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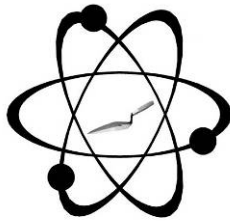
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**SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM ARCHAEOLOGICAL SITES
NEAR LAKE ROBERTS, SOUTHERN NEW MEXICO**

by

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Report Prepared for

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INTRODUCTION

The analysis here of 58 obsidian artifacts from a number of sites near Lake Roberts in southern New Mexico indicates a diverse obsidian provenance assemblage dominated by the Antelope Creek locality at Mule Creek, western New Mexico. Other sources include the other two source localities at Mule Creek, Mule Mountains, and North Sawmill Creek, and a substantial number of artifacts produced from Gwynn/Ewe Canyon obsidian in the Mogollon Highlands (see Tables 1 and 2). Not present in the assemblage are artifacts produced from the Nutt Mountain source recently discovered in Sierra County, New Mexico. Based on the obsidian source provenance, the inhabitants of these sites looked to the north toward the Mogollon Highlands for obsidian raw materials.

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 in the Archaeological 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 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.

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 200 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 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. When barium (Ba) is acquired 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, 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).

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 a USGS obsidian standard is analyzed during each sample run for obsidian artifacts to check machine calibration (Table 1). Source assignments were made with reference to Shackley (1995, 2005) and source standard data at this lab (Tables 1 and 2, and Figures 1 through 4).

DISCUSSION

The obsidian provenance assemblage is dominated by sources in the Mogollon-Datil Volcanic Province of western and southern New Mexico (Figure 1). The compositional similarity in these sources requires a high level of care in assigning to source with EDXRF analysis that is a direct result of the processes occurring in the Mogollon-Datil from about 30 to 17 Ma.

The Mogollon-Datil Volcanic Province Obsidian

Recent research at Mule Creek and the newly discovered Sierra County source, as well as earlier work at Gwynn/Ewe Canyons in the Mogollon Mountains indicates close similarity at the elemental level for these sources (Shackley 2005, 2014). Given the popularity of the Mule Creek sources throughout prehistory, careful discrimination is required, at least in XRF analyses.

The Mule Creek Source Area

The Mule Creek Source Region is one of the most geologically explored archaeological sources of obsidian in the American Southwest (Brooks and Ratté 1985; Ratté 1982; Ratté and Brooks 1983, 1989; Ratté and Hedlund 1981; Rhodes and Smith 1972; Figure 1). Ratté has organized most of the research in the area focusing on mapping and establishing the origin of the volcanics during the Tertiary as originally described by Rhodes and Smith (1972). This region, which is on the boundary between the Basin and Range complex to the west and southwest, and the southeastern edge of the Colorado Plateau, exhibits a silicic geology that is somewhat distinctive from the decidedly peraluminous glass of Cow Canyon with relatively high strontium values and the distinct chemical variability of the Mule Creek glasses (Elston et al. 1976; Ratté et al. 1984; Rhodes and Smith 1972; Shackley 2005). The province has been named Mogollon-Datil for its location and major floristic association (Elston et al. 1976). The region is, in part, characterized by pre-caldera andesites and later high-silica alkali rhyolites in association with caldera formation, subsequent collapse and post-caldera volcanism. Fieldwork and chemical analyses by Ratté and Brooks (1989) lead them to conclude that the Mule Creek Caldera is actually just a graben, although the typical succession from intermediate to silicic volcanism apparently holds. Recent geological work by me and the Keck Foundation field school suggests that Mule Creek could actually be a remnant caldera around 20 ma in age (Shackley 2014).

The obsidian has been directly dated at the Antelope Creek locality to 17.7 ± 0.6 my by K-Ar, and at the Mule Mountain locality at the same age (17.7 ± 1 my by K-Ar; Ratté and Brooks 1983, 1989). A single obsidian marekanite taken from the perlitic lava at the Antelope Creek locality was used in the analysis. Unusual in geological descriptions, the obsidian proper was discussed as an integral part of the regional geology.

Rhyolite of Mule Creek (Miocene). Aphyric, high-silica, alkali-rhyolite domal flows from the Harden Cienega eruptive center along southwestern border of quadrangle [Wilson Mountain 1:24,000 Quad, New Mexico]. Unit **ob**, commonly at the base of the flows, consists of brown, pumiceous glass that grades upward into gray to black perlitic obsidian and obsidian breccia. Extensive ledges of partly hydrated, perlitic obsidian contain nonhydrated obsidian nodules (marekanites) which, when released by weathering, become the Apache tears that are widespread on the surface and within the Gila Conglomerate in this region. Age shown in Correlation is from locality about 1 km south of tank in Antelope Creek in Big Lue Mountains quadrangle adjacent to west edge of Wilson Mountain quadrangle. Thickness of flows is as much as 60 m and unit **ob** as much as 25 m (Ratté and Brooks 1989:map text, bold as in original).

This description adequately characterizes what is found at the other two primary localities (Mule Mountains, and North Sawmill Creek). Aphyric, artifact quality marekanites are remnant within perlitic glass and tuff lava units. Nodules at all localities are up to 15 cm in diameter although most are under 10 cm. The devitrified perlitic lava, quite friable, erodes easily into the local alluvium. As discussed elsewhere, this is relatively unique in Tertiary sources in the Southwest where most of the obsidian breccia and perlitic lava is often completely eroded away leaving only the rhyolite interior of the dome and a consequent inability to assign the surrounding marekanites to a specific dome structure (Shackley 2005; see also Hughes and Smith 1993). Last season (2013) an ashflow tuff locality with very abundant aphyric Antelope Creek marekanites was located at the head of Antelope Creek as it erodes into the San Francisco River. This locality has abundant reduced cores and flakes and represents the probable major source for archaeological obsidian.

The aphyric glass ranges from opaque black to translucent smoky gray with some gray banding. In over 1000 specimens collected from the Mule Creek/North Sawmill Creek group, three are mahogany-brown and black banded similar to Slate Mountain (Wallace Tank) material. Some of the cortex exhibits a silver sheen, but most is a thin black-brown. The material is a fair medium for tool production, but the Antelope Creek East locality obsidian is very brittle much like Los Vidrios, except at the new location discussed above. The pressure reduction potential is, however, very good as seen in the sites in this study. The Mule Mountain glass, and the recently discovered Antelope Creek West locality however, is as good as any in the Southwest.

Gwynn and Ewe Canyons

The Gwynn and Ewe Canyon source is located in Gila National Forest, south central Catron County, New Mexico, at over 2500 m in elevation (Shackley 2005). In an early study (Shackley 1988), this source was not personally mapped or surveyed. My survey in 1993 indicated that marekanites were directly associated with glassy, perlitic rhyolite in Ewe Canyon to the south, although this stream system erodes into Gwynn Canyon. These coalesced domes shown as Feathery Hill on the quadrangle map, exhibit nodule densities in the regolith up to 200 per m². This source is located in Telephone Canyon 7.5' Quad 1963, Catron County, New Mexico. Unmodified marekanites on the domes have maximum diameters near 50 mm, although the vast majority ($\geq 95\%$) are 30 mm and smaller. Bipolar cores and flakes were found on and near Feathery Hill, but in low densities (< 1 per 100 m²). As noted above, marekanites are eroding into the Gwynn Canyon system and possibly the upper San Francisco River, although no nodules were noted in the San Francisco River alluvium as far north as Alma, New Mexico.

During the 2013 field season remnant perlitic domes in Gwynn Canyon indicated abundant marekanites similar to the Feathery Hill locality in Ewe Canyon as reported earlier (Shackley 1988, 1995). EDXRF analysis indicates that the elemental concentrations are

identical between Gwynn and Ewe Canyons. The Gwynn/Ewe Canyon obsidian has been dated by K-Ar to 27.6 ± 1.8 Ma making it the oldest yet dated artifact quality obsidian in the Southwest (Marvin et al. 1987). Currently $^{40}\text{Ar}/^{39}\text{Ar}$ samples have been submitted to SUERC in Scotland from all the major Mogollon-Datil obsidian sources to resolve some of the chronometric issues.

The Sierra County Source

In 2008, on the advice of Tim Church, a "new" source was discovered east of Nutt Mountain in Sierra County, New Mexico in and around UTM 13S 0277679/3615415 $\pm 2\text{m}$ on the 1984 BLM 30/60' Hatch Quad. The source appears to be marekanite remnants in an ashflow tuff, the eruptive center of which has not yet been found. It could be related to the Nutt Mountain rhyolite center, but further investigations in 2013 suggests that the obsidian is coming from a different vent probably to the north. Nodules up to $5/100\text{m}^2$ are present from pea size up to about 5 cm in diameter, and bipolar core reduction evident in all areas. The marekanites may be available as far south as these sites, but it isn't yet known.

The Gwynn Canyon, Sierra County and two of the Mule Creek groups (Antelope Creek and Mule Mountains) are very similar in trace element composition, likely due to a common origin in the Mogollon-Datil rhyolites (see Elston et al. 1976; McIntosh et. al. 1992; Shackley 1995, 1998b). All the Mogollon-Datil sources can be discriminated with Rb, Sr, Zr, Y, Nb as with most rhyolite glasses, but to discriminate Gwynn/Ewe Canyon from Nutt Mountain requires Rb and Ba (Figures 2 through 4; see Shackley 2014). Care must be exercised when attempting to discriminate these source elementally, and since portable XRF (PXRF) instruments cannot acquire the heavier elements like Ba, they are hazardous to use in southern New Mexico contexts generally.

The potential inability to discriminate these sources can be an important issue in western New Mexico late prehistory because these sources are located in very different environments that may have had cultural significance in prehistory. It is possible that during the Mogollon Classic period Gwynn Canyon obsidian could have been controlled by the Cibola branch of the Mogollon while the Mule Creek and Sierra County sources could have been controlled by the Mimbres branch. This may or may not influence the spatial distribution of these obsidian sources in the region and confident source assignment can become crucial. Gwynn/Ewe Canyon obsidian at elevations above 2500 m in elevation are generally well above the elevation favoring maize cultivation and there are virtually no large pueblos at this elevation. Hunting large ungulates, however, is likely in the area. Both deer and elk were seen in the area in the 1990s, and again in 2013.

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Table 1. Elemental concentrations and source assignments for the archaeological specimens by site and sample, and analysis of USGS RGM-1 obsidian standard. All measurements in parts per million (ppm).

Sample	Site	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th	Source
26981-11	LA 4979	712	609	1122	141	442	12	74	104	116		34	40	N. Sawmill Cr (Mule Cr), NM
32880	LA 4980	1504	861	1950	225	367	12	135	125	104		43	39	Antelope Wells, NM
10	LA 47821	891	450	1106	111	180	16	25	114	32	46	22	25	Mule Mountains (Mule Cr), NM
318	LA 47821	809	358	1195	102	253	24	42	104	23		29	36	Antelope Creek (Mule Cr), NM
448	LA 47821	523	362	1129	79	236	21	40	107	26		29	38	Antelope Creek (Mule Cr), NM
454	LA 47821	621	366	1152	87	235	25	42	109	23		26	33	Antelope Creek (Mule Cr), NM
460	LA 47821	633	343	1158	85	243	24	40	108	27		30	36	Antelope Creek (Mule Cr), NM
650	LA 47821	731	367	1179	90	255	24	41	112	24		31	32	Antelope Creek (Mule Cr), NM
652	LA 47821	668	419	1201	160	248	20	41	111	25		28	31	Antelope Creek (Mule Cr), NM
1028	LA 47821	591	392	1164	89	243	22	45	107	29		28	39	Antelope Creek (Mule Cr), NM
1207	LA 47821	542	351	1120	64	225	21	38	107	26		24	31	Antelope Creek (Mule Cr), NM
1214	LA 47821	597	327	1120	69	227	18	37	102	25		29	32	Antelope Creek (Mule Cr), NM
100A	LA 47821	589	360	1156	76	238	23	40	105	23		28	31	Antelope Creek (Mule Cr), NM
1033A	LA 47821	689	350	1150	90	243	21	38	105	27		28	33	Antelope Creek (Mule Cr), NM
1033B	LA 47821	527	357	1146	81	239	20	46	108	27		26	36	Antelope Creek (Mule Cr), NM
1033C	LA 47821	826	453	1267	270	255	18	40	105	26		32	28	Antelope Creek (Mule Cr), NM
1042A	LA 47821	569	346	1143	78	234	22	41	106	27		27	40	Antelope Creek (Mule Cr), NM
1077A	LA 47821	595	371	1150	79	242	24	36	110	19		30	35	Antelope Creek (Mule Cr), NM

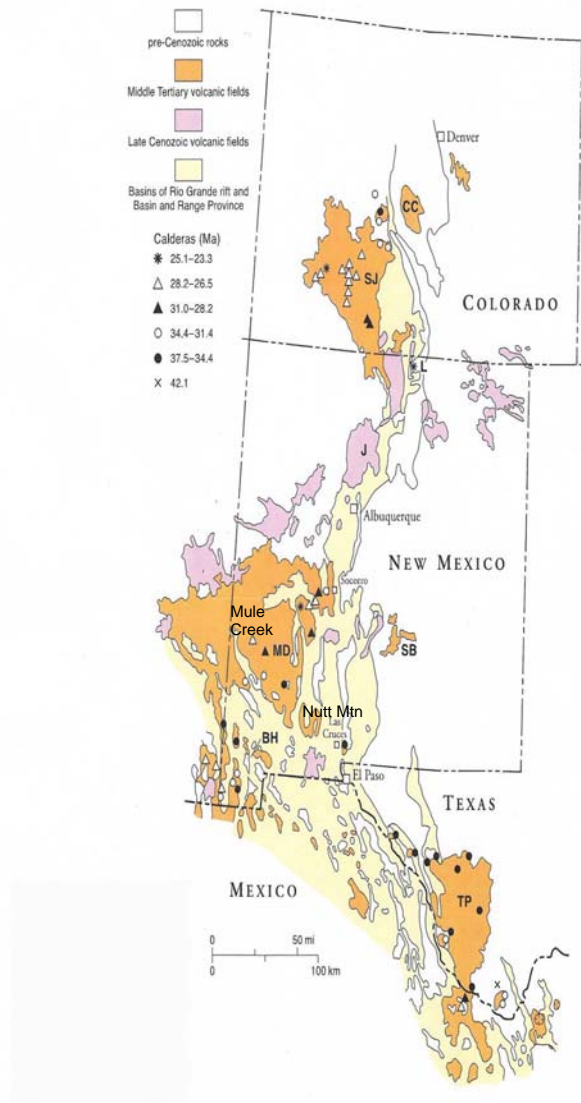
111A	LA 47821	613	386	1175 1	61	250	21	43	114	26		29	30	Antelope Creek (Mule Cr), NM
1122A	LA 47821	1005	402	1119 1	105	216	23	28	149	22	76	32	29	Gwynn/Ewe Canyons, NM
1122B	LA 47821	571	379	1174 4	63	252	22	40	111	35		30	35	Antelope Creek (Mule Cr), NM
1135A	LA 47821	514	310	1107 8	36	226	20	37	109	28		27	32	Antelope Creek (Mule Cr), NM
1166A	LA 47821	916	368	1168 9	120	231	23	38	108	23		27	25	Antelope Creek (Mule Cr), NM
1166B	LA 47821	646	344	1151 8	118	238	23	39	107	22		27	33	Antelope Creek (Mule Cr), NM
1167A	LA 47821	916	407	1208 2	179	239	23	37	104	26		28	31	Antelope Creek (Mule Cr), NM
1167B	LA 47821	657	408	1209 9	82	268	22	41	113	27		32	39	Antelope Creek (Mule Cr), NM
1167C	LA 47821	655	384	1175 3	114	240	19	43	109	26		28	34	Antelope Creek (Mule Cr), NM
1177A	LA 47821	750	344	1122 5	163	219	21	38	99	23		26	30	Antelope Creek (Mule Cr), NM
1177B	LA 47821	653	398	1202 5	103	264	22	40	116	28		33	35	Antelope Creek (Mule Cr), NM
1197A	LA 47821	657	416	1208 8	85	271	22	46	116	27		36	36	Antelope Creek (Mule Cr), NM
1197B	LA 47821	682	365	1185 1	114	250	21	41	112	25		31	40	Antelope Creek (Mule Cr), NM
1198A	LA 47821	601	353	1160 7	75	240	20	41	111	28		30	31	Antelope Creek (Mule Cr), NM
Sample	Site	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th	Source
1202A	LA 47821	566	352	1146 4	42	242	21	41	109	28		31	30	Antelope Creek (Mule Cr), NM
1215A	LA 47821	535	365	1168 3	66	256	23	41	112	24		32	36	Antelope Creek (Mule Cr), NM
1281A	LA 47821	579	372	1172 9	98	251	24	43	108	29		30	35	Antelope Creek (Mule Cr), NM
1356A	LA 47821	671	423	1044 3	58	179	16	24	112	30	34	22	24	Mule Mountains (Mule Cr), NM
2012A	LA 47821	633	385	1168 7	82	246	21	38	108	27		31	33	Antelope Creek (Mule Cr), NM
2027A	LA 47821	590	364	1141 8	73	241	20	43	105	25		27	30	Antelope Creek (Mule Cr), NM

2027B	LA 47821	611	413	1187 0	75	258	20	44	113	29		31	38	Antelope Creek (Mule Cr), NM
2027C	LA 47821	652	420	1219 6	104	260	24	44	117	24		36	37	Antelope Creek (Mule Cr), NM
2027D	LA 47821	626	354	1138 5	57	231	24	36	109	29		27	30	Antelope Creek (Mule Cr), NM
2027E	LA 47821	649	355	1151 6	93	235	20	39	108	26		25	25	Antelope Creek (Mule Cr), NM
2027F	LA 47821	616	354	1152 7	93	242	23	42	111	27		27	30	Antelope Creek (Mule Cr), NM
762A	LA 47821	672	407	1197 3	97	266	23	45	111	25		34	31	Antelope Creek (Mule Cr), NM
958A	LA 47821	891	412	1119 5	68	230	22	34	152	23	20	29	33	Gwynn/Ewe Canyons, NM
971A	LA 47821	1179	509	1216 8	118	271	24	35	167	25		43	43	unknown
17A	LA 127051	644	380	1161 6	107	246	21	41	108	24		30	32	Antelope Creek (Mule Cr), NM
17B	LA 127051	1184	402	9528	94	228	21	32	160	22	71	30	30	Gwynn/Ewe Canyons, NM
21A	LA 127051	734	445	1263 3	184	262	20	43	106	24		39	38	Antelope Creek (Mule Cr), NM
22A	LA 127051	1070	416	1124 4	89	229	23	30	142	21	9	32	37	Gwynn/Ewe Canyons, NM
22B	LA 127051	1491	423	1142 9	157	225	21	27	136	20	7	33	39	Gwynn/Ewe Canyons, NM
22C	LA 127051	774	405	1175 6	125	249	23	40	103	26		31	33	Antelope Creek (Mule Cr), NM
22D	LA 127051	720	351	1155 0	75	233	20	39	107	27		29	32	Antelope Creek (Mule Cr), NM
25A	LA 127051	1265	434	1152 0	122	236	22	30	138	29	67	35	35	Gwynn/Ewe Canyons, NM
28A	LA 127051	1346	507	1222 6	249	247	23	27	126	20	30	36	33	Gwynn/Ewe Canyons, NM
44A	LA 127051	1024	424	1240 7	169	262	22	39	106	25		33	36	Antelope Creek (Mule Cr), NM
113A	LA 127051	511	389	1177 4	87	253	24	42	112	26		30	37	Antelope Creek (Mule Cr), NM
113B	LA 127051	585	382	1157 8	85	243	22	41	106	24		27	31	Antelope Creek (Mule Cr), NM
RGM1-S4		1637	290	1369 8	36	147	106	23	215	7		21	15	standard

RGM1-S4	1597	272	1370	35	146	109	22	210	7	21	12	standard
			7									
RGM1-S4	1553	291	1369	36	148	110	21	218	6	22	16	standard
			5									

Table 2. Crosstabulation of site by source.

		Source							
		Antelope Creek (Mule Cr), NM	Mule Mountains (Mule Cr), NM	N. Sawmill Cr (Mule Cr), NM	Gwynn/Ewe Canyons, NM	Antelope Wells, NM	unknown	Total	
Site	LA 127051	Count	7	0	0	5	0	0	12
		% within Site	58.3%	0.0%	0.0%	41.7%	0.0%	0.0%	100.0%
		% within Source	15.2%	0.0%	0.0%	71.4%	0.0%	0.0%	20.7%
		% of Total	12.1%	0.0%	0.0%	8.6%	0.0%	0.0%	20.7%
	LA 47821	Count	39	2	0	2	0	1	44
		% within Site	88.6%	4.5%	0.0%	4.5%	0.0%	2.3%	100.0%
		% within Source	84.8%	100.0%	0.0%	28.6%	0.0%	100.0%	75.9%
		% of Total	67.2%	3.4%	0.0%	3.4%	0.0%	1.7%	75.9%
	LA 4979	Count	0	0	1	0	0	0	1
		% within Site	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	100.0%
		% within Source	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	1.7%
		% of Total	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	1.7%
	LA 4980	Count	0	0	0	0	1	0	1
		% within Site	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%
		% within Source	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	1.7%
		% of Total	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	1.7%
Total		Count	46	2	1	7	1	1	58
		% within Site	79.3%	3.4%	1.7%	12.1%	1.7%	1.7%	100.0%
		% within Source	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	79.3%	3.4%	1.7%	12.1%	1.7%	1.7%	100.0%



The Mogollon-Datil Volcanic Province (MD on map) and prominent volcanic fields in the North American Southwest.

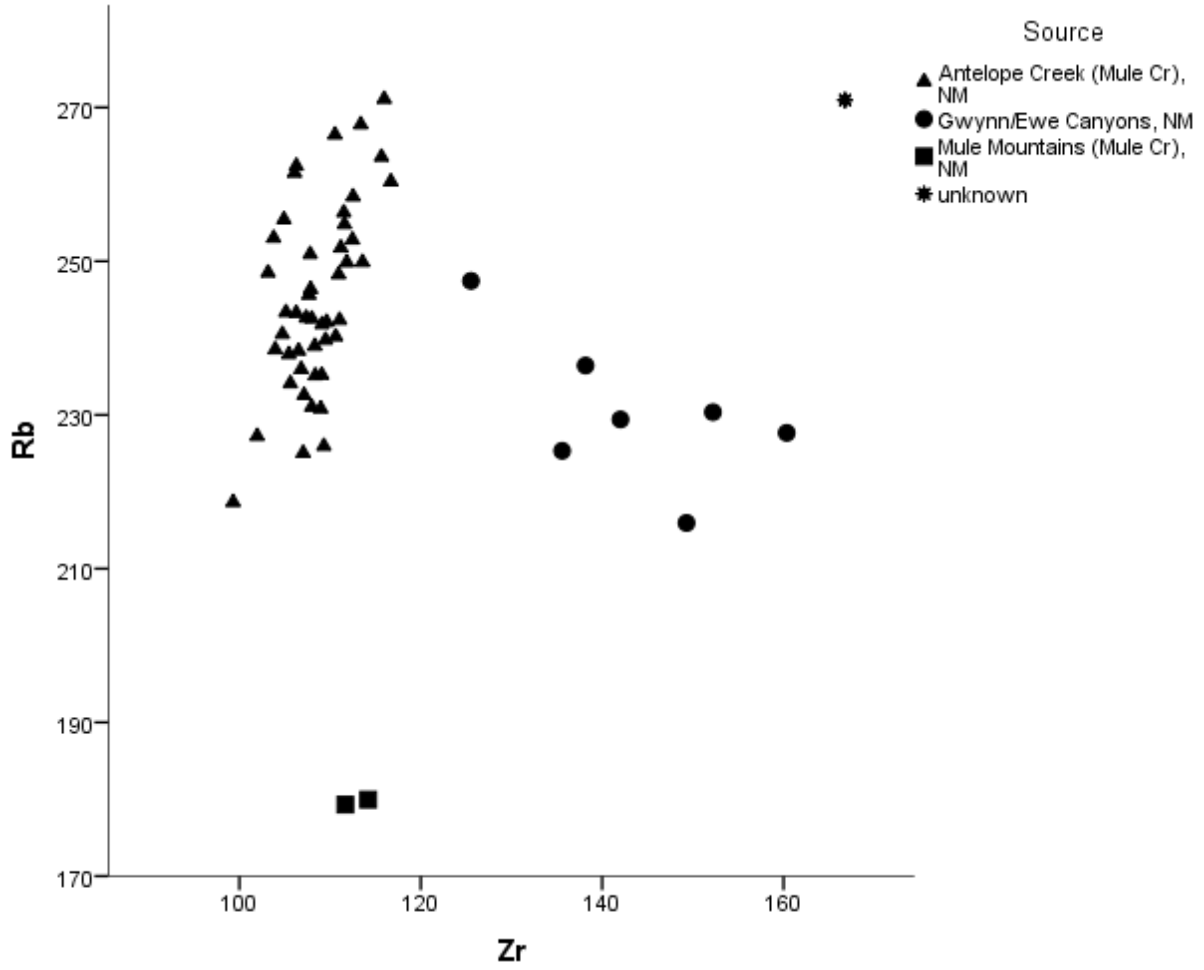


Figure 1. Zr versus Rb bivariate plot of all artifacts. Following plots aid in discrimination.

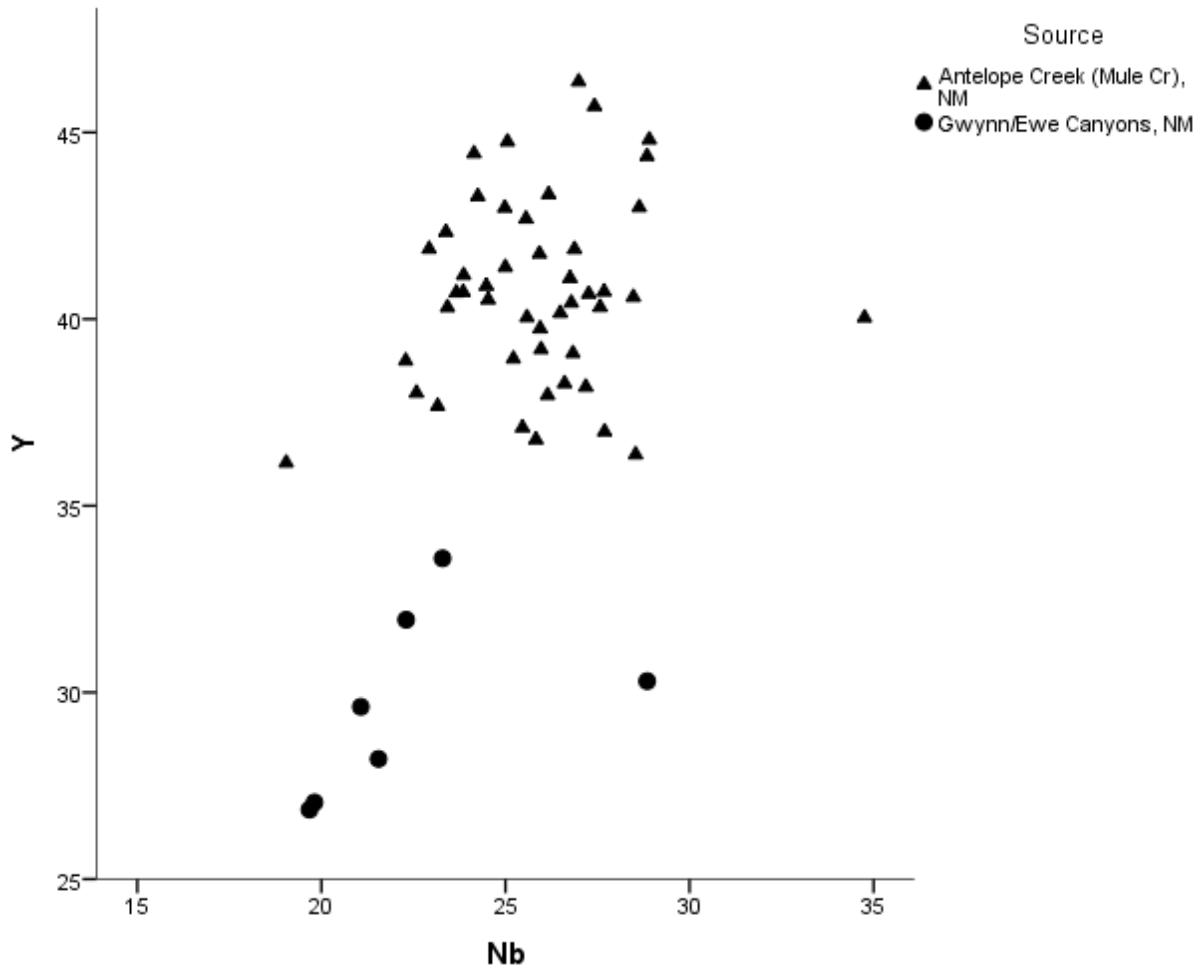


Figure 2. Nb versus y bivariate plot of artifacts assigned to Antelope Creek (Mule Creek) and Gwynn/Ewe Canyon providing discrimination. The Nutt Mountain, Sierra County and Gwynn/Ewe Canyon samples better discriminated in the plot below.

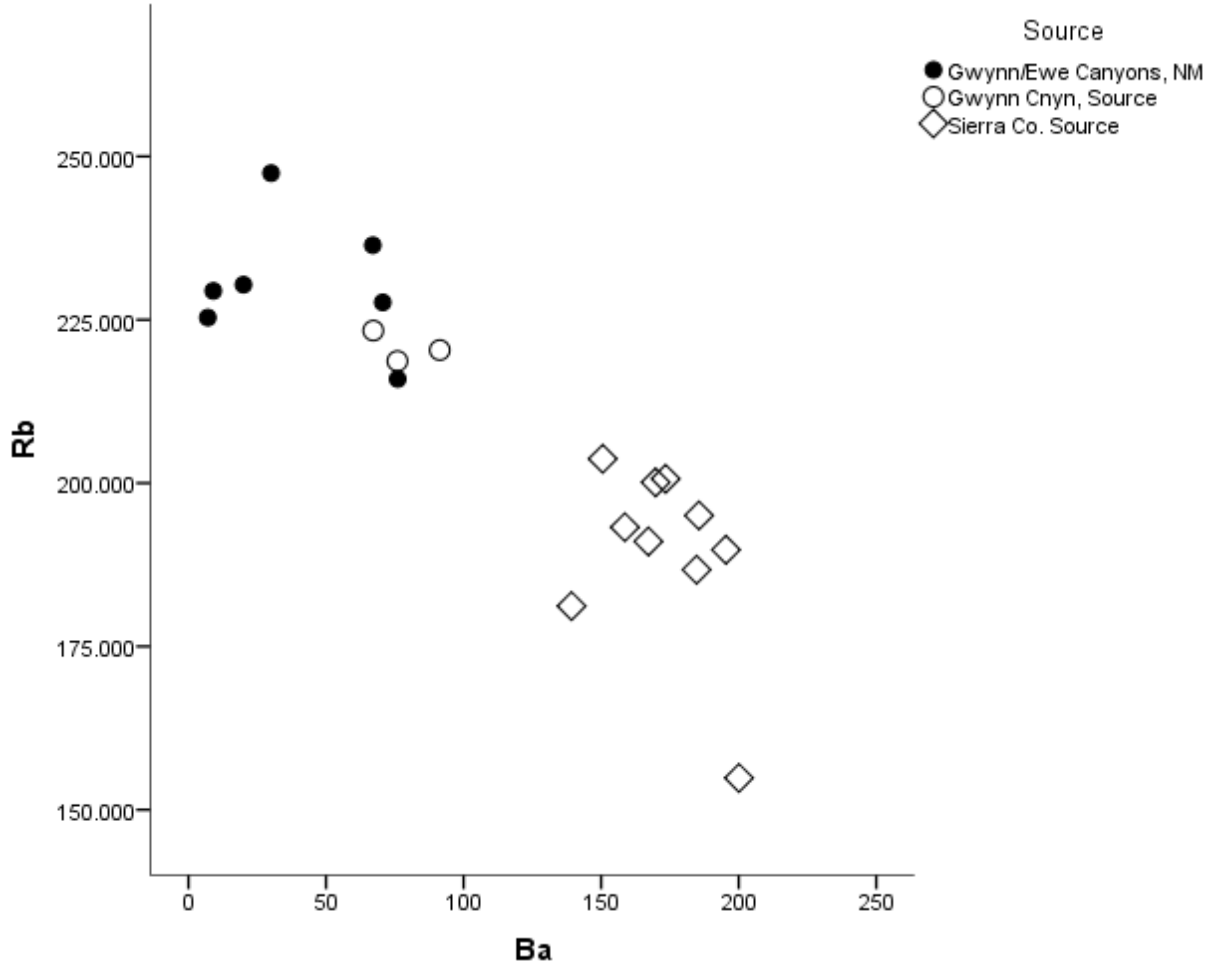


Figure 3. Ba versus Rb plot of Gwynn/Ewe Canyon and Nutt Mountains source standards and the Gwynn/Ewe Canyon assigned artifacts.