GEOARCHAEOLOGICAL XRF LAB

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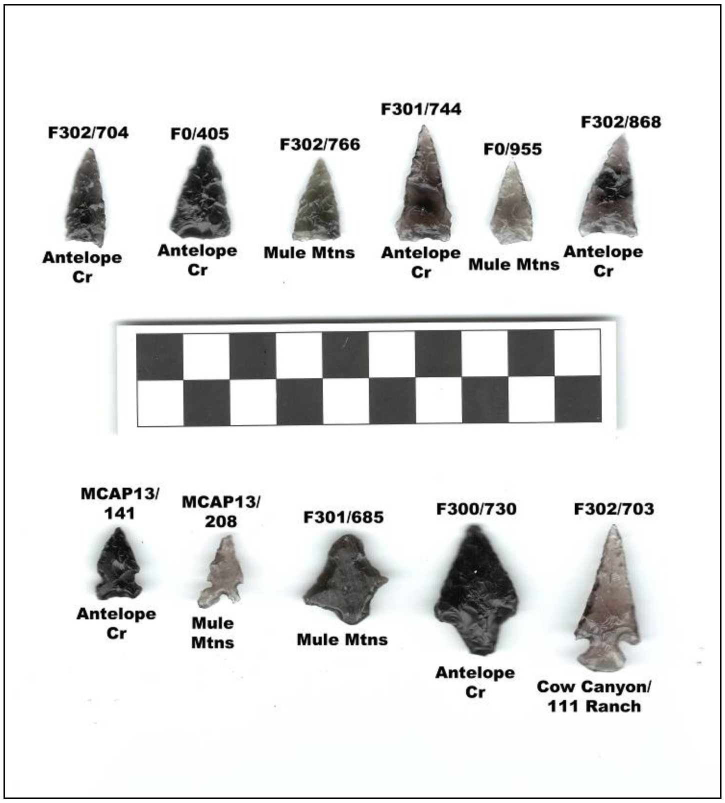
SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM THE DINWIDDIE SITE (LA 106003), CLIFF, WESTERN NEW MEXICO



Sample of projectile points and source provenance from Dinwiddie (see text)

by

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INTRODUCTION

The analysis here of more than 159 obsidian artifacts from the late period Dinwiddie Site (LA 106003) near Cliff, New Mexico indicates a dominance of procurement from Mule Creek sources (97.5%) evenly split between Mule Mountains, the nearest locality, and Antelope Creek farther northwest. Even given the contemporaneity between Dinwiddie and the sites in the Mule Creek Valley proper, the procurement of obsidian for tool production is quite different, here split between Antelope Creek and Mule Mountains (Shackley 2010). This is certainly due to the proximity of the Mule Moutains locality to Dinwiddie. Four artifacts were produced from two other regional sources (Cow Canyon/111 Ranch and Superior) both in Arizona, and one could not be assigned to source (see Tables 1 and 2).

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 (Table 1 and Figures 1 and 2).

DISCUSSION

The Mogollon-Datil Volcanic Province

The Mogollon-Datil volcanic field is part of a discontinuous belt of middle Cenozoic volcanism that runs from the Sierra Madre Oriental in central Mexico, through the Trans-Pecos volcanic field in west Texas, and northward to the San Juan volcanic field in southwestern Colorado (Figure 2). Geological studies of this very large volcanic province began in the 1930s, but in the last decade have essentially ceased as interest grew in other theoretical areas away from studies of crustal extension, particularly for the high-silica fluid depleted rhyolites that produced obsidian (Elston 2008).

Lavas and tuffs erupted from andesitic to silicic volcanoes, domes, and calderas coalesced to form the Mogollon-Datil Volcanic Province in southwestern New Mexico between ~20 to 40 Ma (Chapin et al. 2004; Elston 2008; McIntosh et al. 1991; Ratté et al. 1984). This feature, which includes the mountainous terrain of the Gila Wilderness, covers about 40,000 km2. Initially, andesite volcanism occurred across this region 40 to 36 Ma. Later, both basaltic and andesitic events and silicic calderas formed between 36 and 20 Ma. Many of these eruptive events were very large ignimbrite (tuff) events, many silicic and responsible for the production of obsidian through rapid quenching at the margins and pyroclastic cooling (Elston 2008). During the latter part of the sequence, silicic rhyolite dome complexes were formed as well, sometimes as ring events at the margins of calderas such as at Mule Creek and Gwynn/Ewe (Feathery Hill) Canyons creating the very old artifact quality obsidian (17.7-27.6 by K-Ar) in this important archaeological region (Elston 2008; Ratté 2004; Shackley 2005). The province is composed of two caldera complexes that were active at about the same time. The oldest eruptions of the southern complex occurred in the Organ Mountains near Las Cruces about 36 Ma. Volcanic activity migrated from the Organ Mountains toward the northwest 220 km, ending with the eruption of the 28 million year old Bursum caldera located northwest of Silver City, New Mexico responsible for the Gwynn/Ewe Canyons obsidian dated to 27.6 ± 1.8 Ma by K-Ar). Caldera formation in the northern complex started near Socorro about 32 Ma and migrated toward the southwest, including the Mule Creek caldera complex, one of the most important sources of archaeological obsidian from Paleoindian to the historic period (ca. 14,000 Ka to AD 1540; Hamilton et al. 2013; Mills et al. 2013; Ratté 2004; Shackley 2005). The elemental and isotopic similarity between these obsidian sources is likely the result of near contemporaneous events over the very large area during the latter stages of volcanism in the province sampling similar crustal magma in this case granite plutons (Elston 2008; Shackley 2005).

The Mule Creek Caldera and Ash Flow Sheet Obsidian

Counting secondary deposition, the Mule Creek sources are some of the geographically largest obsidian sources in the Southwest. The obsidian is found in a very extensive late Tertiary ash-flow sheet that covers portions of Greenlee County, Arizona, Catron and Grants Counties, New Mexico (Ratté 2004). The 10+ cm nodule density at the Antelope Creek localities reaches 100s per 5m2, especially on the top of the ash hills. Erosion into the San Francisco and Gila River systems has been occurring for 17 ma (K-Ar date of 17.7 ± 0.6 Ma).

At least four distinct chemical groups are evident, distinguished by Rb, Y, Nb, and Ba, and a lesser extent Zr concentration values, and are named after the localities where marekanites have been found in perlitic lava and ignimbrites: Antelope Creek (East and West localities); Mule Mountains (K-Ar = 17.7 ± 1.9 Ma); and North Sawmill Creek all in New Mexico (from Ratté 2004, and personal communication; Shackley 2005). Additionally, during the 1994 field season, a fourth sub-group was discovered 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 be discovered.

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, it has been recovered as artifacts from western Arizona into Texas, Oklahoma, Kansas, and south well into Mexico (Hamilton et al. 2013; Mills et al. 2013; Taliafero et al. 2010). The Late Classic inhabitants of the Mule Creek area as well as Classic Mimbres appear to have seen this obsidian as a commodity. Clovis knappers in New Mexico often used the obsidian for point production, pointing to the Late Pleistocene value of the area .

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, the locality closest to Dinwiddie and the recently discovered Antelope Creek West locality however, is as good as any in the Southwest.

Dinwiddie Obsidian Projectile Points

The vast majority of projectile points during the late periods in the Southwest are dominated by triangular concave or straight based forms, called Cottonwood Triangular in much of the West (Heizer and Baumhoff 1961; Justice 2002; see also Franklin 1980 for Salado contexts). At least some of these forms could be late stage preforms for the production of side-notched points, but since side-notched obsidian points seem to be uncommon at Dinwiddie, this is likely rarely the case. Most of the obsidian projectile points are typical of late period styles including the concave and straight-base, triangular forms common throughout the West, as well as what have been called Pueblo side-notched by Justice (2002) also common throughout the West, indeed most of western North America during the late periods (Turner and Hester 1985; Whittaker 1984; Figure 3 here). There appears to be an active assemblage of arrowpoint production but little impact damage and rejuvenation evident in the obsidian points. This is likely because of abundant raw material (Mule Mountains obsidian) nearby so that rejuvenation of points was less of an issue.

There was one circular obsidian form in the collection (not illustrated), perhaps an ornament, and sample 685, Feature 301 is flaked unifacially and looks similar to Archaic period cruciforms. It could be a projectile point however.

The corner-notched expanding stemmed point produced from Cow Canyon is also a common form in the Southwest part of what Justice (2002: 240-246) calls the Dolores Cluster, and would also include the stemmed points shown in Figure 3 here. The Cow Canyon specimen could very likely have been procured in exchange from eastern Arizona especially since this form is uncommon in the obsidian assemblage.

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Table 1. Recommended values for USGS RGM-1 obsidian standard and mean and central tendency values from this study. ± = 1st standard deviation.

SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Pb	Th
RGM-1 (Govindaraju 1994)	1600	279	12998	149	108	25	219	8.9	24	15.1
RGM-1 (USGS recommended)[1]	1619±120	279±50	13010±210	150±8	110±10	25[2]	220±20	8.9±0.6	24±3	15±1.3
RGM-1, pressed powder standard (this study, n=9)	1530±34	283±11	13697±29	149±2	108±2	24±1	215±2	8±2	20±1.5	15±3.2

[1] Ti, Mn, Fe calculated to ppm from wt. percent from USGS data.
[2] information value

Table 1. Elemental concentrations and source assignments for the archaeological specimens. All measurements in parts per million (ppm).

Sample	Context/Fea.	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Pb	Th	Source
400	Fea 0	666	356	11557	237	20	38	110	25	27	22	Antelope Cr/Mule Creek
410	Fea 0	567	356	11487	238	23	40	110	28	27	30	Antelope Cr/Mule Creek
423	Fea 0	614	386	11600	241	24	43	113	26	29	34	Antelope Cr/Mule Creek
452	Fea 0	635	390	11707	252	21	43	111	24	31	32	Antelope Cr/Mule Creek
487	Fea 0	804	350	11854	237	26	40	110	26	30	38	Antelope Cr/Mule Creek
516	Fea 0	612	367	11719	249	21	44	112	28	29	32	Antelope Cr/Mule Creek
530	Fea 0	512	341	11423	243	22	42	112	25	31	37	Antelope Cr/Mule Creek
536	Fea 0	586	398	10249	171	16	23	105	29	20	32	Mule Mtns/Mule Creek
405	Fea 0	631	343	11492	242	22	39	112	24	27	29	Antelope Cr/Mule Creek
409-1	Fea 0	651	416	10508	174	19	25	114	31	21	23	Mule Mtns/Mule Creek
409-2	Fea 0	658	434	10540	177	16	25	115	35	22	28	Mule Mtns/Mule Creek
415-1	Fea 0	836	442	10699	183	14	25	116	31	24	29	Mule Mtns/Mule Creek
415-2	Fea 0	519	327	11071	227	20	40	107	26	27	31	Antelope Cr/Mule Creek
434-1	Fea 0	550	357	11384	244	19	43	106	29	27	32	Antelope Cr/Mule Creek
434-2	Fea 0	754	51	1103	20	14	22	11	35	28	31	Mule Mtns/Mule Creek

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439	Fea 0	625	364	11361	233	21	44	106	27	27	38	Antelope Cr/Mule Creek
475-1	Fea 0	767	441	10628	185	16	23	109	33	19	23	Mule Mtns/Mule Creek
475-2	Fea 0	586	376	11694	245	21	45	108	29	28	36	Antelope Cr/Mule Creek
515-1	Fea 0	785	476	10930	184	16	21	110	27	26	25	Mule Mtns/Mule Creek
515-2	Fea 0	1132	436	11747	179	17	23	114	28	26	28	Mule Mtns/Mule Creek
515-3	Fea 0	717	411	10522	173	16	25	113	33	18	25	Mule Mtns/Mule Creek
955	Fea 0	824	516	10990	192	15	25	116	33	21	29	Mule Mtns/Mule Creek
440-1	Fea 300	721	470	10719	196	15	23	109	31	21	23	Mule Mtns/Mule Creek
440-2	Fea 300	753	479	10557	174	15	27	114	34	25	22	Mule Mtns/Mule Creek
440-3	Fea 300	915	480	11058	195	17	26	117	31	30	30	Mule Mtns/Mule Creek
473-1	Fea 300	543	334	9807	134	14	23	96	23	12	22	Superior
Sample	Context/Fea.	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Pb	Th	Source
473-2	Fea 300	1071	669	12126	234	21	26	123	31	35	36	Mule Mtns/Mule Creek?
493	Fea 300	623	376	10134	165	16	21	107	28	17	18	Mule Mtns/Mule Creek
496	Fea 300	772	460	10765	189	16	24	115	35	23	25	Mule Mtns/Mule Creek
550	Fea 300	626	399	11770	255	22	47	114	27	30	37	Antelope Cr/Mule Creek
554-1	Fea 300	821	497	11069	192	15	24	120	32	23	24	Mule Mtns/Mule Creek
554-2	Fea 300	1527	478	12851	186	23	25	122	36	31	28	Mule Mtns/Mule Creek
554-3	Fea 300	876	460	10749	186	17	21	109	33	20	26	Mule Mtns/Mule Creek
621-1	Fea 300	584	330	11489	240	19	42	112	28	25	27	Antelope Cr/Mule Creek
628	Fea 300	550	391	11616	249	20	42	106	25	29	31	Antelope Cr/Mule Creek
632	Fea 300	693	390	11694	243	21	40	104	22	28	37	Antelope Cr/Mule Creek
674-1	Fea 300	720	462	10663	190	16	27	118	32	22	26	Mule Mtns/Mule Creek
674-2	Fea 300	667	384	10151	170	15	27	117	36	17	27	Mule Mtns/Mule Creek
674-3	Fea 300	479	122	9736	-1	25	5	94	6	132	13	not obsidian
677-1	Fea 300	541	352	11087	223	19	37	104	21	25	32	Antelope Cr/Mule Creek
677-2	Fea 300	712	446	10588	184	16	26	112	30	19	29	Mule Mtns/Mule Creek
721-1	Fea 300	641	439	10499	178	15	24	114	31	19	27	Mule Mtns/Mule Creek
727-1	Fea 300	653	42	1046	17	19	23	11	36	23	31	Mule Mtns/Mule Creek

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727-2	Fea 300	873	474	11071	194	17	27	116	29	24	25	Mule Mtns/Mule Creek
727-3	Fea 300	833	474	10904	195	14	28	121	34	25	30	Mule Mtns/Mule Creek
730	Fea 300	607	393	11932	257	21	47	118	31	30	38	Antelope Cr/Mule Creek
756	Fea 300	635	381	11804	248	21	42	107	24	27	46	Antelope Cr/Mule Creek
790-1	Fea 300	976	473	11332	217	17	23	115	30	22	28	Mule Mtns/Mule Creek
790-2	Fea 300	613	398	10330	169	16	21	108	31	19	30	Mule Mtns/Mule Creek
797-1	Fea 300	620	424	10381	172	16	24	111	29	22	23	Mule Mtns/Mule Creek
797-2	Fea 300	762	459	10820	194	17	25	122	31	24	29	Mule Mtns/Mule Creek
860	Fea 300	689	426	10533	187	16	19	115	26	20	20	Mule Mtns/Mule Creek
883	Fea 300	844	433	10813	180	15	23	113	33	25	30	Mule Mtns/Mule Creek
908	Fea 300	524	339	11143	235	19	39	108	30	24	33	Antelope Cr/Mule Creek
929	Fea 300	927	480	11178	181	16	23	115	31	25	26	Mule Mtns/Mule Creek
937	Fea 300	521	371	11394	238	21	40	110	24	26	33	Antelope Cr/Mule Creek
969	Fea 300	716	343	11541	225	26	37	115	24	25	33	Antelope Cr/Mule Creek
970	Fea 300	608	391	10240	166	15	25	111	31	20	26	Mule Mtns/Mule Creek
426-1	Fea 301	655	371	10211	165	15	22	106	28	18	25	Mule Mtns/Mule Creek
426-2	Fea 301	676	457	10544	179	14	24	113	31	23	27	Mule Mtns/Mule Creek
426-3	Fea 301	838	514	11204	194	16	28	123	34	24	24	Mule Mtns/Mule Creek
481	Fea 301	771	451	10645	178	16	23	111	28	23	24	Mule Mtns/Mule Creek
567	Fea 301	732	432	10619	178	14	25	113	31	20	23	Mule Mtns/Mule Creek
577	Fea 301	516	362	11282	236	20	37	108	26	27	36	Antelope Cr/Mule Creek
660-1	Fea 301	610	363	11500	250	22	44	118	28	29	34	Antelope Cr/Mule Creek
660-2	Fea 301	733	446	10656	185	16	25	115	36	20	26	Mule Mtns/Mule Creek
683-1	Fea 301	662	378	11719	243	21	41	111	26	27	40	Antelope Cr/Mule Creek
683-2	Fea 301	612	381	11561	249	20	39	110	27	31	32	Antelope Cr/Mule Creek
683-3	Fea 301	571	382	11793	249	20	40	109	23	33	39	Antelope Cr/Mule Creek
685	Fea 301	833	460	10835	191	16	28	117	30	23	23	Mule Mtns/Mule Creek
688	Fea 301	679	419	12195	272	23	46	119	30	32	38	Antelope Cr/Mule Creek

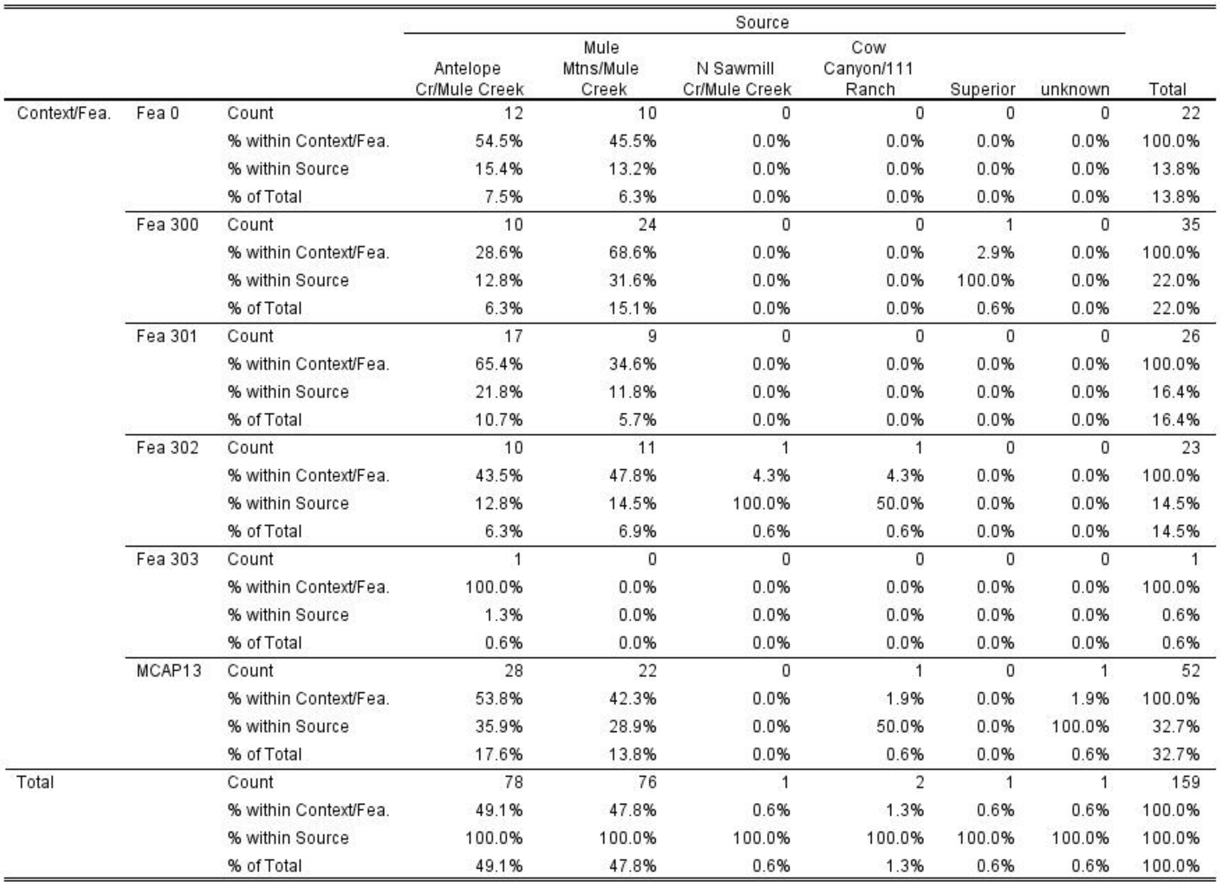
744	Fea 301	743	430	12284	268	22	44	113	30	34	35	Antelope Cr/Mule Creek
748-1	Fea 301	586	380	11824	255	19	41	118	27	26	32	Antelope Cr/Mule Creek
748-2	Fea 301	571	320	11015	229	20	44	104	27	27	29	Antelope Cr/Mule Creek
748-3	Fea 301	875	405	12311	248	22	48	114	32	32	31	Antelope Cr/Mule Creek
Sample	Context/Fea.	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Pb	Th	Source
748-4	Fea 301	698	419	10585	178	15	25	110	32	22	33	Mule Mtns/Mule Creek
748-5	Fea 301	509	339	11268	237	18	42	107	24	25	30	Antelope Cr/Mule Creek
748-6	Fea 301	681	435	10655	181	16	24	113	34	19	24	Mule Mtns/Mule Creek
750	Fea 301	492	342	11095	229	22	43	106	26	26	24	Antelope Cr/Mule Creek
793	Fea 301	583	391	11722	250	22	42	113	22	30	38	Antelope Cr/Mule Creek
833	Fea 301	527	363	11369	236	22	40	108	25	28	33	Antelope Cr/Mule Creek
845	Fea 301	513	377	11386	238	23	43	106	25	26	33	Antelope Cr/Mule Creek
973-1	Fea 301	616	365	11612	243	22	40	114	27	29	38	Antelope Cr/Mule Creek
976	Fea 301	648	364	11622	251	21	44	108	29	33	40	Antelope Cr/Mule Creek
637	Fea 302	456	311	10766	212	19	38	105	27	24	29	Antelope Cr/Mule Creek
637-1	Fea 302	1253	436	12032	180	19	25	119	32	20	26	Mule Mtns/Mule Creek
637-2	Fea 302	531	393	11854	248	17	44	111	27	31	34	Antelope Cr/Mule Creek
700-1	Fea 302	752	451	10691	182	16	23	114	31	23	23	Mule Mtns/Mule Creek
700-10	Fea 302	917	561	11461	217	17	26	124	32	27	26	Mule Mtns/Mule Creek
700-11	Fea 302	598	400	10372	170	14	25	110	35	19	25	Mule Mtns/Mule Creek
700-2	Fea 302	629	519	11090	388	11	73	99	110	32	37	N Sawmill Cr/Mule Creek
700-3	Fea 302	873	475	10959	196	18	26	121	32	25	26	Mule Mtns/Mule Creek
700-4	Fea 302	668	422	10438	175	13	27	111	30	18	26	Mule Mtns/Mule Creek
700-5	Fea 302	579	382	11721	251	19	43	113	31	28	29	Antelope Cr/Mule Creek
700-6	Fea 302	587	398	11999	259	22	46	114	29	32	34	Antelope Cr/Mule Creek
700-7	Fea 302	989	456	11257	186	18	26	114	30	24	30	Mule Mtns/Mule Creek
700-8	Fea 302	668	414	10409	174	14	22	109	28	19	28	Mule Mtns/Mule Creek
700-9	Fea 302	691	437	10590	178	13	22	110	27	21	30	Mule Mtns/Mule Creek
703	Fea 302	806	420	10538	142	88	21	79	18	19	14	Cow Canyon/111 Ranch

704	Fea 302	547	351	11526	248	23	41	108	26	33	33	Antelope Cr/Mule Creek
766	Fea 302	727	450	10656	183	16	23	116	30	22	31	Mule Mtns/Mule Creek
772	Fea 302	553	413	11731	254	21	41	112	24	30	36	Antelope Cr/Mule Creek
828	Fea 302	678	418	10541	178	17	26	112	31	23	27	Mule Mtns/Mule Creek
830	Fea 302	625	386	11632	243	23	40	111	26	32	33	Antelope Cr/Mule Creek
868	Fea 302	492	362	11434	247	20	38	108	28	29	35	Antelope Cr/Mule Creek
905	Fea 302	707	362	11731	251	21	44	115	26	26	25	Antelope Cr/Mule Creek
933	Fea 302	572	325	11161	235	22	44	110	25	25	26	Antelope Cr/Mule Creek
957	Fea 303	616	373	11732	255	23	42	115	26	32	40	Antelope Cr/Mule Creek
104	MCAP13	670	411	10398	171	14	24	110	30	23	27	Mule Mtns/Mule Creek
141	MCAP13	610	374	11778	251	23	45	110	29	30	41	Antelope Cr/Mule Creek
168	MCAP13	645	414	10370	170	13	27	115	35	21	28	Mule Mtns/Mule Creek
175	MCAP13	572	361	11474	240	19	41	108	28	27	35	Antelope Cr/Mule Creek
179	MCAP13	543	377	11679	244	19	40	114	24	29	30	Antelope Cr/Mule Creek
195	MCAP13	816	465	12625	272	23	42	117	32	33	40	Antelope Cr/Mule Creek
208	MCAP13	1004	470	11081	184	15	29	112	31	24	23	Mule Mtns/Mule Creek
213	MCAP13	679	432	10552	185	16	25	115	27	23	25	Mule Mtns/Mule Creek
214	MCAP13	573	396	11615	244	22	41	109	25	27	40	Antelope Cr/Mule Creek
214-2	MCAP13	892	447	12717	270	21	42	122	24	33	38	Antelope Cr/Mule Creek
22	MCAP13	645	453	10704	183	16	21	118	31	25	24	Mule Mtns/Mule Creek
221-1	MCAP13	560	393	11708	252	21	41	113	30	31	38	Antelope Cr/Mule Creek
221-2	MCAP13	662	405	10597	179	15	27	112	26	20	28	Mule Mtns/Mule Creek
233	MCAP13	1017	485	11475	194	16	24	115	31	22	26	Mule Mtns/Mule Creek
237	MCAP13	514	336	11227	233	21	39	110	27	29	30	Antelope Cr/Mule Creek
247	MCAP13	522	359	11675	246	21	44	110	25	31	35	Antelope Cr/Mule Creek
Sample	Context/Fea.	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Pb	Th	Source
253	MCAP13	773	532	11272	204	15	26	121	33	22	34	Mule Mtns/Mule Creek
260	MCAP13	841	488	10915	194	15	27	113	31	26	24	Mule Mtns/Mule Creek
27	MCAP13	604	373	11651	251	20	45	115	28	30	34	Antelope Cr/Mule Creek

275-1	MCAP13	543	343	11527	241	24	47	111	29	32	35	Antelope Cr/Mule Creek
275-2	MCAP13	648	379	11659	248	21	43	110	28	29	38	Antelope Cr/Mule Creek
288	MCAP13	738	362	11426	229	21	42	106	26	30	34	Antelope Cr/Mule Creek
297-1	MCAP13	613	396	12039	257	22	44	113	28	32	43	Antelope Cr/Mule Creek
297-2	MCAP13	854	450	10875	183	14	28	118	29	24	25	Mule Mtns/Mule Creek
330	MCAP13	589	333	11406	232	23	42	109	25	26	30	Antelope Cr/Mule Creek
332	MCAP13	577	333	11178	227	20	40	108	27	27	34	Antelope Cr/Mule Creek
344-1	MCAP13	557	362	11404	236	19	37	108	28	28	30	Antelope Cr/Mule Creek
344-2	MCAP13	659	397	12089	261	23	46	120	29	31	39	Antelope Cr/Mule Creek
344-3	MCAP13	633	463	10585	183	16	21	114	32	19	27	Mule Mtns/Mule Creek
344-4	MCAP13	775	455	10782	179	15	26	113	31	21	22	Mule Mtns/Mule Creek
355	MCAP13	483	307	10879	217	19	39	103	24	22	33	Antelope Cr/Mule Creek
366-1	MCAP13	677	353	11534	238	21	39	113	28	26	35	Antelope Cr/Mule Creek
366-2	MCAP13	849	459	11247	194	17	25	118	33	29	32	Mule Mtns/Mule Creek
366-3	MCAP13	651	387	10505	166	17	24	111	33	18	31	Mule Mtns/Mule Creek
372-1	MCAP13	510	345	11511	248	21	44	110	25	30	34	Antelope Cr/Mule Creek
372-2	MCAP13	883	454	10967	187	17	20	118	35	25	31	Mule Mtns/Mule Creek
382	MCAP13	563	377	11694	248	23	42	110	27	31	30	Antelope Cr/Mule Creek
388	MCAP13	579	336	11367	232	20	44	109	27	26	31	Antelope Cr/Mule Creek
50	MCAP13	712	458	10740	186	14	29	120	36	23	27	Mule Mtns/Mule Creek
52-1	MCAP13	1050	366	12281	224	24	40	112	26	27	30	Antelope Cr/Mule Creek
52-2	MCAP13	1840	411	13053	217	74	30	141	24	22	28	unknown
52-3	MCAP13	903	449	10482	147	89	20	83	14	20	17	Cow Canyon/111 Ranch
52-4	MCAP13	817	443	10802	182	16	26	112	33	20	31	Mule Mtns/Mule Creek
64	MCAP13	763	457	10737	183	15	24	115	32	23	31	Mule Mtns/Mule Creek
66	MCAP13	696	473	10643	182	15	24	116	30	20	27	Mule Mtns/Mule Creek
82	MCAP13	789	412	10488	165	16	24	109	33	17	27	Mule Mtns/Mule Creek
86	MCAP13	699	411	10578	177	16	21	113	29	18	24	Mule Mtns/Mule Creek
89	MCAP13	139	47	1406	24	27	41	11	28	32	31	Antelope Cr/Mule Creek

		2	3	1	1			3				
91-1	MCAP13	538	341	11445	233	23	43	107	28	27	35	Antelope Cr/Mule Creek
91-2	MCAP13	491	327	10837	212	20	38	105	25	21	30	Antelope Cr/Mule Creek
91-3	MCAP13	717	462	10682	185	16	23	114	28	21	23	Mule Mtns/Mule Creek
91-4	MCAP13	556	354	11511	237	23	40	106	28	27	28	Antelope Cr/Mule Creek

Table 2. Crosstabulation of source by locality and collection year. Non-obsidian samples not included.



			Source						
			Antelope Cr/Mule Creek	Mule Mtns/Mule Creek	N Sawmill Cr/Mule Creek	Cow Canyon/111 Ranch	Superior	unknown	Total
Context/Fea.	Fea 0	Count	12	10	0	0	0	0	22
		% within Context/Fea.	54.5%	45.5%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Source	15.4%	13.2%	0.0%	0.0%	0.0%	0.0%	13.8%
		% of Total	7.5%	6.3%	0.0%	0.0%	0.0%	0.0%	13.8%
	Fea 300	Count	10	24	0	0	1	0	35
		% within Context/Fea.	28.6%	68.6%	0.0%	0.0%	2.9%	0.0%	100.0%
		% within Source	12.8%	31.6%	0.0%	0.0%	100.0%	0.0%	22.0%
		% of Total	6.3%	15.1%	0.0%	0.0%	0.6%	0.0%	22.0%
	Fea 301	Count	17	9	0	0	0	0	26
		% within Context/Fea.	65.4%	34.6%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Source	21.8%	11.8%	0.0%	0.0%	0.0%	0.0%	16.4%
		% of Total	10.7%	5.7%	0.0%	0.0%	0.0%	0.0%	16.4%
	Fea 302	Count	10	11	1	1	0	0	23
		% within Context/Fea.	43.5%	47.8%	4.3%	4.3%	0.0%	0.0%	100.0%
		% within Source	12.8%	14.5%	100.0%	50.0%	0.0%	0.0%	14.5%
		% of Total	6.3%	6.9%	0.6%	0.6%	0.0%	0.0%	14.5%
	Fea 303	Count	1	0	0	0	0	0	1
		% within Context/Fea.	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Source	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%
		% of Total	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%
	MCAP13	Count	28	22	0	1	0	1	52
		% within Context/Fea.	53.8%	42.3%	0.0%	1.9%	0.0%	1.9%	100.0%
		% within Source	35.9%	28.9%	0.0%	50.0%	0.0%	100.0%	32.7%
		% of Total	17.6%	13.8%	0.0%	0.6%	0.0%	0.6%	32.7%
Total		Count	78	76	1	2	1	1	159
		% within Context/Fea.	49.1%	47.8%	0.6%	1.3%	0.6%	0.6%	100.0%
		% within Source	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	49.1%	47.8%	0.6%	1.3%	0.6%	0.6%	100.0%

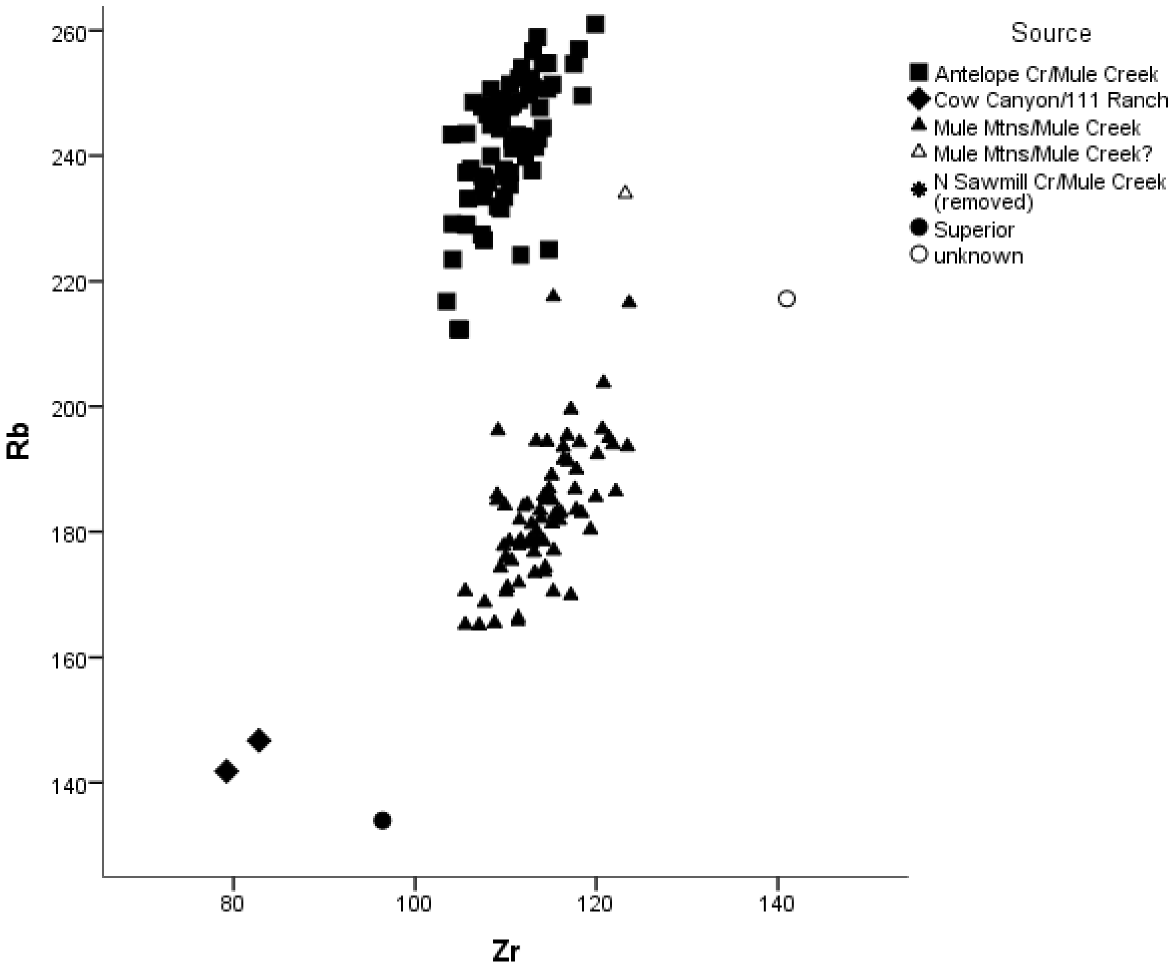


Figure 1. Zr versus Rb bivariate plot of all artifacts. Unique high Rb North Sawmill Creek sample removed for clarity. Following plot aids in discrimination between the Mule Creek localities Antelope Creek and Mule Mountains.

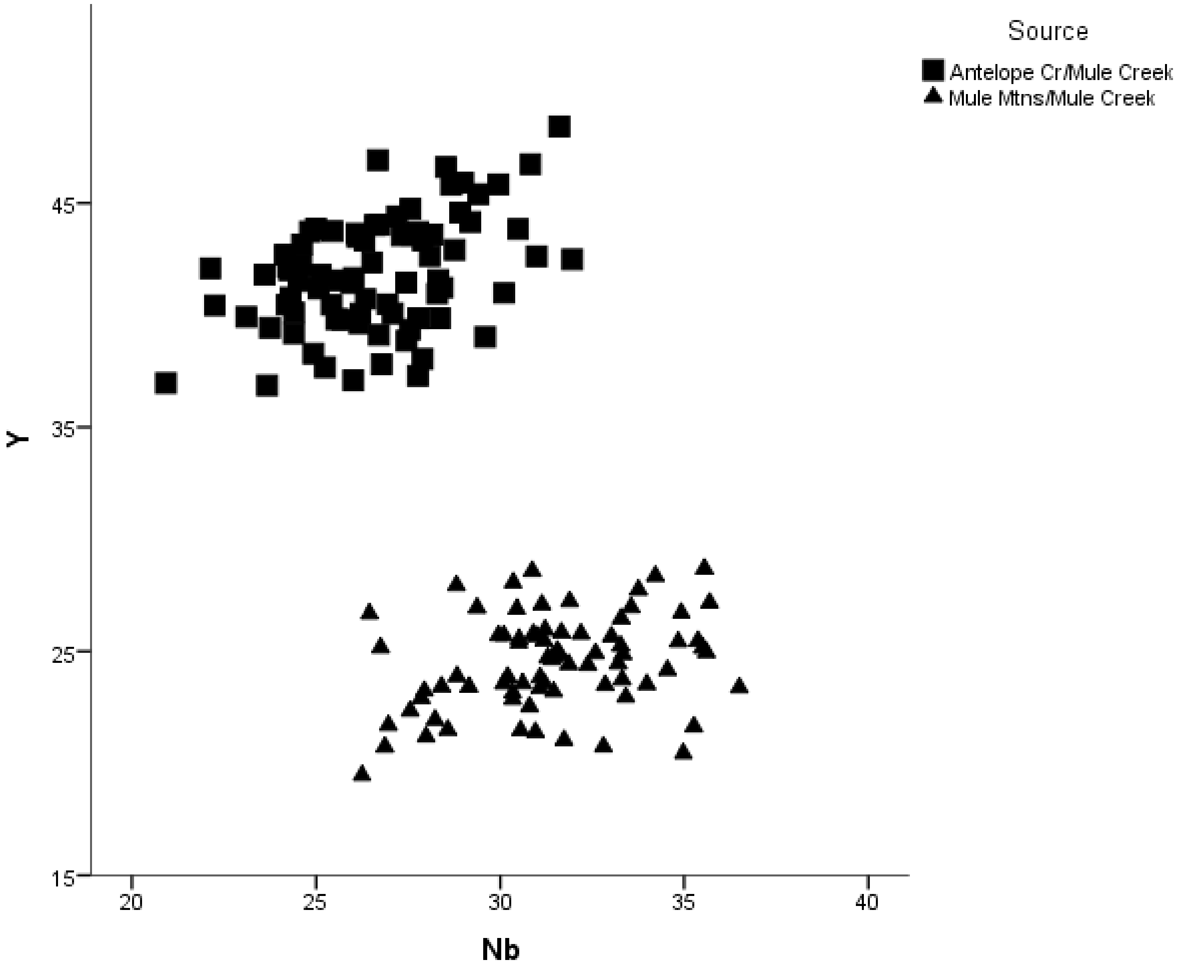


Figure 2. Nb versus Y bivariate plot of the Mule Creek locality artifacts providing greater discrimination.

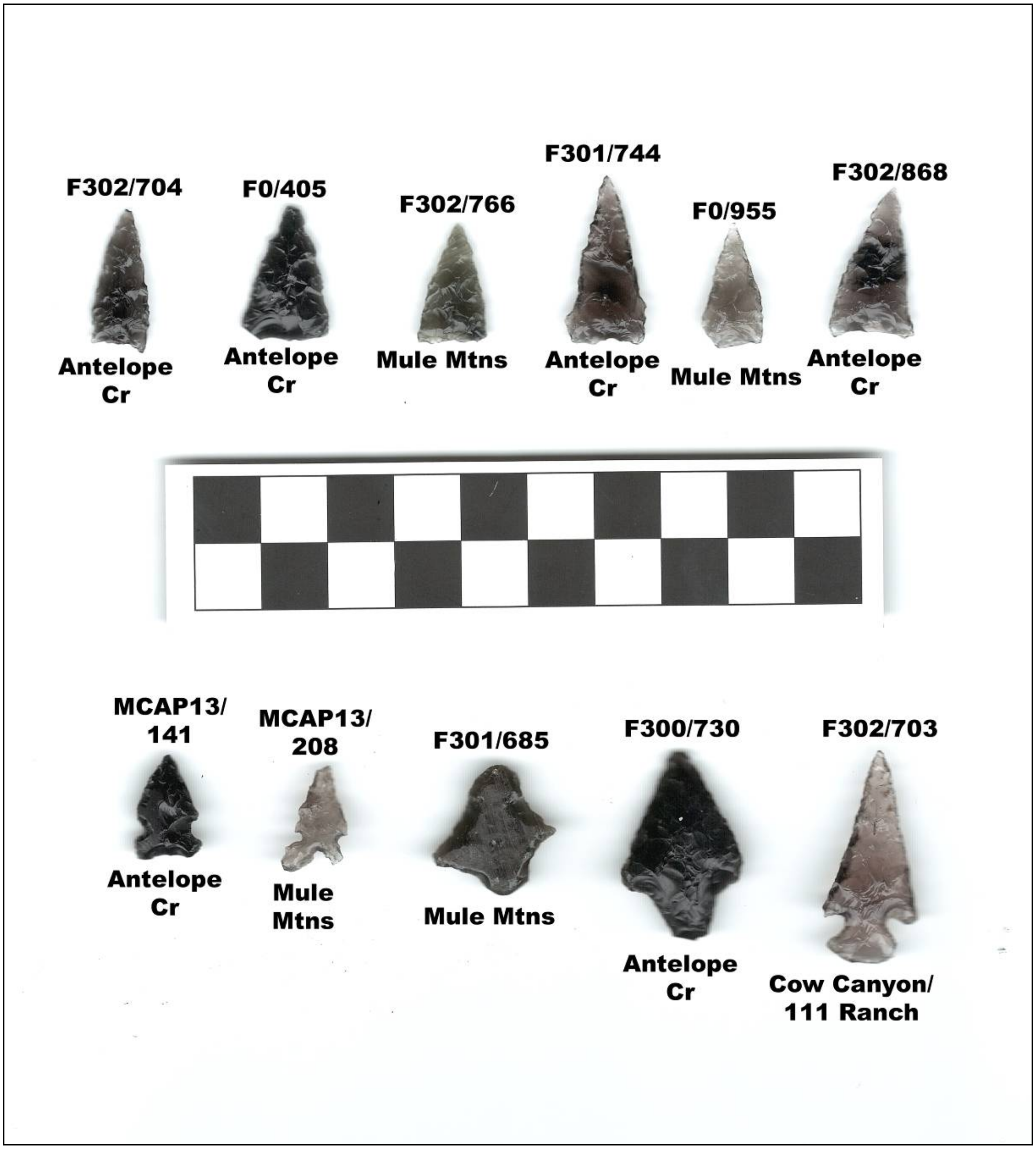


Figure 3. Selected projectile points and source assignments from the Dinwiddie site.