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Source Provenance of Obsidian Artifacts from Astialakwa (LA 1825) Jemez Valley, New Mexico

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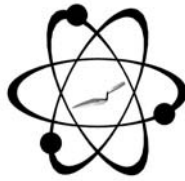
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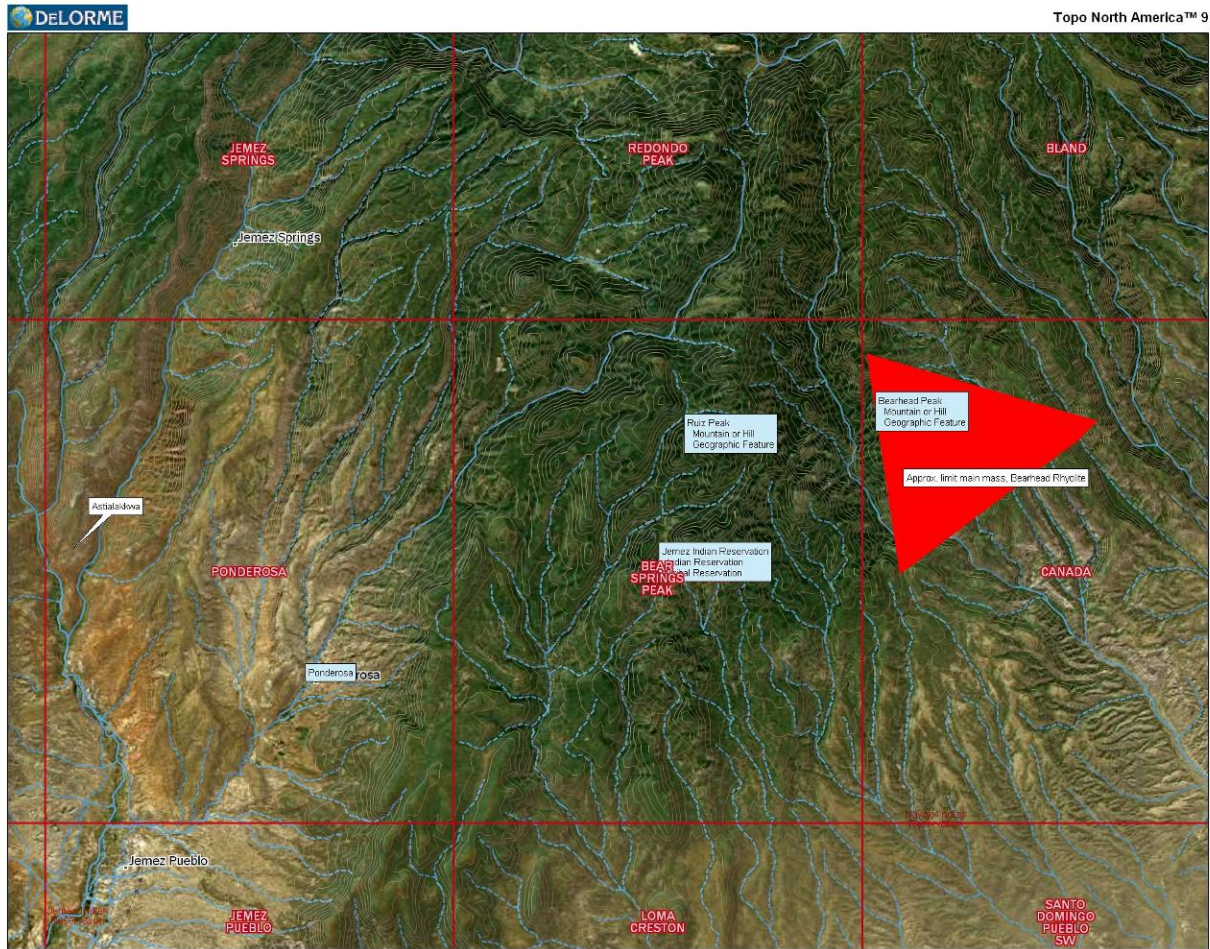


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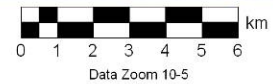
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SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM ASTIALAKWA (LA 1825) JEMEZ VALLEY, NEW MEXICO



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by

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Report Prepared for

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3 March 2012

INTRODUCTION

The analysis here of five obsidian artifacts from LA 1825 is the most unique yet in the Jemez Valley. All five samples appear to be produced from an artifact quality form of Bearhead Rhyolite to the east of the site. To my knowledge, this source has never been recovered in archaeological contexts.

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).

Trace Element Analysis

The trace element and oxide analyses were performed in the Geoarchaeological XRF Laboratory, Albuquerque, New Mexico, using a Thermo Scientific *Quant'X* energy dispersive x-ray fluorescence spectrometer. The spectrometer is equipped with a ultra-high flux peltier air cooled Rh x-ray target with a 125 micron beryllium (Be) window, an x-ray generator that operates from 4-50 kV/0.02-1.0 mA at 0.02 increments, using an IBM PC based microprocessor and WinTrace™ 4.1 reduction software. The spectrometer is equipped with a 2001 min⁻¹ Edwards vacuum pump for the analysis of elements below titanium (Ti). Data is acquired through a pulse processor and analog to digital converter. This is a significant improvement in analytical speed and efficiency beyond the former Spectrace 5000 and *QuanX* analog systems (see Davis et al. 2011; Shackley 2005).

For Ti-Nb, Pb, Th elements the mid-Zb condition is used operating the x-ray tube at 30 kV, using a 0.05 mm (medium) Pd primary beam filter in an air path at 200 seconds livetime to generate x-ray intensity $K\alpha_1$ -line data for elements titanium (Ti), manganese (Mn), iron (as Fe^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 is very low. Trace element intensities were converted to concentration estimates by employing a least-squares 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 acquired, the Rh tube is operated at 50 kV and 0.5 mA in an air path at 200 seconds livetime to generate x-ray intensity $K\alpha_1$ -line data, through a 0.630 mm Cu (thick) filter ratioed to the bremsstrahlung region (see Davis et al. 2011). Further details concerning the petrological choice of these elements in North American obsidians is available in Shackley (1988, 1990, 1995, 2005; also Mahood and Stimac 1991; and Hughes and Smith 1993). A suite of 17 specific standards used for the best fit regression calibration for elements Ti- Nb, Pb, and Th, 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), BCR-2 (basalt), TLM-1 (tonalite), SCO-1 (shale), all US Geological Survey standards, NBS-278 (obsidian) from the National Institute of Standards and Technology, BR-1 (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).

Oxide Analysis

In order to compare the artifact data to published data on Bearhead Rhyolite, an analysis of the major oxides was necessary (Table 2). This is a non-destructive analysis based on a theoretical fundamental parameter method, and as non-destructive it is not necessarily as accurate as destructive XRF analyses (see Lundblad et. al. 2011; Shackley 2011). This analysis was conducted identically to the northern New Mexico dacite study reported in Shackley (2011).

Analysis of the major oxides of Si, Al, Ca, Fe, K, Mg, Mn, Na, and Ti is performed under the multiple conditions elucidated below. This is a fundamental parameter analysis (theoretical with standards). The method is run under conditions commensurate with the elements of interest and calibrated with four USGS standards (RGM-1, rhyolite; AGV-2, andesite; BHVO-1, hawaiiite; BIR-1, basalt), and one Japanese Geological Survey rhyolite standard (JR-1). See Lundblad et al. (2011) for another set of conditions and methods for oxide analyses.

CONDITIONS OF FUNDAMENTAL PARAMETER ANALYSIS¹

Low Za (Na, Mg, Al, Si, P)

Voltage	6 kV	Current	Auto ²
Livetime	100 seconds	Counts Limit	0
Filter	No Filter	Atmosphere	Vacuum
Maximum Energy	10 keV	Count Rate	Low

Mid Zb (K, Ca, Ti, V, Cr, Mn, Fe)

Voltage	32 kV	Current	Auto
Livetime	100 seconds	Counts Limit	0
Filter	Pd (0.06 mm)	Atmosphere	Vacuum
Maximum Energy	40 keV	Count Rate	Medium

High Zb (Sn, Sb, Ba, Ag, Cd)

Voltage	50 kV	Current	Auto
Livetime	100 seconds	Counts Limit	0
Filter	Cu (0.559 mm)	Atmosphere	Vacuum
Maximum Energy	40 keV	Count Rate	High

Low Zb (S, Cl, K, Ca)

Voltage	8 kV	Current	Auto
Livetime	100 seconds	Counts Limit	0
Filter	Cellulose (0.06 mm)	Atmosphere	Vacuum
Maximum Energy	10 keV	Count Rate	Low

¹ Multiple conditions designed to ameliorate peak overlap identified with digital filter background removal, least squares empirical peak deconvolution, gross peak intensities and net peak intensities above background.

² Current is set automatically based on the mass absorption coefficient.

The data from the WinTrace software were translated directly into Excel for Windows and into SPSS for statistical manipulation. In order to evaluate these quantitative determinations, machine data were compared to measurements of known standards during each run (Tables 1 and 2). RGM-1 is analyzed during each sample run for obsidian artifacts to check machine calibration (Tables 1 and 2). Source assignments made by reference to source data at Berkeley and Shackley (1995, 2005), but see discussion of Bearhead Rhyolite below.

The Jemez Mountains and the Sierra de los Valles

A more complete discussion of the archaeological sources of obsidian in the Jemez Mountains is available in Shackley (2005:64-74). Distributed in archaeological contexts over as great a distance as Government Mountain in the San Francisco Volcanic Field in northern Arizona, the Quaternary sources in the Jemez Mountains, most associated with the collapse of the Valles Caldera, are distributed at least as far south as Chihuahua through secondary deposition in the Rio Grande, and east to the Oklahoma and Texas Panhandles through exchange. And like the sources in northern Arizona, the nodule sizes are up to 10 to 30 cm in

diameter; El Rechuelos, Cerro Toledo Rhyolite, and Valles Rhyolite (Valles Rhyolite derived from the Cerro del Medio dome complex) glass sources are as good a media for tool production as anywhere. Until the recent land exchange of the Baca Ranch properties, the Valles Rhyolite primary domes (i.e., Cerro del Medio) have been off-limits to most research. The discussion of this source group here is based on collections by Dan Wolfman and others, facilitated by Los Alamos National Laboratory, and the Museum of New Mexico, and recent sampling of all the major sources courtesy of the Valles Caldera National Preserve (VCNP; Shackley 2005; Wolfman 1994).

There are at least four eruptive events in the last 8.7 million years that have produced the four or five chemical groups in the Jemez Mountains (Figure 1).

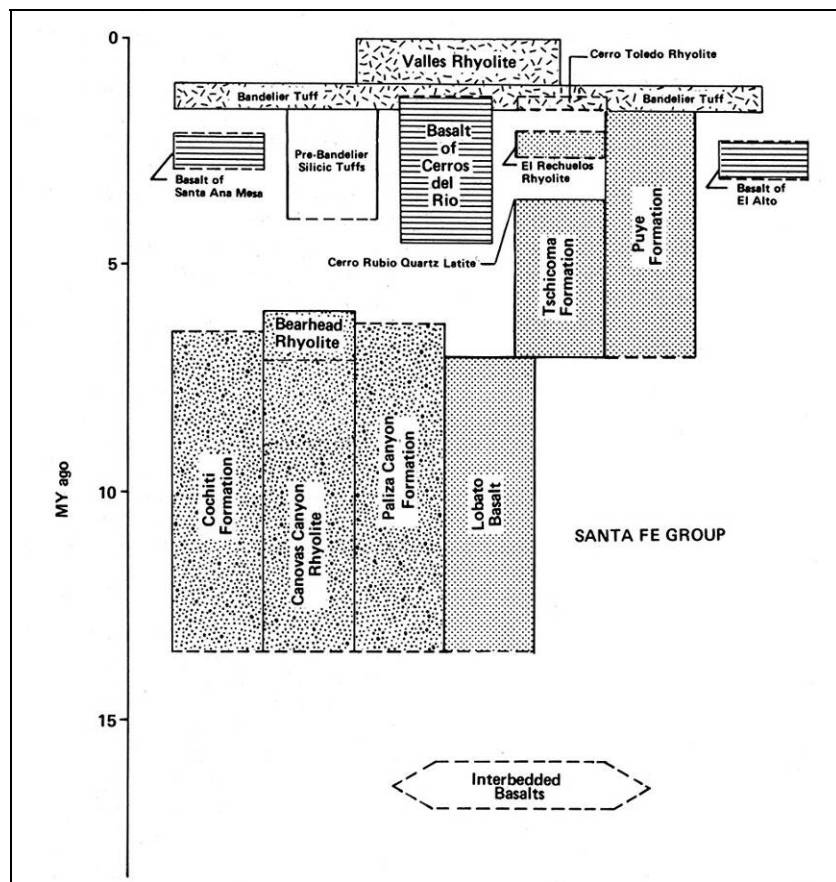


Figure 1. Generalized stratigraphic relations of the major volcanic and alluvial units in the Jemez Mountains (from Gardner et al. 1986). Note the near overlapping events at this scale for the Cerro Toledo and Valles Rhyolite members, and the position of Cerro Toledo Rhyolite at the upper termination of the Puye Formation.

The earliest is the Bear Springs Peak source, part of Canovas Canyon Rhyolite that is dated to about 8.7 mya, firmly in the Tertiary (Kempton et al. 2004; Figure 2 here). This source is a typical Tertiary marekanite source with remnant nodules embedded in a perlitic matrix. It is located in a dome complex including Bear Springs Peak on Santa Fe National Forest and radiating to the northeast through Jemez Nation land (Shackley 2009a). While the nodule sizes are small, the glass is an excellent media for tool production and has been found archaeologically at Zuni and in secondary deposits as far south as Las Cruces (Church 2000; Shackley 2009a).

The second relevant eruptive event that produced artifact quality obsidian is the El Rechuelos Rhyolite. This source, not present in these sites, is what I consider the best media for tool production of the group. It dates to about 2.4 million years ago, and nodules at least 10 cm in diameter are present in a number of domes north of dacite Polvadera Peak, the incorrect vernacular name for this source.

About 1.4 mya, the first caldera collapse occurred in the Jemez Mountains, called Cerro Toledo Rhyolite. This very large event produced the Bandelier Tuffs and spread ash flows many kilometers into the area and horizontally southwest from what is now Rabbit Mountain and the Cerro Toledo domes to the east. These large ash flow sheets are responsible for the great numbers of Cerro Toledo obsidian that is present in the Quaternary Rio Grande alluvium all the way to Chihuahua (Church 2000; Shackley 2005). This source is present relatively near to these sites on terraces over the canyons leading to the south such as Cochiti Canyon (Shackley 2005).

The second caldera collapse, that produced the Valles Rhyolite member of the Tewa Formation, called Valles Rhyolite here, occurred around one million years ago and created most of the geography of the current Valles Caldera. A number of rhyolite ring domes were produced on the east side of the caldera, but only Cerro del Medio produced obsidian. Indeed, the Cerro del Medio dome complex produced millions of tons of artifact quality glass, and is the volumetrically largest obsidian source in the North American Southwest challenged only by Government Mountain in the San Francisco Volcanic Field. This source was apparently

preferred by Folsom knappers, as well as those in all periods since. Valles Rhyolite (Cerro del Medio) stone does not erode outside the caldera, and had to be originally procured in the caldera proper (Shackley 2005).

Bearhead Rhyolite. While Bearhead Rhyolite obsidian is mentioned in the archaeological literature, as far as I know, it has never been reported in archaeological contexts since it was assumed that the obsidian was not artifact quality (Baugh and Nelson 1987; Glascock et al. 1999; Nelson 1998 unpublished data; Shackley 2005). My experience in the Bearhead Rhyolite formation is that it was only vitrophyric glass, not a good media for tool production. The assemblage at LA 1825 appears to undermine that assumption.

Bearhead Rhyolite, while part of a number of geological studies, has not been a focus of much geological research (Chamberlin and McIntosh 2007; Ellisor et al. 1996; Smith et al. 1970). It appears to overlie the Canovas Canyon Rhyolite in the southern Jemez Mountains and is dated to around 6.73-6.89 mya by $^{40}\text{Ar}/^{39}\text{Ar}$ post dating Canovas Canyon Rhyolite (Bear Springs Peak obsidian) at about 8-9 mya (Chamerlin and McIntosh 2007; Kempter et al. 2004; see Figure 1 here). The major oxide and trace element chemistry of the two, however is quite different; Bear Springs Peak obsidian has substantially higher Ba concentrations, and while also a high silica rhyolite, is not as high as Bearhead Rhyolite (Shackley 2005; Table 1 and 2 here).

The few analyses of Bearhead Rhyolite have produced very different results, likely due to sampling differences (Baugh and Nelson 1987; Chamberlin and McIntosh 2007; Ellisor et al. 1996; Nelson 1998 unpublished data). The Nelson (1998 unpublished) and the geological studies show a close similarity to the samples in this assemblage (Chamberlin and McIntosh 2007; Ellisor et al. 1996). The data do not match any other published obsidian in western North America. The assumption here then is that the obsidian from LA 1825 is from some outcrop of Bearhead Rhyolite in the southern Jemez Mountains.

Table 1. Source provenance of the archaeological samples and analysis of USGS RGM-1. All measurements in parts per million (ppm).

Sample	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Ba	N b	Pb	Th	Probable source
109	969	25 1	1056 0	76	15 7	21	27	11 4	12 1	14	14	12	Bearhead Rhy.
111	100 1	23 1	1063 5	11 6	15 3	21	25	11 3	17 3	11	15	17	Bearhead Rhy.
112	891	22 0	1009 5	45	15 9	21	27	11 3	14 0	19	15	14	Bearhead Rhy.
114	939	26 1	1105 8	13 7	17 4	18	27	11 6	16 4	14	23	24	Bearhead Rhy.
500	109 4	24 5	1065 1	10 0	15 8	19	21	11 2	16 9	15	16	19	Bearhead Rhy.
RGM1- S4	160 6	29 3	1326 9	39	15 0	11 0	24	21 8	78 2	11	20	14	standard

Table 2. Major oxide values for sample 112. All measurement in weight percent.

Sample	SiO ₂	Al ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	MgO	MnO	Na ₂ O	TiO ₂
112	77.19	7.044	1.5811	2.194	8.784	<.001	0.0512	2.86	0.083
RGM1-S4	74.49	12.157	1.4918	2.271	5.166	<.001	0.0529	3.89	0.272

Conclusion

It appears that the understanding of sources of archaeological obsidian in the Jemez Mountains, particularly in the southern portion, is still poor. This is partly due to a general lack of studies of archaeological obsidian in the area until this and the former Jemez Valley study (Shackley 2009b). The geoarchaeological understanding of the sources of archaeological obsidian in the southern Jemez Mountains obviously deserves greater field and laboratory work.

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