comm	49-8-44	979.6	371.7	7740.2	162.1	6.7	20.0	72.1	48.7	El Rechuelos
Evans Site	99-10-4	927.5	391.6	10373.2	173.8	5.0	49.8	181.7	53.0	Valle Grande
Evans Site	99-10-5	799.6	364.5	6987.1	148.9	5.0	21.7	70.3	46.0	El Rechuelos
Evans Site	99-10-3	735.6	253.6	8522.4	143.3	6.2	39.5	154.0	44.9	Valle Grande
Evans Site	99-10-2	990.7	414.5	10647.5	174.8	5.3	48.5	181.6	57.0	Valle Grande
Evans Site	99-10-1	822.6	436.2	7418.4	170.3	7.0	23.3	75.8	51.3	El Rechuelos
Rattlesnake Pt	49-3-272	773.8	408.6	10794.7	171.4	3.1	48.1	174.3	56.8	Valle Grande
Rattlesnake Pt	49-3-271	883.6	393.8	10490.3	169.8	6.7	45.3	167.7	55.8	Valle Grande
Rattlesnake Pt	49-3-269	974.3	319.9	9392.4	152.7	5.6	40.2	161.6	49.2	Valle Grande
Rattlesnake Pt	49-3-270	974.7	401.4	7343.7	157.8	7.4	24.6	70.7	44.0	El Rechuelos
Archuleta	50-6-46	797.7	412.8	7162.1	161.9	5.3	24.1	70.3	48.3	El Rechuelos
Archuleta	50-6-47	887.1	424.6	7526.8	172.0	5.8	27.7	73.1	49.1	El Rechuelos
Archuleta	50-6-48	837.6	383.3	7548.8	159.7	6.5	22.6	71.5	50.8	El Rechuelos
Archuleta	50-6-49	793.1	425.8	7400.0	163.5	7.5	19.4	68.5	45.8	El Rechuelos
Archuleta	50-6-50	775.7	349.3	6965.1	154.6	6.0	24.1	68.4	43.9	El Rechuelos
Archuleta	50-6-51	725.7	389.1	7273.3	162.6	7.0	23.4	72.4	45.3	El Rechuelos
Archuleta	56-6-52	785.2	395.3	7142.7	165.4	5.9	24.2	70.3	45.0	El Rechuelos
Archuleta	56-6-53	807.2	444.5	7299.2	170.8	6.4	26.3	70.8	47.5	El Rechuelos
Archuleta	56-6-54	797.9	355.4	6881.0	151.6	5.1	21.5	71.6	41.1	El Rechuelos
Hormigas Site	49-9-19	1100.0	388.5	10716.7	163.0	5.2	47.2	167.1	54.9	Valle Grande

SITE	SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Source
Hormigas Site	49-9-36	8931.6	313.8	6733.1	147.4	9.7	22.5	66.8	44.8	El Rechuelos
Hormigas Site	49-9-23	10197.4	343.7	6760.7	148.1	8.1	20.9	65.9	48.0	El Rechuelos
Hormigas Site	49-9-18	941.0	416.5	10207.9	178.1	8.8	43.7	177.4	60.1	Valle Grande
Hormigas Site	49-9-17	1043.6	373.2	10876.0	170.5	6.1	44.9	176.6	56.6	Valle Grande
Tower 1	49-9-5	1056.0	380.7	10230.4	167.8	2.8	45.8	167.5	53.8	Valle Grande
Tower 1	49-9-40	1031.8	416.9	7608.1	165.1	6.6	21.4	75.2	46.5	El Rechuelos
Tower 1	49-9-39	792.7	390.3	7175.3	162.6	7.7	22.4	69.6	48.0	El Rechuelos
Tower 1	49-9-38	929.6	380.6	10161.4	171.2	6.0	42.1	173.3	54.5	Valle Grande
Tower 1	49-9-37	988.8	375.6	10673.3	171.0	5.5	43.9	177.8	59.3	Valle Grande
Tower 1	49-9-41	845.1	448.6	7527.7	162.0	7.2	21.7	67.6	48.0	El Rechuelos

Table 3. Crosstabulation of source provenance by site.

SITE		SOURCE		Total
		El Rechuelos	Valle Grande	
Archuleta	Count	9		9
	% within SITE	100.0%		100.0%
	% within SOURCE	30.0%		14.5%
	% of Total	14.5%		14.5%
Burriones	Count		1	1
	% within SITE		100.0%	100.0%
	% within SOURCE		3.1%	1.6%
	% of Total		1.6%	1.6%
Carricito Comm	Count	3	1	4
	% within SITE	75.0%	25.0%	100.0%
	% within SOURCE	10.0%	3.1%	6.5%
	% of Total	4.8%	1.6%	6.5%
Evans Site	Count	2	3	5
	% within SITE	40.0%	60.0%	100.0%
	% within SOURCE	6.7%	9.4%	8.1%
	% of Total	3.2%	4.8%	8.1%
Hormigas Site	Count	2	3	5
	% within SITE	40.0%	60.0%	100.0%
	% within SOURCE	6.7%	9.4%	8.1%
	% of Total	3.2%	4.8%	8.1%
Largo-Leeson 1	Count	5	5	10
	% within SITE	50.0%	50.0%	100.0%
	% within SOURCE	16.7%	15.6%	16.1%
	% of Total	8.1%	8.1%	16.1%
Largo-Leeson 2	Count	5	13	18
	% within SITE	27.8%	72.2%	100.0%
	% within SOURCE	16.7%	40.6%	29.0%
	% of Total	8.1%	21.0%	29.0%
Rattlesnake Pt	Count	1	3	4
	% within SITE	25.0%	75.0%	100.0%
	% within SOURCE	3.3%	9.4%	6.5%
	% of Total	1.6%	4.8%	6.5%
Tower 1	Count	3	3	6
	% within SITE	50.0%	50.0%	100.0%
	% within SOURCE	10.0%	9.4%	9.7%
	% of Total	4.8%	4.8%	9.7%
TOTAL	Count	30	32	62
	% within SITE	48.4%	51.6%	100.0%
	% within SOURCE	100.0%	100.0%	100.0%
	% of Total	48.4%	51.6%	100.0%

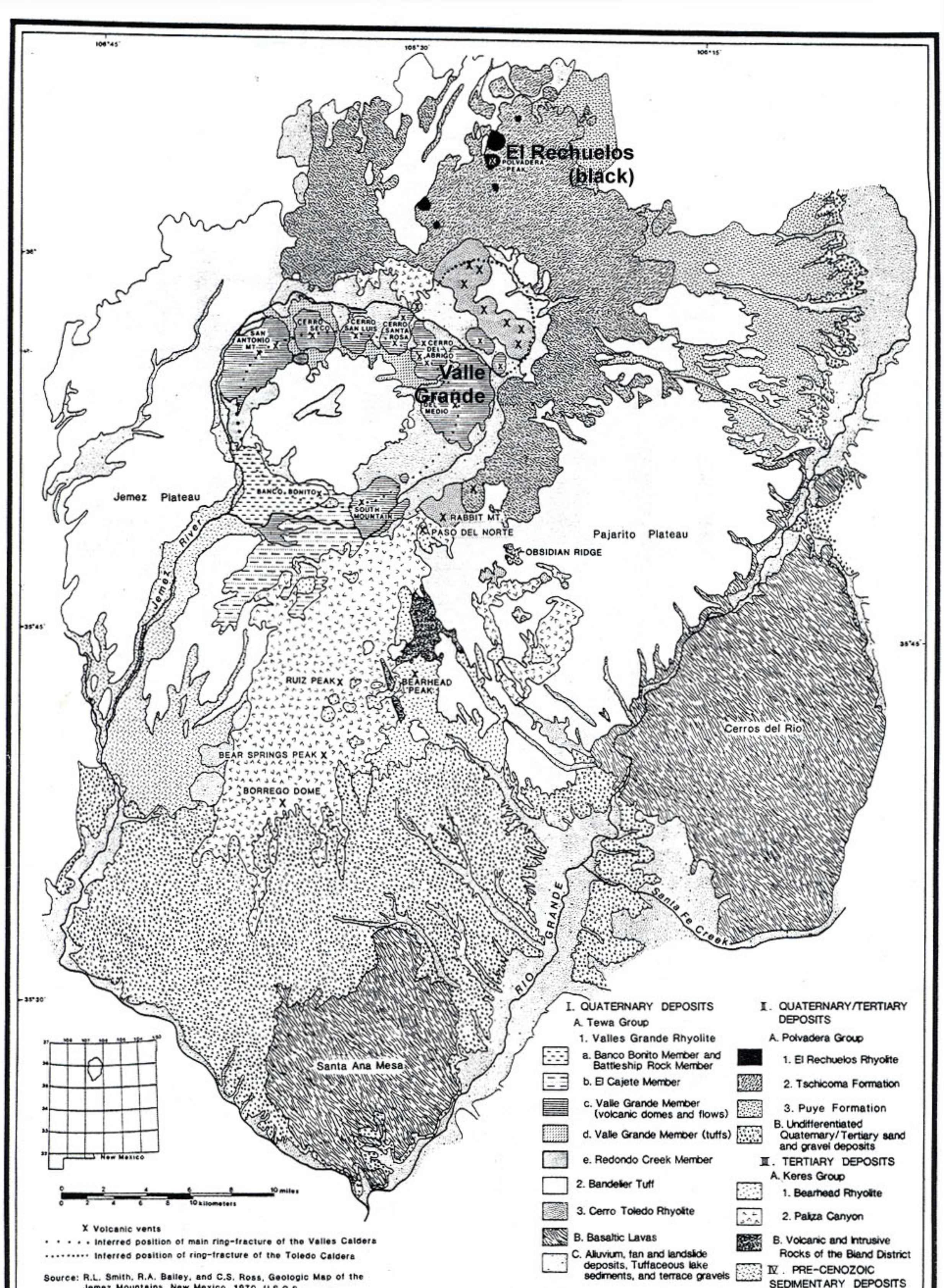

Figure 1. Geology of the Jemez Mountains, northern New Mexico (from Baugh and Nelson 1987; Smith et al. 1970).

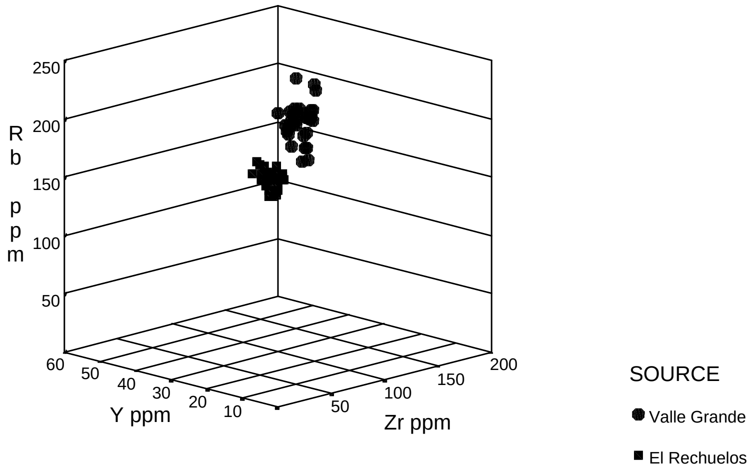

Figure 2. Rb, Sr, Zr plot of archaeological samples from all sites.

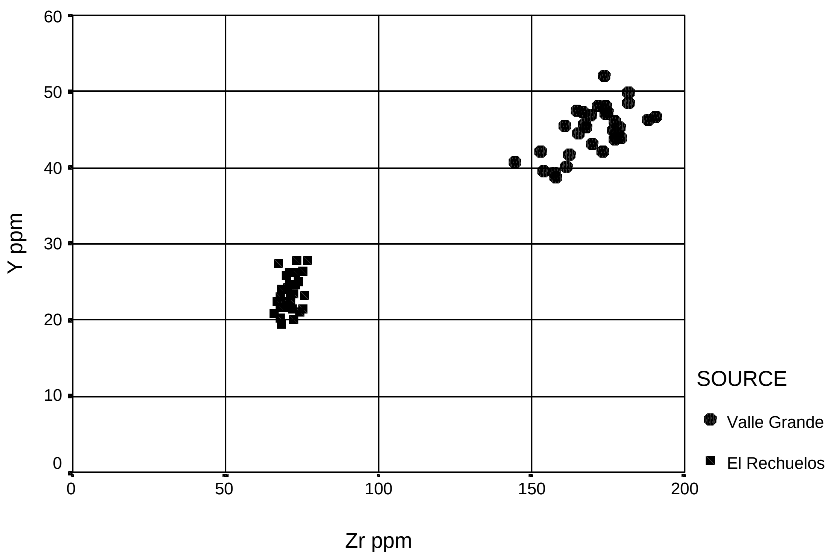

Figure 3. Y versus Zr biplot of the archaeological specimens from all sites.