**Title**

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# SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM THE DOS POBRES/SAN JUAN PROJECT, GRAHAM COUNTY, ARIZONA

by

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## INTRODUCTION

The analysis here of 96 obsidian artifacts from Graham County indicates a predictable dominance of local Cow Canyon raw material with some minor Mule Creek source groups. A discussion of these sources is provided relevant to the source assignments.

## LABORATORY SAMPLING, ANALYSIS AND INSTRUMENTATION

This assemblage was analyzed on a Spectrace/Thermo *QuanX* energy-dispersive x-ray spectrometer at the Archaeological XRF Laboratory, Department of Earth and Planetary Sciences at the University of California, Berkeley. All samples were analyzed whole with little or no formal preparation. The results presented here are quantitative in that they are derived from “filtered” intensity values ratioed to the appropriate x-ray continuum regions through a least squares fitting formula rather than plotting the proportions of the net intensities in a ternary system (McCarthy and Schamber 1981; Schamber 1977). Or more essentially, these data through the analysis of international rock standards, allow for inter-instrument comparison with a predictable degree of certainty (Hampel 1984).

The spectrometer is equipped with an electronically cooled Cu x-ray target with a 125 micron Be window, an x-ray generator that operates from 4-50 kV/0.02-2.0 mA at 0.02 increments, using an IBM PC based microprocessor and WinTrace™ reduction software. The x-ray tube is operated at 30 kV, 0.14 mA, using a 0.05 mm (medium) Pd primary beam filter in an air path at 200 seconds livetime to generate x-ray intensity $K\alpha$-line data for elements titanium (Ti), manganese (Mn), iron (as $Fe^T$), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb). Weight percent iron ($Fe_2O_3^T$) can be derived by multiplying ppm estimates by 1.4297(10-4). Trace element intensities were converted to concentration estimates by employing a least-squares calibration line 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). Further details concerning the petrological choice of these elements in Southwest obsidians is available in Shackley (1992, 1995, 2003; also Mahood and Stimac 1990; and Hughes and Smith 1993). Specific standards used for the best fit regression calibration for elements Ti through Nb include G-2 (basalt), AGV-1 (andesite), GSP-1, SY-2 (syenite), BHVO-1 (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), all US Geological Survey standards, and BR-N (basalt) from the Centre de Recherches Pétrographiques et Géochimiques in France, and JR-1 and JR-2 obsidian standards from the Japan Geological Survey (Govindaraju 1994). In addition to the reported values here, Ni, Cu, Zn, Th, and Ga were measured, but these are rarely useful in discriminating glass sources and are not generally reported.

The data from both systems 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. An analysis of RGM-1 analyzed during each run is included in Table 1. Source nomenclature follows Shackley (1988, 1995, 1998, 2005). Further information on the laboratory instrumentation can be found at: http://www.swxrflab.net/. Trace element data exhibited in Table 1 are reported in parts per million (ppm), a quantitative measure by weight (see also Figures 1 and 2).

## DISCUSSION

While the distribution of obsidian source provenance in these sites appears to be entirely local, an understanding of the history of both the primary eruptive events and the secondary distribution through time of the sources is relevant (Figures 3 and 4). A discussion of the two major sources in the assemblage below elucidates the issues.

**Cow Canyon**

It appears that 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 (Figure 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 4). The density of nodules at Eagle Creek approximately 15 km west of the primary contexts at Cow Canyon is up to 1 per 10$m^2$, and less than 100 times lower in the Gila River (Shackley 1992). Again, these nodules are mixed with the Mule Creek marekanites in the 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.

Recent unpublished analyses by the Berkeley Archaeological XRF Lab of over 300 obsidian samples from Late Middle Archaic to Early Agricultural contexts at 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 very similar to the results in this study. Most, if not all of the raw nodules were procured from the Gila River alluvium in the Safford and San Carlos Valleys, although Cow Canyon material is more common in the 111 Ranch Formation than the Quaternary alluvium of the Gila River.

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 1990:374-388).

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 possibly reaching the Blue River 15 km east, and west into the Eagle Creek system and then directly into the Gila River. 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 $5m^2$. There are no published sources on this locality other than the county geology map (Wilson and Moore 1958), and Shackley (1988, 1995, 2005).

## Mule Creek Source Area

One of the most startling recent discoveries is the chemical variability in the Mule Creek obsidian (Shackley 1995, 1998). In the earlier study, I noted two "outliers" collected at Mule Creek with significantly higher rubidium concentration values (Shackley 1988:767). These outliers have now been identified as a distinct chemical group, often mixed in the regional Gila Conglomerate with three other chemical groups. The geology in the area is complex and has been studied by Ratté, and others for some time (Brooks and Ratté 1985; Ratté 1982, 2004; Ratté and Brooks 1983, 1989; Ratté and Hedlund 1981; Rhodes and Smith 1972). Primary in situ perlite localities for three of the chemical groups have been located.

At least four distinct chemical groups are evident, distinguished by Rb, Y, Nb, and Ba, and a lesser extent Sr, and Zr elemental concentrations, and are named after the localities where marekanites have been found in perlitic lava: Antelope Creek; Mule Mountains; and Mule Creek/North Sawmill Creek all in New Mexico (see Shackley 1995, 1998). 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 western Arizona north of Clifton called provisionally San Francisco River nodules. While in situ nodules have not yet been found they are certainly located somewhere west of Blue River and north and west of the San Francisco River since none of this ‘low zirconium’ sub-group was discovered in alluvium upstream from the juncture of the Blue and San Francisco Rivers. The genetic relationship between the Mule Creek localities is apparent in the trace element three-dimensional plot (Figure 1), and signifies the very complex nature of the Mule Creek silicic geology, with subsequent depositional mixing in the Gila Conglomerate. Glass at other Tertiary sources in the Southwest, such as Sauceda Mountains and Antelope Wells, also appear to exhibit more than one chemical mode, although not as distinct as Mule Creek or Mount Taylor, discussed below

(LeTourneau 1994; Shackley 1988, 1990, 1998, 2005). The Mule Creek case is unusual because the chemical groups are not always spatially discrete and occur together in the extensive Gila Conglomerate which is mainly composed of Mule Creek rhyolite and tuffs in the area where the marekanites do occur (see Ratté and Brooks 1989).

*The Mogollon-Datil Province and the Mule Creek 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, 2004; Ratté and Brooks 1983, 1989; Ratté and Hedlund 1981; Rhodes and Smith 1972; Figure 4). 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 (Ratté et al. 1984; Rhodes and Smith 1972; Shackley 1988, 1990). The province has been named Mogollon-Datil for its location and major floristic association (Elston 1965; 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. Most recently, 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 obsidian has been directly dated at the Antelope Creek locality (locality 1 in Figure 4 here) to 17.7±0.6 mya by K-Ar, and at the Mule Mountain locality at the same age (17.7±1 mya by K-Ar; Ratté 2004; 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; Locality 1 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, 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; see also Ratté 2004).

This description adequately characterizes what is found at the other two primary localities (Mule Mountains, and Mule Creek/North Sawmill Creek; see Figure 4). Aphyric, artifact quality marekanites are remnant within perlitic glass lava units. Nodules at all localities are up to 10 cm in diameter although most are under 5 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 1988, 1995; see also Bouška 1993; Hughes and Smith 1993). This glass, as well as the Cow Canyon obsidian, has been found in late period Hohokam and Salado sites west in the Phoenix and Tonto Basins, and in significant quantities at Casa Grande, as well as throughout western New Mexico (Bayman and Shackley 2000; Mitchell and Shackley 1995).

Collections from: USGS Mule Creek 7.5' Quad, Gila National Forest, Grant County, New Mexico; and a road cut at the junction of AZ Hwy 78 and Coal Canyon, Greenlee County, Arizona.  1990s collections: Antelope Creek locality; USGS Harden Cienega New Mexico-Arizona 7.5’ Quad, Gila National Forest, Grant County, New Mexico; Mule Mountain locality; USGS Bear Mountain 7.5’ Quad, and adjoining Mule Creek 7.5’ Quad.

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 is very brittle much like Los Vidrios.  The pressure reduction potential is, however, very good.  The Mule Mountain glass, however, is as good as any in the Southwest, and appears to dominate archaeological assemblages in the western New Mexico region (Shackley 1995, 1998).

The most recent references include Ratté’s excellent mapping study and recent paper (Ratté 2004; Ratté and Brooks 1983, 1989), and Shackley’s examination of the secondary depositional extent of the source into the Safford and San Carlos Valleys to the west (1992, 1998, 2005).

## Specific Comments on the Assemblage

While it is impossible to determine whether the prehistoric knappers in these sites procured the Cow Canyon obsidian from the primary sources north of the project sites, or south in the Gila River alluvium, the distances are so small that it makes little difference (Figure 3).

The same can be said for the Mule Creek source material. The one unknown does not match any known and reported source in the Southwest, however the chemistry (200-300 ppm Rb and Zr) is similar to those in the basin and range region of Chihuahua, such as Sierra Fresnal as reported in Shackley (2005). It does not, however, fit the elemental composition of any of these sources specifically.

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Table 1. Elemental concentrations and source assignments for the archaeological specimens.

| Sample | Ti | Mn | Fe | Rb | Sr | Y | Zr | Nb | Source |
|---|---|---|---|---|---|---|---|---|---|
| 159-1-2 | 960 | 489 | 6402 | 141 | 84 | 21 | 81 | 20 | Cow Canyon |
| 160-1-1 | 944 | 514 | 6658 | 142 | 85 | 17 | 84 | 21 | Cow Canyon |
| 160-14-1 | 1136 | 507 | 8008 | 137 | 132 | 17 | 124 | 17 | Cow Canyon |
| 160-16-1 | 1262 | 544 | 8037 | 139 | 132 | 20 | 126 | 15 | Cow Canyon |
| 160-18-1 | 1407 | 655 | 8525 | 140 | 118 | 30 | 137 | 15 | Cow Canyon |
| 160-19-1 | 1376 | 436 | 6950 | 118 | 120 | 4 | 118 | 10 | Cow Canyon |
| 160-20-1 | 1230 | 485 | 8134 | 136 | 132 | 8 | 124 | 20 | Cow Canyon |
| 168-10-1 | 830 | 415 | 12066 | 283 | 9 | 91 | 253 | 64 | unknown |
| 168-14-1 | 1154 | 420 | 6954 | 122 | 122 | 20 | 115 | 17 | Cow Canyon |
| 168-31-1 | 1152 | 534 | 7942 | 134 | 134 | 17 | 127 | 19 | Cow Canyon |
| 168-40-1 | 1196 | 530 | 8028 | 140 | 136 | 16 | 123 | 17 | Cow Canyon |
| 168-42-1 | 1266 | 473 | 8110 | 137 | 139 | 16 | 123 | 16 | Cow Canyon |
| 168-5-1 | 1136 | 478 | 7594 | 130 | 129 | 20 | 120 | 15 | Cow Canyon |
| 168-57-1 | 1017 | 449 | 7329 | 129 | 128 | 13 | 117 | 19 | Cow Canyon |
| 168-63-1 | 1122 | 515 | 7811 | 138 | 135 | 21 | 121 | 14 | Cow Canyon |
| 168-67-2 | 1189 | 475 | 7801 | 140 | 132 | 17 | 119 | 17 | Cow Canyon |
| 168-67-3 | 1147 | 428 | 7427 | 134 | 132 | 16 | 117 | 13 | Cow Canyon |
| 168-71-1 | 1218 | 476 | 8128 | 132 | 132 | 17 | 125 | 19 | Cow Canyon |
| 168-79-9 | 1145 | 515 | 7742 | 132 | 129 | 12 | 127 | 16 | Cow Canyon |
| 168-90-1 | 1124 | 497 | 7714 | 140 | 132 | 12 | 126 | 9 | Cow Canyon |
| 168-9-1 | 1380 | 513 | 7598 | 134 | 130 | 14 | 126 | 12 | Cow Canyon |
| 169-100-2 | 1294 | 493 | 8014 | 137 | 135 | 16 | 114 | 13 | Cow Canyon |
| 169-149-1 | 939 | 449 | 7221 | 134 | 127 | 13 | 123 | 14 | Cow Canyon |
| 169-151-1 | 1544 | 626 | 7895 | 138 | 110 | 20 | 116 | 21 | Cow Canyon |
| 169-178-1 | 1166 | 532 | 8049 | 138 | 144 | 22 | 121 | 19 | Cow Canyon |
| 169-205-1 | 1186 | 403 | 7023 | 122 | 118 | 13 | 111 | 15 | Cow Canyon |
| 169-232-4 | 969 | 393 | 7941 | 220 | 21 | 41 | 110 | 31 | Mule Cr/AC-MM |
| 169-255-1 | 1285 | 479 | 10331 | 109 | 110 | 23 | 89 | 7 | Cow Canyon |
| 169-26-1 | 1084 | 630 | 7847 | 137 | 149 | 19 | 119 | 21 | Cow Canyon |
| 169-26-2 | 1107 | 500 | 7872 | 132 | 138 | 16 | 119 | 4 | Cow Canyon |
| 169-26-3 | 1110 | 490 | 7784 | 131 | 134 | 23 | 117 | 15 | Cow Canyon |
| 169-26-4 | 1092 | 479 | 6929 | 115 | 103 | 22 | 116 | 19 | Cow Canyon |
| 169-26-5 | 1336 | 695 | 9612 | 148 | 145 | 18 | 119 | 15 | Cow Canyon |
| 169-26-6 | 1106 | 480 | 7836 | 120 | 124 | 23 | 115 | 20 | Cow Canyon |
| 169-26-7 | 1106 | 475 | 6924 | 122 | 123 | 15 | 117 | 14 | Cow Canyon |
| 169-26-8 | 1218 | 510 | 7779 | 134 | 139 | 16 | 133 | 11 | Cow Canyon |
| 169-28-1 | 1262 | 646 | 8391 | 138 | 115 | 19 | 134 | 26 | Cow Canyon |
| 169-301-1 | 1686 | 479 | 7620 | 124 | 126 | 5 | 105 | 16 | Cow Canyon |
| 169-305-3 | 1543 | 480 | 6693 | 128 | 116 | 5 | 113 | 20 | Cow Canyon |
| 169-3-1 | 1338 | 520 | 7513 | 127 | 134 | 18 | 122 | 13 | Cow Canyon |
| 169-312-2 | 1362 | 634 | 7376 | 147 | 88 | 21 | 89 | 4 | Cow Canyon |
| 169-312-3 | 1112 | 584 | 7937 | 138 | 116 | 25 | 129 | 14 | Cow Canyon |
| 169-330-6 | 1368 | 583 | 8310 | 132 | 134 | 19 | 122 | 12 | Cow Canyon |
| 169-37-3 | 987 | 475 | 9234 | 248 | 20 | 45 | 115 | 33 | Mule Cr/AC-MM |
| 169-412-1 | 1105 | 535 | 7682 | 139 | 131 | 18 | 120 | 12 | Cow Canyon |
| 169-415-3 | 1485 | 531 | 8304 | 135 | 139 | 17 | 120 | 19 | Cow Canyon |
| 169-415-4 | 1303 | 480 | 8074 | 136 | 133 | 18 | 121 | 23 | Cow Canyon |
| 169-420-2 | 1392 | 611 | 9138 | 150 | 143 | 19 | 131 | 12 | Cow Canyon |
| 169-42-4 | 1178 | 405 | 8271 | 161 | 94 | 27 | 166 | 16 | Cow Canyon |
| 169-432-36 | 1545 | 543 | 7765 | 125 | 130 | 13 | 108 | 16 | Cow Canyon |

| Sample | Ti | Mn | Fe | Rb | Sr | Y | Zr | Nb | Source |
|---|---|---|---|---|---|---|---|---|---|
| 169-432-37 | 1106 | 625 | 8163 | 137 | 110 | 24 | 132 | 18 | Cow Canyon |
| 169-432-38 | 1322 | 566 | 8150 | 138 | 129 | 10 | 126 | 14 | Cow Canyon |
| 169-432-39 | 1353 | 898 | 8443 | 440 | 10 | 58 | 98 | 121 | Mule Cr/N Sawmill |
| 169-432-40 | 1763 | 609 | 8916 | 163 | 134 | 14 | 117 | 19 | Cow Canyon |
| 169-433-1 | 1319 | 533 | 7292 | 121 | 123 | 15 | 118 | 16 | Cow Canyon |
| 169-435-13 | 1402 | 515 | 7895 | 133 | 133 | 18 | 125 | 17 | Cow Canyon |
| 169-438-13 | 1216 | 446 | 7772 | 141 | 144 | 16 | 124 | 13 | Cow Canyon |
| 169-438-14 | 1011 | 500 | 7234 | 126 | 133 | 10 | 108 | 25 | Cow Canyon |
| 169-438-15 | 1217 | 484 | 7669 | 110 | 107 | 22 | 103 | 22 | Cow Canyon* |
| 169-442-3 | 1117 | 531 | 7898 | 141 | 135 | 15 | 132 | 15 | Cow Canyon |
| 169-442-4 | 1083 | 553 | 6782 | 144 | 85 | 18 | 78 | 25 | Cow Canyon |
| 169-442-5 | 1100 | 655 | 8223 | 144 | 116 | 19 | 131 | 26 | Cow Canyon |
| 169-445-2 | 1144 | 493 | 8022 | 146 | 138 | 18 | 128 | 11 | Cow Canyon |
| 169-447-6 | 1080 | 541 | 6819 | 137 | 84 | 19 | 76 | 24 | Cow Canyon* |
| 169-447-7 | 1069 | 507 | 8049 | 139 | 143 | 16 | 119 | 21 | Cow Canyon |
| 169-450-11 | 1535 | 490 | 8120 | 139 | 151 | 20 | 115 | 14 | Cow Canyon |
| 169-57-3 | 1243 | 500 | 7589 | 123 | 135 | 16 | 120 | 19 | Cow Canyon |
| 169-64-1 | 1081 | 646 | 8133 | 143 | 116 | 18 | 137 | 19 | Cow Canyon |
| 169-71-1 | 1232 | 561 | 7827 | 135 | 107 | 23 | 124 | 19 | Cow Canyon |
| 169-71-2 | 1118 | 477 | 7495 | 133 | 135 | 14 | 115 | 12 | Cow Canyon |
| 188-20-1 | 941 | 553 | 6499 | 141 | 84 | 24 | 78 | 24 | Cow Canyon? |
| 191-24-2 | 1065 | 500 | 6775 | 148 | 86 | 23 | 92 | 12 | Cow Canyon |
| 196-1-1 | 1358 | 425 | 6784 | 122 | 97 | 6 | 115 | 10 | Cow Canyon |
| 203-25-1 | 947 | 431 | 7886 | 229 | 14 | 43 | 112 | 25 | Mule Cr/AC-MM |
| 215-82-2 | 1187 | 465 | 7732 | 125 | 121 | 20 | 122 | 11 | Cow Canyon |
| 220-1-1 | 1235 | 258 | 6696 | 185 | 20 | 36 | 102 | 24 | Mule Cr/AC-MM |
| 269-124-12 | 885 | 407 | 7279 | 207 | 19 | 37 | 101 | 27 | Mule Cr/AC-MM |
| 269-132-1 | 1023 | 510 | 6607 | 135 | 88 | 14 | 78 | 7 | Cow Canyon |
| 269-160-5 | 850 | 734 | 7551 | 429 | 9 | 73 | 109 | 131 | Mule Cr/N Sawmill |
| 269-160-6 | 874 | 663 | 6562 | 379 | 8 | 74 | 109 | 124 | Mule Cr/N Sawmill |
| 269-179-18 | 940 | 500 | 6567 | 143 | 86 | 17 | 78 | 16 | Cow Canyon |
| 269-196-10 | 1056 | 450 | 6162 | 130 | 80 | 17 | 83 | 18 | Cow Canyon |
| 269-196-9 | 1336 | 520 | 8218 | 140 | 144 | 7 | 115 | 17 | Cow Canyon |
| 269-200-9 | 892 | 721 | 7165 | 399 | 13 | 69 | 96 | 124 | Mule Cr/N Sawmill |
| 269-22-1 | 1091 | 459 | 6364 | 125 | 101 | 17 | 97 | 18 | Cow Canyon |
| 269-240-10 | 887 | 497 | 6086 | 133 | 81 | 22 | 86 | 17 | Cow Canyon |
| 269-245-4 | 948 | 388 | 8202 | 236 | 22 | 39 | 112 | 21 | Mule Cr/AC-MM |
| 269-249-1 | 1000 | 485 | 6538 | 149 | 88 | 22 | 89 | 17 | Cow Canyon |
| 269-262-1 | 786 | 598 | 6380 | 369 | 12 | 64 | 98 | 115 | Mule Cr/N Sawmill |
| 269-263-2 | 1076 | 500 | 7790 | 134 | 141 | 15 | 118 | 22 | Cow Canyon |
| 269-263-3 | 903 | 412 | 8368 | 233 | 20 | 38 | 114 | 30 | Mule Cr/AC-MM |
| 269-307-1 | 925 | 681 | 6632 | 382 | 5 | 71 | 99 | 122 | Mule Cr/N Sawmill |
| 269-310-1 | 1224 | 591 | 7991 | 141 | 109 | 26 | 134 | 18 | Cow Canyon |
| 269-35-4 | 970 | 801 | 7669 | 434 | 6 | 75 | 107 | 130 | Mule Cr/N Sawmill |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 269-60-3 | 1080 | 433 | 6109 | 131 | 84 | 23 | 77 | 10 | Cow Canyon |
| 269-77-7 | 1122 | 594 | 7945 | 129 | 100 | 19 | 130 | 12 | Cow Canyon |
| RGM1-S3 | 1557 | 328 | 12907 | 146 | 110 | 22 | 215 | 10 | standard |
| RGM1-S3 | 1536 | 291 | 13033 | 152 | 112 | 20 | 224 | 7 | standard |
| RGM-1-S3 | 1599 | 308 | 12925 | 146 | 111 | 23 | 216 | 5 | standard |
| RGM-1-S3 | 1665 | 322 | 12981 | 150 | 109 | 23 | 221 | 4 | standard |
| RGM-I-S3 | 1529 | 328 | 12862 | 151 | 109 | 22 | 225 | 6 | standard |

* These samples were slightly below the size limit for EDXRF and fall outside the elemental concentrations for these sources, but still likely from those sources (see Davis et al. 1998).

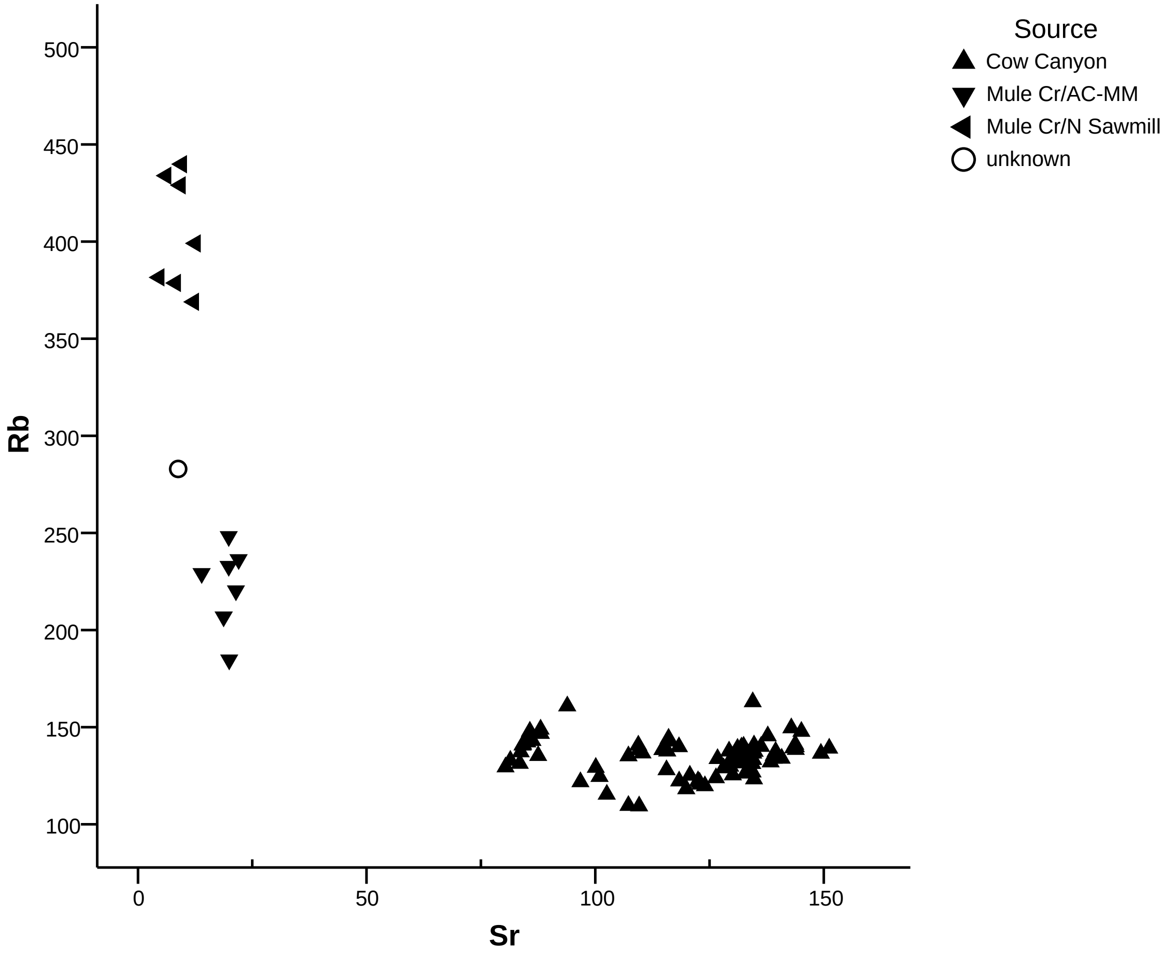

Figure 1. Rb versus Sr biplot of the elemental concentrations for the archaeological specimens.

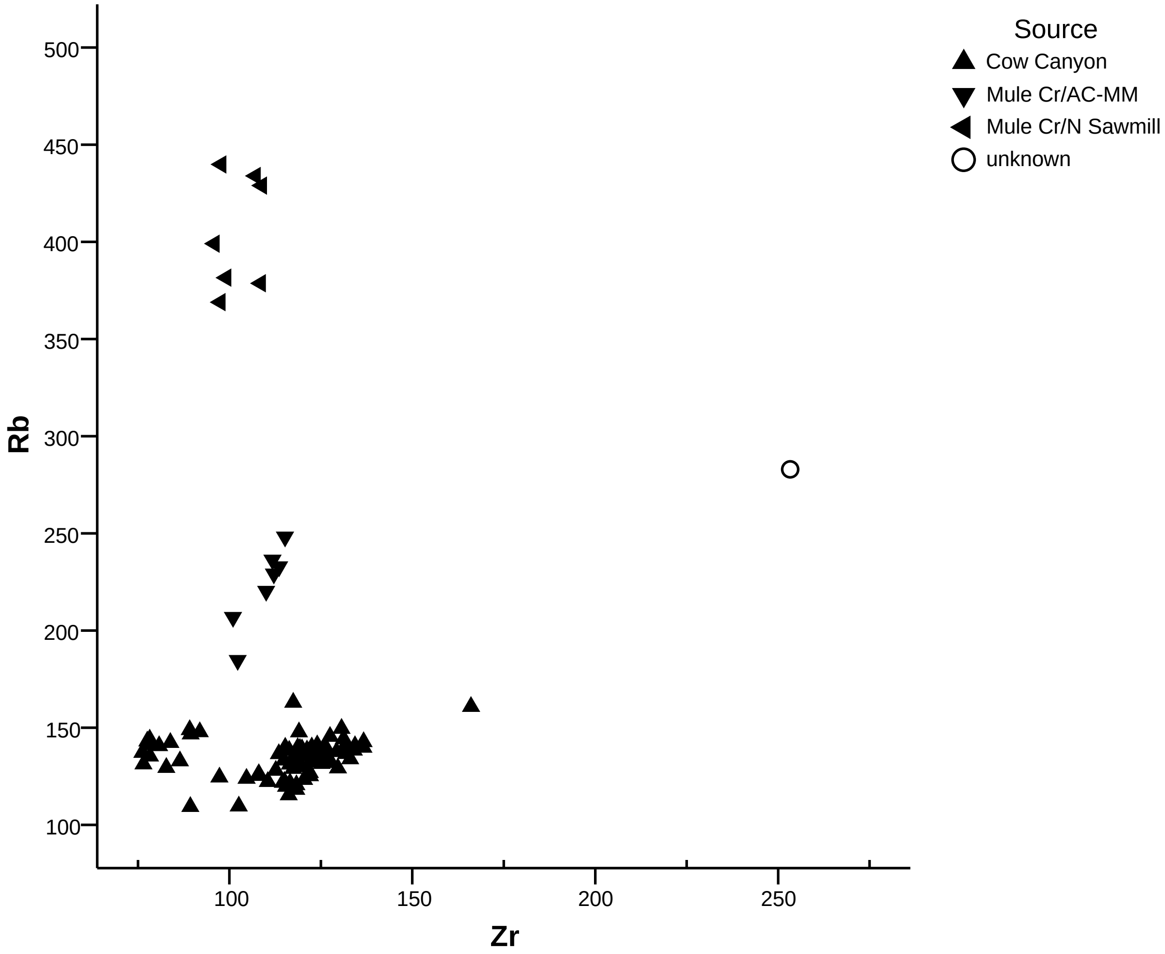

Figure 2. Rb versus Zr biplot of the archaeological specimens.

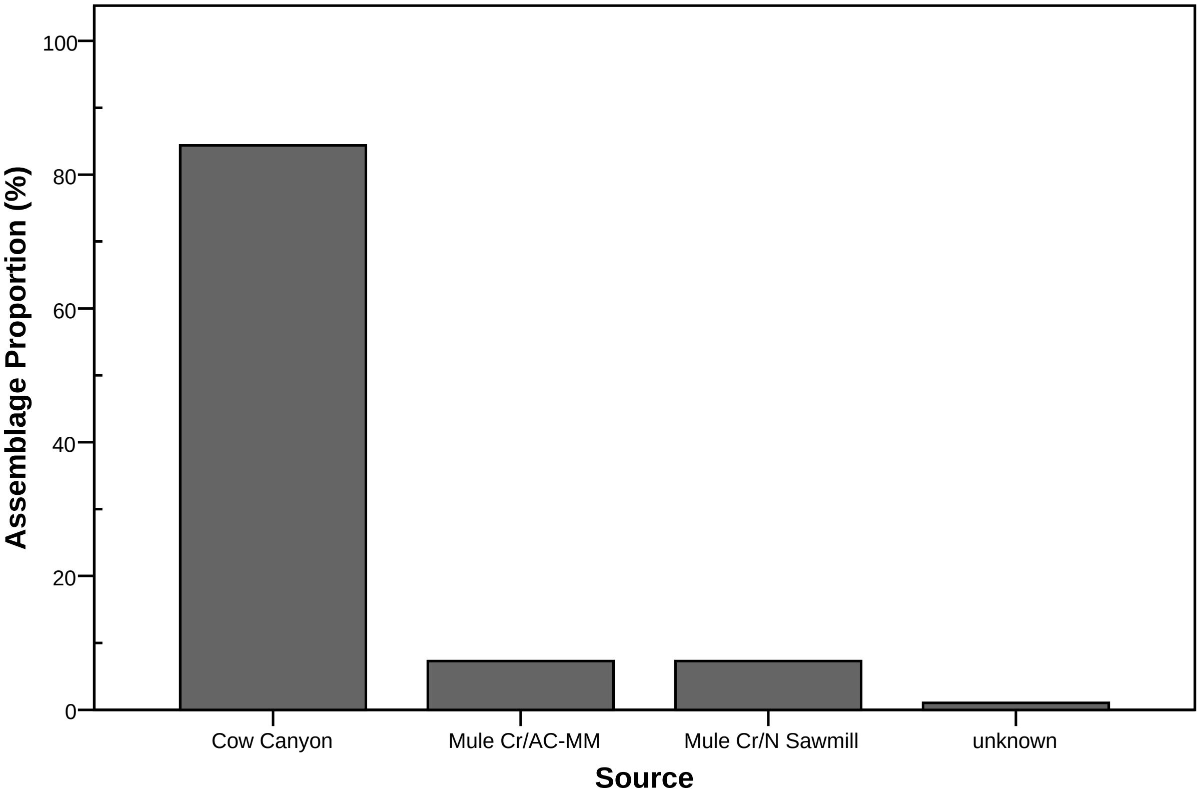

Figure 3. Distribution of obsidian source provenance for all sites combined.

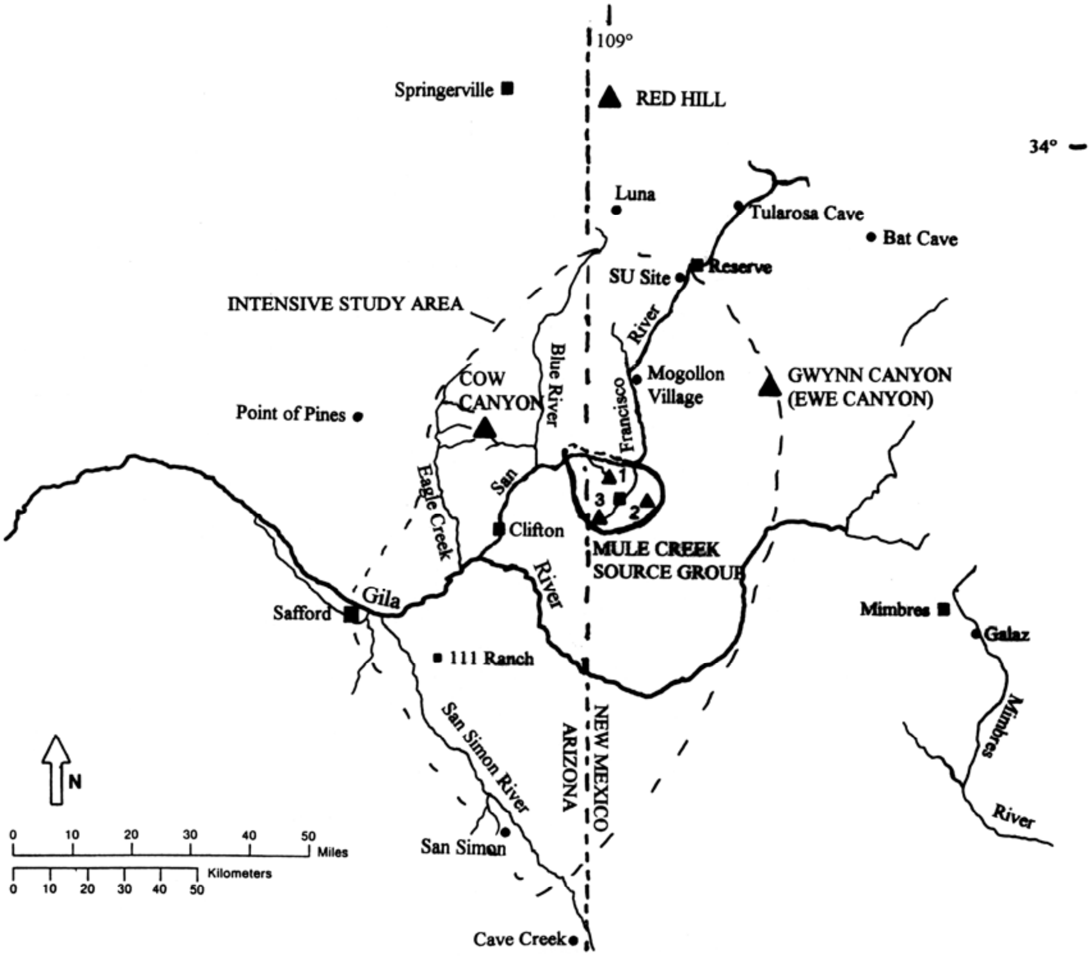

Figure 4. The eastern Arizona/western New Mexico region and sources of archaeological obsidian. Sources = filled triangles; modern towns = filled squares; archaeological sites = filled circles (from Shackley 2005).