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SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM A NUMBER OF SITES IN THE BIG BEND REGION OF SOUTHWEST TEXAS

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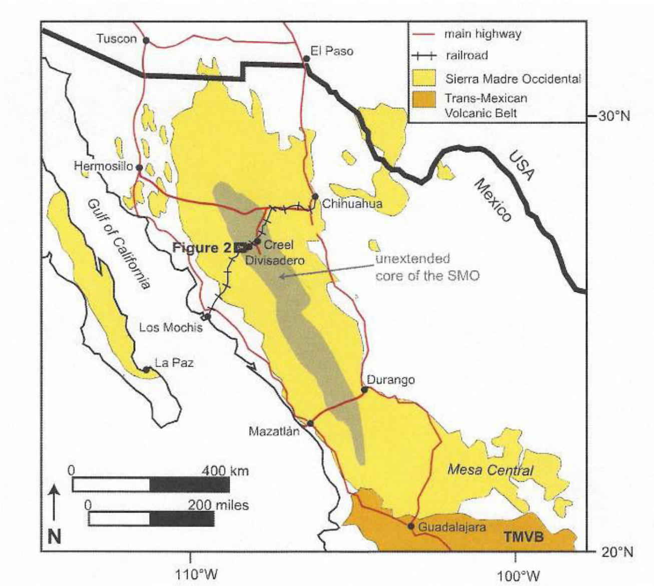

Sierra Madre Occidental volcanic rocks in the northwest Mexico/southwestern Texas region (see Figure 1 here)

by

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INTRODUCTION

The analysis here of 55 obsidian artifacts from a number of sites in the Big Bend Region of southwest Texas indicates procurement of obsidian for tool production from sources in New Mexico, Chihuahua, and a significant as yet unlocated source possibly from the Big Bend region (TX Unknown A). This diverse provenance assemblage is dominated by Cerro Toledo Rhyolite obsidian, a Rio Grande secondary deposit source from northern New Mexico, Los Jagueyes a secondary source along the Rio Santa Maria in northeastern Chihuahua, Sierra Fresnal in the range by the same name, and Lago Fredrico, another source defined by only two source standards (Shackley 2005; see Figures 1 and 2 here). The number of as yet located primary sources in northwest Mexico and probably southwest Texas frustrates provenance studies in the region (cf Lintz et al. 2014; Hughes 2019). Included is a short discussion of the regional geology as relevant for geoarchaeological studies as well as a short description of the sources, and a discussion of results.

ANALYSIS AND INSTRUMENTATION

All archaeological samples are analyzed whole. The results presented here are quantitative in that they are derived from "filtered" intensity values ratioed to the appropriate x-ray continuum regions through a least squares fitting formula rather than plotting the proportions of the net intensities in a ternary system (McCarthy and Schamber 1981; Schamber 1977). Or more essentially, these data through the analysis of international rock standards, allow for inter-instrument comparison with a predictable degree of certainty (Hampel 1984; Shackley 2011).

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

Trace Element Analysis

The analysis for mid Zb condition elements Ti-Nb, Pb, Th, the x-ray tube is operated at 30 kV, using a 0.05 mm (medium) Pd primary beam filter in an air path at 100 seconds livetime to generate x-ray intensity $K\alpha_1$-line data for elements titanium (Ti), manganese (Mn), iron (as $Fe_2O_3^T$), cobalt (Co), nickel (Ni), copper, (Cu), zinc, (Zn), gallium (Ga), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), niobium (Nb), lead (Pb), and thorium (Th). Not all these elements are reported since their values in many volcanic rocks are very low. Trace element intensities were converted to concentration estimates by employing a linear calibration line ratioed to the Compton scatter established for each element from the analysis of international rock standards certified by the National Institute of Standards and Technology (NIST), the US. Geological Survey (USGS), Canadian Centre for Mineral and Energy Technology, and the Centre de Recherches Pétrographiques et Géochimiques in France (Govindaraju 1994). Line fitting is linear (XML) for all elements. When barium (Ba) is analyzed in the High Zb condition, the Rh tube is operated at 50 kV and up to 1.0 mA, ratioed to the bremsstrahlung region (see Davis 2011; Shackley 2011a). Further details concerning the petrological choice of these elements in Southwest obsidians is available in Shackley (1988, 1995, 2005; also Mahood and Stimac 1991; and Hughes and Smith 1993). Nineteen specific pressed powder standards are used for the best fit regression calibration for elements Ti-Nb, Pb, Th, and Ba, and include G-2 (basalt), AGV-2 (andesite), GSP-2 (granodiorite), SY-2 (syenite), BHVO-2 (hawaiite), STM-1 (syenite), QLO-1 (quartz latite), RGM-1 (obsidian), W-2 (diabase), BIR-1 (basalt), SDC-1 (mica schist), TLM-1 (tonalite), SCO-1 (shale), NOD-A-1 and NOD-P-1 (manganese) all US Geological Survey standards, NIST-278 (obsidian), U.S. National Institute of Standards and Technology, BE-N (basalt) from the Centre de Recherches Pétrographiques et Géochimiques in France, and JR-1 and JR-2 (obsidian) from the Geological Survey of Japan (Govindaraju 1994).

The data from the WinTrace software were translated directly into Excel for Windows and into SPSS ver. 21 and JMP 12.0.1 for statistical manipulation. The USGS rhyolite standard RGM-1 is analyzed during each sample run of ≤ 20 samples for obsidian artifacts to evaluate machine calibration (Table 1). Source assignments were made by reference to source data at http://swxrflab.net/swobsrcs.htm, Hughes 2019; Lintz et al. 2014, and Shackley (1995, 2005; Shackley et al. 2018).

GEOLOGICAL BACKGROUND

The geology relevant for obsidian studies in Chihuahua and southwest Texas is dominated by the Sierra Madre Occidental straddling what is now northern Chihuahua, eastern Sonora, and the Big Bend region of southwest Texas (Bryan et al. 2002; Ferrari et al. 2007; see Figure 1 here). Understanding the geology of the Sierra Madre and by extension the understanding of geological sources of obsidian has been frustrated by the difficulty of access to much of the region. Greater than 90% of the geology is unmapped and an appropriate scale further frustrating the discovery of relevant archaeological obsidian sources. The southern region has received some geoarchaeological research on obsidian sources, but that area seems to include only calc-alkalic sources and not the many peralkaline sources so distinctive to the north (Fralick et al. 1998).

The Sierra Madre and outlying basin and range is the third largest single block of rhyolite on Earth, and the largest Cenozoic block in the New World, including much quenched silicic lava that produced obsidian (McDowell and Clabaugh 1979; McDowell and Keizer 1977; Figures 1 and 2). Much of this rhyolite, and by definition obsidian, was produced through volcanism and re-melting crustal granitoids that have a very similar composition over a very large area, most occurring during the Neogene between about 36 and 27 Ma (see Murray et al. 2014; McDowell and Keizer 1977; Shackley et al. 2018). Most of these rhyolites including obsidian sources are part of very large ash flow tuff events that often cover thousands of hectares, some subsequently eroded in to the generally north flowing rivers and on into interior drainage basins like Lago Fredrico (c.f. Lintz et al. 2014; Shackley et al. 2018; Figures 1 and 2 here). Many of these rhyolites and obsidian are classified as peralkaline rocks with distinctive relatively high Fe and Zr, such as Antelope Wells, Los Jagueyes, Lago Fredrico, Lago Barreal, and the as yet unlocated source called TX Unknown A here (see Tables 1 and 2). Many other obsidian sources, particularly in the basin and range portion of Chihuahua are calc-alkalic rhyolites, some with relatively high Sr such as Selene and Sierra Fresnal (see Fralick et al. 1998; Kibler et al. 2014). Following is a short description of the major sources in the northern Chihuahua region. See Shackley (2005; Figure 2 here) for discussions of the sources north of the border that are present in this assemblage, including the secondary deposit obsidian found in Quaternary sediments of the Rio Grande likely as far south as the Big Bend region of Texas; Cerro Toledo Rhyolite, and Valles Rhyolite (Cerro del Medio) originally from the Jemez Mountains in northern New Mexico, and Grants Ridge and Horace/La Jara Mesa sources in the

Mount Taylor Volcanic Field in northwest New Mexico (Shackley 2005, 2012; see also updated online discussion at http://swxrflab.net/swobsrcs.htm). Indeed, Cerro Toledo Rhyolite obsidian is the most common source in this assemblage and the most commonly recovered source in Rio Grande Quaternary alluvium at least as far as Las Cruces (Church 2000; Shackley 2005, 2012).

Chihuahuan and Sonoran, and Possible Texas Obsidian Sources

The northwestern Mexican region including the Big Bend region has remained relatively unknown with regard to obsidian source provenance while the region of the Southwest north of the international border was much more favored, in part due to access (Lintz et al. 2014; Shackley 1988, 1989, 1995, 2005; Shackley et al. 2018). A number of sources in Chihuahua and Sonora were reported by archaeologists and samples sent to this laboratory (i.e. Agua Fria, Lago Fredrico, Sierra la Breña, Lago Barreal). Sierra la Breña and Lago Barreal rarely occur in archaeological contexts, but Lago Barreal has been found in sites in the Big Bend area including this study, likely due to its location just west of the Texas/Chihuahua line (Shackley 2010). In the late 1990s an expedition with members of the El Paso group of the Texas Archaeological Society and I investigated a portion of northern Chihuahua over a two week period. The major sources discovered included the coalesced primary domes of Sierra Fresnal and the Los Jagueyes secondary deposits. In the early 2000s a group of Mexican geologists discovered the Selene source solving one of the long term "unknowns" in the border area and a major source in northwest Mexico and in the international four corners region, although not present in this assemblage (Kibler et al. 2014). In the late 1990s Alan Phelps, then with the El Paso branch of the Texas Archaeological Society sent seven unreduced presumably geological nodules from Lago Fredrico in northern Chihuahua. Five of the nodules were from the relatively nearby primary source of Sierra Fresnal. Two nodules were produced from a peralkaline source not then seen in archaeological contexts, but present in this study as well as at Cerro Juanequeña and Cerro Canelo in northern Chihuahua (Shackley 1999, 2019; Figures 3 through 5 here).

Sierra Fresnal

Over 3.9% of the assemblage was produced from the Sierra Fresnal source, a large set of coalesced rhyolite domes near Lago Fresnal and Lago Guzman (see Shackley 2005:83-84). This is one of the few known sources in Chihuahua with a primary location, and its elemental composition is calc-alkalic and not peralkaline, and appears to not be part of the Sierra Madre volcanic province. The nodules have eroded north at least as far as Nuevo Casas Grandes and into Lago Fredrico. Five of the nodules collected by Alan Phelps at Lago Fredrico are now considered part of the Sierra Fresnal source.

Los Jagueyes and Lago Fredrico

Los Jagueyes is a group of source marekanites discovered on a distributary channel of the Rio Santa Maria, and the source farthest south in this assemblage. The marekanites are secondary deposits, and the primary source(s) have not been located, but have been found frequently in all archaeological contexts in the region including some Archaic sites recently in the region (Dolan et al. 2017, 2019; Shackley 2019). This typical peralkaline obsidian with high Fe and Zr can be discriminated from Antelope Wells and Lago Fredrico, but the distinction must be made carefully. Rubidium is lower and zirconium is higher at Los Jagueyes, but at 95% confidence the two confidence ellipses are close (see Figure 3). Further complicating the issue is that the two source nodules collected at Lago Fredrico over 100 km northwest are very similar in composition (see Figure 3). As shown in the Figure 3 plots, based on these two source samples it is assumed here that if the artifact exhibits a composition over 300 ppm Rb, and 2000 ppm Zr it is assigned to Lago Fredrico. Under those thresholds it is assigned to Los

Jagueyes. Again, both these sources are secondary deposits, and I have not personally visited Lago Fredrico. The proportion of these sources in the assemblage is disproportionate with only 5.9% for Lago Fredrico, but 21.6% for Los Jagueyes.

Cienega Creek Welded Tuff Source

Located in southwest Presidio County, Texas this source occurs as glassy remnants in an ash flow tuff deposit of the Morita Ranch Formation dating to the early Oligocene (Lintz et al. 2014). According to Lintz et al., the obsidian is vitrophyric and "shatters into blocky chunks (2014:284). The samples in this assemblage that match the composition of this source are small, but do appear to be debitage, so there was some prehistoric interest in the source (Table 1). I suspect that the site where these occur is near the ash flow tuff. The "unknowns" in this assemblage do not appear to be from this source as reported in Lintz et al. (2014:288-289).

Other Unlocated Sources

Four of the artifacts were produced from sources that are as yet unlocated and not seen in analyses at this lab (see Table 1 and 2). They are not from the more southern Chihuahuan sources as reported by Fralick et al. (1998).

Nearly 12% of the artifacts in the assemblage is from a source with relatively high Zr that I have not seen in Chihuahuan assemblages but have been seen by other laboratories. Hughes in January of this year analyzed three artifacts that also exhibit the same elemental concentration from Spirit Eye Cave (41PS25) in Presidio County, Texas in the Big Bend region (Hughes 2019). Given that somewhat extensive studies of obsidian artifacts in Chihuahua have not recovered artifacts produced from this source, I have taken the liberty of calling it TX Unknown A. If the primary source is discovered it could be in far northeast Chihuahua, but could also be located in the Big Bend region of Texas where Sierra Madre Occidental rhyolites are present (see Figure 1).

It is readily apparent that northwest Mexico, and probably southwest Texas remain mainly unknown with regard to the location and understanding of archaeological sources of obsidian unlike the Southwestern region north of the border (Shackley 2005). Much is left to be done.

Results of the Analysis

Figures 3 through 5 illustrate the stepped analytical procedure used to discriminate the sources (Shackley et al. 2018). In Figure 3 the elemental similarity between the three major peralkaline obsidian source in the region is apparent. While these sources are 100s of kilometers distant, as discussed above are similar compositionally due to re-melting the grantitoid basement in the region (see also Shackley et al. 2018). The stepped analytical process using various elements to discriminate the source provenance is apparent in Figures 4 through 6. The calc-alkalic sources are easier to discriminate due to differing eruptive sequences or fractionation of the re-melted crust (Shackley et al. 2018).

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Table 1. Elemental concentrations and source assignments for the obsidian artifacts and USGS RGM-1 rhyolite standard. All measurements in parts per million (ppm).

CBBS#	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Source
14	654	548	9932	135	210	15	71	184	100	Cerro Toledo Rhy
15	1496	994	34141	353	291	17	158	1418	122	Los Jagueyes
16	767	671	19010	186	285	10	97	787	120	TX Unknown A
17	913	313	9749	81	298	45	62	160	28	Sierra Fresnal
18	430	470	9452	158	269	25	84	215	133	Cienega/Rancheria Cr
19	850	582	8071	267	467	16	80	124	187	Horace/La Jara Mesa-Mt Taylor
20	448	472	8540	143	188	9	67	172	88	Cerro Toledo Rhy
21	657	396	8480	66	157	13	48	165	60	Valles Rhy (Cerro del Medio)
22	887	736	19391	211	288	15	91	808	105	TX Unknown A
23	659	525	10094	117	211	10	64	180	86	Cerro Toledo Rhy
24	1784	1087	31811	356	255	29	144	1236	107	Los Jagueyes
25	3942	2003	174065	124	2	9	4	17	5	not obsidian
26	936	514	10017	81	192	14	38	165	55	Valles Rhy (Cerro del Medio)
27	463	418	8178	121	235	20	82	202	132	Cienega/Rancheria Cr
28	1213	949	32973	315	286	14	158	1472	134	Los Jagueyes
29	4818	68796	6683	544	55	184	32	54	1	not obsidian
30	596	485	8899	103	204	15	62	177	91	Cerro Toledo Rhy
31	1141	364	10210	89	225	90	27	156	12	Agua Fria, SON
32	356	692	6722	176	537	14	80	117	190	Grants Ridge-Mt Taylor
33	320	772	7515	190	557	9	75	119	189	Grants Ridge-Mt Taylor
34	585	492	9628	123	213	14	63	175	94	Cerro Toledo Rhy
35	812	531	10066	137	200	30	62	168	88	Cerro Toledo Rhy
36	1384	975	34806	327	293	14	163	1470	119	Los Jagueyes
37	1343	854	29689	341	270	17	151	1371	115	Los Jagueyes
38	971	870	22200	240	303	9	108	828	118	TX Unknown A
39	1315	869	30068	363	271	10	150	1349	123	Los Jagueyes
40	14317	64053	173969	5563	108	664	1	175	1	not obsidian
41	1603	834	28698	334	256	13	147	1345	116	Los Jagueyes
42	530	481	9970	144	265	19	86	212	135	Cienega/Rancheria Cr
43	616	452	8797	107	197	9	67	178	92	Cerro Toledo Rhy

44	1089	754	25525	247	263	12	147	1353	121	Los Jagueyes
CBBS#	**Ti**	**Mn**	**Fe**	**Zn**	**Rb**	**Sr**	**Y**	**Zr**	**Nb**	**Source**
45	1237	635	16613	131	226	11	74	601	42	Lago Barreal
46	972	330	10148	64	302	41	60	159	37	Sierra Fresnal
47	1783	1117	39392	322	281	11	175	1752	132	Los Jagueyes
48	323	411	1715	10	0	18	2	22	1	not obsidian
49	1559	724	20464	227	248	9	83	612	33	Lago Barreal
50	459	574	8281	239	508	16	92	133	221	Horace/La Jara Mesa-Mt Taylor
51	1927	1232	46898	381	383	13	237	2215	167	Lago Fredrico
52	422	759	7113	192	570	9	81	125	195	Grants Ridge-Mt Taylor
53	1452	925	32941	354	289	16	161	1396	124	Los Jagueyes
54	356	686	6549	163	541	9	78	113	187	Grants Ridge-Mt Taylor
55	1006	790	19969	207	301	14	92	813	115	TX Unknown A
56	1563	973	33805	334	320	17	159	1528	130	Los Jagueyes
57	1718	788	23167	219	270	9	81	661	39	Lago Barreal
58	855	808	20259	237	300	10	98	815	109	TX Unknown A
59	1807	1188	44775	360	372	16	240	2241	174	Lago Fredrico
60	731	648	15979	186	260	10	90	754	114	TX Unknown A
61	1617	660	13602	127	206	103	56	362	69	unknown
62	612	442	5381	43	119	19	25	98	29	unknown
63	842	483	6318	73	118	20	25	100	28	unknown
64	557	459	8923	121	203	9	59	177	89	Cerro Toledo Rhy
65	1468	381	11374	79	243	155	22	175	9	unknown
66	2288	1287	49585	411	405	20	245	2245	175	Lago Fredrico
67	1427	715	20244	168	246	9	81	640	32	Lago Barreal
68	1514	778	21969	183	261	9	79	654	43	Lago Barreal
RGM1-S6	1484	309	12958	19	151	105	20	211	10	standard
RGM1-S6	1479	307	12999	17	146	106	23	213	7	standard

Table 2. Frequency distribution of obsidian sources in the assemblage. Samples that are not obsidian omitted.

		Frequency	Percent
Source	Agua Fria, SON	1	2.0
	Cerro Toledo Rhy	8	15.7
	Cienega/Rancheria Cr	3	5.9
	Grants Ridge-Mt Taylor	4	7.8
	Horace/La Jara Mesa-Mt Taylor	2	3.9
	Lago Barreal	5	9.8
	Lago Fredrico	3	5.9
	Los Jagueyes	11	21.6
	Sierra Fresnal	2	3.9
	TX Unknown A	6	11.8
	Valles Rhy (Cerro del Medio)	2	3.9
	unknown	4	7.8
	Total	51	100.0

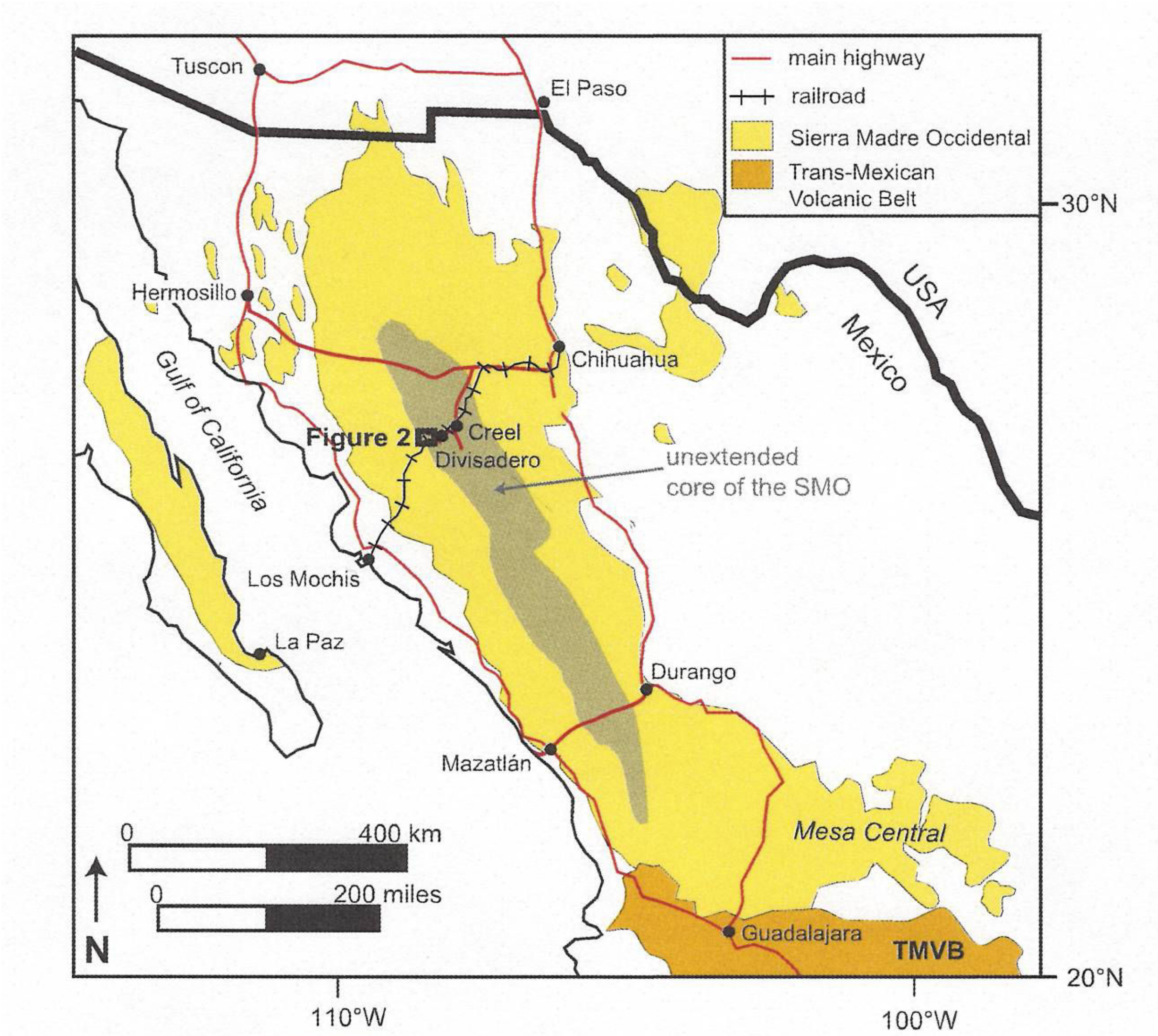


Figure 1. The Sierra Madre Occidental and Trans-Mexican Volcanic Belt in northwest Mexico. Most of the Sierra Madre is composed of rhyolite lava, much of which produced obsidian including the peralkaline lavas common in the region. Some of the volcanics from the volcanic province are present in southwest Texas (from Murray et al. 2014).

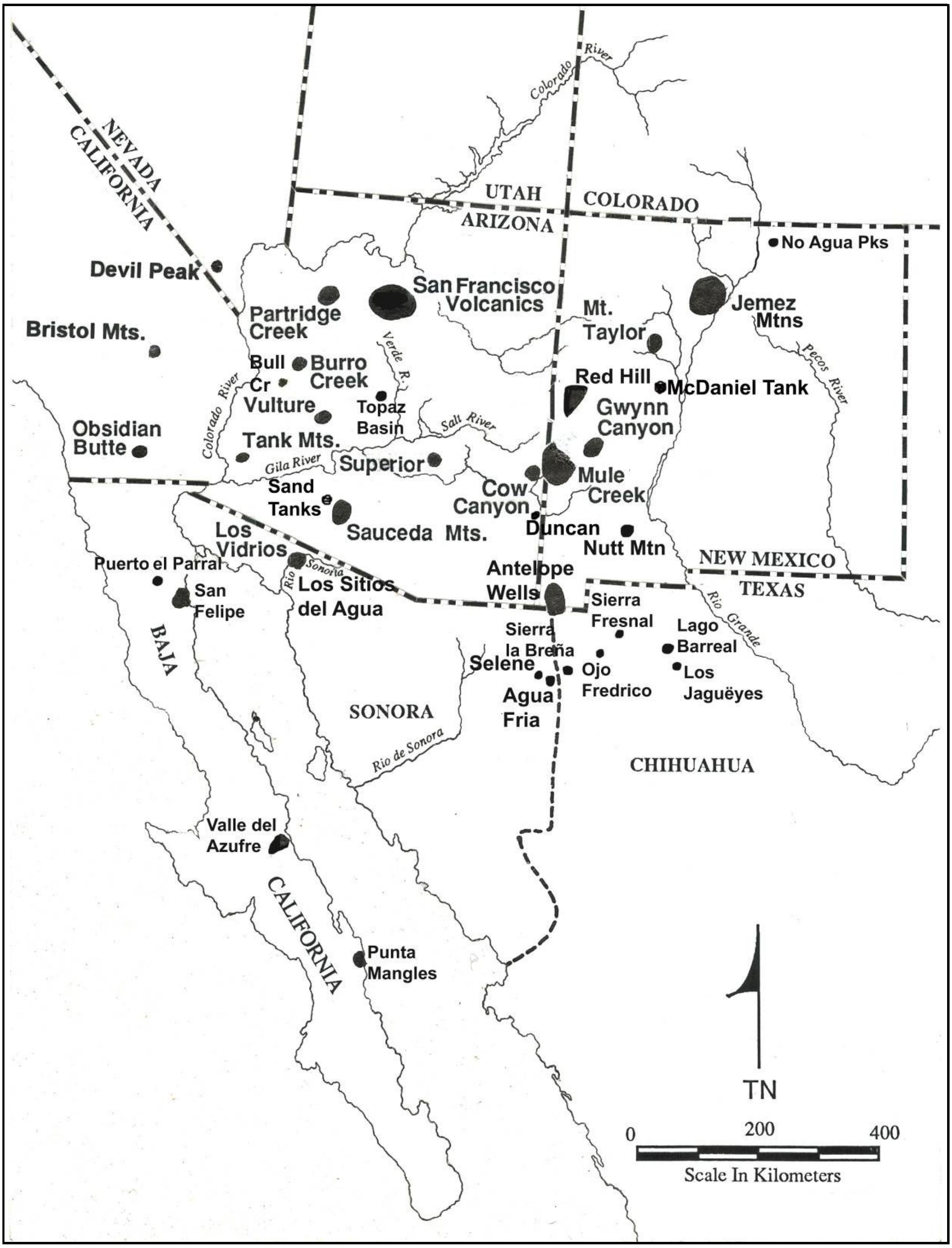


Figure 2. Sources of archaeological obsidian in the North American Southwest. Locations are approximate at this scale (adapted from Shackley 2005). Ojo Fredrico and Lago Fredrico are the same locality.

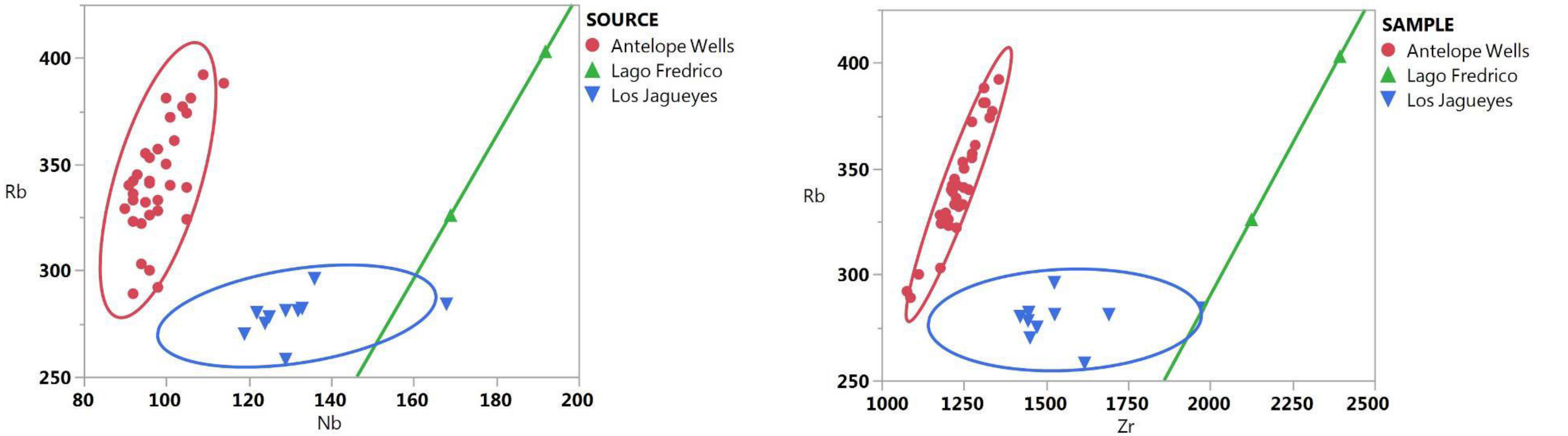


Figure 3. Nb/Rb and Zr/Rb bivariate plots of the three peralkaline obsidian sources from Chihuahua in this lab's collection. Lago Fredrico (5.9%) and Los Jagueyes (21.6%) are present in this assemblage. Confidence ellipses at 95%. Given that the Lago Fredrico "source" is known from only two specimens for this study an artifact is considered from Lago Fredrico when Rb is over 300 ppm and Zr is over 2000 ppm (see text). Until further source material or preferably the primary source is located this will remain the case.

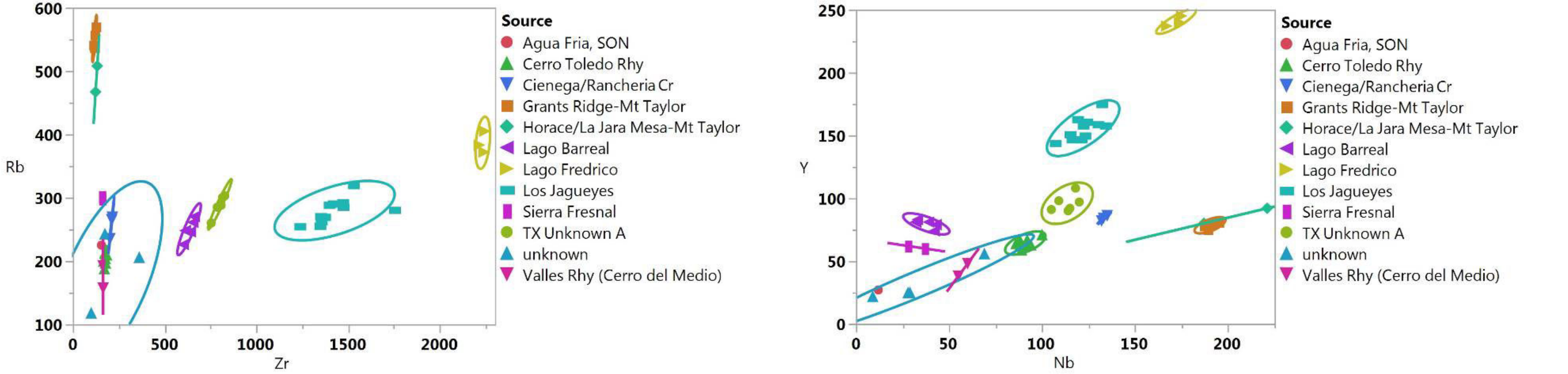
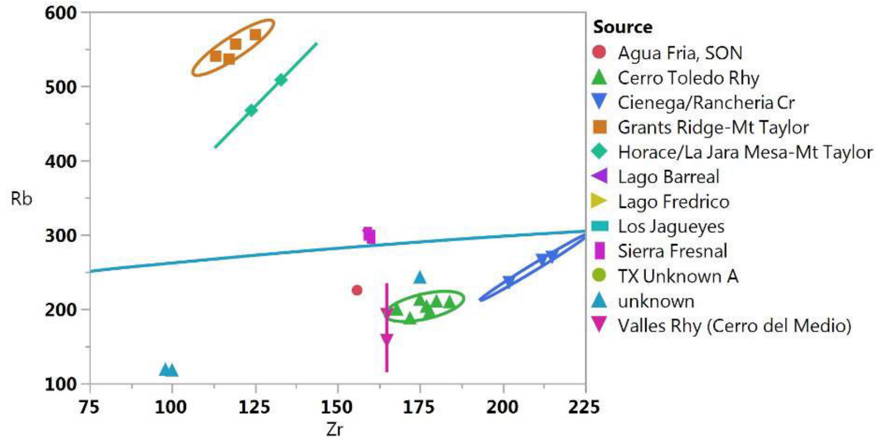


Figure 4. Zr/Rb and Y/Nb bivariate plot of all the samples. Discrimination of the Mount Taylor, Los Jagueyes, Lago Fredrico, Lago Barreal, Sierra Fresnal, Cienega/Rancheria Creek and TX Unknown A is evident in these plots. Confidence ellipses at 95%.



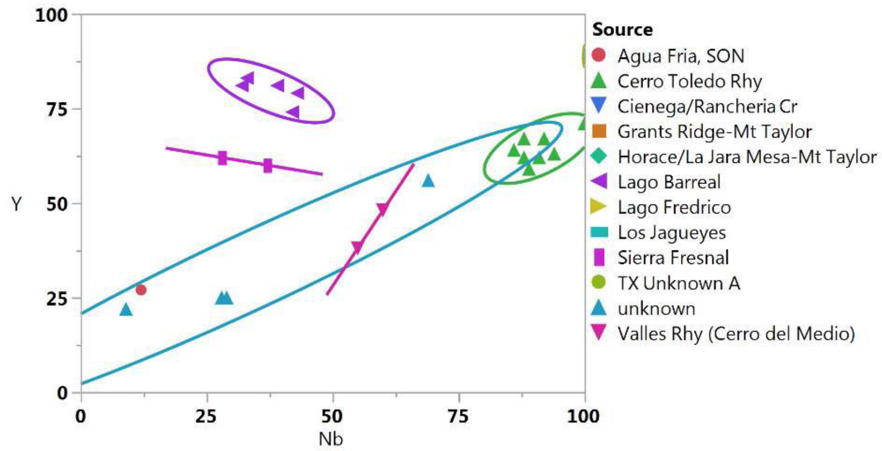


Figure 5. Here the lower elements from Figure 4 are isolated providing better discrimination of these sources. Note that at 95% confidence in the ellipses that the "unknowns" are grouped together. This does not mean that they are related to the Valles Rhyolite obsidian source in northern New Mexico/Rio Grande secondary deposits. Its is only an artifact of the statistical plotting routine. Cerro Toledo Rhyolite and Valles Rhyolite, while similar in composition separate well on the rare earth element Y and Nb.

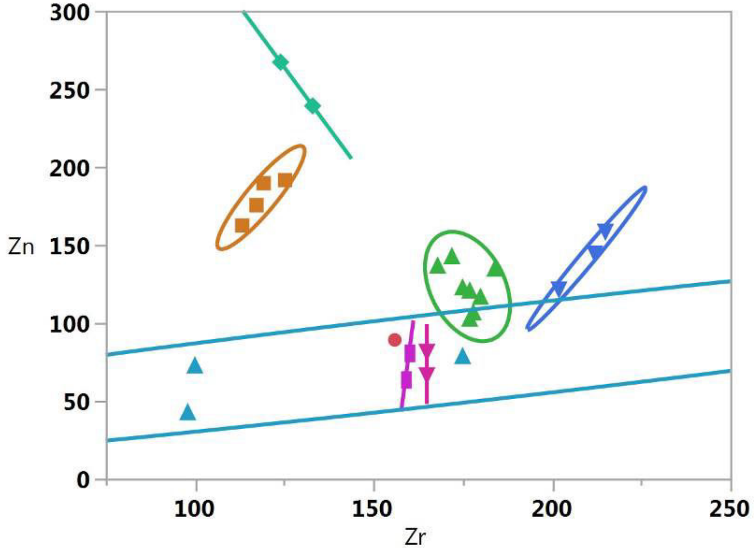


Figure 6. A Zr/Zn plot of some of the artifacts providing further discrimination, including the Jemez Lineament sources from Mount Taylor and the Jemez Mountains (see also text for Figure 5). Confidence ellipses at 95%.