Title

SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM THE CORNER SITE AND DANIELS VALLEY, CABEZA PRIETA WILDLIFE REFUGE, SOUTHWESTERN ARIZONA

Author

Shackley, M. Steven

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GEOARCHAEOLOGICAL XRF LAB
A GREEN SOLAR FACILITY

GEOARCHAEOLOGICAL X-RAY FLUORESCENCE SPECTROMETRY LABORATORY
8100 WYOMING BLVD., SUITE M4-158 ALBUQUERQUE, NM 87113 USA

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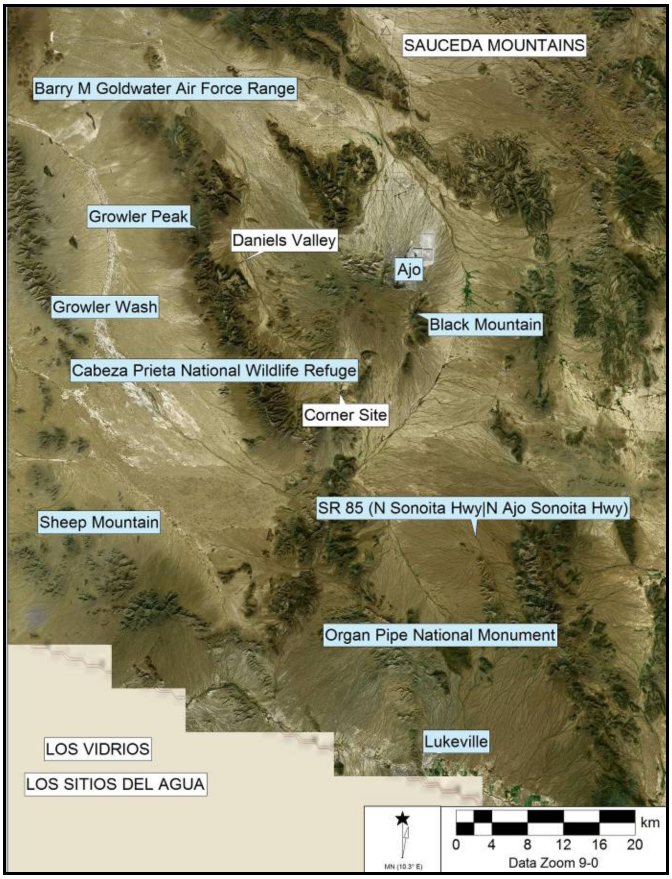

Satellite aerial orthophoto of the site locations, relevant obsidian sources (in capitals), and prominent features

by
M. Steven Shackley Ph.D., Director
Geoarchaeological XRF Laboratory
Albuquerque, New Mexico

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Introduction

The 22 obsidian artifacts, and one possible iron meteorite from two sites on Cabeza Prieta Wildlife Refuge, southwestern Arizona were produced from three of the sources previously recovered from sites on the refuge, Los Vidrios, Sonora (40.9%), Los Sitios del Agua (22.7%), and Sauceda Mountains (36.4%; see Shackley 2015, 2016, 2017; Table 1 and Figure 1 here). As in the previous study, the assemblage suggests that the local environment was important, with connections to the north and south apparent (see cover image). The composition of the high iron rock is similar to iron meteorites, although confirmation of this assignment is underway.

Laboratory Sampling, Analysis and Instrumentation

All archaeological and source 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).

Trace Element Analyses

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 $Fe_2O_3^T$), 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 quadratic 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. Further details concerning the petrological choice of these elements in Southwest obsidians is available in Shackley (1988, 1995, 2005; also Mahood and Stimac 1990; and Hughes and Smith 1993). Nineteen specific pressed powder standards are used for the best fit regression calibration for elements Ti-Nb, Pb, Th, and Ba, include G-2 (basalt), AGV-2 (andesite), GSP-2 (granodiorite), SY-2 (syenite), BHVO-2 (hawaiite), STM-1 (syenite), QLO-1 (quartz latite), RGM-1 (obsidian), W-2 (diabase), BIR-1 (basalt), SDC-1 (mica schist), TLM-1 (tonalite), SCO-1 (shale), NOD-A-1 and NOD-P-1 (manganese) all US Geological Survey standards, NIST-278 (obsidian), U.S. National Institute of Standards and Technology, BE-N (basalt) from the Centre de Recherches Pétrographiques et Géochimiques in France, and JR-1 and JR-2 (obsidian) from the Geological Survey of Japan (Govindaraju 1994).

The data from the WinTrace software were translated directly into Excel for Windows and SPSS (ver. 21) and JMP 12.0.1 software for statistical manipulation. In order to evaluate these quantitative determinations, machine data were compared to measurements of known standards during each run. RGM-1 a USGS obsidian standard was analyzed during each sample run for plutonic rock samples to check machine calibration (Table 1 and Figure 1). MBH Analytical leaded bronze standard 32XLB17 standard was used for the major and minor oxide analysis of the possible iron meteorite sample (Table 3 and Figure 2).

Major and Minor Oxide Analysis of Iron Rock

Analysis of the major oxides of Si, Al, Ca, Fe, K, Mg, Mn, Na, and Ti is performed under the multiple conditions elucidated below. This fundamental parameter analysis (theoretical with standards), while not as accurate as destructive analyses (pressed powder and fusion disks) is usually within a few percent of actual, based on the analysis of USGS RGM-1 obsidian standard (see also Shackley 2011a). The fundamental parameters (theoretical) method is run under conditions commensurate with the elements of interest and calibrated with 11 USGS standards (RGM-1, rhyolite; AGV-2, andesite; BHVO-1, hawaiite; BIR-1, basalt; G-2, granite; GSP-2, granodiorite; BCR-2, basalt; W-2, diabase; QLO-1, quartz latite; STM-1, syenite), and one Japanese Geological Survey rhyolite standard (JR-1). See Lundblad et al. (2011) for another set of conditions and methods for oxide analyses.

CONDITIONS OF FUNDAMENTAL PARAMETER ANALYSIS[1]

Low Za (Na, Mg, Al, Si, P)

Voltage	6 kV	Current	Auto[2]
Livetime	100 seconds	Counts Limit	0
Filter	No Filter	Atmosphere	Vacuum
Maximum Energy	10 keV	Count Rate	Low

Mid Zb (K, Ca, Ti, V, Cr, Mn, Fe)

Voltage	32 kV	Current	Auto
Livetime	100 seconds	Counts Limit	0
Filter	Pd (0.06 mm)	Atmosphere	Vacuum
Maximum Energy	40 keV	Count Rate	Medium

High Zb (Sn, Sb, Ba, Ag, Cd)

Voltage	50 kV	Current	Auto
Livetime	100 seconds	Counts Limit	0
Filter	Cu (0.559 mm)	Atmosphere	Vacuum
Maximum Energy	40 keV	Count Rate	High

Low Zb (S, Cl, K, Ca)

Voltage	8 kV	Current	Auto
Livetime	100 seconds	Counts Limit	0
Filter	Cellulose (0.06 mm)	Atmosphere	Vacuum
Maximum Energy	10 keV	Count Rate	Low

[1] Multiple conditions designed to ameliorate peak overlap identified with digital filter background removal, least squares empirical peak deconvolution, gross peak intensities and net peak intensities above background.

[2] Current is set automatically based on the mass absorption coefficient.

Discussion

As noted above, the vast majority of obsidian artifacts were produced from sources in the local region (northern Sonoran Desert). The direction of the sources, Los Sitios del Agua and Los Vidrios, Sonora to the south, and Sauceda Mountains to the north, indicates a concentration of local source procurement (Tables 1 and 2 and Figure 1; see cover image). All of the Sonoran Desert obsidian sources are generally equal media for tool production in quality and nodule size, although Los Vidrios can be very brittle in hard hammer percussion, but equal to the others for pressure work (Martynec et al. 2011; Shackley 2005).

One sample from Daniels Valley is not obsidian, but has the possible morphology and composition that suggests it could be a meteorite (see http://meteorites.wustl.edu/metcomp/ ;Table 3 and Figure 2 here). It is not certain and I have contacted EPS at Washington University in St. Louis for confirmation.

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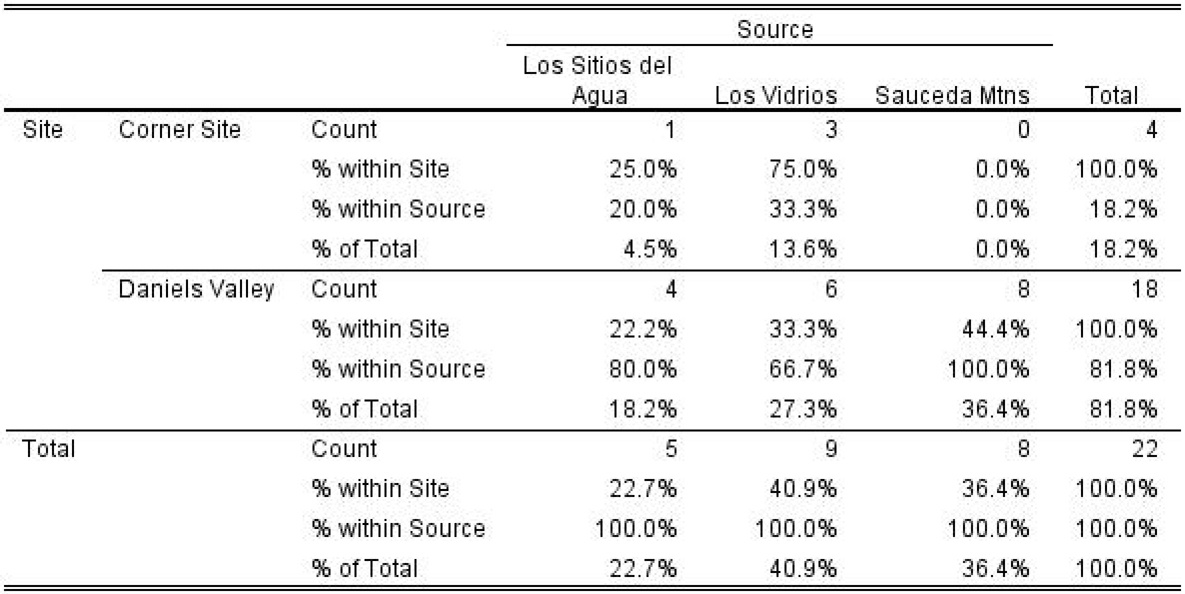
Table 1. Elemental concentrations for the artifacts by site and USGS RGM-1 rhyolite standard.

Sample	Site	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Source
1	Daniels Valley	1440	368	10804	48	161	78	33	212	20	1151	Sauceda Mtns, AZ
2	Daniels Valley	1646	418	11935	86	182	81	35	212	22	1117	Sauceda Mtns, AZ
3	Daniels Valley	1313	466	25098	188	149	16	85	727	51	76	Los Sitios del Agua, SON
4	Daniels Valley	1296	481	24650	172	152	19	82	729	54	67	Los Sitios del Agua, SON
5	Daniels Valley	1472	388	10851	72	167	75	31	202	25	1162	Sauceda Mtns, AZ
6	Daniels Valley	1554	410	11214	82	166	76	30	199	24	1117	Sauceda Mtns, AZ
7	Daniels Valley	1508	300	11109	75	161	105	31	182	16	970	Sauceda Mtns, AZ
8	Daniels Valley	1352	329	10154	58	148	72	32	187	17	1011	Sauceda Mtns, AZ
9	Daniels Valley	937	255	13104	113	272	20	71	225	31	14	Los Vidrios, SON
11	Daniels Valley	1328	483	23475	154	146	12	80	728	53	92	Los Sitios del Agua, SON
13	Daniels Valley	4749	11602	2116798	10	94	74	5	27	1	178	not obsidian
14	Daniels Valley	1350	450	23423	168	147	18	78	722	54	74	Los Sitios del Agua, SON
15	Daniels Valley	964	271	12590	124	254	15	69	221	35	0	Los Vidrios, SON
16	Daniels Valley	888	265	13040	122	260	15	66	221	24	25	Los Vidrios, SON
17	Daniels Valley	921	250	12336	133	245	21	66	218	37	17	Los Vidrios, SON
18	Daniels Valley	1548	346	10718	49	162	72	32	205	27	1173	Sauceda Mtns, AZ
21	Daniels Valley	889	259	12273	123	243	17	69	221	33	26	Los Vidrios, SON
22	Daniels Valley	1449	353	10235	52	150	67	34	191	25	1056	Sauceda Mtns, AZ
10	Corner Site	1048	293	14256	153	280	16	74	230	35	8	Los Vidrios, SON

12	Corner Site	930	269	12393	122	245	12	73	217	31	39	Los Vidrios, SON
19	Daniels Valley	1118	293	14157	196	277	20	68	220	25	0	Los Vidrios, SON
20	Corner Site	1274	431	22124	158	141	15	77	690	49	69	Los Sitios del Agua, SON
23	Corner Site	991	291	14357	155	281	15	73	228	30	0	Los Vidrios, SON
RGM1-S4		1527	285	13246	42	146	107	25	229	12	815	standard
RGM1-S4		1645	298	13134	44	143	106	28	219	9	835	standard

Table 2. Crosstabulation of obsidian source by site.



			Source			
			Los Sitios del Agua	Los Vidrios	Sauceda Mtns	Total
Site	Corner Site	Count	1	3	0	4
		% within Site	25.0%	75.0%	0.0%	100.0%
		% within Source	20.0%	33.3%	0.0%	18.2%
		% of Total	4.5%	13.6%	0.0%	18.2%
	Daniels Valley	Count	4	6	8	18
		% within Site	22.2%	33.3%	44.4%	100.0%
		% within Source	80.0%	66.7%	100.0%	81.8%
		% of Total	18.2%	27.3%	36.4%	81.8%
Total		Count	5	9	8	22
		% within Site	22.7%	40.9%	36.4%	100.0%
		% within Source	100.0%	100.0%	100.0%	100.0%
		% of Total	22.7%	40.9%	36.4%	100.0%

Table 3. Major, minor and trace elements for Sample 13, Daniels Valley.

Sample	**Na2O**	**MgO**	**Al2O3**	**SiO2**	**P2O5**	**K2O**	**CaO**	**TiO2**	**V2O5**	**Cr2O3**	**MnO**	**Fe2O3**
	%	%	%	%	%	%	%	%	%	%	%	%
13	0.595	1.232	4.135	32.842	0	0.19	0.313	0.049	0	0.018	0.671	59.729
32XLB17	0	4.988	0.829	0.102	0	0	0	0	0	0	0.353	0.843

	Cl	**Co**	**Ni**	**Cu**	**Zn**	**Ga**	**Rb**	**Sr**	**Y**	**Zr**	**Nb**	**Ba**	**Pb**	**Th**
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
13	43	24	24	166	10	11	94	74	5	27	1	178	96	4
RGM1-S4	2941	<1	16	8	42	18	146	107	25	229	12	815	20	15

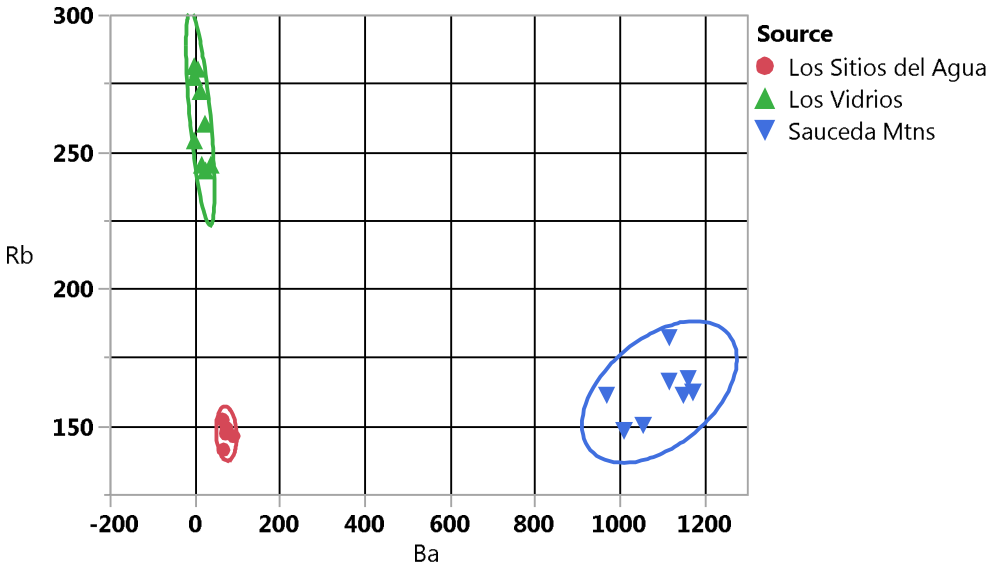


Figure 1. Ba/Rb bivariate plot of the archaeological obsidian samples. Confidence ellipses at 95%.

Figure 2. Possible meteorite sample (13) from Daniels Valley