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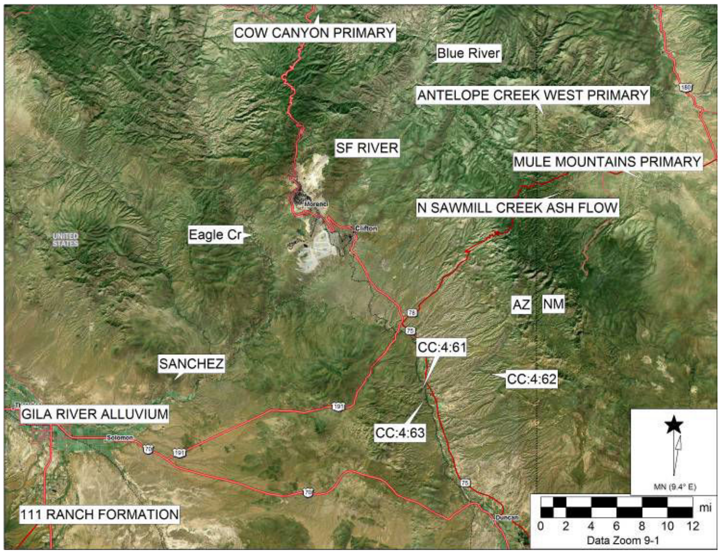

by

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INTRODUCTION

The analysis here of 109 artifacts from three excavated sites from the University of Texas, San Antonio field school, indicates procurement of four of the regional obsidian sources from the Mogollon-Datil Volcanic Province in western New Mexico and eastern Arizona, a similar distribution to the surface collections from these and other sites in the project area (see Shackley 2015; Shackley et al. 2016a). The assemblage overall is dominated by obsidian from the Antelope Creek West locality at Mule Creek, New Mexico, followed by the North Sawmill Creek group, and two artifacts produced from the Mule Mountains source at Mule Creek. All of the four sources are present in San Francisco and Gila River Quaternary alluvium, but there are reasons to infer that at least some of the artifacts were produced from obsidian procured from the primary sources to the north and east (see discussion).

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 University of California, Berkeley. 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.

For the analysis of 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 but Fe where a derivative fitting is used to improve the fit for iron and thus for all the other elements. Further details concerning the petrological choice of these elements in Southwest obsidians is available in Shackley (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). RGM-1 a USGS obsidian standard from Glass Mountain, Medicine Lake Highlands is analyzed during each sample run of 20 to check stability of machine calibration (Table 1). Source assignments were made by comparison to source standards in the laboratory (Shackley 1995, 2005, http://swxrflab.net/swobsrcs.htm; see Tables 2 and 3 and Figures 1 and 2 here; see also Shackley et al. 2016a).

DISCUSSION

While it is typical to see local procurement of secondary deposit obsidian from the San Francisco and Gila River alluvium contexts in sites in this area, the presence of angular cortex on bipolar cores and debitage, and the frequency of North Sawmill Creek obsidian in the excavated assemblage, a source rare in river alluvial contexts, suggests that at least some of the artifacts were produced from obsidian procured from the Mule Creek and Cow Canyon primary sources (see Shackley 1998, 2005). Additionally, a source provenance study of a nearby Middle Archaic site (AZ CC:3:76 ASM) further suggests primary raw material procurement for the field school sites, since North Sawmill Creek obsidian was absent in this relatively large Middle Archaic assemblage (see Shackley 2005:131-133).

Sources in the Assemblage

A discussion of sources is offered in the way of understanding procurement. See also (Shackley 1988, 1989, 1995, 1998, 2005; Shackley et al. 2016a).

Cow Canyon/111 Ranch

The secondary depositional extent of this source is much greater than originally mapped (Shackley 1988). This Tertiary source is eroding east into the Blue River, south into the San Francisco River and west into the Gila River as originally noted, but also erodes in much higher density west into Eagle Creek west of the Blue River, and on south into the Gila River and up to 20 km south into the San Simon River Valley (Figures 3 and 4). A number of "pockets" of Cow Canyon glass have been located in the San Simon River Valley in Pliocene/Pleistocene sediments of the 111 Ranch Formation the result of considerably higher sedimentation rates in these periods than currently (Figure 3). The density of nodules at Eagle Creek approximately 15 km west of the primary contexts at Cow Canyon is up to 1 per $10m^2$, and less than 100 times lower in the Gila River (Shackley 1998). These nodules are mixed with the Mule Creek marekanites in the San Francisco and Gila River alluvium. Nodules up to 5 cm in diameter have been recovered in the 111 Ranch Formation, as large as those at the primary source to the north, suggesting that the sediment load during the Plio-Pleistocene was very great.

Unpublished analyses by the Berkeley Geoarchaeological XRF Lab of over 300 obsidian samples from McEuen Cave (AZ W:13:6 ASM) in the Gila Mountains about 30 km north of the Gila River at Geronimo, indicates that Cow Canyon obsidian comprises over 80% of the assemblage. Most, if not all of the raw nodules were likely procured from the Gila River alluvium in the Safford and San Carlos Valleys (Shackley et al. 2016b).

Cow Canyon obsidian was also the only obsidian source known from the Murray Springs Clovis site in southern Arizona. Two of the fluted points were produced from this glass, likely from nodules around 5 cm in diameter, and probably through bipolar reduction. This is the earliest indication of both obsidian procurement and bipolar technology in the southern Southwest (Shackley 1989:374-388, 2007).

The "primary source" is located in Apache National Forest, central Greenlee County, Arizona. This is a relatively small primary source along and east of Arizona Hwy 191 located in a Tertiary rhyolite body. The nodules are found within an eroded rhyolite/ash unit that appears to be a remnant dome structure. Perlite or vitrophyre was not evident. The nodules are common in a rhyolite regolith on top of the dome as well as the rhyolite/ash alluvium at the base of the slopes. Nodules up to 5 cm in diameter are available, but most of the nodules are near or less than 4 cm. The density of nodules is fairly high in places, up to 5 per m^2. Cortex is mainly a thin gray-black. The interior glass is aphyric and the color is as variable as the mid-Tertiary marekanite sources. The most common color/opacity is a near transparent brown-green sometimes with thin banding. A few specimens exhibit a nearly opaque aphyric gray-green banded megascopic character.

The nodules are eroding and funneled into the Cow Canyon Creek/Turkey Creek system reaching the Blue River 15 km east. Reduced nodules and flakes occur everywhere on the regolith and in the alluvium. The pattern of reduction is similar to Vulture with sporadic bipolar reduction throughout the source area. These specific areas may reach 10-20 per m^2. Overall the rejected core/flake density is less than 1 per 5m^2. Published sources on this locality other than the county geology map (Wilson and Moore 1958), include Shackley (1988, 1995, 1998, 2005).

The Duncan Obsidian Source. Exhibiting similar elemental concentrations as the Cow Canyon and 111 Ranch sources, this source discovered during the 2016 UTSA field school, is compositionally distinct. It does, however, follow the compositional similarity typical of Mogollon-Datil Volcanic Province rhyolites that have been derived from the large Precambrian granite pluton that underlies the province (Elston 2001; Shackley et al. 2016a). Although the Duncan source is near the project sites, no artifacts matching this composition were present in any of the surface or excavated samples. Why this source was ignored is vexing.

The Mule Creek Lava and Ash Flow Obsidian Complex

Including secondary deposition, the Mule Creek sources are some of the geographically largest obsidian sources in the Southwest (Figure 4). Recent research into the Mogollon-Datil Volcanic Province obsidian sources has considerably expanded our understanding of the geochronology and geochemistry of these important sources in prehistory (Mills et al. 2013a, 2013b; Shackley 2015; Shackley et al. 2016a).

The obsidian is, in part, found in a very extensive late Tertiary ash-flow sheet that covers portions of Greenlee County, Arizona, and Catron and Grants Counties, New Mexico (Ratté, 2004; Figure 3 here). The 10+ cm nodule size density at the Antelope Creek West locality reaches 100s per $5m^2$, especially on the top of the ash hills. Erosion into the San Francisco and Gila River systems has been occurring from the Mule Creek sources for 21.98 ± 0.02 Ma with the Mule Mountains event, and even more so with the volumetrically and numerically superior 19.433 ± 0.013 Ma Antelope Creek West event that is located just above the San Francisco River Canyon (Shackley, 1998, 2005; Shackley et al. 2016a; see Figures3 and 4).

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. The caldera structure seen originally by Rhodes and Smith (1972) does seem sensible on first blush, with a central graben surrounded by what could be interpreted as post-collapse ring eruptions including the structures discussed here; the Mule Mountains dome complex, North Sawmill Creek ash flow, and the Antelope Creek dome complex and ash flows (Figure 4). Elston has discussed the different definitions of calderas and cauldrons, and defined a cauldron from Smith and Bailey (1968) "as a structural term for 'all volcanic subsidence structures'" (Elston, 2001:51). He further observes that "in southwestern New Mexico we see faulted and eroded mid-Tertiary cauldron substructures and at best remnants of original caldera topography" (Elston, 2001:51). Using these criteria, Mule Creek could be considered a cauldron.

The obsidian was originally directly dated at the Antelope Creek locality (Antelope Creek East locality herein) to 17.7±0.6 Ma by K-Ar, and at the Mule Mountain locality at the same statistical age (17.7±1 Ma by K-Ar; Ratté and Brooks, 1983, 1989). $^{40}Ar/^{39}Ar$ results in the Shackley et al. (2016a) study suggest that the K-Ar dating of obsidian at the Antelope Creek locality (Antelope Creek East here) were inaccurate, with the Antelope Creek locality now dated at 19.56 ± 0.04 Ma and Mule Mountains considerably older at 21.98 ± 0.02 Ma. A single obsidian marekanite sampled from the perlitic lava at the Antelope Creek East locality by Ratté was used in the original K-Ar dating, as was the marekanite in this study (Jim Ratté, personal communication 2003, and Ratté, 2004; Shackley et al. 2016a). Unusual for geological descriptions of the time, the obsidian proper was discussed as an integral part of the regional geology by Ratté and Brooks in 1989:

> 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; Antelope Creek East locality herein]. 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 (marekenites) which, when released by weathering [termed marekanites here], 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, bracketed comments by Shackley).

Shackley's (1995, 2005) study of Ratté's original locality (now Antelope Creek East) indicated that all of the marekanites exhibit perlitic cracking, and are generally poor media for chipped stone tool production, even though Ratté and Brooks characterized them as "non-hydrated" (see above). Shackley has experimented using bipolar reduction on hundreds of marekanites from this locality since the 1980s and has found only perlitic marekanites, none of them artifact quality (Shackley, 1988, 2005). Furthermore, there are virtually no bipolar cores or flakes present over the large perlitic dome complex at this locality, suggesting as well, that it was not a major toolstone quarry in prehistory (see Shackley, 2005:53-55). Given the poor quality of Antelope Creek obsidian, why were so many Antelope Creek artifacts occurring in prehistoric sites in the region for 14,000 years of prehistory? It was a conundrum for decades with no apparent resolution until the Antelope Creek West locality was discovered in 2013, an ash flow tuff deposit with abundant high artifact quality obsidian marekanites up to 100 mm in largest dimension and plentiful reduced cores and flakes throughout the deposit (Figure 4).

Additionally, the location at the head of Cienega Creek and Antelope Creek flowing directly into the San Francisco River explained the relatively abundant secondary deposits of Antelope Creek obsidian flowing into the Gila River system as much as 100 stream km to the west, and relevant for sites in this study (Shackley 1992, 1998, 2005; Figure 4 here). None of the Antelope Creek obsidian recovered in Gila River alluvium downstream were of the perlitic character seen at Antelope Creek East, indeed recent research indicates that they would not survive stream transport for any distance (Shackley 1992, 1998, 2005, 2012). The elemental composition of the two Antelope Creek localities overlaps significantly, and both differ considerably from the other Mule Creek Complex obsidian sources (Shackley et al. 2016a; Figures 1 and 2 here).

At least four distinct chemical groups are evident in Mule Creek area sources, distinguished by Rb, Sr, Y, Nb, Zr, and Ba, concentration values, and are named after the localities where marekanites have been found in perlitic lava and ignimbrites, originally named by Ratté: Antelope Creek (East and West localities 19+ Ma); Mule Mountains (ca. 22 Ma); and North Sawmill Creek (17+ Ma) all in New Mexico (Ratté 2004, Shackley, 2005). Additionally, during the 1994 field season, a fourth sub-group was discovered as secondary deposits in the San Francisco River alluvium near Clifton, Arizona and in older alluvium between Highway 191 and Eagle Creek in eastern Arizona north of Clifton (Shackley 2005). This ‘low zirconium’ sub-group was discovered in alluvium upstream from the juncture of the Blue and San Francisco Rivers, but the primary source has not been discovered. It is rare in archaeological contexts in the region, and not present in this assemblage.

The Antelope Creek locality after Government Mountain, Arizona, and the Jemez Mountains sources in northern New Mexico was the most significant source of obsidian in prehistory from Paleoindian through historic times, recovered in sites in the region in much greater frequency than any other of the Mogollon-Datil obsidians. Indeed, Antelope Creek obsidian has been recovered as artifacts from western Arizona into Texas, Oklahoma, Kansas, and south well into Mexico (Duff et al. 2012; Hamilton et al., 2013; Mills et al., 2013a, 2013b; Taliafero et al., 2010). The Late Classic inhabitants of the Mule Creek area as well as the Classic Mimbres appear to have seen this obsidian as a commodity. Clovis knappers during the late Pleistocene in New Mexico often used the obsidian for point production, pointing to the Late Pleistocene significance of the area. Mule Creek, in part due to the abundant water, high water table and relatively low elevation, was an important area for human occupation for 14,000 years as it remains today, particularly in the Late Classic of the late 13th and early 14th centuries (Mills et al. 2013a, 2013b).

CONCLUSION

The obsidian source provenance study here, while indicating a regional procurement pattern, nevertheless points to frequent use of the uplands both north and east of these sites as was seen in the surface sample. We know that the Mule Creek area was relatively densely populated during the Late Classic, and drew people to the Mule Creek graben from points throughout the Southwest (Mills et al. 2013a, 2013b). Research for the last decade or more also indicates the prominence of these source throughout prehistory from Paleoindian to at least the Late Classic (Hamilton et al. 2013; Mills et al. 2013a, 2013b; Shackley 1989, 1998, 2005; 2015; Shackley et al. 2016a). It appears that the inhabitants of the UTSA field school sites were just as involved in the region as in all other time periods, the details of which will be left to others.

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

Sample/Bag #	**Site**	**Mn**	**Fe**	**Zn**	**Rb**	**Sr**	**Y**	**Zr**	**Nb**	**Source**
206	AZ CC:4:61	426	12867	256	247	20	44	102	18	Antelope Cr-Mule Creek
208	AZ CC:4:61	385	12126	123	243	23	40	117	29	Antelope Cr-Mule Creek
213	AZ CC:4:61	662	11450	76	459	11	78	112	126	N Sawmill Cr-Mule Creek
225	AZ CC:4:61	534	11399	129	387	14	71	108	105	N Sawmill Cr-Mule Creek
228	AZ CC:4:61	498	11260	87	193	12	25	124	37	Mule Mtns-Mule Creek
239	AZ CC:4:61	502	11228	145	198	18	23	115	29	Mule Mtns-Mule Creek
246	AZ CC:4:61	561	12475	219	160	126	21	144	19	Cow Canyon
250	AZ CC:4:61	584	13345	112	157	125	25	137	19	Cow Canyon
255	AZ CC:4:61	373	12055	93	258	24	41	121	27	Antelope Cr-Mule Creek
274	AZ CC:4:61	501	11890	96	139	112	22	132	19	Cow Canyon
278	AZ CC:4:61	380	11871	108	251	27	44	114	29	Antelope Cr-Mule Creek
279	AZ CC:4:61	436	12677	148	263	25	41	112	26	Antelope Cr-Mule Creek
297	AZ CC:4:61	570	10884	73	426	12	79	105	124	N Sawmill Cr-Mule Creek
298	AZ CC:4:61	615	11348	124	448	14	71	123	121	N Sawmill Cr-Mule Creek
306	AZ CC:4:61	418	12602	102	264	26	41	113	23	Antelope Cr-Mule Creek
308	AZ CC:4:61	367	12339	179	234	24	42	108	22	Antelope Cr-Mule Creek
420	AZ CC:4:61	644	11547	138	447	15	81	112	113	N Sawmill Cr-Mule Creek
427	AZ CC:4:61	669	12027	134	498	14	82	115	122	N Sawmill Cr-Mule Creek
452	AZ CC:4:61	417	12164	73	270	30	45	121	39	Antelope Cr-Mule Creek
462	AZ CC:4:61	469	11418	75	139	141	25	129	12	Cow Canyon
468	AZ CC:4:61	399	11606	109	232	20	42	106	18	Antelope Cr-Mule Creek
537	AZ CC:4:61	418	12280	95	258	20	46	126	28	Antelope Cr-Mule Creek
546	AZ CC:4:61	466	14191	182	274	21	45	116	25	Antelope Cr-Mule Creek
570	AZ CC:4:61	405	12202	122	269	29	42	121	32	Antelope Cr-Mule Creek
592	AZ CC:4:61	383	11663	81	247	23	42	115	24	Antelope Cr-Mule Creek

594	AZ CC:4:61	621	11169	142	432	15	74	104	115	N Sawmill Cr-Mule Creek
621	AZ CC:4:61	462	12874	216	257	26	36	108	25	Antelope Cr-Mule Creek
233-1	AZ CC:4:61	370	11606	72	244	25	42	120	24	Antelope Cr-Mule Creek
233-2	AZ CC:4:61	443	13759	238	252	31	36	106	21	Antelope Cr-Mule Creek
237-1	AZ CC:4:61	377	12330	94	234	23	45	115	30	Antelope Cr-Mule Creek
237-2	AZ CC:4:61	583	11569	91	441	15	75	107	120	N Sawmill Cr-Mule Creek
257-1	AZ CC:4:61	509	11716	88	177	100	22	99	20	Cow Canyon
257-2	AZ CC:4:61	596	11160	85	434	11	80	110	126	N Sawmill Cr-Mule Creek
403-1	AZ CC:4:61	466	11946	182	132	125	15	115	13	Cow Canyon
408-1	AZ CC:4:61	458	12872	202	257	25	39	109	22	Antelope Cr-Mule Creek
408-2	AZ CC:4:61	405	13065	110	221	27	38	108	24	Antelope Cr-Mule Creek
408-3	AZ CC:4:61	425	12535	141	259	23	43	114	27	Antelope Cr-Mule Creek
408-4	AZ CC:4:61	368	11595	67	244	22	39	116	26	Antelope Cr-Mule Creek
408-5	AZ CC:4:61	576	10979	109	441	9	74	111	116	N Sawmill Cr-Mule Creek
410-1	AZ CC:4:61	379	11507	50	244	23	39	115	26	Antelope Cr-Mule Creek
410-2	AZ CC:4:61	416	11240	107	133	127	17	115	18	Cow Canyon
417-1	AZ CC:4:61	403	12100	94	253	21	40	114	26	Antelope Cr-Mule Creek
417-2	AZ CC:4:61	426	12637	195	262	21	42	112	26	Antelope Cr-Mule Creek
417-3	AZ CC:4:61	640	11925	212	430	16	69	101	104	N Sawmill Cr-Mule Creek
Sample/Bag #	**Site**	**Mn**	**Fe**	**Zn**	**Rb**	**Sr**	**Y**	**Zr**	**Nb**	**Source**
486-1	AZ CC:4:61	383	12615	231	238	25	36	107	18	Antelope Cr-Mule Creek
486-2	AZ CC:4:61	426	12265	82	260	23	47	121	24	Antelope Cr-Mule Creek
486-3	AZ CC:4:61	448	12425	262	232	23	38	101	22	Antelope Cr-Mule Creek
487-1	AZ CC:4:61	560	11369	121	460	9	74	109	121	N Sawmill Cr-Mule Creek
487-2	AZ CC:4:61	368	12161	214	235	26	37	110	18	Antelope Cr-Mule Creek
487-3	AZ CC:4:61	400	12430	118	259	25	44	118	22	Antelope Cr-Mule Creek
511-1	AZ CC:4:61	388	11552	54	246	25	49	116	32	Antelope Cr-Mule Creek
511-2	AZ CC:4:61	373	11470	61	228	22	38	112	26	Antelope Cr-Mule Creek

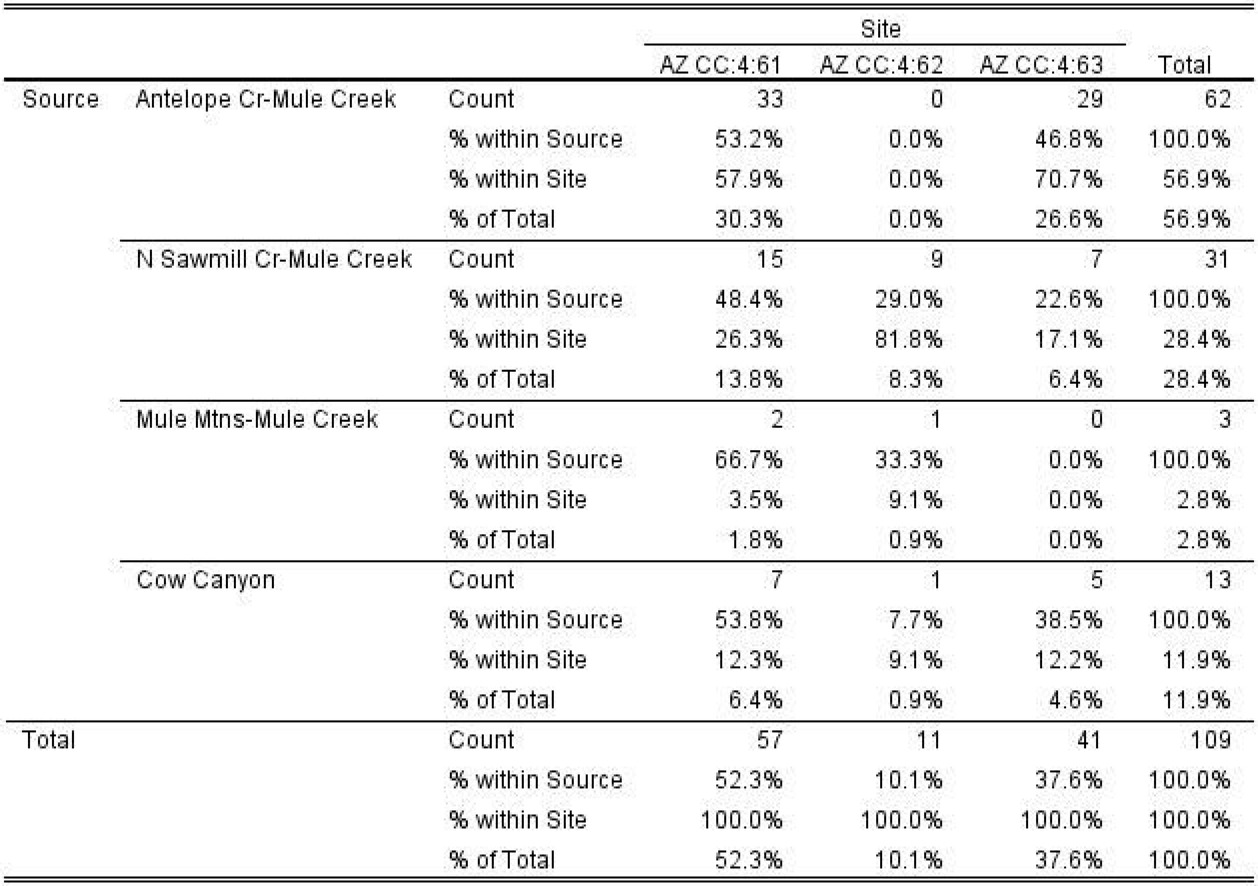
514-1	AZ CC:4:61	403	12360	115	260	24	39	114	31	Antelope Cr-Mule Creek
514-2	AZ CC:4:61	392	11860	125	247	23	43	113	26	Antelope Cr-Mule Creek
554-1	AZ CC:4:61	537	12312	96	419	17	77	110	119	N Sawmill Cr-Mule Creek
554-2	AZ CC:4:61	712	13027	358	463	17	67	106	100	N Sawmill Cr-Mule Creek
554-3	AZ CC:4:61	567	13612	170	398	16	69	105	100	N Sawmill Cr-Mule Creek
10-1	AZ CC:4:62	651	11537	140	467	18	77	109	115	N Sawmill Cr-Mule Creek
10-2	AZ CC:4:62	617	11524	158	442	13	70	110	114	N Sawmill Cr-Mule Creek
14-1	AZ CC:4:62	629	11417	222	415	14	66	98	104	N Sawmill Cr-Mule Creek
14-2	AZ CC:4:62	675	11917	238	446	12	72	105	104	N Sawmill Cr-Mule Creek
14-3	AZ CC:4:62	486	11288	82	192	21	31	128	31	Mule Mtns-Mule Creek
14-4	AZ CC:4:62	676	11428	133	477	14	80	108	121	N Sawmill Cr-Mule Creek
15	AZ CC:4:62	409	11129	54	132	134	21	125	19	Cow Canyon
16-1	AZ CC:4:62	643	11403	94	439	12	75	111	113	N Sawmill Cr-Mule Creek
16-2	AZ CC:4:62	794	13160	220	504	13	70	119	116	N Sawmill Cr-Mule Creek
16-3	AZ CC:4:62	613	11533	117	470	11	79	112	120	N Sawmill Cr-Mule Creek
16-4	AZ CC:4:62	592	11015	98	437	13	76	109	117	N Sawmill Cr-Mule Creek
70-1	AZ CC:4:63	368	11624	80	241	24	40	116	25	Antelope Cr-Mule Creek
70-2	AZ CC:4:63	432	12254	120	269	18	43	114	25	Antelope Cr-Mule Creek
72-1	AZ CC:4:63	425	10546	55	148	87	20	85	17	Cow Canyon
72-2	AZ CC:4:63	429	12255	123	264	24	45	118	29	Antelope Cr-Mule Creek
78-1	AZ CC:4:63	427	10686	53	152	90	21	90	16	Cow Canyon
78-2	AZ CC:4:63	510	11195	69	167	93	22	96	19	Cow Canyon
78-3	AZ CC:4:63	374	11473	62	246	21	43	118	23	Antelope Cr-Mule Creek
78-4	AZ CC:4:63	464	13004	138	288	26	51	130	32	Antelope Cr-Mule Creek
78-5	AZ CC:4:63	369	11361	185	217	24	42	104	21	Antelope Cr-Mule Creek
78-6	AZ CC:4:63	663	11626	156	487	13	70	114	126	N Sawmill Cr-Mule Creek
78-7	AZ CC:4:63	454	12167	91	256	24	39	117	29	Antelope Cr-Mule Creek
96	AZ CC:4:63	421	12152	83	253	21	42	117	35	Antelope Cr-Mule Creek

98-1	AZ CC:4:63	377	11450	62	242	22	47	118	24	Antelope Cr-Mule Creek
98-2	AZ CC:4:63	382	11685	67	244	25	47	116	25	Antelope Cr-Mule Creek
98-3	AZ CC:4:63	355	11184	72	221	22	41	112	32	Antelope Cr-Mule Creek
99-1	AZ CC:4:63	537	10864	78	414	13	81	108	110	N Sawmill Cr-Mule Creek
99-2	AZ CC:4:63	438	10638	57	146	86	20	86	17	Cow Canyon
99-3	AZ CC:4:63	486	11130	113	159	100	24	88	21	Cow Canyon
99-4	AZ CC:4:63	417	11910	121	258	21	35	116	32	Antelope Cr-Mule Creek
99-5	AZ CC:4:63	362	11820	90	251	23	42	124	30	Antelope Cr-Mule Creek
99-6	AZ CC:4:63	394	11765	109	249	23	45	119	26	Antelope Cr-Mule Creek
99-7	AZ CC:4:63	692	11643	141	473	10	77	127	124	N Sawmill Cr-Mule Creek
99-8	AZ CC:4:63	386	11793	98	244	24	46	115	17	Antelope Cr-Mule Creek
99-9	AZ CC:4:63	407	11969	133	258	21	45	113	30	Antelope Cr-Mule Creek

Sample/Bag #	**Site**	**Mn**	**Fe**	**Zn**	**Rb**	**Sr**	**Y**	**Zr**	**Nb**	**Source**
109-1	AZ CC:4:63	358	11316	54	233	22	47	117	27	Antelope Cr-Mule Creek
109-2	AZ CC:4:63	397	11846	90	260	20	46	121	28	Antelope Cr-Mule Creek
109-3	AZ CC:4:63	412	12435	110	282	23	46	129	27	Antelope Cr-Mule Creek
109-4	AZ CC:4:63	432	12071	121	252	19	43	113	31	Antelope Cr-Mule Creek
167-1	AZ CC:4:63	557	11054	95	424	14	79	106	118	N Sawmill Cr-Mule Creek
167-2	AZ CC:4:63	400	12088	152	244	22	47	113	30	Antelope Cr-Mule Creek
145-1	AZ CC:4:63	506	12158	88	274	26	46	121	29	Antelope Cr-Mule Creek
145-2	AZ CC:4:63	461	12441	190	260	22	38	104	27	Antelope Cr-Mule Creek
154-1	AZ CC:4:63	704	11916	147	475	12	75	115	117	N Sawmill Cr-Mule Creek
154-2	AZ CC:4:63	388	11661	96	237	26	42	110	25	Antelope Cr-Mule Creek
154-3	AZ CC:4:63	396	11932	124	253	24	43	110	27	Antelope Cr-Mule Creek
154-4	AZ CC:4:63	696	11585	139	461	12	75	118	119	N Sawmill Cr-Mule Creek
179	AZ CC:4:63	350	11172	61	234	27	44	107	24	Antelope Cr-Mule Creek
149	AZ CC:4:63	418	12506	195	247	26	37	112	20	Antelope Cr-Mule Creek
198	AZ CC:4:63	444	12733	208	259	23	39	109	23	Antelope Cr-Mule Creek

199	AZ CC:4:63	427	12029	58	262	26	45	124	27	Antelope Cr-Mule Creek
200	AZ CC:4:63	695	11845	157	496	14	82	114	122	N Sawmill Cr-Mule Creek
RGM1-S4		298	13726	41	147	107	28	225	11	standard
RGM1-S4		316	13806	39	148	105	26	215	7	standard
RGM1-S4		293	13776	36	152	111	25	220	8	standard
RGM1-S4		285	13653	40	149	109	30	224	5	standard
RGM1-S4		290	13784	41	146	105	22	226	5	standard
RGM1-S4		292	13702	44	146	105	24	225	11	standard

Table 3. Crosstabulation of source by archaeological site.



			Site			
			AZ CC:4:61	AZ CC:4:62	AZ CC:4:63	Total
Source	Antelope Cr-Mule Creek	Count	33	0	29	62
		% within Source	53.2%	0.0%	46.8%	100.0%
		% within Site	57.9%	0.0%	70.7%	56.9%
		% of Total	30.3%	0.0%	26.6%	56.9%
	N Sawmill Cr-Mule Creek	Count	15	9	7	31
		% within Source	48.4%	29.0%	22.6%	100.0%
		% within Site	26.3%	81.8%	17.1%	28.4%
		% of Total	13.8%	8.3%	6.4%	28.4%
	Mule Mtns-Mule Creek	Count	2	1	0	3
		% within Source	66.7%	33.3%	0.0%	100.0%
		% within Site	3.5%	9.1%	0.0%	2.8%
		% of Total	1.8%	0.9%	0.0%	2.8%
	Cow Canyon	Count	7	1	5	13
		% within Source	53.8%	7.7%	38.5%	100.0%
		% within Site	12.3%	9.1%	12.2%	11.9%
		% of Total	6.4%	0.9%	4.6%	11.9%
Total		Count	57	11	41	109
		% within Source	52.3%	10.1%	37.6%	100.0%
		% within Site	100.0%	100.0%	100.0%	100.0%
		% of Total	52.3%	10.1%	37.6%	100.0%

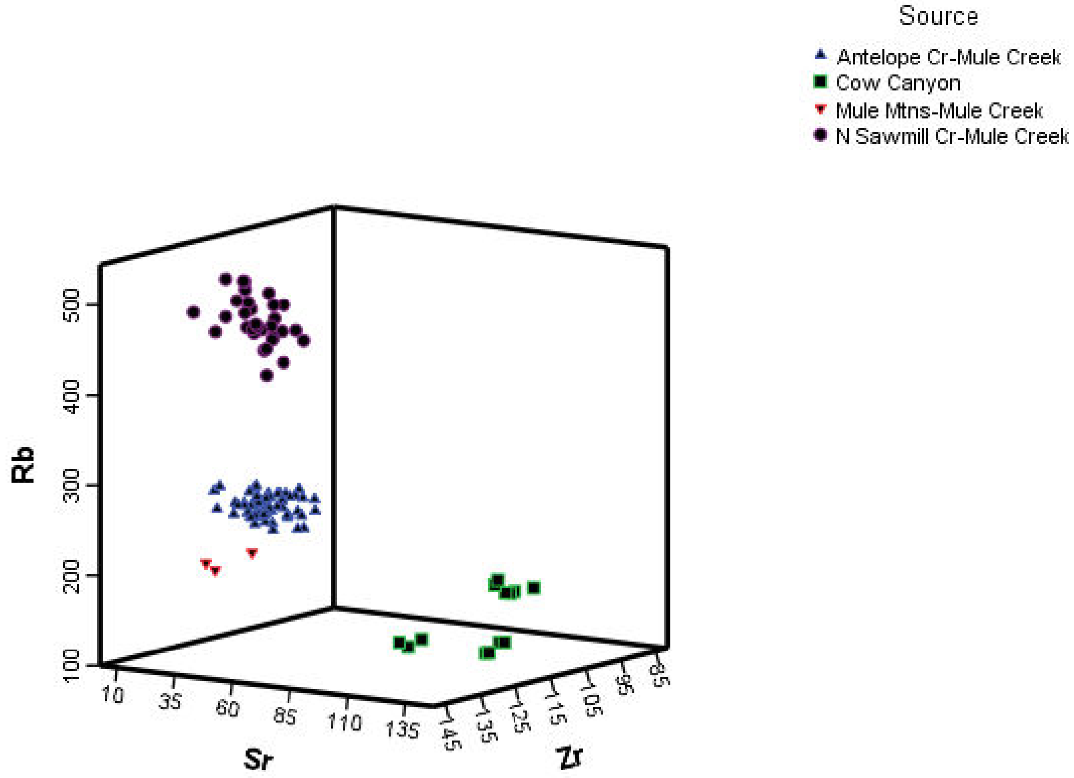


Figure 1. Three-dimensional plot of Sr, Rb, Zr concentrations for all the archaeological specimens from all sites.

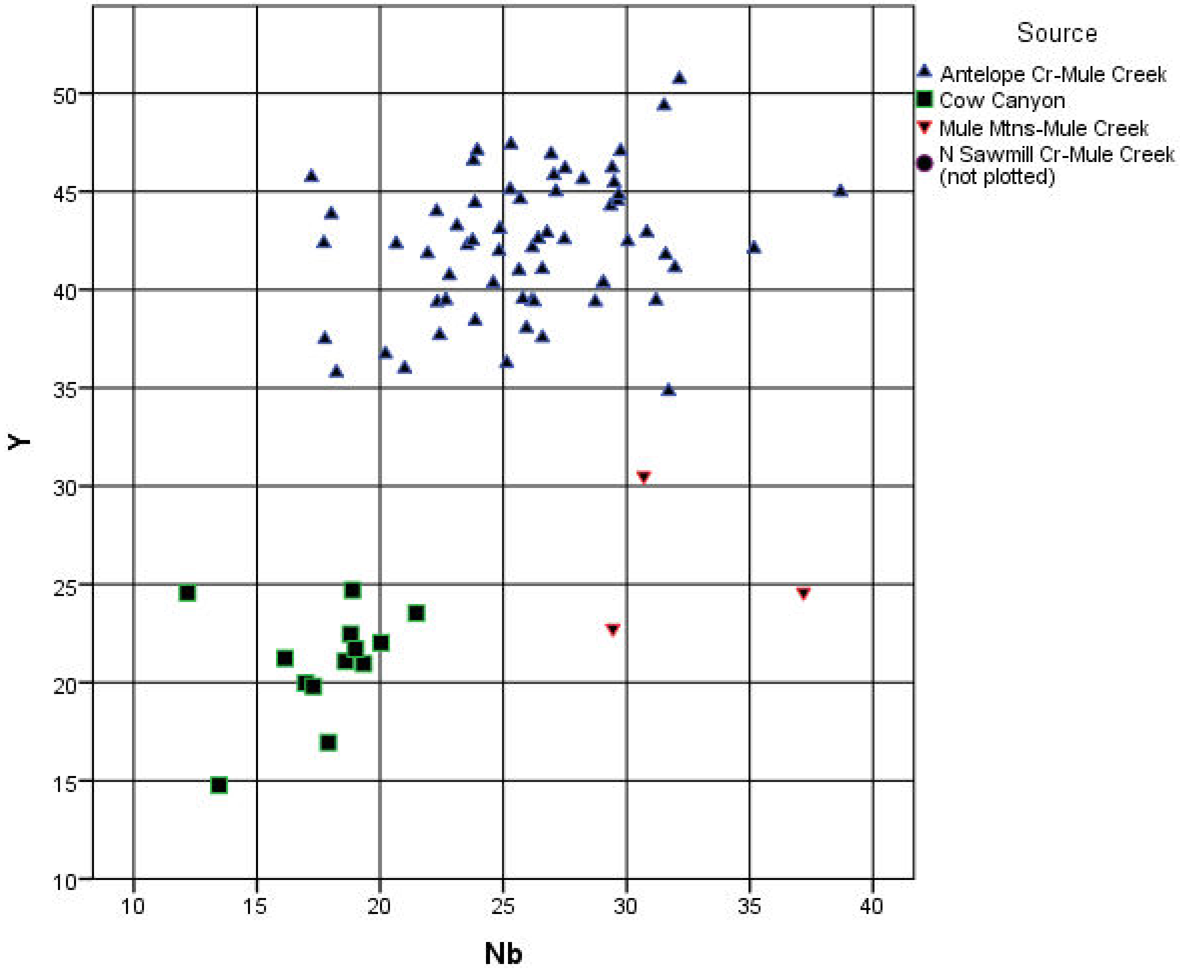


Figure 2. Bivariate plot of Nb versus Y elemental concentrations with North Sawmill Creek samples removed to provide greater discrimination.

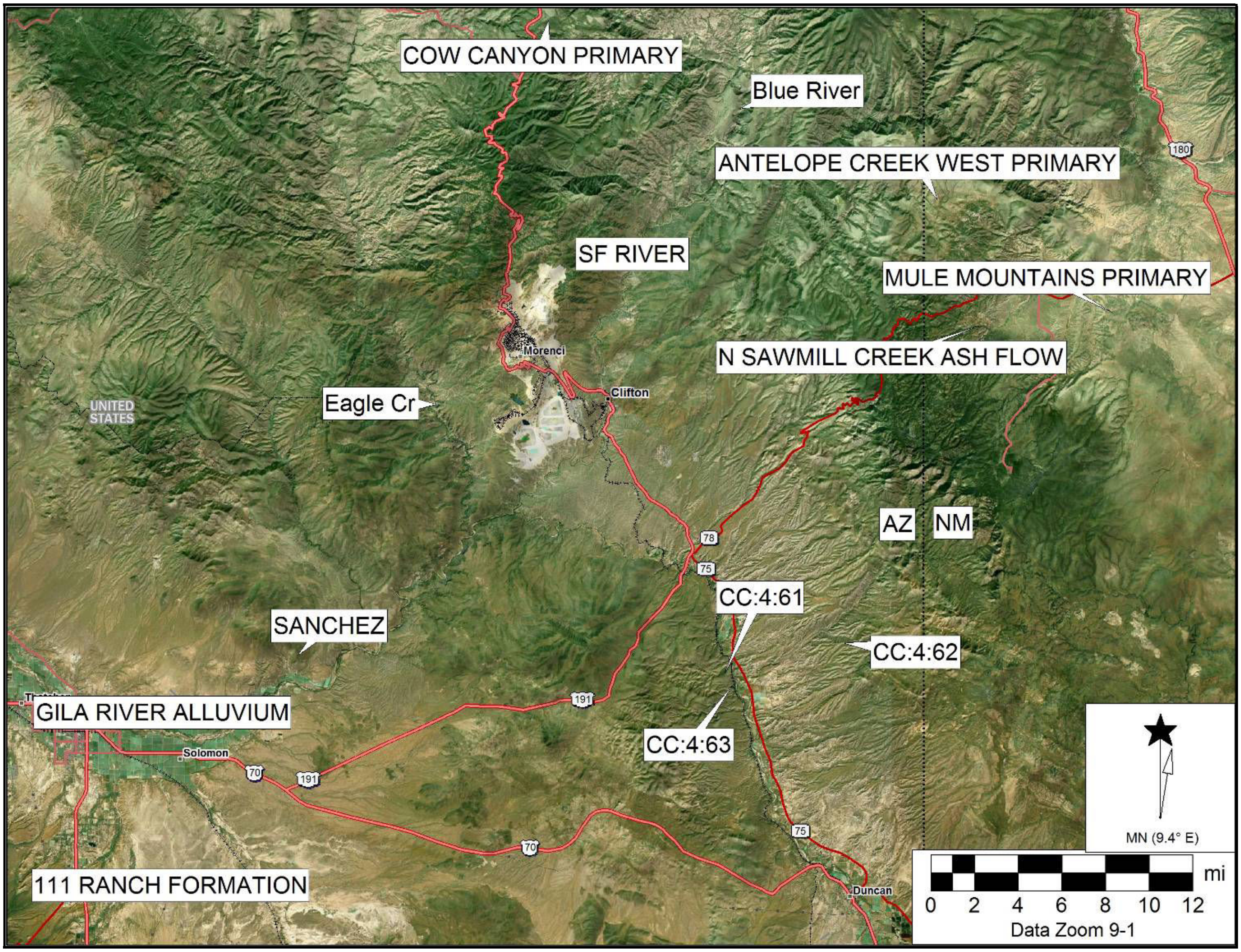


Figure 3. Digital elevation model of site locations, obsidian sources in the assemblage, and relevant features.

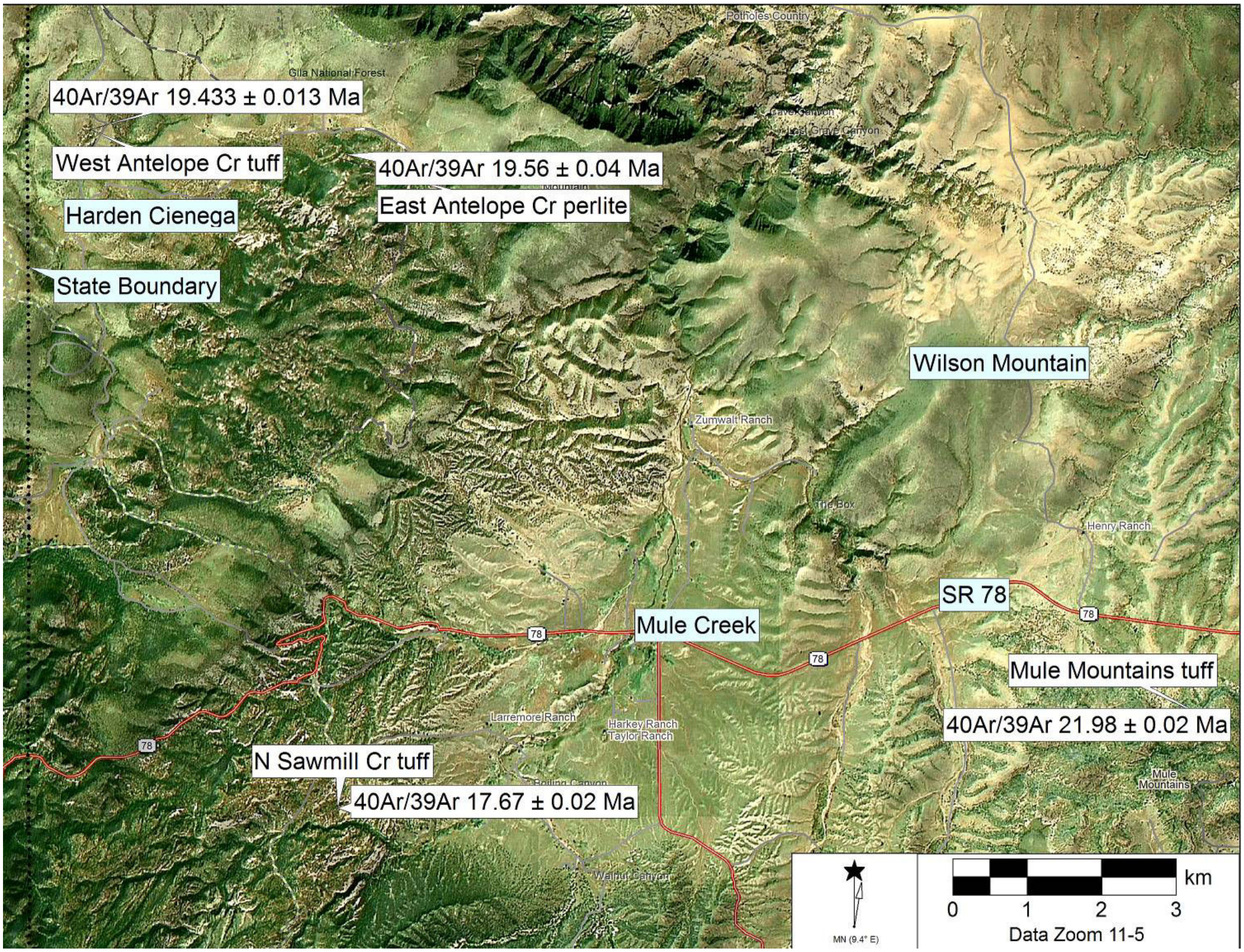


Figure 4. Mule Creek source localities (from Shackley et al. 2016a).