Title

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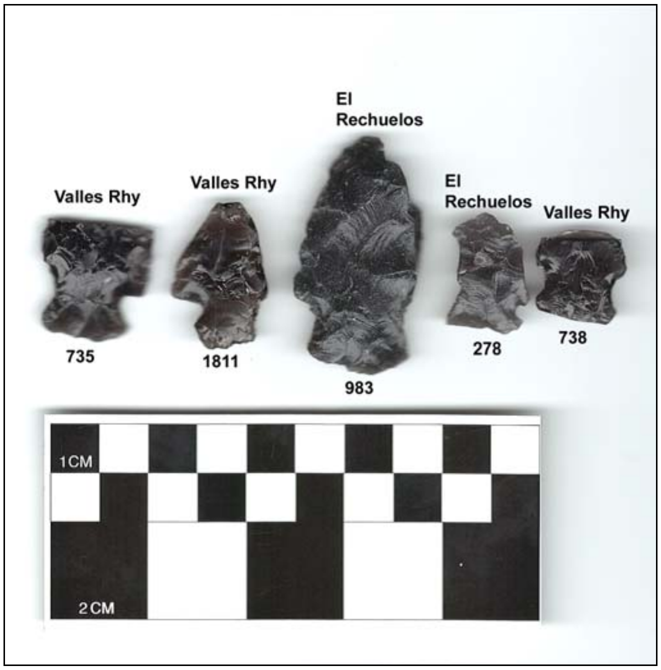

Impact fractured dart points from the Falls Creek rockshelters

by

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INTRODUCTION

The analysis here of 40 obsidian artifacts from the Falls Creek rockshelters in southern Colorado. All of the artifacts were produced from one of three obsidian sources in the Jemez Mountains both pre-caldera and caldera events. The assemblage is dominated by Valles Rhyolite (Cerro del Medio) obsidian (52.5%), and given the large sizes of the artifacts some with cortex were certainly procured in the caldera proper.

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 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 2011).

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 quadratic 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).

The data from the WinTrace software were translated directly into Excel for Windows and into SPSS for statistical manipulation (Table 1). In order to evaluate these quantitative determinations, machine data were compared to measurements of known standards during each run (Table 1). RGM-1 is analyzed during each sample run for obsidian artifacts to check machine calibration (Table 1). Source assignments made by reference to source data at the laboratory (see Shackley 1995, 2005, and http://swxrflab.net/swobsrcs.htm; see Table 2 here).

DISCUSSION

Before a discussion of the source provenance of the samples, a short discussion of the Jemez Mountains sources is in order. Following this is a short discussion of the samples proper.

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) had 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 chemical groups in the Jemez Mountains (Figure 1).

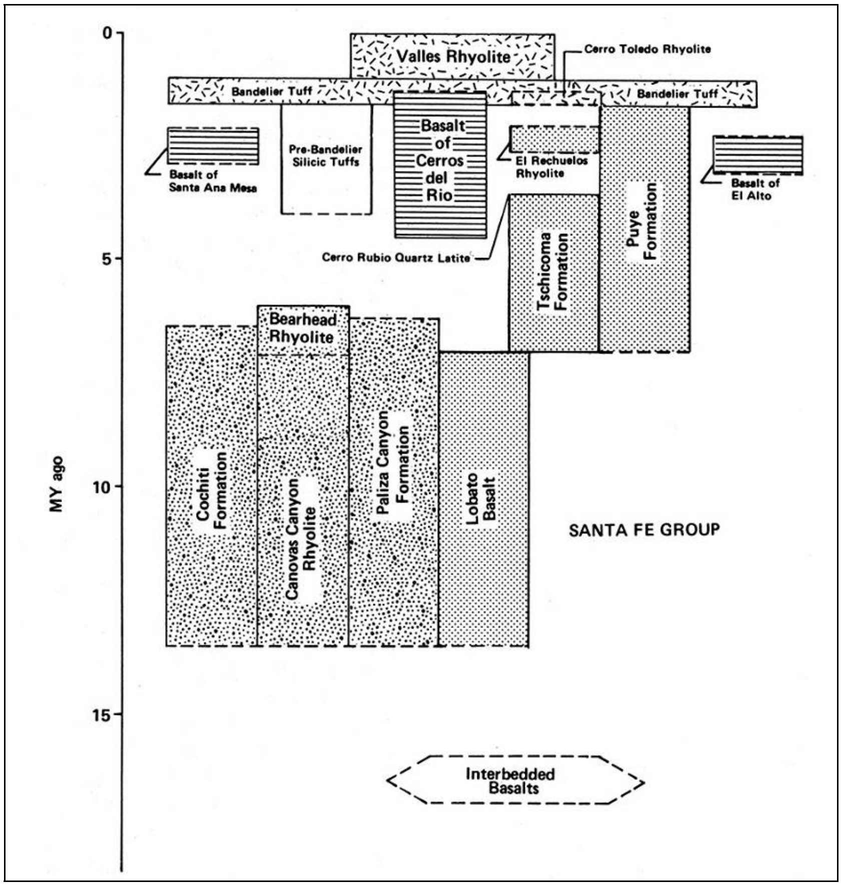

Figure 1. Generalized stratigraphic relations of the major volcanic and alluvial units in the Jemez Mountains (from Gardner et al. 1986). Note the near overlapping events at this scale for the Cerro Toledo and Valles Rhyolite members, and the position of Cerro Toledo Rhyolite at the upper termination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

The earliest pre-caldera obsidian is the Bear Springs Peak source, part of Canovas Canyon Rhyolite that is dated to about 8.7 mya, firmly in the Tertiary (Kempter et al. 2004; Figure 1 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 2009). 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 2013). Four of the samples were produced from this source (Table 1 and 2).

Part of the same Keres Member as Canovas Canyon Rhyolite is Paliza Canyon Rhyolite. They have similar elemental chemistry and are likely nearly contemporaneous. This source is rare in archaeological contexts, the primary vent is yet unknown, but occurs in Rio Grande alluvium (Church 2000; Shackley 2014).

The second relevant eruptive event that produced artifact quality obsidian is the El Rechuelos Rhyolite. This source, present as one sample here, 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. El Rechuelos has eroded through the Rio Chama into the Rio Grande and has also been found in alluvium into southern New Mexico (Church 2000; Shackley 2013).

About 1.4 mya, the first caldera collapse occurred in the Jemez Mountains, called the Cerro Toledo Rhyolite event an initial phase of the Tewa Formation. 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 quantity of Cerro Toledo obsidian that is present in the Quaternary Rio Grande alluvium all the way to Chihuahua (Church 2000; Shackley 2005, 2013).

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 or rhyolite ring domes were produced on the east side of the caldera, but only Cerro del Medio produced artifact quality 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 the Government Mountain dome complex in the San Francisco Volcanic Field. Cerro del Medio obsidian was apparently preferred by Folsom knappers, as well as those in all periods since, including the knappers that produced this assemblage. While Cerro Toledo probably appears in archaeological contexts in New Mexico sites with greater frequency, it is likely because it is distributed in secondary contexts. Valles Rhyolite (Cerro del Medio), dominating here importantly does not erode outside the caldera, in any quantity and size and likely had to be originally procured in the caldera proper (Shackley 2005, 2013). Parenthetically, the Valles Rhyolite samples here are nearly completely without spherulites, typical of what Ana Steffen calls the "monster quarry" locality near the top of Cerro del Medio. I have seen many of the procurement localities on the dome and the "monster quarry" is the one locality that is typically free of spherulites.

The large size of many of the artifacts here, including the projectile points and bifaces (see cover image) suggests that most if not all the obsidian was originally procured from the Jemez Mountains and not secondary contexts. It is certainly possible that the obsidian raw material was procured directly by these prehistoric knappers from the Jemez Mountains region during trips south, or could have been exchanged with Basketmaker groups in the region (Table 2 and Figure 2).

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Table 1. Elemental concentrations for the archaeological specimens and the USGS RGM-1 standard by test unit. All measurements in parts per million (ppm).

Sample	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Pb	Th	Source
278	542	444	5502	156	3	26	70	42	26	15	El Rechuelos Rhy
281	586	380	8361	160	5	43	169	47	27	18	Valles Rhy (Cerro del Medio)
282	612	414	4986	158	12	26	70	44	26	17	El Rechuelos Rhy
666	606	450	5431	160	4	24	70	42	28	23	El Rechuelos Rhy
706	470	519	9367	213	1	63	187	86	33	25	Cerro Toledo Rhy
734	495	427	5348	156	4	25	66	38	26	21	El Rechuelos Rhy
735	503	372	8226	155	4	45	168	47	27	19	Valles Rhy (Cerro del Medio)
738	566	393	8655	161	6	45	164	49	26	22	Valles Rhy (Cerro del Medio)
739	435	405	4966	149	5	20	67	37	26	20	El Rechuelos Rhy
859	552	388	8368	156	4	43	167	47	25	14	Valles Rhy (Cerro del Medio)
900	519	443	5292	154	5	22	69	40	28	19	El Rechuelos Rhy
983	586	423	5108	154	6	23	71	40	26	25	El Rechuelos Rhy
1043	544	426	5135	151	2	21	64	36	28	19	El Rechuelos Rhy
1044	539	408	8989	163	1	43	173	48	27	21	Valles Rhy (Cerro del Medio)
1049	495	403	4883	139	5	22	64	35	25	19	El Rechuelos Rhy
1078	447	523	9331	210	2	63	180	87	35	32	Cerro Toledo Rhy
1113	653	455	5890	161	5	27	71	40	27	20	El Rechuelos Rhy
1115	806	402	5397	154	3	22	64	39	29	18	El Rechuelos Rhy
1191	541	419	5148	155	6	21	69	40	30	24	El Rechuelos Rhy
1194	528	568	9993	218	0	67	185	84	32	22	Cerro Toledo Rhy
1198	616	450	9747	172	5	45	179	51	32	23	Valles Rhy (Cerro del Medio)
1219	618	412	9462	163	4	48	169	48	26	20	Valles Rhy (Cerro del Medio)
1811	514	388	8991	161	5	44	173	46	28	18	Valles Rhy (Cerro del Medio)
1918	494	344	7599	145	4	42	162	47	24	19	Valles Rhy (Cerro del Medio)
2625	600	509	6083	167	7	24	72	43	31	22	El Rechuelos Rhy
2650	551	374	8266	157	5	43	161	48	25	19	Valles Rhy (Cerro del Medio)
2651	507	365	7908	156	4	42	155	47	23	20	Valles Rhy (Cerro del Medio)
4271	586	372	8203	158	4	43	166	50	26	19	Valles Rhy (Cerro del Medio)
4651	492	36	7979	15	4	43	15	51	26	21	Valles Rhy (Cerro del

		8		1			8				Medio)
4821	513	402	8780	159	3	45	172	52	27	18	Valles Rhy (Cerro del Medio)
4822	654	447	9337	168	4	47	170	49	29	22	Valles Rhy (Cerro del Medio)
4823	609	400	8782	163	3	47	170	48	28	22	Valles Rhy (Cerro del Medio)
4824	562	413	9253	166	5	42	168	50	28	22	Valles Rhy (Cerro del Medio)
4846	544	436	5212	149	6	24	65	41	27	23	El Rechuelos Rhy
4847	516	436	5360	158	5	24	66	39	28	26	El Rechuelos Rhy
4848	659	434	9931	179	3	45	182	51	26	19	Valles Rhy (Cerro del Medio)
4849	636	413	8741	163	5	44	166	47	26	23	Valles Rhy (Cerro del Medio)
4850	588	419	5263	150	4	23	69	44	27	24	El Rechuelos Rhy
4851	638	438	9452	172	6	46	174	51	28	21	Valles Rhy (Cerro del Medio)
4852	684	449	9781	170	4	44	178	51	28	16	Valles Rhy (Cerro del Medio)
RGM1-S4	1611	296	13051	148	102	25	222	13	26	17	standard
RGM1-S4	1532	288	13028	150	101	23	227	10	25	12	standard
RGM1-S4	1517	283	13028	153	103	23	225	10	23	14	standard

Table 2. Frequency distribution of source provenance in the sites.

		Frequency	Percent
Source	Valles Rhy (Cerro del Medio)	21	52.5
	El Rechuelos Rhy	16	40.0
	Cerro Toledo Rhy	3	7.5
	Total	40	100.0

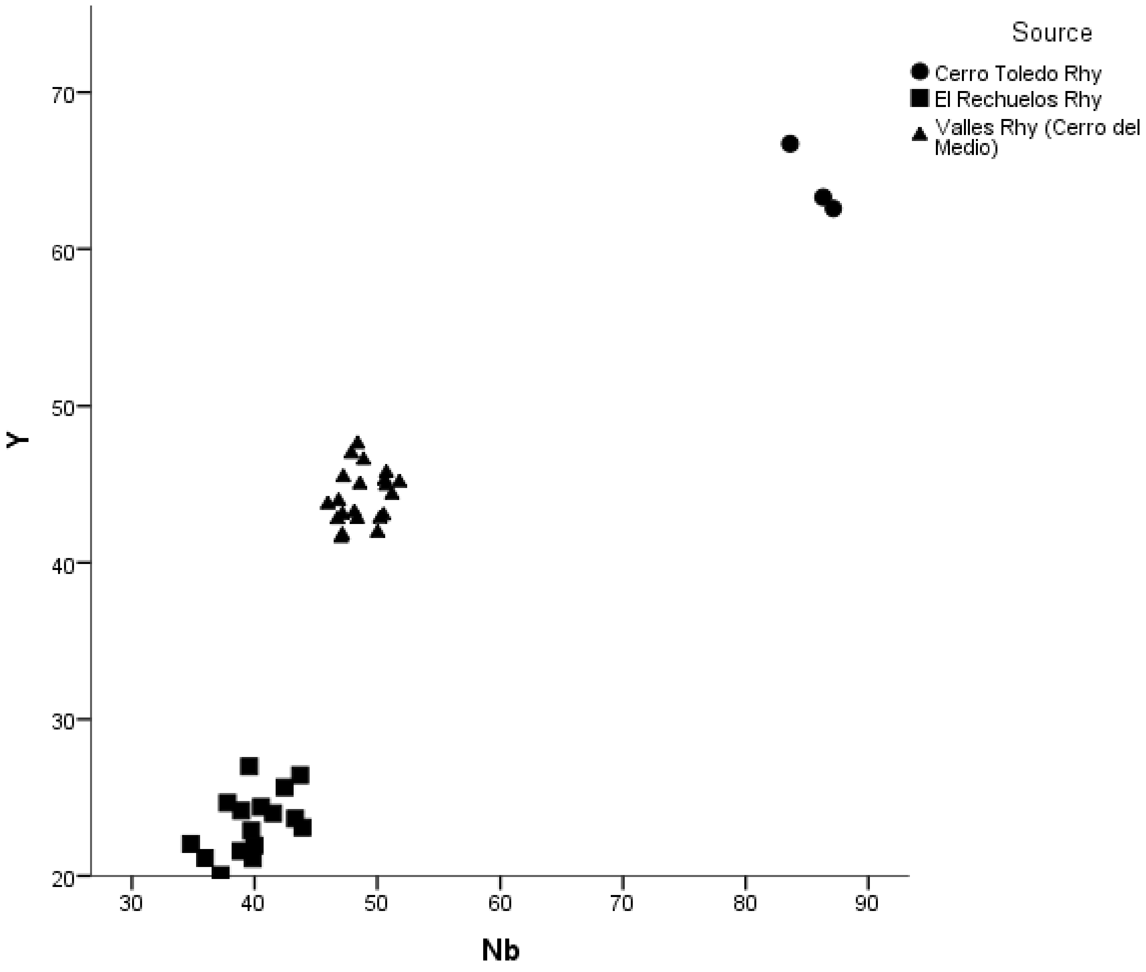

Figure 2. Nb versus Y bivarite plot of the archaeological specimens.