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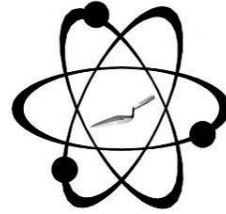
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Publication Date

2020-03-12

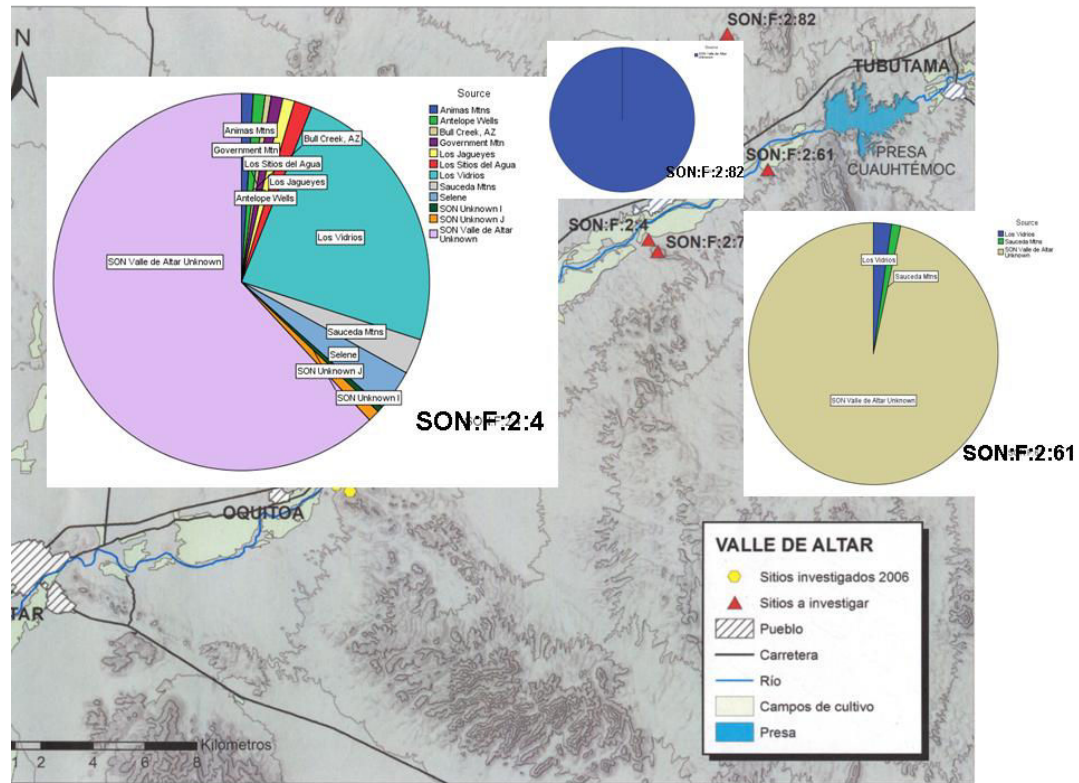
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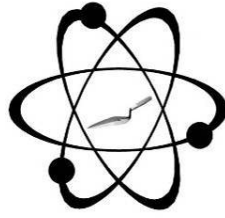


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SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM THREE ARCHAEOLOGICAL SITES IN THE VALLE DE ALTAR, NORTHERN SONORA, MEXICO



Relative frequencies of obsidian source provenance in the three sites. Obsidian provenance diversity decreased from west to east with a dominance of SON Valle de Altar Unknown



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**SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM THREE
ARCHAEOLOGICAL SITES IN THE VALLE DE ALTAR, NORTHERN
SONORA, MEXICO**

by

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12 March 2020

INTRODUCTION

The analysis here of 300 artifacts (12 not obsidian and a few not analyzed) from three sites (SON:F:2:4, 61, and 82) in the Valle de Altar in the northern State of Sonora, Mexico indicates a very diverse provenance assemblage with known sources on both sides of the border, including Arizona, New Mexico, Chihuahua and Sonora, and a large proportion of, as yet, unlocated sources (73.9%) dominated by one unusual trachyte obsidian source (72.9%). The main unknown source is likely located somewhere along the Río Altar or somewhere above that stream basin, and called provisionally here *SON Valle de Altar Unknown*. The diversity of obsidian source provenance decreases from west to east as the unknown source dominates the assemblage (see cover image). This study is one of the largest archaeological obsidian provenance studies in Sonora, and despite the number of "unknown" sources provides a good basis for further archaeological and geoarchaeological research in Sonora (see also Shackley 2019a). Following is a discussion of the provenance patterns overall for all sites including an analysis by site most of which have been reported in previous preliminary reports except for SON:F:2:82 which was comprised entirely of artifacts produced from SON Valle de Altar Unknown (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 in 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 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 100 seconds livetime to generate x-ray intensity $K\alpha_1$ -line data for elements titanium (Ti), manganese (Mn), iron (as $\text{Fe}_2\text{O}_3^{\text{T}}$), 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 below detection limits. 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 but Fe where a derivative fitting is used to improve the fit for iron and thus for all the other elements. When barium (Ba)

and cerium (Ce) is analyzed in the High Zb condition, the Rh target 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, 2011; Shackley et al. 2016, 2018; 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, Ba, and Ce include G-2 (granite), AGV-2 (andesite), GSP-2 (granodiorite), SY-2 (syenite), BHVO-2 (hawaiite), STM-1 (syenite), QLO-1 (quartz latite), RGM-1 (rhyolite), 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 (ver. 21) and/or JMP 12.0.1 and IGPET 2000 for statistical analyses. In order to evaluate these quantitative determinations, machine data were compared to measurements of known standards during each run of ≤ 19 . RGM-1 a USGS rhyolite standard or G-2 a USGS granite standard is analyzed during each sample run for obsidian artifacts to check machine calibration (Table 1). Source assignments were made by reference to Shackley (1995, 2005, 2019b; Shackley et al. 2018 and updated at <http://swxrflab.net/swobsrsrcs.htm>; see data tables and figures following.

Table 1. USGS RGM-1 and G-2 standard measurements and USGS recommended values. All measurements in part per million (ppm).

SAMPLE	Ti	Mn	Fe¹	Rb	Sr	Y	Zr	Nb	Ba	Ce
RGM-1 (USGS recommended)	1619±12 0	279±5 0	13010±210	150± 8	110±1 0	25 ²	220±2 0	8.9±0. 6	810±46	47±4
RGM-1, pressed powder standard (this study, n=6)	1543±40	300±7	13241±80	147± 3	108±2	26± 2	221±3	11±3	814±7	43±14
G-2 (USGS recommended)	2878±18 0	232±7 7	18605±118 9	170± 3	478±2	11± 2	309±3 5	12 ²	1880±2 3	160±10
G-2, pressed powder standard (this study, n=10)	2563±52	286±1 4	16942±105	169± 2	466±3	13± 2	287±4	13±3	1746±9 6	110±10

¹ Fe as total Fe₂O₃+

² USGS information value only

DISCUSSION OF THE RESULTS OF THE XRF ANALYSIS

For the sites SON:F:2:61 and 82 the dominance of SON Valle de Altar Unknown was such that a statistical analysis to determine source was not an issue, particularly given that SON:F:2:4 had much greater diversity of source provenance including sources from both sides of the international border (Table 2). The similarity in composition of Antelope Wells from New Mexico, and Los Jagueyes from Chihuahua both a considerable distance from SON:F:2:4 and the proposed SON Valle de Altar Unknown required some statistical evaluation. Typically, similar to a factor and then cluster analysis, elements that appear to yield the greatest variability among a group of sources are plotted until the most parsimonious plot is obtained, then a confidence ellipse is generated overlying the plot of the variables (artifacts in this case; Baxter 1992,1994). Figures 1 through 3 display these results. After this using the plot discriminating these three sources, the plotting was used in subsequent sites (SON:F:2:61 and 82), although given that all artifacts from SON:F:2:82 were from the unknown source, those artifacts were not plotted.

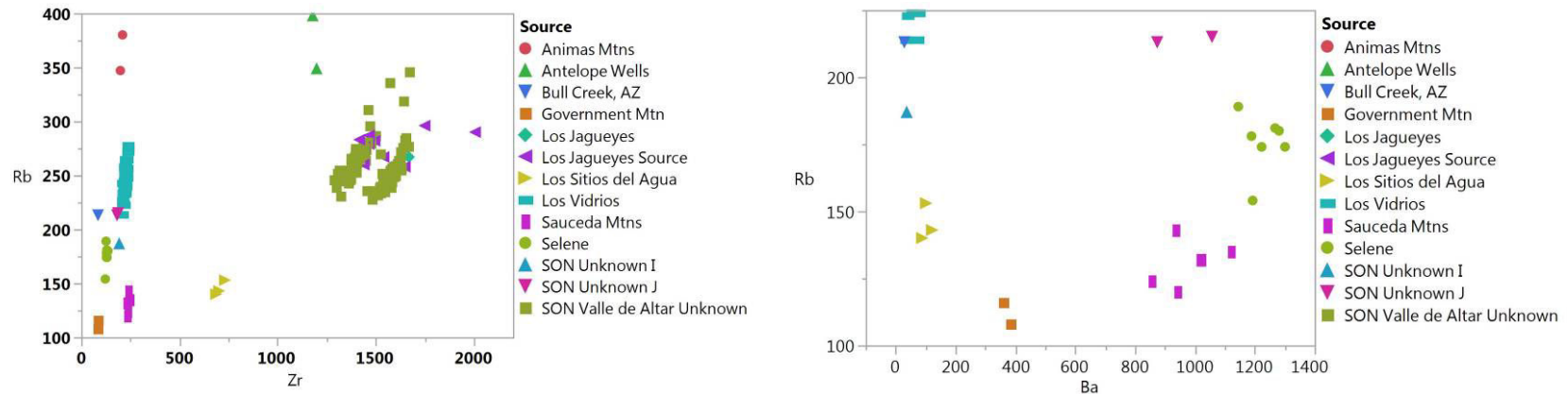


Figure 1. Zr/Rb (left) bivariate plot of all samples from SON:F:2:4 providing discrimination of Animas Mountains, Antelope Wells, Government Mountain, Los Sitios del Agua, and Saucedá Mountains (see plots below for more clarity). Ba/Rb bivariate plot of these high Ba samples providing discrimination of Government Mountain, Los Sitios del Agua, Saucedá Mountains, Selene, and the Sonora Unknowns I and J.

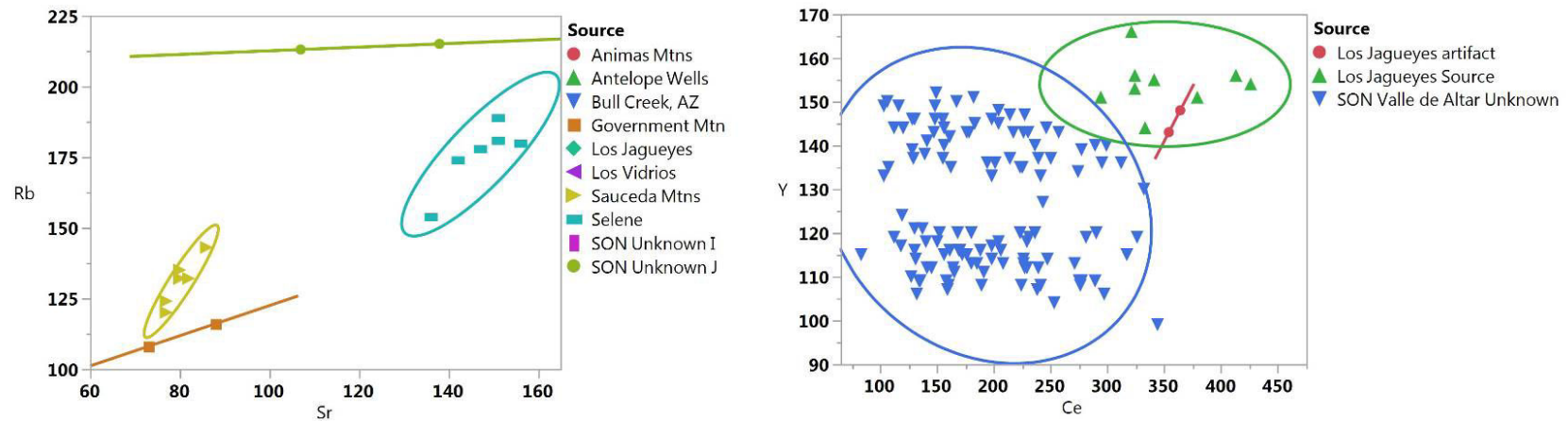


Figure 2. Left - Sr/Rb bivariate plot of the high Sr assigned samples from SON:F:2:4 providing discrimination for Bull Creek, Government Mountain, Los Vidrios, Saucedá Mountains, Selene, and SON Unknown J. Right - Ce/Y bivariate plot of the Los Jagueyes source standards, Los Jagueyes assigned artifacts, and the SON Valle de Altar suspected, but unlocated source. Note that the SON Valle de Altar Unknown group consists of two separate but closely related source groups similar to the Saucedá Mountains source (Shackley 2005). They are likely from the same magma source with chronological/fractionation processes that apparently occurred. In this analysis only Y and Ce provide discrimination between the known and unknown source. While it is likely that SON Valle de Altar Unknown is somewhere in or around that Valle de Altar, only the discovery of the primary source will provide clarity between these two sources (see text). Confidence ellipses at 95%.

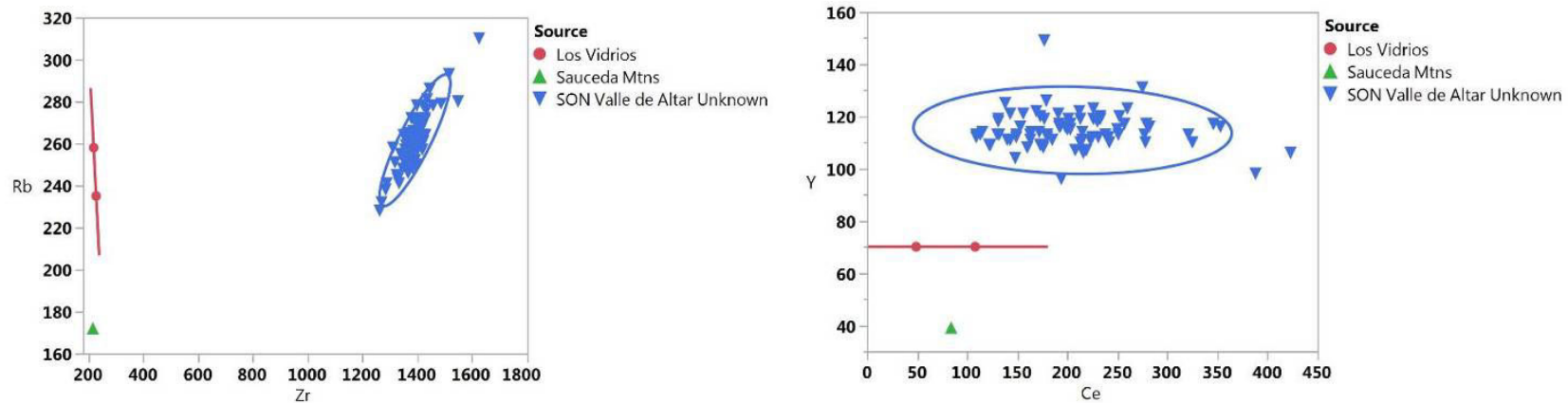


Figure 3. Zr/Rb and Ce/Y bivariate plots of the archaeological specimens from SON:F:2:61. Confidence ellipses at 95%.

DISTRIBUTION OF OBSIDIAN SOURCE PROVENANCE IN SONORA

While there have been some obsidian provenance studies in Chihuahua, particularly recently, Sonora has remained essentially unknown in this regard (Dolan et al. 2017, 2019; Fralick et al. 1998; Hard and Roney 1999; Shackley 2005, 2019a). The current project reported here remedies the situation, in part, but more is always needed, particularly since over 70% of the artifacts were produced from sources as yet unlocated (see Appendix Table, Table 2 and Figures 4 and 5).

Table 2. Crosstabulation of site by source. Non-obsidian samples removed.

Source		Site SON:			Total
		F:2:4	F:2:61	F:2:82	
Animas Mtns	Count	2	0	0	2
	% within Source	100.0%	0.0%	0.0%	100.0%
	% within Site SON:	1.0%	0.0%	0.0%	0.7%
	% of Total	0.7%	0.0%	0.0%	0.7%
Antelope Wells	Count	2	0	0	2
	% within Source	100.0%	0.0%	0.0%	100.0%
	% within Site SON:	1.0%	0.0%	0.0%	0.7%
	% of Total	0.7%	0.0%	0.0%	0.7%
Bull Creek, AZ	Count	1	0	0	1
	% within Source	100.0%	0.0%	0.0%	100.0%
	% within Site SON:	0.5%	0.0%	0.0%	0.3%
	% of Total	0.3%	0.0%	0.0%	0.3%
Government Mtn	Count	2	0	0	2
	% within Source	100.0%	0.0%	0.0%	100.0%
	% within Site SON:	1.0%	0.0%	0.0%	0.7%
	% of Total	0.7%	0.0%	0.0%	0.7%
Los Jagueyes	Count	2	0	0	2
	% within Source	100.0%	0.0%	0.0%	100.0%
	% within Site SON:	1.0%	0.0%	0.0%	0.7%
	% of Total	0.7%	0.0%	0.0%	0.7%
Los Sitios del Agua	Count	3	0	0	3
	% within Source	100.0%	0.0%	0.0%	100.0%
	% within Site SON:	1.5%	0.0%	0.0%	1.0%
	% of Total	1.0%	0.0%	0.0%	1.0%
Los Vidrios	Count	47	2	0	49
	% within Source	95.9%	4.1%	0.0%	100.0%
	% within Site SON:	23.9%	2.4%	0.0%	17.0%
	% of Total	16.3%	0.7%	0.0%	17.0%
Sauceda Mtns	Count	6	1	0	7
	% within Source	85.7%	14.3%	0.0%	100.0%
	% within Site SON:	3.0%	1.2%	0.0%	2.4%
	% of Total	2.1%	0.3%	0.0%	2.4%
Selene	Count	7	0	0	7
	% within Source	100.0%	0.0%	0.0%	100.0%
	% within Site SON:	3.6%	0.0%	0.0%	2.4%
	% of Total	2.4%	0.0%	0.0%	2.4%
SON Unknown I	Count	1	0	0	1
	% within Source	100.0%	0.0%	0.0%	100.0%
	% within Site SON:	0.5%	0.0%	0.0%	0.3%
	% of Total	0.3%	0.0%	0.0%	0.3%
SON Unknown J	Count	2	0	0	2
	% within Source	100.0%	0.0%	0.0%	100.0%
	% within Site SON:	1.0%	0.0%	0.0%	0.7%
	% of Total	0.7%	0.0%	0.0%	0.7%
SON Valle de Altar Unknown	Count	122	82	6	210
	% within Source	58.1%	39.0%	2.9%	100.0%
	% within Site SON:	61.9%	96.5%	100.0%	72.9%
	% of Total	42.4%	28.5%	2.1%	72.9%
Total	Count	197	85	6	288
	% within Source	68.4%	29.5%	2.1%	100.0%
	% within Site SON:	100.0%	100.0%	100.0%	100.0%
	% of Total	68.4%	29.5%	2.1%	100.0%

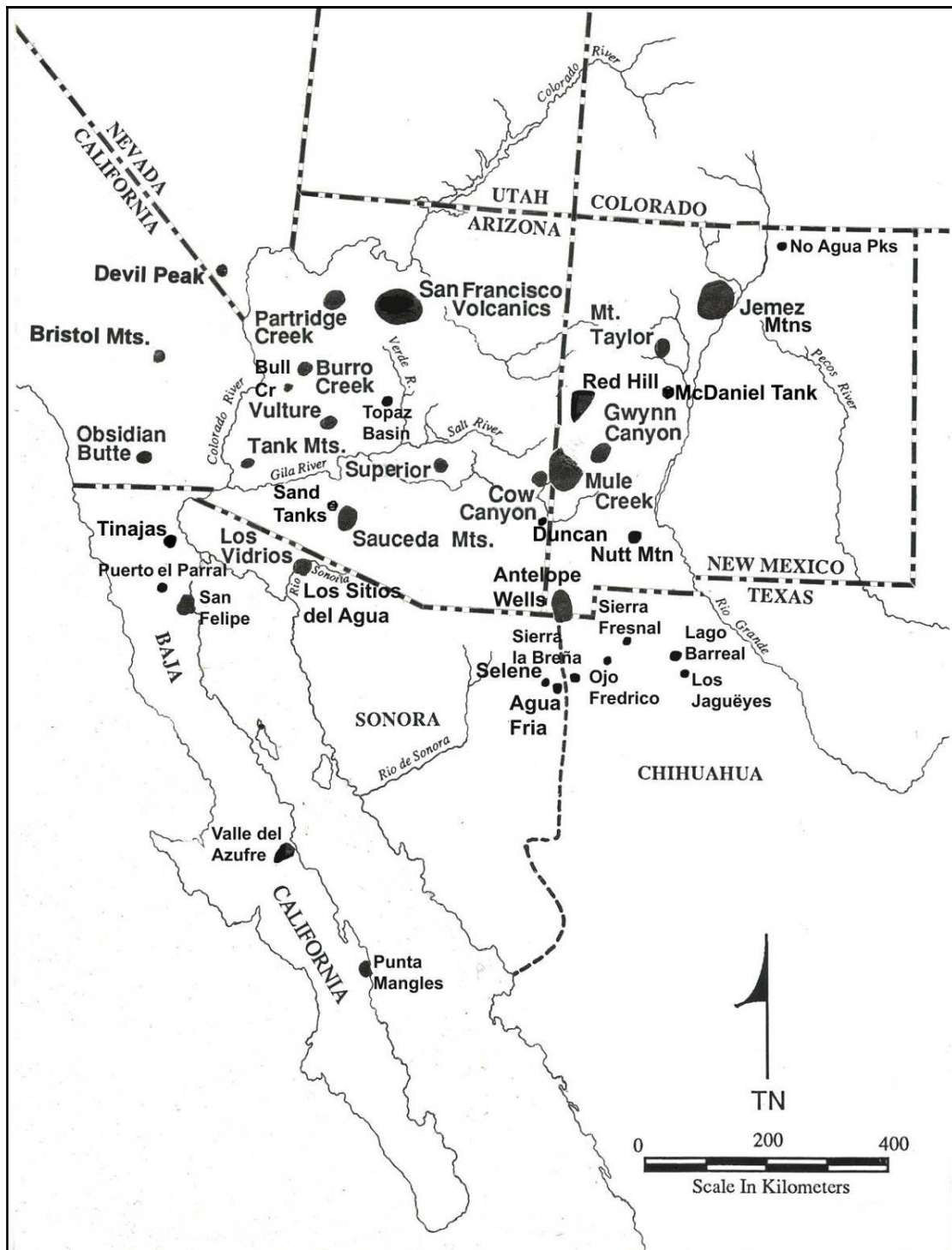


Figure 4. Approximate location of known sources of archaeological obsidian in the North American Southwest. Adapted from Panich et al. 2017; Shackley 1989, 2005, 2019b; Shackley et al. 2018.

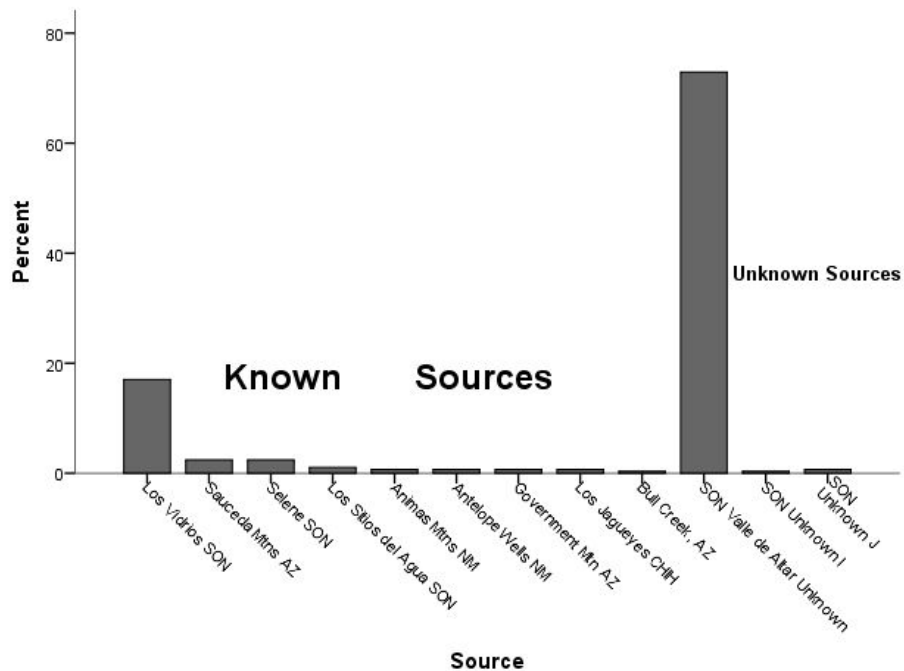


Figure 5. Frequency (percentage) histogram of the distribution of source provenance (all sites) from Table 2.

Despite the paucity of known sources, this study does reveal some patterns of archaeological value. Sources such as Government Mountain and Bull Creek from northern and western Arizona over 400 km north have not been seen in northern Sonoran sites until now. Bull Creek in western Arizona is rare in U.S. Southwestern sites overall, but the elemental concentrations are within all elements in the source standard, so the assignment appears reliable at this time. Artifacts produced from Government Mountain are commonly recovered throughout Arizona, New Mexico, and less so in Colorado and Utah. This is the first occurrence in Sonora known to this laboratory since the mid-1980s (Shackley 1988, 1989, 1995, 2005). It did occur in the Archaic portion of the Murray Springs Clovis site in far southern Arizona, so it is not that unexpected given the importance of the source in what is now the SW/NW region (Shackley 2007).

Los Vidrios, the most commonly recovered known source in the assemblage is located in northwest Sonora part of the Sierra Pinacate volcanic field west of the Río Sonoyta near the U.S./Mexican border, and has been recovered on both sides of that border in some quantity. The one Chihuahuan source, Los Jagueyes nearly 500 km southeast of these sites has rarely been reported in Sonora and is located east of the Sierra Madre and could indicate contact with groups to the east (Dolan et al. 2019; Shackley 2019a). A recent Archaic Period project by Emiliano Gallaga in northwest Chihuahua recovered obsidian artifacts produced from the Agua Fria source in the Sierra Madre, so contact and/or procurement ranges distributed throughout Chihuahua and Sonora are likely (Dolan et al 2019; Shackley 1989, 1996, 2005). Los Sitios del Agua, located just east of Rancho Los Vidrios along the Río Sonoyta while an excellent media for tool production is not commonly recovered in archaeological contexts on either side of the international border occurring only sporadically for reasons unknown (Martyneec et al. 2011).

The Selene source located in the Río Bavispe region in the Sierra Madre near the Chihuahua/Sonora border has been recovered on both sides of the international border, and is a relatively large nodule source of excellent quality (Kibler et al. 2014). It is the most commonly recovered Sonoran source after Los Vidrios north of U.S./Mexican border, and has been found in Chihuahua as well as Sonora (Dolan et al. 2019).

Antelope Wells and Animas Mountains in the boot heel of New Mexico, the former also found on the Chihuahua side, are commonly recovered in the region. I would have expected to see more Antelope Wells in these sites, but the "local" unknown was evidently more commonly used. Saucedo Mountains is a very commonly recovered source in Arizona and northwest Sonoran archaeological contexts, particularly common during the Hohokam Late Classic (Shackley 2005, 2019c).

The Unlocated (Unknown) Sources

Finally, the number of, as yet, unlocated sources deserves some discussion. Among the three sites here, the frequency of the unknowns, particularly what I'm calling SON Valle de Altar Unknown increased in frequency from west to east. At SON:F:2:4 to the west, sources from Arizona, Chihuahua, as well as Sonora comprised 36.5% of the assemblage (Table 2; Appendix Table). Nearly 63% however is from unknown sources. The next site to the east SON:F:2:61 exhibited only two samples produced from Los Vidrios, and one from Saucedo Mountains comprising only 3.5% of total; SON Valle de Altar Unknown the remainder (see Table 2 and Appendix Table). At SON:F:2:82 the entire assemblage was produced from the Valle de Altar unlocated source, but the sample was comprised of only six artifacts (Table 2).

The largest source group, as mentioned above, is what is now called the SON Valle de Altar Unknown due to its dominance in sites along the Río Altar and to the north (see cover image; Table 2 and Figure 5). This was apparently a major source in this part of the northern Sonoran region and deserves to be located, not just for archaeological purposes, but for geoarchaeological purposes as well (see Shackley 2005). It is impossible to determine without sampling at the primary source what the potential elemental variability might be. Without that it is possible to assume that it is all one source or the opposite that it constitutes more than one source, particularly given the apparent bimodal elemental character (see Figure 2). Determining the location of this source should be a primary focus in the future. Given that most of the artifacts at SON F:2:61 and 82 were from this unlocated source, it seems reasonable that the source is relatively nearby. Additionally the large XRF analysis of obsidian artifacts from sites to the west, east and south of this study did not detect this source in the assemblage further suggesting that the obsidian source is relatively nearby (Shackley 2019a, 2020).

One further point that could aid in the discovery of the source is the oxide composition of this source and rock type determination (Table 3 and Figure 6). The oxides indicate that this

obsidian is not necessarily a rhyolite, but a relatively high silica trachyte obsidian, fairly rare in nature (Lajčaková and Kraus 1993). This is probably why the nodule size is relatively small, at least based on the archaeological evidence here.

Table 3. Oxide concentrations for one sample of SON Valle de Altar Unknown from SON:F:2:82. All measurements in weight percent.

Sample	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃	:Σ
	%	%	%	%	%	%	%	%	%	%	
73651A	2.54	0.00	5.97	66.66	0.00	8.77	1.07	0.49	0.28	12.73	98.51
RGM1-S4	4.03	0.00	12.97	73.85	0.00	4.95	1.41	0.26	0.04	2.23	99.74

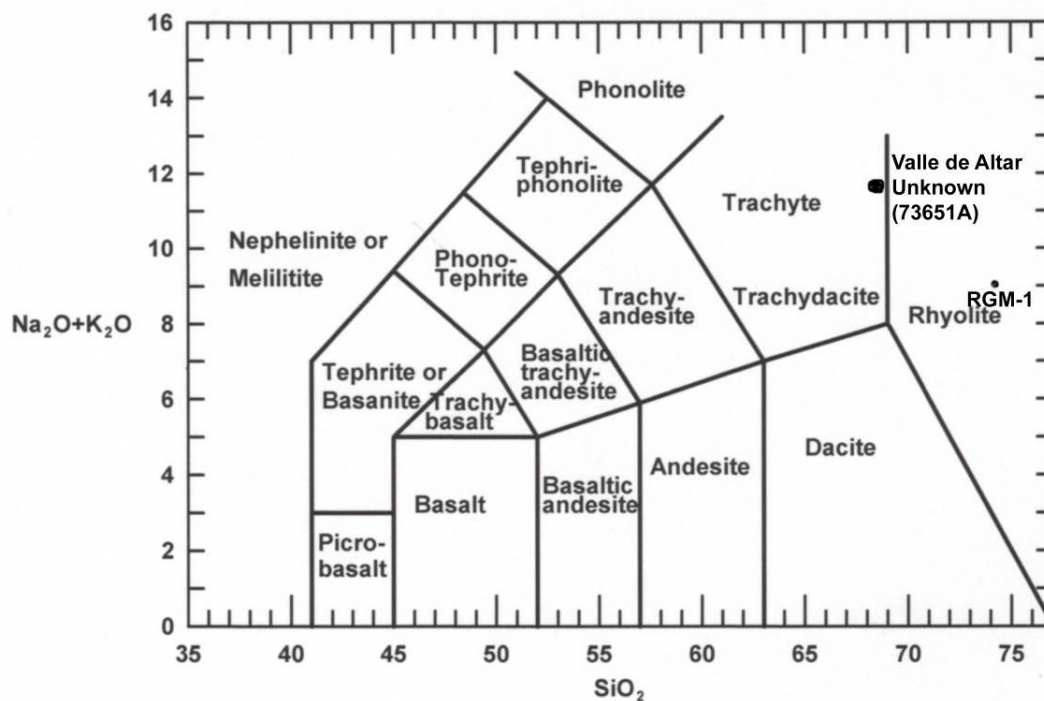


Figure 6. TAS plot of one sample of Valle de Altar Unknown, a relatively high silica trachyte obsidian from SON:F:2:82, and USGS RGM-1 rhyolite standard (Le Maitre et al. 1989).

REFERENCES CITED

- Baxter, M.J.
1992 Archaeological Uses of the Biplot-A Neglected Technique. In *Computer Applications and Quantitative Methods in Archaeology*, edited by G. Lock, and J. Moffett, pp. 141-148. BAR International Series S557, Oxford.
- 1994 *Exploratory Multivariate Analysis in Archaeology*. Edinburgh University Press.
- Davis, K.D., T.L. Jackson, M.S. Shackley, T. Teague, and J.H. Hampel
2011 Factors Affecting the Energy-Dispersive X-Ray Fluorescence (EDXRF) Analysis of Archaeological Obsidian. In *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology*, edited by M.S. Shackley, pp. 45-64. Springer, New York.
- Dolan, S.G., M.E. Whalen, P.E. Minnis, and M.S. Shackley
2017 Obsidian in the Casas Grandes world: procurement, exchange, and interaction in Chihuahua, Mexico, CE 1200-1450. *Journal of Archaeological Science Reports*: 11:555-567.
- Dolan, S.G., E. Gallaga, and M.S. Shackley
2019 Obsidian Provenance Data Reveals New Insights into Archaic Lifeways in Chihuahua, Mexico. *Lithic Technology* 44:237-256.
- Fralick, P.W., J.D. Stewart, and A.C. MacWilliams
1998 Geochemistry of West-Central Chihuahua Obsidian Nodules and Implications for the Derivation of Obsidian Artefacts. *Journal of Archaeological Science* 25:1023-1038.
- Govindaraju, K.
1994 1994 Compilation of Working Values and Sample Description for 383 Geostandards. *Geostandards Newsletter* 18 (special issue).
- Hampel, Joachim H.
1984 Technical Considerations in X-ray Fluorescence Analysis of Obsidian. In *Obsidian Studies in the Great Basin*, edited by R.E. Hughes, pp. 21-25. Contributions of the University of California Archaeological Research Facility 45. Berkeley.
- Hard, Robert J. and John R. Roney
1999 An Archaeological Investigation of Late Archaic Cerros de Trincheras Sites in Chihuahua, Mexico. Report to Consejo de Arqueología, Instituto Nacional de Antropología e Historia, Mexico.
- Hildreth, W.
1981 Gradients in Silicic Magma Chambers: Implications for Lithospheric Magmatism. *Journal of Geophysical Research* 86:10153-10192.
- Hughes, Richard E., and Robert L. Smith
1993 Archaeology, Geology, and Geochemistry in Obsidian Provenance Studies. In *Scale on Archaeological and Geoscientific Perspectives*, edited by J.K. Stein and A.R. Linse, pp. 79-91. Geological Society of America Special Paper 283.
- Kibler, K.W., H.R. Hinojosa-Prieto, M.S. Shackley, and H. J. Hinojosa García
2014 The Selene Obsidian Source (Formerly Sonora Unknown B) of the Upper Rio Bavispe Basin, Sonora, Mexico. *Kiva* 80:168-192.

- Lajčaková, A. and I. Kraus
 1993 Volcanic Glasses. In *Natural Glasses*, edited by V. Bouska, pp. 85-121. Ellis Horwood, Chichester, England.
- Le Maitre, R., Bateman, P.; Dudek, A., Keller, J., Lameyre, J., Le Bas, M., Sabine, P., Schmid, R., Sorensen, H., Streckeisen, A., Woolley, A., Zanettin, B.
 1989 *A Classification of Igneous Rocks and Glossary of Terms: Recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Igneous Rocks*, edited by R.W. Le Maitre. Blackwell, Oxford. 193 p.
- Mahood, Gail A., and James A. Stimac
 1990 Trace-Element Partitioning in Pantellerites and Trachytes. *Geochemica et Cosmochimica Acta* 54:2257-2276.
- Martyneec, R., Davis, R., and M.S. Shackley
 2011 The Los Sitios del Agua Obsidian Source (Formerly AZ Unknown A) and Recent Archaeological Investigations Along the Rio Sonoyta, Northern Sonora. *Kiva* 76(4):413-429.
- McCarthy, J.J., and F.H. Schamber
 1981 Least-Squares Fit with Digital Filter: A Status Report. In *Energy Dispersive X-ray Spectrometry*, edited by K.F.J. Heinrich, D.E. Newbury, R.L. Myklebust, and C.E. Fiori, pp. 273-296. National Bureau of Standards Special Publication 604, Washington, D.C.
- Panich, L.M., M.S. Shackley, and A. Porcayo Michellini
 2017 A Reassessment of Archaeological Obsidian from Southern Alta California and Northern Baja California. *California Archaeology* 9:53-77.
- Schamber, F.H.
 1977 A Modification of the Linear Least-Squares Fitting Method which Provides Continuum Suppression. In *X-ray Fluorescence Analysis of Environmental Samples*, edited by T.G. Dzubay, pp. 241-257. Ann Arbor Science Publishers.
- Shackley, M. Steven
 1988 Sources of Archaeological Obsidian in the Southwest: An Archaeological, Petrological, and Geochemical Study. *American Antiquity* 53(4):752-772.
- 1989 *Early Hunter-Gatherer Procurement Ranges in the Southwest: Evidence from Obsidian Geochemistry and Lithic Technology*. Ph.D. dissertation, Department of Anthropology, Arizona State University, Tempe.
- 1995 Sources of Archaeological Obsidian in the Greater American Southwest: An Update and Quantitative Analysis. *American Antiquity* 60(3):531-551.
- 1996 Range and Mobility in the Early Hunter-Gatherer Southwest. In *Early Formative Adaptations in the Southern Southwest*, edited by Barbara Roth, pp. 5-16. Monographs in World Prehistory 25. Prehistory Press, Madison.
- 2005 *Obsidian: Geology and Archaeology in the North American Southwest*. University of Arizona Press, Tucson.
- 2007 Sources of Obsidian at the Murray Springs Clovis Sites: A Semi-Quantitative X-ray Fluorescence Analysis. In *Murray Springs: A Clovis Site with Multiple Activity Areas in the San Pedro Valley, Arizona*, edited by C.V. Haynes, Jr., and B.B. Huckell, pp. 250-254. University of Arizona Anthropological Papers 71, Tucson.

- 2011 An Introduction to X-Ray Fluorescence (XRF) Analysis in Archaeology. In *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology*, edited by M.S. Shackley, pp. 7-44. Springer, New York.
- 2019a Source Provenance of Obsidian Artifacts from Archaeological Contexts in Three Regions Of Sonora, Mexico. Report prepared for G. Sanchez, INAH, Sonora, Mexico and M. Pailes, Department of Anthropology, University of Oklahoma.
- 2019b Natural and Cultural History of the Obsidian Butte Source, Imperial County, California. *California Archaeology* 11:21-43.
- 2019c The Patayan and Hohokam: A View from Alta and Baja California. *Journal of Arizona Archaeology* 6:83-98.
- 2020 Obsidian Source Provenance from Archaeological Sites in the Puerto Peñasco Area of Northwest Sonora. Chapter submitted to Douglas Mitchell, Scottsdale, Arizona.
- Shackley, M.S., F. Goff, and S.G. Dolan
- 2016 Geologic Origin of the Source of Bearhead Rhyolite (Paliza Canyon) Obsidian, Jemez Mountains, Northern New Mexico. *New Mexico Geology* 38:52-62.
- Shackley, M.S., L.E. Morgan, and D. Pyle
- 2018 Elemental, isotopic, and geochronological variability in Mogollon-Datil Volcanic Province archaeological obsidian, southwestern USA: solving issues of inter-source discrimination. *Geoarchaeology* 33:486-497.

APPENDIX TABLE (ALL SITES, ALL SAMPLES)

Sample	Site SON:	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	Th	Source
76529	F:2:4	1644	811	34449	275	15	119	1425	111	0	112	39	23	SON Valle de Altar Unknown
76524A	F:2:4	1142	364	8865	154	136	19	122	10	1193	53	22	17	Selene SON Valle de Altar
76601A	F:2:4	1652	820	34339	264	14	146	1625	135	0	155	46	43	Unknown SON Valle de Altar
76779A1	F:2:4	1364	657	30139	239	9	140	1577	143	13	289	35	22	Unknown SON Valle de Altar
76779A2	F:2:4	1565	750	32346	250	11	148	1579	129	0	204	39	25	Unknown SON Valle de Altar
76783A	F:2:4	1296	382	9371	181	151	23	130	9	1268	57	25	20	Selene SON Valle de Altar
76823A1	F:2:4	1509	713	33381	260	12	147	1613	137	37	227	43	36	Unknown SON Valle de Altar
76823A2	F:2:4	1495	732	32418	250	14	133	1558	136	24	241	34	30	Unknown SON Valle de Altar
76823A3	F:2:4	1544	818	32923	271	16	113	1400	115	0	185	34	30	Unknown SON Valle de Altar
76863A	F:2:4	932	272	13267	243	16	67	215	30	39	112	28	32	Los Vidrios
76901A	F:2:4	1177	392	9362	174	149	23	128	12	1223	32	28	18	Selene SON Valle de Altar
76901A	F:2:4	1478	694	31144	258	12	113	1388	106	48	208	40	42	Unknown SON Valle de Altar
76917A1	F:2:4	1638	726	30630	236	21	127	1454	124	0	243	37	37	Unknown SON Valle de Altar
76917A2	F:2:4	1542	697	32541	259	11	149	1596	140	3	148	41	30	Unknown SON Valle de Altar
76938A	F:2:4	1546	699	31218	252	13	140	1564	127	65	236	41	42	Unknown SON Valle de Altar
77202A	F:2:4	1497	763	30922	285	16	116	1473	118	0	206	38	23	Unknown SON Valle de Altar
77233A	F:2:4	1193	447	22435	140	16	78	687	51	89	126	16	12	Los Sitios del Agua SON Valle de Altar
77237A	F:2:4	1387	577	27593	232	16	130	1509	133	6	332	35	20	Unknown SON Valle de Altar
77289A	F:2:4	1017	286	13298	261	19	71	225	29	57	50	30	25	Los Vidrios
77313A	F:2:4	1091	721	11232	380	15	75	210	54	22	46	25	31	Animas Mtns SON Valle de Altar
77387A	F:2:4	1501	717	33080	254	12	143	1571	134	38	176	43	24	Unknown SON Valle de Altar
77425A	F:2:4	1521	708	31802	249	12	144	1552	133	10	156	43	33	Unknown

77482A	F:2:4	1628	817	33704	269	20	119	1404	109	25	231	40	43	SON Valle de Altar
77491A	F:2:4	5613	777	34145	5	94	20	44	1	64	0	0	4	Unknown
77502A	F:2:4	1545	774	32168	266	16	112	1374	114	20	141	38	35	not obsidian
77520A	F:2:4	1036	250	13352	265	21	64	232	34	63	85	34	35	SON Valle de Altar
79619A	F:2:4	1482	801	34415	276	11	146	1637	137	8	130	42	33	Unknown
79636A	F:2:4	1564	755	33409	267	12	118	1410	110	44	204	37	32	SON Valle de Altar
79636A	F:2:4	1638	803	34235	251	14	117	1362	108	0	198	37	35	Unknown
79728A	F:2:4	1626	698	31336	255	15	109	1356	107	0	134	33	43	SON Valle de Altar
79779A	F:2:4	1372	734	31850	256	15	111	1382	107	34	191	40	33	Unknown
79813A	F:2:4	1636	787	34601	275	13	118	1396	102	0	140	37	33	SON Valle de Altar
79951A	F:2:4	1372	312	14776	135	80	39	249	23	1121	70	22	12	Unknown
79967A	F:2:4	942	264	12317	242	16	63	221	35	107	122	24	38	Sauceda Mtns
	Site													Los Vidrios
Sample	SON:	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	Th	Source
79984A	F:2:4	960	637	10597	347	14	74	199	48	0	76	26	29	Animas Mtns
80028A	F:2:4	1572	817	32460	261	12	115	1384	108	11	176	33	27	SON Valle de Altar
80209A1	F:2:4	1363	674	29151	240	16	134	1541	133	41	274	34	31	Unknown
80209A2	F:2:4	1470	741	31436	277	14	107	1434	117	0	238	40	34	SON Valle de Altar
80219A	F:2:4	1303	423	9970	189	151	20	126	15	1145	31	27	26	Unknown
80219A1	F:2:4	885	239	11698	239	36	65	217	26	47	98	26	36	Selene
80219A2	F:2:4	976	287	13636	272	20	68	236	35	91	76	28	29	Los Vidrios
80219A3	F:2:4	1596	750	31715	251	18	115	1359	110	36	317	34	27	Los Vidrios
80240A	F:2:4	1432	678	29999	269	12	104	1439	113	27	253	36	36	SON Valle de Altar
80317A	F:2:4	1689	753	35553	283	24	150	1647	141	0	106	43	39	Unknown
80335A	F:2:4	1525	731	32520	247	13	141	1562	129	9	141	37	28	SON Valle de Altar
														Unknown

80335A	F:2:4	1334	753	31820	263	16	120	1396	108	0	180	37	35	SON Valle de Altar
80359A	F:2:4	1459	720	32208	255	23	140	1574	133	17	156	39	30	Unknown
80369A	F:2:4	1423	724	32450	256	12	144	1592	134	10	246	39	44	SON Valle de Altar
80374A1	F:2:4	1443	698	30316	235	11	136	1545	126	0	194	39	28	Unknown
80374A2	F:2:4	1607	722	32416	251	13	133	1545	131	0	103	36	24	SON Valle de Altar
80382A1	F:2:4	1464	713	32946	257	13	143	1630	137	41	147	36	20	Unknown
80382A2	F:2:4	1478	663	31472	254	12	146	1598	142	6	148	40	27	SON Valle de Altar
80453A	F:2:4	912	274	13792	273	16	73	237	28	40	60	28	35	Unknown
80489A1	F:2:4	1595	833	35150	258	15	138	1601	131	35	139	36	22	Los Vidrios
80489A2	F:2:4	1463	723	30932	246	40	136	1567	138	20	201	37	32	SON Valle de Altar
80526A	F:2:4	1342	676	29101	243	18	119	1360	109	4	326	37	34	Unknown
80564A	F:2:4	1469	752	33364	272	12	120	1425	109	5	168	34	28	SON Valle de Altar
80569A	F:2:4	1603	752	33460	258	21	143	1606	135	34	257	42	30	Unknown
80569A	F:2:4	1415	697	30427	255	15	106	1313	106	19	132	36	40	SON Valle de Altar
80575A	F:2:4	1490	755	31301	246	18	106	1353	103	12	297	27	28	Unknown
80575A	F:2:4	1124	276	12646	120	77	40	234	16	942	40	16	14	Sauceda Mtns
80744A	F:2:4	1483	712	30873	259	15	116	1381	110	70	188	31	30	SON Valle de Altar
81298A	F:2:4	1407	780	32460	267	12	116	1401	111	12	161	34	38	Unknown
81400A	F:2:4	1482	700	31136	252	14	143	1601	133	12	354	32	37	Los Jagueyes
81427A	F:2:4	1275	641	26683	231	15	109	1321	108	0	275	25	40	SON Valle de Altar
81453A	F:2:4	1202	285	13213	132	80	40	230	21	1016	26	20	21	Unknown
81466A	F:2:4	1565	791	34366	255	14	150	1628	143	0	167	38	38	Sauceda Mtns
														SON Valle de Altar
														Unknown

Sample	Site	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	Th	Source
81492A	F:2:4	1373	631	26942	240	13	139	1523	127	6	277	38	26	SON Valle de Altar
81512A1	F:2:4	950	286	13931	278	20	69	237	26	49	63	30	33	Unknown
81512A2	F:2:4	1486	757	32953	276	10	120	1442	113	10	236	37	32	Los Vidrios
81514A	F:2:4	915	242	11990	236	15	69	221	25	40	104	24	23	SON Unknown J
81521A1	F:2:4	1337	402	10319	213	107	27	182	23	874	50	25	20	SON Unknown J
81521A2	F:2:4	1657	401	11639	215	138	25	187	27	1057	74	19	17	SON Valle de Altar
81564A	F:2:4	1189	625	30490	336	17	137	1571	117	0	129	45	38	Unknown
81581A	F:2:4	1329	398	9332	178	147	20	128	13	1189	42	21	15	Selene
81581A	F:2:4	1635	802	34164	264	12	113	1387	115	31	226	35	40	SON Valle de Altar
81640A	F:2:4	774	521	10030	116	88	22	85	53	360	23	32	13	Unknown
81689A1	F:2:4	1710	789	35753	257	12	137	1608	140	71	239	38	25	Government Mtn
81689A2	F:2:4	1567	773	30034	245	16	108	1316	105	42	160	31	26	SON Valle de Altar
81889A	F:2:4	971	241	12272	248	18	67	222	29	18	42	28	26	Unknown
81916A1	F:2:4	1491	767	32706	280	13	121	1475	116	29	130	35	31	Los Vidrios
81916A2	F:2:4	1537	820	33172	267	16	116	1396	105	0	130	37	28	SON Valle de Altar
81921A	F:2:4	1551	765	32000	264	18	112	1379	104	0	227	34	33	Unknown
81931A	F:2:4	1500	754	33229	287	13	121	1498	112	48	137	37	32	SON Valle de Altar
81931A	F:2:4	1221	308	13493	132	82	34	236	19	1023	43	15	19	Unknown
81943A	F:2:4	1564	797	34695	264	14	149	1616	138	0	103	46	24	Sauceda Mtns
81958A	F:2:4	928	238	11716	234	20	71	212	32	59	99	25	30	SON Valle de Altar
81958A	F:2:4	1368	335	15347	143	86	39	240	18	936	30	25	21	Unknown
81965A1	F:2:4	901	236	10618	214	38	65	206	34	34	144	28	32	Los Vidrios
81965A2	F:2:4	977	254	12656	256	17	67	230	35	32	79	26	24	Los Vidrios
81965A3	F:2:4	959	261	13031	258	37	68	220	28	88	50	25	26	Los Vidrios
81965A4	F:2:4	977	262	13029	256	17	71	231	27	108	43	26	32	Los Vidrios
82002A	F:2:4	925	263	11756	234	13	62	223	33	53	112	22	26	Los Vidrios

82027A1	F:2:4	823	224	11073	214	19	59	208	33	73	163	20	28	Los Vidrios
82027A2	F:2:4	1538	713	30533	253	14	108	1379	110	16	224	31	37	SON Valle de Altar
82043A	F:2:4	3402	1275	168515	9	13	5	19	1	58	0	8	4	Unknown
82047A	F:2:4	1564	765	33702	255	13	146	1597	133	5	128	42	26	not obsidian
82106A	F:2:4	906	261	12461	253	24	71	229	27	11	61	25	26	SON Valle de Altar
82144A	F:2:4	790	231	11397	233	18	64	219	29	55	148	22	23	Unknown
82163A	F:2:4	1418	782	32847	257	13	143	1602	143	42	217	38	31	Los Vidrios
82181A	F:2:4	1410	735	33162	258	13	145	1607	142	0	204	35	34	SON Valle de Altar
82186A	F:2:4	1324	753	20174	349	10	135	1199	112	26	122	38	37	Unknown
82205A	F:2:4	1198	342	9735	213	28	34	85	10	29	40	29	20	Antelope Wells
82210-1	F:2:4	1622	853	37058	311	16	115	1460	106	57	83	39	33	Bull Creek, AZ
Sample	SON:	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	Th	Source
82210-2	F:2:4	1588	781	33763	280	10	117	1455	113	0	118	40	37	SON Valle de Altar
82210-3	F:2:4	1302	712	28172	246	17	114	1367	109	5	247	36	30	Unknown
82210A	F:2:4	959	275	13320	265	18	68	224	34	37	47	28	40	Los Vidrios
82210A1	F:2:4	5006	864	38122	2	73	19	48	1	0	6	3	7	not obsidian
82210A2	F:2:4	1518	732	30121	247	15	119	1372	106	0	281	35	19	SON Valle de Altar
82210A3	F:2:4	1469	764	32690	268	10	114	1395	106	19	198	33	22	Unknown
82211A1	F:2:4	1398	684	31802	249	12	144	1561	123	0	120	39	19	SON Valle de Altar
82211A2	F:2:4	2230	1351	133648	4	12	4	21	6	35	0	0	4	Unknown
82213A	F:2:4	1018	263	13063	257	17	72	232	31	35	60	28	29	not obsidian
82232A	F:2:4	1534	713	33902	296	18	110	1469	112	26	127	39	28	Los Vidrios
82246A1	F:2:4	1413	735	32472	265	14	113	1418	112	3	180	32	32	SON Valle de Altar
82246A2	F:2:4	1583	809	33256	272	9	120	1395	107	48	152	36	30	Unknown
82257A	F:2:4	1606	791	32206	257	18	112	1388	100	16	145	36	25	SON Valle de Altar
														Unknown

82257A	F:2:4	1178	391	9114	174	142	25	131	19	1301	60	23	19	Selene
82257A1	F:2:4	1468	759	32001	262	13	108	1392	110	15	276	41	35	SON Valle de Altar
82257A2	F:2:4	1292	656	29098	234	68	136	1525	123	23	312	39	21	Unknown
82281A	F:2:4	1578	737	32269	262	15	118	1373	105	0	150	37	26	SON Valle de Altar
82289A1	F:2:4	1534	771	32615	281	16	115	1459	113	21	156	40	35	Unknown
82289A2	F:2:4	1513	719	31771	272	9	124	1418	109	0	119	36	28	SON Valle de Altar
82289A3	F:2:4	1541	781	33731	277	18	113	1448	112	0	185	34	43	Unknown
82302A	F:2:4	1474	825	20498	398	16	129	1179	98	14	108	38	28	Antelope Wells
82308A	F:2:4	1442	677	31765	252	9	143	1580	137	46	178	38	26	SON Valle de Altar
82308A	F:2:4	1486	740	31571	262	15	112	1404	107	37	229	37	27	Unknown
82317A	F:2:4	1678	844	34515	267	13	113	1443	108	23	271	35	24	SON Valle de Altar
82317A	F:2:4	1297	287	13261	124	77	38	237	16	856	53	19	23	Unknown
82322A	F:2:4	1556	738	31895	248	15	140	1566	134	0	299	36	35	Sauceda Mtns
82357A1	F:2:4	1345	696	30424	252	18	142	1531	138	35	161	38	27	SON Valle de Altar
82357A2	F:2:4	1836	874	39490	285	14	144	1653	144	28	112	48	42	Unknown
82362A	F:2:4	815	261	12456	256	18	67	227	30	6	48	26	30	Los Vidrios
82418A	F:2:4	971	232	11029	223	19	62	218	28	40	120	23	38	Los Vidrios
82424A	F:2:4	980	266	13372	251	15	69	225	29	57	97	26	27	Los Vidrios
82427A	F:2:4	1437	712	30626	244	9	135	1581	143	0	107	37	26	SON Valle de Altar
82588A	F:2:4	3620	1200	170330	0	12	4	17	2	0	67	0	4	Unknown
82606A	F:2:4	1320	619	26926	228	9	133	1481	135	15	198	36	32	not obsidian
82713A	F:2:4	1561	738	32624	257	13	151	1581	137	12	182	33	35	SON Valle de Altar
Sample	SON:	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	Th	Source
82713A1	F:2:4	975	250	13340	265	12	69	226	34	65	107	27	34	Los Vidrios

82713A2	F:2:4	1264	568	27418	270	12	137	1523	144	26	250	44	31	SON Valle de Altar
82713A3	F:2:4	954	270	12251	239	22	67	222	32	39	95	35	31	Unknown
82786A	F:2:4	1426	758	32653	268	12	115	1414	112	16	172	32	33	Los Vidrios
														SON Valle de Altar
82798A	F:2:4	1613	766	31678	263	11	109	1399	110	15	135	33	31	Unknown
82863A	F:2:4	895	258	12604	248	15	68	231	33	42	60	29	29	Los Vidrios
														SON Valle de Altar
82866A	F:2:4	1359	684	29513	246	13	99	1287	94	0	344	29	25	Unknown
														SON Valle de Altar
83033A	F:2:4	1431	684	30923	239	12	137	1519	123	19	155	35	32	Unknown
83054A	F:2:4	959	251	12546	251	17	67	230	26	52	56	25	35	Los Vidrios
														SON Valle de Altar
83155A	F:2:4	1519	740	31652	264	15	112	1447	103	27	239	37	35	Unknown
83225A	F:2:4	867	252	11844	227	15	64	210	26	81	104	26	24	Los Vidrios
														SON Valle de Altar
83230A	F:2:4	1462	727	33926	346	13	143	1671	131	0	230	49	25	Unknown
														SON Valle de Altar
83230A1	F:2:4	1431	645	29381	236	50	135	1481	123	60	162	37	26	Unknown
														SON Valle de Altar
83230A2	F:2:4	1346	711	29630	265	20	116	1399	111	30	169	33	31	Unknown
														SON Valle de Altar
83396A	F:2:4	1558	832	32999	265	15	112	1391	110	21	164	33	48	Unknown
83433A	F:2:4	946	265	12953	244	17	72	223	32	81	76	28	37	Los Vidrios
														SON Valle de Altar
84340A	F:2:4	1311	690	30267	243	11	143	1560	141	38	226	40	24	Unknown
														SON Valle de Altar
84359A	F:2:4	1735	798	34752	266	17	120	1412	111	21	223	38	27	Unknown
84393A	F:2:4	913	246	11261	225	26	58	212	30	55	86	23	33	Los Vidrios
84486A	F:2:4	747	500	9411	108	73	21	84	55	384	12	28	14	Government Mtn
														SON Valle de Altar
84544A	F:2:4	1391	744	30793	253	15	120	1400	106	6	290	37	29	Unknown
84583A1	F:2:4	929	261	11951	249	17	67	226	27	35	64	24	35	Los Vidrios
84583A2	F:2:4	894	275	12309	240	20	71	216	32	41	105	23	35	Los Vidrios
														SON Valle de Altar
84586A1	F:2:4	1600	750	32092	249	16	147	1593	141	30	214	38	29	Unknown
														SON Valle de Altar
84586A2	F:2:4	1521	761	32011	244	14	137	1540	131	21	214	40	34	Unknown
84621A	F:2:4	947	252	12862	259	24	65	222	31	62	70	20	23	Los Vidrios

84621A	F:2:4	1543	803	33790	267	9	116	1391	111	0	170	33	32	SON Valle de Altar
84661A	F:2:4	981	258	12767	243	17	66	210	27	72	85	29	30	Unknown
84676A	F:2:4	948	278	12555	251	13	66	227	34	22	66	27	44	Los Vidrios
84682A	F:2:4	1611	740	32714	258	13	135	1592	142	29	223	40	40	SON Valle de Altar
84742A1	F:2:4	958	264	12851	257	13	63	220	32	0	86	23	30	Unknown
84742A2	F:2:4	1413	772	32074	260	14	109	1379	108	0	289	40	43	Los Vidrios
84779A	F:2:4	2676	1392	143712	8	9	4	17	2	0	45	0	4	SON Valle de Altar
84781A	F:2:4	1040	273	13878	260	20	69	226	32	75	100	30	41	Unknown
84848A	F:2:4	1408	738	32897	261	14	146	1609	143	41	198	43	31	Los Vidrios
84848A	Site													SON Valle de Altar
Sample	SON:	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	Th	Source
84881A	F:2:4	1069	267	12468	245	18	64	219	33	59	83	25	31	Unknown
84901A	F:2:4	1388	478	25563	153	18	78	732	57	102	69	21	15	Los Vidrios
84901A	F:2:4	905	285	12326	241	17	71	218	37	73	109	23	16	Los Sitios del Agua
84912A	F:2:4	1477	695	30864	244	16	139	1535	122	12	128	35	24	Los Vidrios
84934A	F:2:4	1234	406	9637	180	156	20	136	15	1281	52	22	16	SON Valle de Altar
85010A	F:2:4	1632	758	33464	258	12	114	1400	101	50	131	32	27	Selene
85016A	F:2:4	1635	791	34307	250	16	136	1600	145	58	295	35	34	SON Valle de Altar
85077A	F:2:4	1691	800	35883	272	12	149	1626	137	43	116	46	34	Unknown
85091A	F:2:4	1500	719	31167	265	13	108	1380	107	28	241	35	31	SON Valle de Altar
85176A	F:2:4	876	249	11895	238	16	64	221	29	55	71	25	29	Unknown
85176A	F:2:4	1007	242	12154	251	16	62	221	30	26	85	26	31	Los Vidrios
85206A	F:2:4	1365	651	26995	239	14	111	1298	89	22	165	27	20	SON Valle de Altar
85215A	F:2:4	1345	712	30338	253	16	114	1380	107	0	226	31	36	Unknown
85215A	F:2:4	876	204	9438	187	16	59	193	31	37	134	16	17	SON Valle de Altar
85215A	F:2:4	1607	731	34301	274	11	118	1450	112	14	229	39	26	SON Unknown I
85227A	F:2:4	1532	812	36545	277	12	152	1666	143	15	149	49	35	SON Valle de Altar

														Unknown
														SON Valle de Altar
85317A	F:2:4	1451	710	29530	254	13	109	1368	111	22	277	32	33	Unknown
85337A	F:2:4	944	253	12188	245	16	65	226	33	81	104	21	40	Los Vidrios
85353A1	F:2:4	921	267	12061	240	18	65	227	29	39	70	26	32	Los Vidrios
														SON Valle de Altar
85356A	F:2:4	1508	769	32106	265	14	109	1373	102	0	158	32	46	Unknown
														SON Valle de Altar
85393A	F:2:4	1433	756	32568	258	13	145	1590	126	23	183	36	29	Unknown
85398A	F:2:4	873	255	11126	224	13	61	210	33	77	169	22	30	Los Vidrios
														SON Valle de Altar
85414A	F:2:4	1268	618	28991	319	14	135	1641	126	23	225	47	51	Unknown
85436A	F:2:4	1674	827	35079	267	11	148	1669	148	23	364	33	23	Los Jagueyes
														SON Valle de Altar
85449A	F:2:4	1439	677	30130	251	16	108	1366	110	51	189	33	34	Unknown
85458A	F:2:4	1294	462	22509	143	17	77	702	46	122	118	19	31	Los Sitios del Agua
85470A	F:2:4	946	262	12670	250	21	65	224	25	70	70	32	30	Los Vidrios
														SON Valle de Altar
85486A	F:2:4	1595	676	29626	252	15	107	1304	108	0	159	37	28	Unknown
92195A	F:2:4	907	238	12279	234	15	65	219	35	68	125	26	31	Los Vidrios
														SON Valle de Altar
29478A	F:2:61	1635	792	33166	270	12	113	1408	110	0	130	35	42	Unknown
														SON Valle de Altar
29758A	F:2:61	1724	778	34337	278	21	109	1398	111	28	122	41	45	Unknown
														SON Valle de Altar
29777A1	F:2:61	1571	855	35395	279	14	116	1486	122	19	282	37	35	Unknown
														SON Valle de Altar
29777A2	F:2:61	1549	775	33976	271	12	116	1421	113	11	198	37	38	Unknown
														SON Valle de Altar
29823A	F:2:61	1320	742	31279	260	9	121	1386	114	8	191	34	28	Unknown
														SON Valle de Altar
29862A	F:2:61	1520	730	31468	253	14	111	1346	108	0	163	37	32	Unknown
	Site													
Sample	SON:	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	Th	Source
														SON Valle de Altar
29883A	F:2:61	1614	744	34317	278	11	121	1457	115	0	156	37	38	Unknown
														SON Valle de Altar
30056A1	F:2:61	1576	746	32404	264	28	117	1411	118	28	346	32	34	Unknown
														SON Valle de Altar
30056A2	F:2:61	1668	696	30761	250	29	112	1394	97	13	241	29	29	Unknown

30061A	F:2:61	1529	795	35796	293	13	126	1515	119	0	179	40	30	SON Valle de Altar
														Unknown
30160A1	F:2:61	1655	810	34841	272	11	120	1427	112	30	252	38	42	SON Valle de Altar
														Unknown
30160A2	F:2:61	1540	705	31680	251	17	112	1318	97	13	149	29	24	SON Valle de Altar
														Unknown
30226A	F:2:61	860	252	11966	235	19	70	228	32	69	108	24	29	Los Vidrios
														SON Valle de Altar
30241A	F:2:61	1612	764	32471	265	18	110	1368	103	0	242	33	37	Unknown
														SON Valle de Altar
61429A	F:2:61	1533	762	33143	271	13	116	1427	113	30	193	36	34	Unknown
														SON Valle de Altar
61588A	F:2:61	1606	845	33669	261	14	112	1391	102	23	231	37	43	Unknown
														SON Valle de Altar
61651A	F:2:61	1335	738	31444	257	11	122	1418	106	8	212	35	32	Unknown
														SON Valle de Altar
61692A	F:2:61	1637	763	32966	259	9	116	1358	109	9	153	40	40	Unknown
														SON Valle de Altar
61733A	F:2:61	1514	752	31673	257	15	114	1355	97	0	172	35	25	Unknown
														SON Valle de Altar
61747A	F:2:61	1430	725	31141	254	16	112	1358	110	38	225	38	35	Unknown
														SON Valle de Altar
61759A	F:2:61	1605	819	33485	269	16	111	1408	110	0	143	40	33	Unknown
														SON Valle de Altar
61768A	F:2:61	1491	765	32041	257	14	113	1397	117	0	180	38	21	Unknown
														SON Valle de Altar
61810A	F:2:61	1510	733	29888	245	14	106	1324	105	0	216	36	26	Unknown
														SON Valle de Altar
61825A	F:2:61	1763	866	35083	271	16	111	1407	103	22	143	35	31	Unknown
														SON Valle de Altar
61845A1	F:2:61	1470	649	28454	238	15	96	1284	106	0	194	30	40	Unknown
														SON Valle de Altar
61845A2	F:2:61	1388	642	28942	280	16	149	1548	148	20	177	48	22	Unknown
														SON Valle de Altar
61845A3	F:2:61	1506	705	30581	248	13	109	1346	101	0	173	36	31	Unknown
														SON Valle de Altar
61866A	F:2:61	1412	763	33177	266	13	118	1410	110	2	230	36	19	Unknown
														SON Valle de Altar
61957A	F:2:61	1525	759	31277	262	16	108	1361	106	15	160	29	31	Unknown
														SON Valle de Altar
61972A	F:2:61	991	275	12941	258	13	70	219	27	64	49	23	28	Los Vidrios
61977A	F:2:61	1727	823	36600	276	14	114	1433	110	0	115	44	36	SON Valle de Altar

62046A	F:2:61	1770	757	32539	263	24	119	1404	109	34	201	33	28	Unknown
62089A	F:2:61	1590	760	32170	255	14	115	1380	104	0	203	32	28	Unknown
62138A	F:2:61	1668	737	32567	259	14	111	1389	120	8	185	32	23	Unknown
62282A	F:2:61	1550	733	30617	256	13	114	1367	102	1	215	32	22	Unknown
62358A	F:2:61	1534	685	31890	260	14	123	1418	103	11	226	33	26	Unknown
62458A	F:2:61	1563	687	29979	258	14	110	1311	100	16	213	31	33	Unknown
62471A	F:2:61	1762	815	33159	232	31	106	1269	105	0	423	33	34	Unknown
62713A	F:2:61	3069	1122	163000	4	10	4	16	4	4	-5	-1	4	not obsidian
62776A	F:2:61	1298	687	27561	241	12	111	1333	114	8	223	27	32	Unknown
62820A	F:2:61	1534	689	30087	251	12	109	1354	106	33	175	30	24	Unknown
Sample	SON:	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	Th	Source
62958A1	F:2:61	1548	738	30090	252	24	116	1391	110	8	353	34	33	Unknown
62958A2	F:2:61	1544	726	31188	260	13	117	1388	109	12	257	35	42	Unknown
63164A	F:2:61	1383	736	31864	261	11	113	1389	111	20	132	38	41	Unknown
63229A	F:2:61	1453	754	33762	268	11	121	1407	118	16	143	35	26	Unknown
63302A	F:2:61	5767	886	40296	3	74	23	46	3	0	-11	5	4	not obsidian
63367A	F:2:61	6617	1011	48077	2	77	25	58	1	9	31	-1	4	not obsidian
63637A	F:2:61	1853	693	28089	228	48	98	1262	106	0	388	26	40	Unknown
63867A	F:2:61	1580	760	31424	255	22	108	1339	99	43	176	37	26	Unknown
63920A	F:2:61	1550	775	32068	261	16	113	1386	109	0	238	37	34	Unknown
64037A	F:2:61	4681	1692	217575	6	12	15	16	6	6	13	-1	4	not obsidian
64069A	F:2:61	1552	722	29758	241	45	104	1288	97	36	148	29	26	SON Valle de Altar

														Unknown
64179A	F:2:61	1421	697	30114	246	14	117	1366	110	55	279	34	24	SON Valle de Altar
														Unknown
64205A	F:2:61	1431	721	31505	259	15	115	1378	107	0	200	36	18	SON Valle de Altar
														Unknown
64527A	F:2:61	1558	718	31024	257	12	120	1401	117	24	233	32	36	SON Valle de Altar
														Unknown
64665A	F:2:61	1569	743	31583	251	14	113	1383	109	0	321	35	29	SON Valle de Altar
														Unknown
64770A	F:2:61	1675	848	34873	270	14	117	1392	95	26	203	36	30	SON Valle de Altar
														Unknown
64836A	F:2:61	1598	797	33479	265	16	116	1379	105	0	192	35	29	SON Valle de Altar
														Unknown
64847A	F:2:61	1799	955	39995	278	13	123	1421	108	7	260	44	37	SON Valle de Altar
														Unknown
65211A	F:2:61	1559	758	33261	264	12	113	1423	109	17	109	35	35	SON Valle de Altar
														Unknown
65287A	F:2:61	1615	742	32135	257	16	112	1385	111	37	109	32	36	SON Valle de Altar
														Unknown
65293A	F:2:61	1525	720	30404	252	11	110	1369	111	0	278	32	32	SON Valle de Altar
														Unknown
65419A	F:2:61	1382	715	31066	259	12	119	1415	110	18	226	31	18	SON Valle de Altar
														Unknown
65509A	F:2:61	1534	750	31723	266	13	111	1384	112	53	140	29	32	SON Valle de Altar
														Unknown
65594A1	F:2:61	1414	716	29314	251	9	107	1371	110	0	208	34	25	SON Valle de Altar
														Unknown
65594A2	F:2:61	1538	796	33939	270	19	125	1422	112	0	138	40	29	SON Valle de Altar
														Unknown
65851A	F:2:61	1629	771	34169	268	18	114	1417	107	36	164	34	32	SON Valle de Altar
														Unknown
65864A	F:2:61	1590	819	34505	264	15	113	1372	108	0	149	32	35	SON Valle de Altar
														Unknown
66102A1	F:2:61	1546	723	29627	243	14	111	1328	106	0	215	28	33	SON Valle de Altar
														Unknown
66102A2	F:2:61	3232	1571	137510	0	14	4	16	1	1	81	-1	4	not obsidian
														SON Valle de Altar
66106A	F:2:61	1528	746	33266	270	11	118	1413	108	15	131	38	25	Unknown
														SON Valle de Altar
66130A	F:2:61	1635	791	35316	286	15	109	1445	104	0	123	35	23	Unknown
														SON Valle de Altar
69649A	F:2:61	1442	716	32387	257	12	113	1373	108	5	163	41	40	SON Valle de Altar

69945A	F:2:61	1492	777	33032	261	13	119	1422	113	5	213	32	29	Unknown SON Valle de Altar
69951A	F:2:61	1508	739	31383	260	16	115	1384	110	32	250	32	20	Unknown SON Valle de Altar
69975A1	F:2:61	1677	394	11616	172	82	39	216	27	1105	84	20	30	Unknown Sauceda Mtns
Sample	SON:	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	Th	Source
69975A2	F:2:61	1477	799	33721	272	24	113	1414	111	12	113	42	31	Unknown SON Valle de Altar
70327A	F:2:61	1442	723	29332	247	113	110	1362	107	0	325	34	34	Unknown SON Valle de Altar
72500A	F:2:61	1106	622	27401	310	15	131	1625	132	1	275	35	33	Unknown SON Valle de Altar
72530A	F:2:61	1390	689	29837	248	14	117	1382	118	1	346	37	37	Unknown SON Valle de Altar
72534A	F:2:61	1510	764	33130	259	14	119	1391	105	0	131	38	29	Unknown SON Valle de Altar
72782A	F:2:61	1485	811	33069	264	12	119	1429	106	29	177	32	29	Unknown SON Valle de Altar
72793A	F:2:61	1596	776	32771	264	18	113	1417	114	0	277	38	35	Unknown SON Valle de Altar
72958A	F:2:61	1432	698	30348	254	13	113	1373	102	4	251	30	25	Unknown
73030A	F:2:61	3128	1041	32966	1	59	13	37	10	0	27	0	4	not obsidian SON Valle de Altar
73055A	F:2:61	1487	834	34577	266	13	119	1396	103	40	233	32	40	Unknown SON Valle de Altar
73094A	F:2:61	1645	822	35582	281	10	122	1435	117	9	169	38	36	Unknown SON Valle de Altar
73318A	F:2:61	1549	740	31641	271	15	117	1403	104	19	192	34	22	Unknown SON Valle de Altar
73390A	F:2:61	1571	723	31133	259	13	120	1388	100	0	173	26	34	Unknown SON Valle de Altar
73414A	F:2:61	1336	745	31071	264	17	112	1349	108	35	180	33	32	Unknown SON Valle de Altar
73477A	F:2:61	1390	775	32796	272	10	107	1378	113	3	219	32	40	Unknown SON Valle de Altar
73651A	F:2:82	1628	722	33808	273	15	123	1439	116	20	294	32	27	Unknown SON Valle de Altar
73685A	F:2:82	1464	766	32179	255	13	114	1426	114	0	286	33	37	Unknown

74042A	F:2:82	1502	780	32996	269	12	121	1436	112	2	242	39	35	SON Valle de Altar Unknown
74068A	F:2:82	1486	723	31651	243	17	134	1575	132	21	314	36	26	SON Valle de Altar Unknown
76209A	F:2:82	1434	700	31251	273	14	112	1442	110	21	275	37	34	SON Valle de Altar Unknown
76307A	F:2:82	1487	770	34277	274	15	116	1403	110	46	178	32	37	SON Valle de Altar Unknown