AN ENERGY-DISPERSIVE X-RAY FLUORESCENCE ANALYSIS OF OBSIDIAN ARTIFACTS FROM SOUTHERN NEW MEXICO

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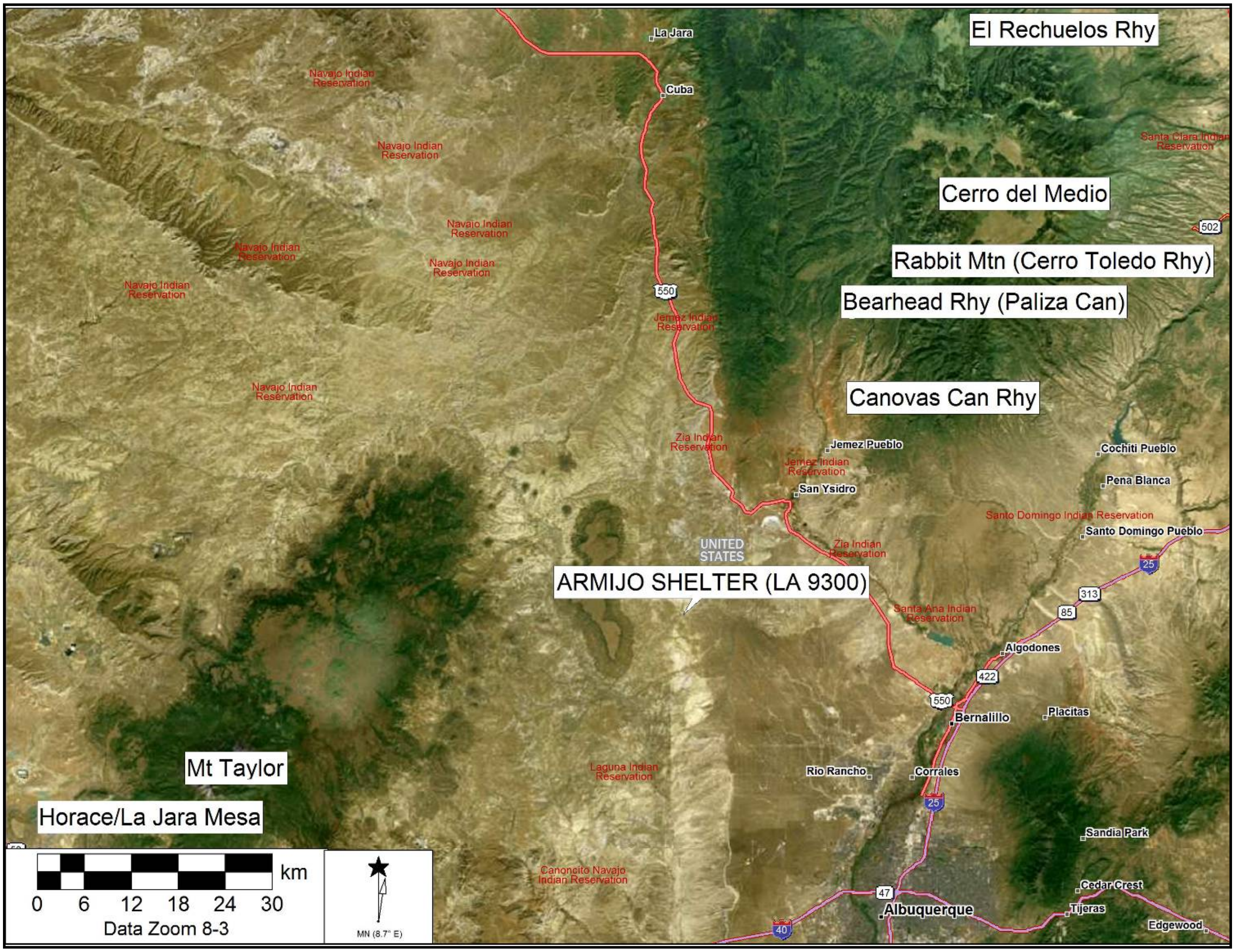

Digital elevation model of Armijo Shelter, location of regional obsidian sources, and prominent features

SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM ARMIJO SHELTER, CENTRAL NEW MEXICO

by

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Report Prepared for

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INTRODUCTION

The analysis here of 72 obsidian projectile points from Armijo Shelter (LA 9300) is dominated by the production of projectile ponts from obsidian sources along the Jemez Lineament, mainly sources from the Jemez Mountains (94.4%) north of the site, and one of the two Mount Taylor sources (Horace/La Jara Mesa) south of the project area (5.6%). Nearly 42% of the obsidian projectile points were produced from the Valles Rhyolite (Cerro del Medio) source in Valles Caldera in the Jemez Mountains. While over 94% of the artifacts were produced from one of the sources in the Jemez Mountains, mainly Valles Rhyolite or Cerro del Medio Rhyolite obsidian (70.9%), a few were produced from the two pre-caldera Keres Group sources Bearhead Rhyolite (8.3%) and Canovas Canyon Rhyolite (9.7%). Only 5.6% of the projectile points were produced from the Horace/La Jara Mesa obsidian in the Mount Taylor Volcanic Field to the south, although the distance to source is approximately equal to the sourthern Jemez Mountain sources (see cover image).

LABORATORY SAMPLING, 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; Shackley 2011).

All analyses for this study were conducted on a ThermoScientific *Quant'X* EDXRF spectrometer, located at the Geoarchaeological XRF Laboratory, Albuquerque, New Mexico. It is equipped with a thermoelectrically Peltier cooled solid-state Si(Li) X-ray detector, with a 50 kV, 50 W, ultra-high-flux end window bremsstrahlung, Rh target X-ray tube and a 76 µm (3 mil) beryllium (Be) window (air cooled), that runs on a power supply operating from 4-50 kV/0.02-1.0 mA at 0.02 increments. The spectrometer is equipped with a 200 l min^{-1} Edwards vacuum pump, allowing for the analysis of lower-atomic-weight elements between sodium (Na) and titanium (Ti). Data acquisition is accomplished with a pulse processor and an analogue-to-digital converter. Elemental composition is identified with digital filter background removal, least squares empirical peak deconvolution, gross peak intensities and net peak intensities above background.

Trace Element Analysis

The analysis for mid Zb condition elements Ti-Nb, Pb, Th, the x-ray tube is operated at 30 kV, using a 0.05 mm (medium) Pd primary beam filter in an air path at 100 seconds livetime to generate x-ray intensity Ka-line data for elements titanium (Ti), manganese (Mn), iron (as $Fe_2O_3^T$), 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 are very low. Trace element intensities were converted to concentration estimates by employing a linear 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. When barium (Ba) is analyzed in the High Zb condition, the Rh tube is operated at 50 kV and up to 1.0 mA, ratioed to the bremsstrahlung region (see Davis 2011; Shackley 2011). Further details concerning the petrological choice of these elements in Southwest obsidians is available in Shackley (1988, 1995, 2005; also Mahood and Stimac 1991; and Hughes and Smith 1993). Nineteen specific pressed powder standards are used for the best fit regression calibration for elements Ti-Nb, Pb, Th, and Ba, and 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), TLM-1 (tonalite), SCO-1 (shale), NOD-A-1 and NOD-P-1 (manganese) all US Geological Survey standards, NIST-278 (obsidian), U.S. National Institute of Standards and Technology, BE-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).

Statistical and Graphical Source Assignment.

The data from the WinTrace^{TM} software were translated directly into Excel for Windows software for manipulation and on into SPSS, ver. 21 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 a USGS obsidian standard is analyzed during each sample run of ≤20 samples for obsidian artifacts to check machine calibration (Appendix Table).

Source assignments were made by reference to the laboratory data base (see Shackley 1995, 2005; Shackley et al. 2016). Further information on the laboratory instrumentation and source data can be found at: http://www.swxrflab.net (see Appendix Table for all data and Figure 1 in text). Trace element data exhibited in the Appendix Table are reported in parts per million (ppm), a quantitative measure by weight, unless otherwise noted.

The elemental concentrations for the artifact data are assigned to source by a stepped statistical and graphical method, outlined in Shackley et al. (2017). Given the dominance of Jemez Lineament sources (i.e. Jemez Mountain and Mount Taylor sources) a Nb versus Y plot was initially used for all artifacts from all sites (see Figure 1). This effectively discriminates the two major sources in the Jemez Mountains Cerro Toledo Rhyolite from Valles Rhyolite (Cerro del Medio) and from the Mount Taylor sources. Next, in order to discriminate the higher Sr and Zr pre-caldera sources, Sr versus Zr is plotted (Figure 1).

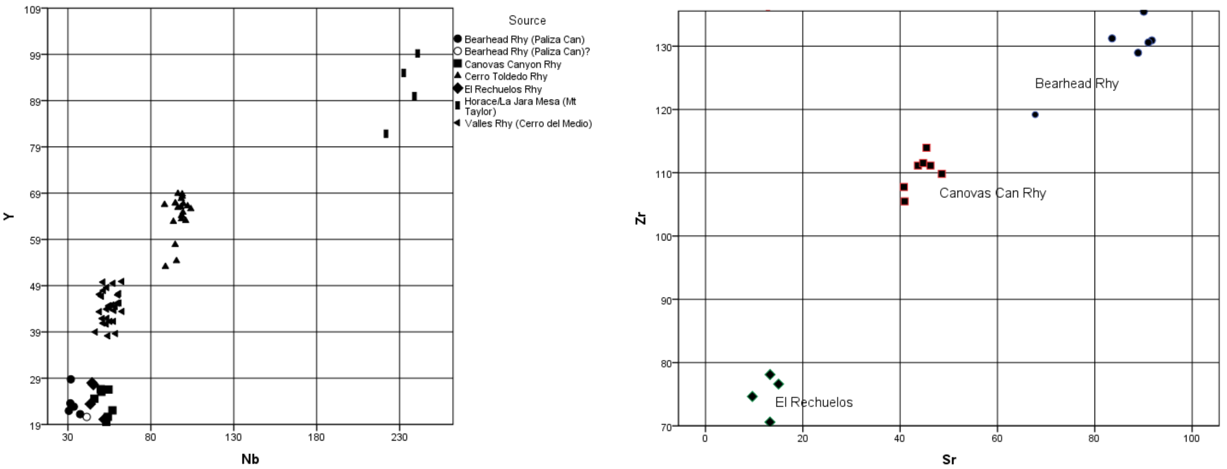


Figure 1. Nb versus Y bivariate plot of all the obsidian artifacts from all sites (left), and a Sr versus Zr plot of the pre-caldera higher Sr and Zr sources providing discriminatory clarity.

THE JEMEZ LINEAMENT: MOUNT TAYLOR AND JEMEZ MOUNTAINS SOURCES

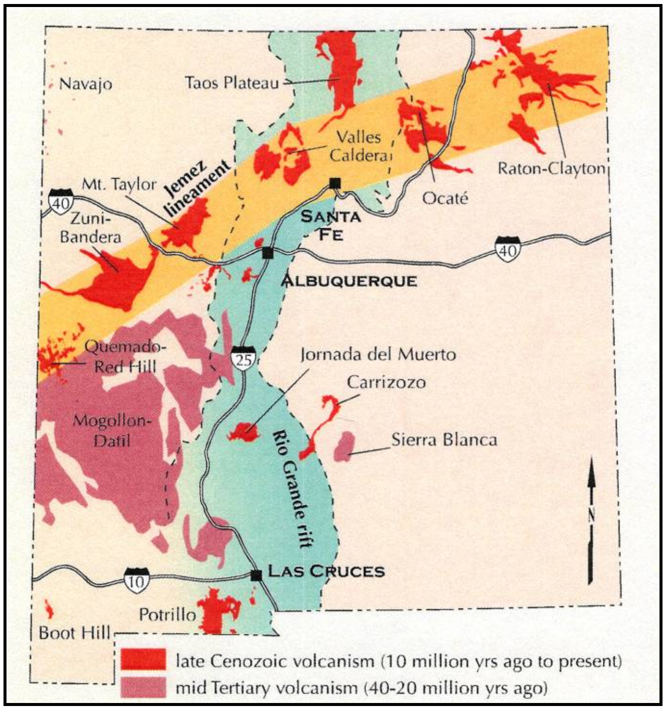


Figure 2. The Jemez Lineament in northern New Mexico (from *NM Earth Matters*, Winter 2006).

All of the obsidian used to produce artifacts from Armijo Shelter were procured from one of two volcanic fields along the Jemez Lineament; the Mount Taylor Volcanic Field or the Jemez Mountains and Valles Caldera Volcanic Field (Figure 2). The Jemez lineament, first identified and named by Mayo (1958), is marked by a prominent alignment of Cenozoic volcanic centers (Figure 2). Several workers have postulated a Precambrian ancestry for the lineament (Aldrich et al. 1983, and references therein). U-Pb geochronologic data suggest that it marks the southward limit of pre-1.7 Ga crust (Wooden and Dewitt 1991). The idea that the Jemez lineament is an important crustal boundary is supported by a long history of reactivation. Strickland et al. (2003) suggest that the Jemez lineament may be a province boundary between the Yavapai (1.8-1.7 Ga) and Mazatzal (1.67-1.65 Ga) crustal provinces. It's location at the boundaries of the Rio Grande Rift, the Colorado Plateau, and the Basin and Range Complex appears to be reflected in the trace element chemistry with relatively high Y and Nb for North American rhyolites, a result of mantle sampling (Baker and Ridley 1970; Shackley 1998, 2005 and see discussions below). It appears to coincide with a region of low-velocity mantle and a possible zone of partial melting, not unexpected in this environment (Karlstrom and Humphreys 1998; Dueker et al. 2001).

The Regional Sources of Archaeological Obsidian

The Mount Taylor Volcanic Field

The "Grants Ridge" source of archaeological obsidian in the Mount Taylor Volcanic Field in northwestern New Mexico has been systematically sampled and analyzed nearly every year since 1997 (Shackley 1998, 2005; Figure 3 here). Previous chemical analyses by Baugh and Nelson (1987) and others have generally been based on grab samples from the East Grants Ridge area. My more recent analysis of archaeological obsidian from the Zuni and Hopi areas suggested that, unlike the somewhat vitrophyric glass from Grants Ridge, prehistoric knappers often preferred an aphyric glass that while chemically similar, does not elementally covary with samples from Grants Ridge. Systematic survey and sampling in 1997 resulted in the discovery of another source on Horace Mesa to the east of East Grants Ridge. These nodules up to 10 cm in diameter are aphyric and are generally a better medium for tool production. The chemistry differs in a number of incompatibles, but appears to be derived from the same magma source of high silica rhyolite, a late Tertiary and early eruptive phase in the Mount Floyd field (Goff et al. 2008). A complete major, minor, and trace analysis has been completed using the Philips PW2400 WXRF at Berkeley and published in Shackley (1998; see also http://swxrflab.net/grants.htm). The Mount Taylor obsidian appears to be yet another example of chemical gradients in silicic melts that have archaeological relevance (see Shackley, 1995, 2005).

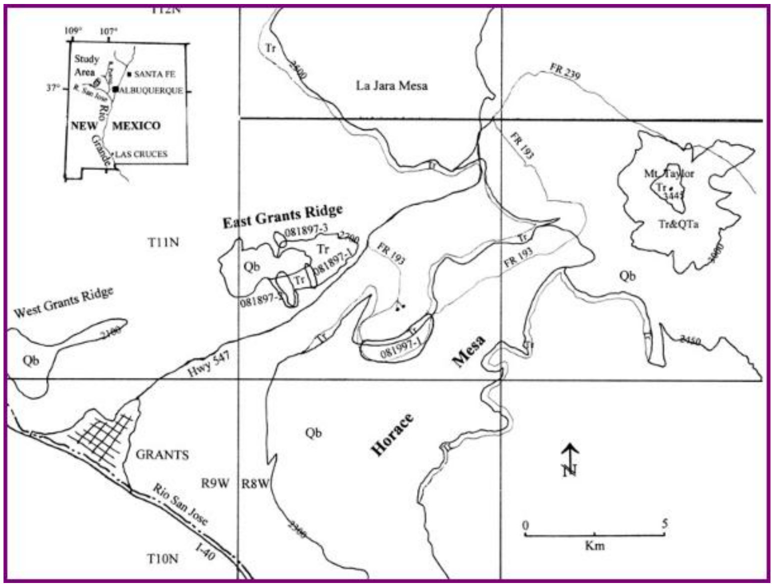


Figure 3. The Mount Taylor Volcanic Field and Grants Ridge and Horace/La Jara Mesa obsidian sources (from Shackley 1998).

In 2013 as part of the Keck Foundation Geoarchaeological Field School, La Jara Mesa was sampled on the mesa top and in the road cut and ash flow where Hwy 547 cuts through La Jara Mesa (see Figure 3). The distinction between Horace and La Jara mesas is mainly due to a normal fault that separates the two, but this research and that of Goff et. al (2008) indicates that the ash flow on Horace and La Jara mesas are a single unit, now dated to 3.26 ± 0.04 Ma by $Ar^{40/39}$ (Goff et al. 2008). Lipman and Mehnert (1979) dated the East Grants Ridge glass at an unknown locality by K/Ar at 3.34 ± 0.16 Ma, potentially older, but statistically similar, given the vagaries of early K/Ar dating. The subsequent analysis and plot of Nb/Y/Rb indicates this relationship and the distinction between Horace/La Jara mesa and East Grants Ridge obsidian (Shackley 1998b, see Figure 1 here). Again, the obsidian from both Horace and La Jara Mesas is generally aphyric as opposed to the vitrophyric fabric at East Grants Ridge. The Grants Ridge obsidian, however, is an adequate media for tool production and formal tools including projectile points were produced from this obsidian in prehistory.

Jemez Mountains and the Valles Caldera

A more complete discussion of the archaeological sources of obsidian in the Jemez Mountains is available in Shackley (2005:64-74; see cover image). Distributed in archaeological contexts over as great a distance as Government Mountain in the San Francisco Volcanic Field in northern Arizona, some of the Tertiary and 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, north and east to the Oklahoma and Texas Panhandles, and well into California through exchange (Steffen 2016). And like the sources in northern Arizona, the nodule sizes are from to 10 to 30 cm in diameter, indeed boulders a meter or more in diameter are present at Cerro del Medio; 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, and Santa Fe National Forest (VCNP; Shackley 2005; Wolfman 1994).

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 late 1960s (Bailey et al. 1969; Gardner et al. 1986, 2007; Heiken et al. 1986; Self et al. 1986; Smith et al. 1970; Figure 4). 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, and Glascock et al's (1999) more intensive analysis of these sources including the No Agua Peak source in the Mount San Antonio field on the Taos Plateau at the Colorado/New Mexico border, as well as Shackley (2005).

There are at least five eruptive events in the last 8.7 million years that have produced the five chemical groups in the Jemez Mountains (Figure 4).

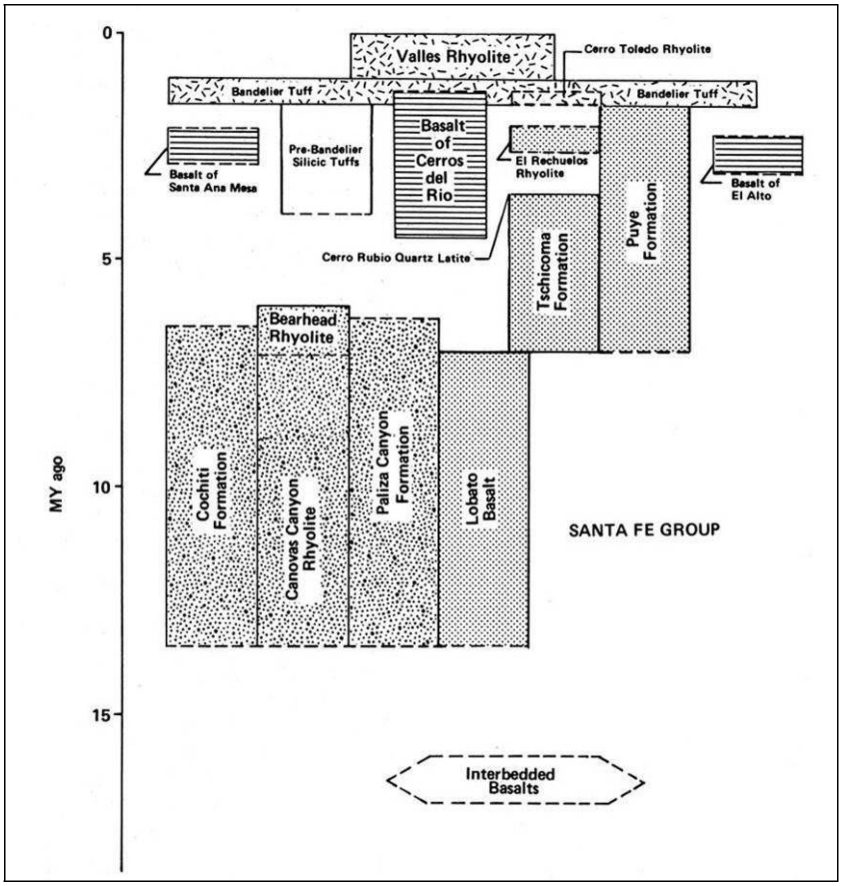


Figure 4. Generalized stratigraphic relations of the major volcanic and alluvial units in the Jemez Mountains (from Gardner et al. 1986). Note the near overlapping events at this scale for the Cerro Toledo and Valles Rhyolite members, and the position of Cerro Toledo Rhyolite at the upper termination of the Puye Formation.

Canovas Canyon Rhyolite. The earliest pre-caldera event that produced artifact quality obsidian is the Bear Springs Peak source, part of Canovas Canyon Rhyolite of the Keres Group that is dated to about 8.7 Ma, firmly in the Neogene (Kempter et al. 2004; Figure 4 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, and used for point production at Armijo Shelter (Church 2000; Shackley 2012).

Bearhead Rhyolite (Paliza Canyon). Recently, Fraser Goff, Sean Dolan, and I investigated the previously called "Paliza Canyon" source in the southern Jemez Mountains (Shackley et al. 2016). All the known sources of archaeological obsidian in the Jemez Mountains of northern New Mexico have been well dated and chemically, stratigraphically, and isotopically studied for a number of years, mainly due to the geologically recent extraordinary caldera collapse events - all except one, traditionally called Paliza Canyon (Baugh and Nelson 1987; Gardner et al. 1986; Glascock et al. 1999; Goff et al. 1996; Kues et al. 2007; Nelson 1984; Self et al. 1986; Shackley 2005; Spell and Harrison 1993; Wolfman 1994).

Paliza Canyon was originally reported as a source of archaeological obsidian by Fred Nelson in 1984 and Tim Baugh and Fred Nelson in 1987 as a small nodule source; they analyzed four samples from Paliza Canyon proper (Baugh, personal communication 2013; Baugh and Nelson 1987:317; also Nelson 1984:52). Church (2000) and Shackley (2012) have both reported the presence of Paliza Canyon obsidian in the Rio Grande Quaternary alluvium at least as far south as Las Cruces, New Mexico, and it occurs in Pueblo Revolt period sites in the Jemez Springs region in the southern Jemez Mountains, many of the sites near Paliza Canyon (Liebmann 2012; Shackley 2009; Figure 5 here).

Baugh and Nelson's collection was apparently from the southwestern portion of the Redondo Peak 7.5' USGS Quad in Paliza Canyon (Nelson 1984; Figure 5 here). The collection reported in the Shackley et al. (2016) study was in the northwest corner of the adjacent Bear Springs Peak 7.5' USGS Quad just south of Paliza Canyon in what is mapped as part of the El Cajete tephra deposit adjacent to Tertiary volcanoclastic gravels, and the adjacent portion of the Redondo Peak 7.5' USGS Quad, probably near the location of the Baugh and Nelson collection area (Kempter et al. 2003; Figure 5 here). At both collection localities, the tephra is morphologically very similar to El Cajete sediments seen at various points in the Jemez Mountains, but analyses indicates a dacite composition, now considered to be part of the Paliza Canyon Formation of the Keres Group. The largest marekanite recovered previously was only about 4 mm in largest dimension, but most were 1- 2 mm. Given that Paliza Canyon secondary deposit samples at Tijeras Wash south of Albuquerque over 150 stream km south of the southern Jemez Mountains are up to 3 mm in largest dimension, obsidian from the primary source, must be larger than the marekanites recovered in September 2013. As a media for tool production this smoky gray to nearly transparent obsidian is equal to other Jemez Mountains sources, likely why it is present in project sites. In 2015, Shackley and Goff recovered marekanites up to 100 mm in diameter, and frequently 50-70 mm in the Paliza Canyon drainage directly below an unnamed Bearhead Rhyolite dome (F04-31) where Goff had previously located Bearhead Rhyolite obsidian in-situ (see Shackley et al. 2016). Later that year, on the south slope of dome F04-31, Shackley recovered one nodule 17 cm in diamter and many more half that size (ca. 50+ mm). The rhyolite at this dome was dated by Goff with Ar $^{40/39}$ to 7.62 ± 0.44 Ma, slightly later than the other Keres Group obsidian Canovas Canyon Rhyolite (Gardner et al. 1986; Goff et al. 1996, 2006; Justet 1996; Kelley et al. 2013). It is somewhat unfortunate that this obsidian was originally named "Paliza Canyon" since it is not related to the rocks in the Paliza Canyon Formation, and instead obsidian as part of Bearhead Rhyolite. Bearhead Rhyolite obsidian should be used from now on in the literature (Shackley et al. 2016).

While the source study of the two Keres Group obsidians did not show any compositional overlap between Bearhead Rhyolite and Canovas Canyon Rhyolite, one projectile point at Armijo was produced from obsidian that appears to be mid-way between the elemental concentrations of both sources (Strata B, sample 9756, see Appendix Table, and Figure 1).

Given that more than 50 source samples have been analyzed between these two sources, this composition appears unique. Barium analyzed is closer to Bearhead Rhyolite, and was assigned to that source (see Appendix, Table).

El Rechuelos Rhyolite. The third relevant pre-caldera eruptive event that produced artifact quality obsidian is El Rechuelos Rhyolite. This source, represented in this assemblage, is what I consider one of the best media for tool production of the group. It dates to about 2.4 Ma, 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.

Tewa Group Sources: Cerro del Medio and Valles Rhyolite. About 1.4 Ma, 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 southeast from what is now Rabbit Mountain and east into the Rio Grande from 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 2012; Figures 1 and 7 here).

The second caldera collapse, that produced the Valles Rhyolite member of the Tewa Formation, called Valles Rhyolite here, occurred around 1.2 Ma and created most of the geography of the current Valles Caldera (Gardner et al. 2007). A number of rhyolite ring domes were formed 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 Government Mountain in the San Francisco Volcanic Field. This source was apparently preferred by Folsom knappers, as well as those in all periods since (Steffen 2016). While Cerro Toledo Rhyolite often appears in archaeological contexts in New Mexico sites with greater frequency, it is likely because it is distributed in secondary contexts, and the dominance of Valles Rhyolite in the El Segundo sites which are not downstream from Cerro Toledo buoys this inference. Valles Rhyolite (Cerro del Medio) stone has not eroded outside the caldera to the extent as Cerro Toledo Rhyolite, and had to be originally procured in the caldera proper (Shackley 2005, 2012).

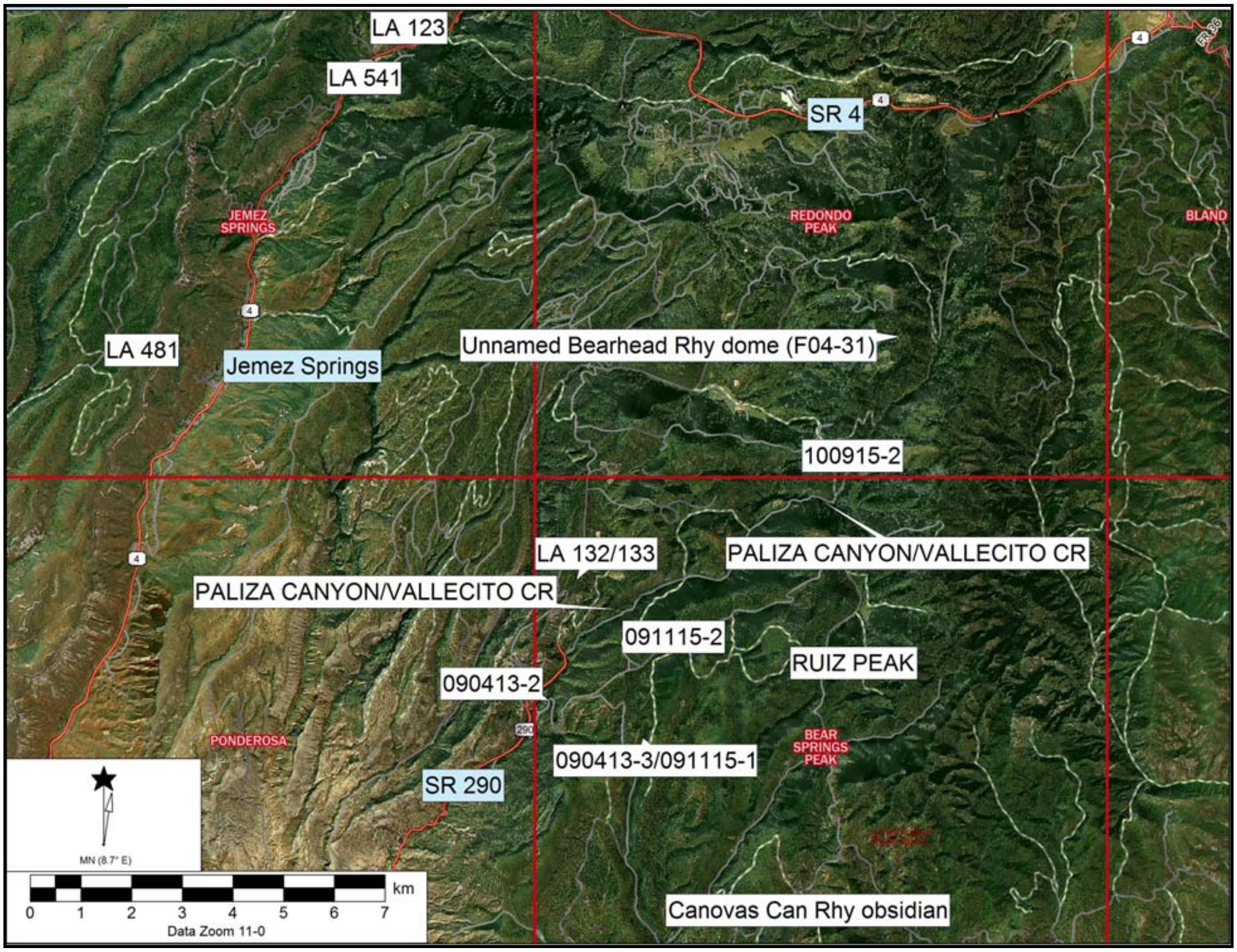


Figure 5. Jemez Mountains southern pre-caldera and Toledo and Valles caldera sources of archaeological obsidian, collection localities, location of primary Bearhead Rhyolite dome (F04-31) and local Pueblo Revolt sites (from Shackley et al. 2016).

RESULTS OF THE EDXRF ANALYSIS OF THE ARTIFACTS

As noted above, 72 obsidian projectile points were analyzed for source provenance from Armijo Shelter (Appendix Table and Table 1 and Figure 6 here). Also as noted above, the assemblages taking all sites together is dominated by Jemez Mountains sources with only 5.6% from the Mount Taylor source, shown graphically in Figure 6.

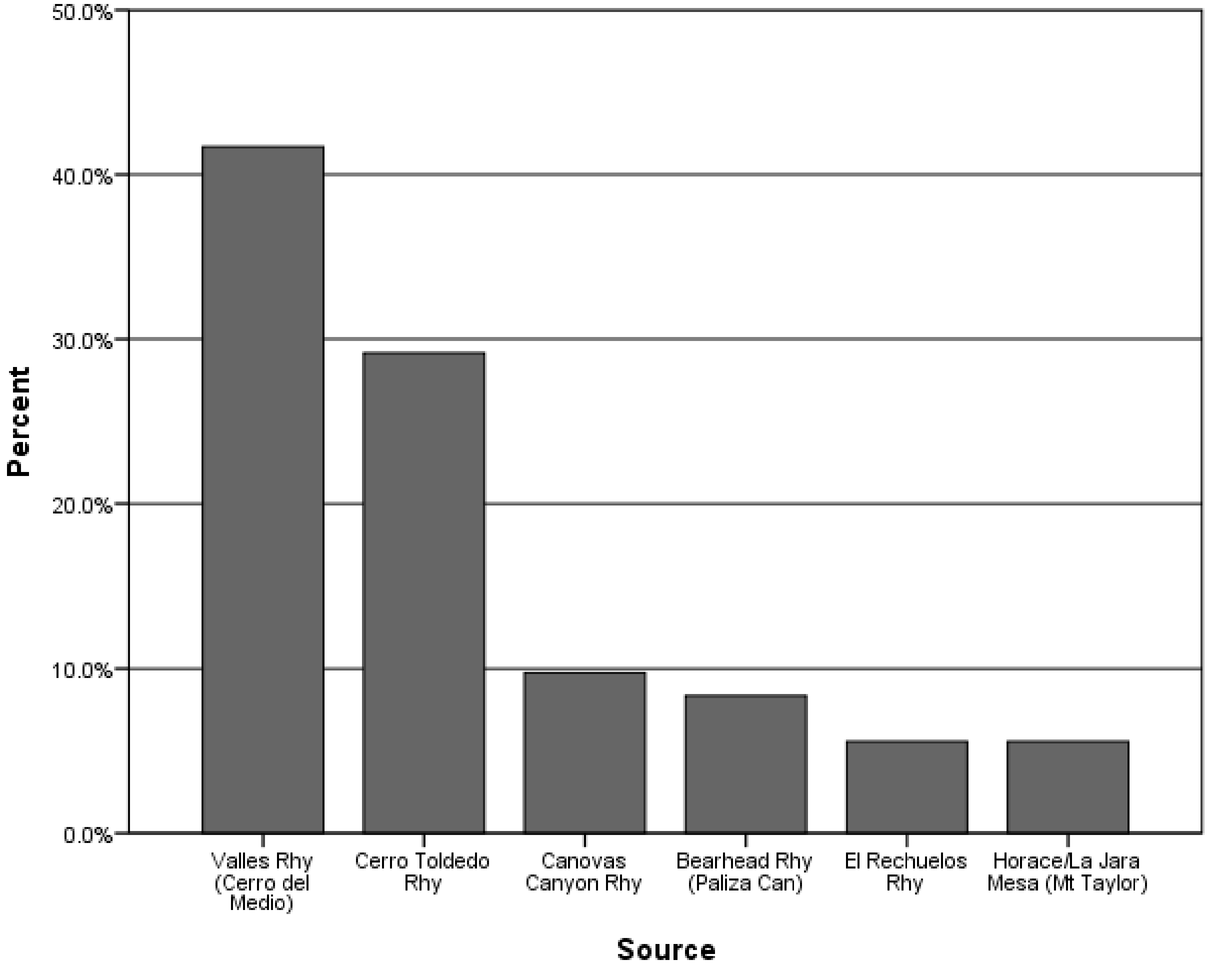
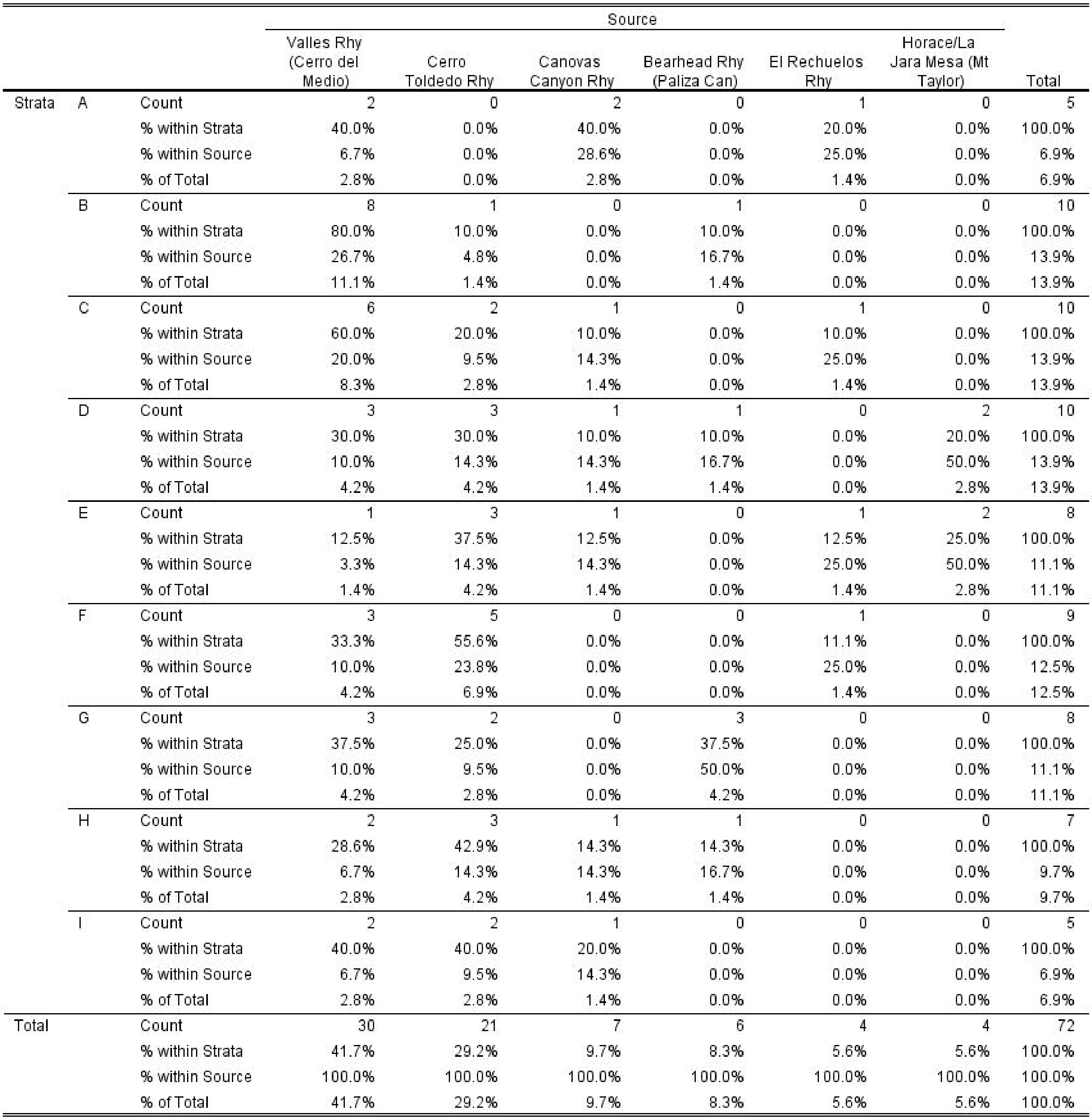


Figure 6. Frequency distribution of obsidian sources for all sites.

Table 1. Crosstabulation of source by strata at Armijo Shelter.



			Source						
			Valles Rhy (Cerro del Medio)	Cerro Toldedo Rhy	Canovas Canyon Rhy	Bearhead Rhy (Paliza Can)	El Rechuelos Rhy	Horace/La Jara Mesa (Mt Taylor)	Total
Strata	A	Count	2	0	2	0	1	0	5
		% within Strata	40.0%	0.0%	40.0%	0.0%	20.0%	0.0%	100.0%
		% within Source	6.7%	0.0%	28.6%	0.0%	25.0%	0.0%	6.9%
		% of Total	2.8%	0.0%	2.8%	0.0%	1.4%	0.0%	6.9%
	B	Count	8	1	0	1	0	0	10
		% within Strata	80.0%	10.0%	0.0%	10.0%	0.0%	0.0%	100.0%
		% within Source	26.7%	4.8%	0.0%	16.7%	0.0%	0.0%	13.9%
		% of Total	11.1%	1.4%	0.0%	1.4%	0.0%	0.0%	13.9%
	C	Count	6	2	1	0	1	0	10
		% within Strata	60.0%	20.0%	10.0%	0.0%	10.0%	0.0%	100.0%
		% within Source	20.0%	9.5%	14.3%	0.0%	25.0%	0.0%	13.9%
		% of Total	8.3%	2.8%	1.4%	0.0%	1.4%	0.0%	13.9%
	D	Count	3	3	1	1	0	2	10
		% within Strata	30.0%	30.0%	10.0%	10.0%	0.0%	20.0%	100.0%
		% within Source	10.0%	14.3%	14.3%	16.7%	0.0%	50.0%	13.9%
		% of Total	4.2%	4.2%	1.4%	1.4%	0.0%	2.8%	13.9%
	E	Count	1	3	1	0	1	2	8
		% within Strata	12.5%	37.5%	12.5%	0.0%	12.5%	25.0%	100.0%
		% within Source	3.3%	14.3%	14.3%	0.0%	25.0%	50.0%	11.1%
		% of Total	1.4%	4.2%	1.4%	0.0%	1.4%	2.8%	11.1%
	F	Count	3	5	0	0	1	0	9
		% within Strata	33.3%	55.6%	0.0%	0.0%	11.1%	0.0%	100.0%
		% within Source	10.0%	23.8%	0.0%	0.0%	25.0%	0.0%	12.5%
		% of Total	4.2%	6.9%	0.0%	0.0%	1.4%	0.0%	12.5%
	G	Count	3	2	0	3	0	0	8
		% within Strata	37.5%	25.0%	0.0%	37.5%	0.0%	0.0%	100.0%
		% within Source	10.0%	9.5%	0.0%	50.0%	0.0%	0.0%	11.1%
		% of Total	4.2%	2.8%	0.0%	4.2%	0.0%	0.0%	11.1%
	H	Count	2	3	1	1	0	0	7
		% within Strata	28.6%	42.9%	14.3%	14.3%	0.0%	0.0%	100.0%
		% within Source	6.7%	14.3%	14.3%	16.7%	0.0%	0.0%	9.7%
		% of Total	2.8%	4.2%	1.4%	1.4%	0.0%	0.0%	9.7%
	I	Count	2	2	1	0	0	0	5
		% within Strata	40.0%	40.0%	20.0%	0.0%	0.0%	0.0%	100.0%
		% within Source	6.7%	9.5%	14.3%	0.0%	0.0%	0.0%	6.9%
		% of Total	2.8%	2.8%	1.4%	0.0%	0.0%	0.0%	6.9%
Total		Count	30	21	7	6	4	4	72
		% within Strata	41.7%	29.2%	9.7%	8.3%	5.6%	5.6%	100.0%
		% within Source	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	41.7%	29.2%	9.7%	8.3%	5.6%	5.6%	100.0%

Discussion

Most obvious in the results of the source provenance of the projectile points at Armijo Shelter is the dominance of Jemez Mountains sources to the north, and the scarcity of Mount Taylor sources used to produce the points (see Table 1 and Figure 6 here). While the sample size in each strata at Armijo is relatively small, there are some patterns that deserve discussion. With regard to the Mount Taylor obsidian, these projectile points produced from Horace/La Jara Mesa are concentrated in only Strata D and E (see Table 1). With only four samples it is hazardous to conjecture, but this could be a continual occupation at this time at the shelter when the procurement range included territory to the south, rather than exclusively to the north as in the other strata, probably other occupations (Table 1). However, there were projectile points in Strata D and E produced from Jemez Mountains sources, so if these strata represent discrete occupations of the same group, then the procurement range included territory north and south. Again, the sample sizes are relatively small.

With regard to the selection of obsidian raw material represented in this assemblage, the dominance of Valles Rhyolite (Cerro del Medio) which is a greater distance than Cerro Toledo Rhyolite obsidian at Rabbitt Mountain, and canyons to the south, and more than the relatively closer Keres Group obsidians follows the pattern of procurement typical from Archaic through Late Classic times (Shackley 2005, 2015, 2016; Shackley et al. 2016). Valles Rhyolite obsidian was also dominant at the Archaic El Segundo sites to the northwest, and the Late Archaic farming village of San Luis de Cabezón (LA 110946) approximately 30 km northwest of Armijo, but the southern Jemez sources were prominent as well (Shackley 2015, 2016; Shackley et al. 2016). Whether the inhabitants of Armijo Shelter at various times were in contact with those at San Luis de Cabezón and sites at El Segundo, or indeed the same people is impossible to know, but the obsidian source provenance and projectile point styles suggests that this could be the case. Indeed, a procurement range of this size is typical of arid land hunter-gatherers, based on obsidian source provenance (Shackley 1989, 1996, 2005).

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APPENDIX

Elemental concentrations for the obsidian artifacts, and USGS RGM-1 rhyolite standard. All measurements in parts per million (ppm) except Fe reported in weight percent as Fe_2O_3.

FS#	Strata	Ti	Mn	Fe%	Zn	Rb	Sr	Y	Zr	Nb	Ba	Source
9505	A	703	409	0.90	96	163	13	44	169	59		Valles Rhy (Cerro del Medio)
9506	A	641	390	0.50	46	147	13	23	71	43		El Rechuelos Rhy
9510	A	770	420	0.99	98	170	18	44	170	58		Valles Rhy (Cerro del Medio)
9511	A	784	408	0.59	42	114	41	27	105	54		Canovas Canyon Rhy
9512	A	808	419	0.63	44	115	44	26	111	50		Canovas Canyon Rhy
9504	B	977	442	1.00	123	163	13	45	167	57		Valles Rhy (Cerro del Medio)
9516	B	844	397	0.94	110	166	12	44	160	53		Valles Rhy (Cerro del Medio)
9517	B	705	380	0.89	91	156	13	47	172	49		Valles Rhy (Cerro del Medio)
9523	B	666	408	0.94	104	168	11	47	175	60		Valles Rhy (Cerro del Medio)
9526	B	717	486	0.92	102	206	9	69	180	99		Cerro Toldedo Rhy
9527	B	614	395	0.89	67	157	11	39	164	47		Valles Rhy (Cerro del Medio)
9528	B	747	415	0.94	95	168	13	42	164	51		Valles Rhy (Cerro del Medio)
9756	B	1026	449	0.73	62	116	68	21	119	41	944	Bearhead Rhy (Paliza Can)
9791	B	699	405	0.89	66	161	15	47	163	50		Valles Rhy (Cerro del Medio)
9792	B	749	401	0.85	79	154	12	41	165	58		Valles Rhy (Cerro del Medio)
9546	C	795	434	0.98	105	183	18	50	174	51		Valles Rhy (Cerro del Medio)
9560	C	756	375	0.91	81	161	13	45	170	55		Valles Rhy (Cerro del Medio)
9563	C	625	406	0.90	79	166	18	39	168	59		Valles Rhy (Cerro del Medio)
9578	C	645	422	0.98	84	172	12	48	173	52		Valles Rhy (Cerro del Medio)
9582	C	689	377	0.84	63	154	11	44	155	55		Valles Rhy (Cerro del Medio)
9583	C	630	480	0.92	95	207	9	66	185	102		Cerro Toldedo Rhy
9587	C	654	405	0.53	41	158	15	28	77	44		El Rechuelos Rhy
9604	C	841	459	0.64	62	119	45	27	114	50		Canovas Canyon Rhy
9608	C	699	426	0.94	78	167	12	41	177	51		Valles Rhy (Cerro del Medio)
9613	C	678	531	1.00	109	212	10	68	173	99		Cerro Toldedo Rhy
9524	D	772	517	0.97	110	218	9	66	181	98		Cerro Toldedo Rhy
9626	D	528	508	0.94	103	214	10	66	189	104		Cerro Toldedo Rhy
9627	D	903	481	0.69	42	125	49	22	110	57		Canovas Canyon Rhy
9632	D	1242	483	0.74	84	103	89	22	129	31		Bearhead Rhy (Paliza Can)
9633	D	690	432	0.92	85	166	16	45	172	60		Valles Rhy (Cerro del Medio)
9634	D	626	399	0.91	102	175	11	44	163	55		Valles Rhy (Cerro del Medio)
9641	D	544	492	0.92	98	208	9	67	172	95	820	Cerro Toldedo Rhy

9646	D	498	653	0.95	218	563	11	99	150	241	Horace/La Jara Mesa (Mt Taylor)
9648	D	435	578	0.83	209	516	16	95	144	232	Horace/La Jara Mesa (Mt Taylor)
9650	D	799	362	0.83	64	150	14	43	163	49	Valles Rhy (Cerro del Medio)
2675-67	E	853	556	1.02	121	209	9	69	180	96	Cerro Toldedo Rhy
9653	E	470	622	0.94	206	533	13	90	144	239	Horace/La Jara Mesa (Mt Taylor)
9658	E	791	402	0.91	81	168	15	41	159	53	Valles Rhy (Cerro del Medio)
9665	E	669	456	0.69	161	462	13	82	136	222	Horace/La Jara Mesa (Mt Taylor)
9666	E	778	505	0.95	104	212	11	67	182	88	Cerro Toldedo Rhy
9669	E	548	403	0.51	48	151	10	28	75	45	El Rechuelos Rhy
9670	E	757	506	0.94	106	215	9	63	180	101	Cerro Toldedo Rhy
9730	E	868	487	0.62	49	120	45	25	112	46	Canovas Canyon Rhy
9688	F	926	480	1.14	90	185	15	50	188	63	Valles Rhy (Cerro del Medio)
9698	F	582	466	0.82	90	197	9	54	172	95	Cerro Toldedo Rhy
9702	F	581	462	0.87	119	198	10	65	173	99	Cerro Toldedo Rhy
9703	F	702	408	0.97	75	160	16	43	175	63	Valles Rhy (Cerro del Medio)
9707	F	535	493	0.94	110	209	9	66	176	96	Cerro Toldedo Rhy
9714	F	641	360	0.79	66	151	12	45	162	55	Valles Rhy (Cerro del Medio)
9724	F	638	410	0.53	36	161	13	20	78	52	El Rechuelos Rhy
9729	F	721	544	1.01	112	212	12	67	176	100	Cerro Toldedo Rhy
9732	F	710	483	0.95	108	212	12	64	188	99	Cerro Toldedo Rhy
9736	G	1202	490	0.75	48	99	92	23	131	34	Bearhead Rhy (Paliza Can)
9740	G	1285	481	0.76	57	100	90	29	135	32	Bearhead Rhy (Paliza Can)
9741	G	667	461	0.90	99	203	12	63	183	98	Cerro Toldedo Rhy
9742	G	1179	535	0.75	46	100	91	24	131	31	Bearhead Rhy (Paliza Can)
9743	G	622	485	0.89	107	203	10	58	184	95	Cerro Toldedo Rhy
9747	G	549	348	0.74	60	149	11	41	156	55	Valles Rhy (Cerro del Medio)
9751	G	719	411	0.92	99	164	18	42	172	54	Valles Rhy (Cerro del Medio)
9774	G	872	376	0.85	75	158	14	38	166	54	Valles Rhy (Cerro del Medio)
9706	H	688	494	0.95	117	211	9	67	184	95	Cerro Toldedo Rhy
9763	H	949	506	0.72	43	126	46	21	111	54	Canovas Canyon Rhy
9766	H	1202	493	0.70	46	100	84	21	131	37	Bearhead Rhy (Paliza Can)
9769	H	655	393	0.70	89	179	11	53	159	89	Cerro Toldedo Rhy
9771	H	613	428	0.99	77	171	10	50	173	57	Valles Rhy (Cerro del Medio)

9775	H	727	530	1.00	109	218	12	68	176	98		Cerro Toldedo Rhy
9776	H	710	424	0.99	76	166	13	45	177	61		Valles Rhy (Cerro del Medio)
9780	I	834	409	0.62	45	118	41	19	108	53		Canovas Canyon Rhy
9785	I	495	443	0.84	98	200	13	63	172	94		Cerro Toldedo Rhy
9786	I	723	524	1.04	117	216	13	64	182	99		Cerro Toldedo Rhy
9788	I	810	414	0.99	82	172	15	49	172	54		Valles Rhy (Cerro del Medio)
9789	I	737	398	0.91	72	169	14	47	174	61		Valles Rhy (Cerro del Medio)
RGM1-S5		1478	309	1.32	38	146	104	27	223	13		standard
RGM1-S5		1567	285	1.31	40	152	108	25	218	14		standard
RGM1-S5		1452	296	1.31	44	145	106	25	220	13		standard
RGM1-S5		1405	305	1.30	38	148	107	26	219	8		standard