Title
SOURCE PROVENANCE OF OBSIDIAN ARTIFACTS FROM THE CIENEGA PHASE EARLY AGRICULTURE PERIOD SITE OF LOS POZOS (AZ AA:12:91 ASM), SANTA CRUZ RIVER BASIN, TUCSON, ARIZONA

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Location of sources of obsidian (bold) used to produce the artifacts at Los Pozos, the site location (bold italics), and significant features (blue background)

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by

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Report Prepared for

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INTRODUCTION

The analysis here of 177 obsidian artifacts from the Cienega Phase Early Agricultural Los Pozos site in the Santa Cruz River basin in Tucson, Arizona indicates a very diverse provenance assemblage with sources in all Cardinal directions from the western and eastern Sonoran Desert, the Arizona Uplands, to northwest Mexico (Sonora and Chihuahua). Some of these sources (i.e. Cow Canyon) have been recovered from Los Pozos in the past as discussed below. The diversity of sources with a procurement radius of approximately 250 km in all directions was not evident before this, in part due to the rarity of obsidian in Cienega Phase sites in the Tucson Basin. After a discussion of the laboratory procedures and instrumentation, a discussion of the results and a brief comment on technology within the obsidian projectile point assemblage is offered.

LABORATORY SAMPLING, ANALYSIS AND INSTRUMENTATION

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

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

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

The data from the WinTrace software were translated directly into Excel for Windows software for manipulation and on into SPSS for Windows for statistical analyses. In order to evaluate these quantitative determinations, machine data were compared to measurements of known standards during each run. RGM-1 a USGS obsidian standard is analyzed during each sample run for obsidian artifacts to check machine calibration (Table 1). Source assignments were made with reference to Shackley (1995, 2005; Shackley et al. 2016, 2018) and source standard data at this lab (Tables 2 and 3 and Figure 1; see also http://swxrflab.net/swobsrcs.htm).

The Stepwise Analytical Trajectory

It is always satisfying to analyze a relatively large obsidian artifact assemblage and discover that the artifacts were produced from many different sources in all Cardinal directions. However, as the number of sources increases, the potential for miss-assignment to a source increases (Shackley 2005, 2011; Shackley et al. 2018). While Rb, Sr, Y, Zr, Nb, and Ba are useful incompatible (high or large lithophile) discriminating elements in rhyolite obsidian with XRF, they are best employed in a stepwise fashion - a stepped analytical trajectory, since some sources have very similar elemental compositions even though they are not derived from the same magma source and can be hundreds if not thousands of kilometers distant (i.e. Sauceda Mountains and Cow Canyon both relatively high Sr sources, see Figure 1). The trajectory of analysis using these elements for this assemblage is accomplished by using biplots:

1. Sr and Rb of all the assigned sources based on comparison with known source standards (see http://swxrflab.net/swobsrcs.htm) begins to discriminate Cow

Canyon and Sauceda Mountains and Sand Tanks with considerable overlap of the remaining sources (see Figure 1).

2. Zr and Rb effectively discriminates the northern Sonoran sources Los Vidrios, Antelope Wells (El Berrendo) and Los Sitios del Agua (see Figure 1).
3. Sauceda Mountains and Cow Canyon the two most common sources in this assemblage require care in discrimination. Rb, Sr and Ba are generally useful even though both sources have multiple chemical groups (see Figure 1).
4. Finally, while Sand Tanks and Superior (Picketpost Mountain) can be discriminated using Rb, Sr, and Zr, they are more effectively discriminated with Ba and Rb (see Figure 1).

There are situations where using multivariate statistical analysis (i.e. hierarchical cluster, discriminant, PCA) can be useful in discrimination, although there are hazards with this approach (see Baxter 1992a, 1992b, 1994a, 1994b; Johnson and Wichern 1998; Shackley 1998; c.f Glascock et al. 1998). Compositional data are not multivariate normal, but many multivariate statistical methods assume that they are. This often results in groupings in the matrices that really do not exist (Baxter 1994). Biplots can solve this issue when combined with confidence ellipses based on the mean values of a given group (source in our case) and each individual observation compared to that mean generating a confidence level (see Figure 1). Here, level of confidence indicates the probability with which the estimation of the location of a statistical parameter (in this case the arithmetic mean in relation to the population, for us the source) in a sample is also true for the population. Taken another way if you were to replicate your sampling from the underlying obsidian source standard distribution many times and each time calculate a confidence ellipse, then 90% of the ellipses (the level chosen in this study) so constructed would contain the underlying mean. The splay of individual measurements in the x-y plot indicates deviation from that population (source) mean.

DISCUSSION

In some ways it is difficult to discuss the obsidian source provenance assemblage comparatively at Los Pozos since it is essentially in a data vacuum with little contemporaneous assemblages to compare. While a few obsidian artifacts have been recovered from Cienega Phase sites in the Tucson Basin and elsewhere (i.e. McEuen Cave in the Gila Mountains of east-central Arizona; Shackley 1998, 2001, 2005, 2015), it is uncommon enough that the assemblage at Los Pozos will serve as an obsidian provenance "type site" for some time, perhaps indefinitely for this time period. Having said that, however, there are a number of issues that deserve comment.

Why Such Diversity of Obsidian Source Provenance?

The relationship between mobility/sedentism and "exotic" material has been bludgeoned to death in the archaeological literature. I'm not going to repeat it here. Suffice it to say that it is easy to determine the source of an obsidian artifact, but difficult to determine how it got into archaeological record (Ward 1977; Shackley 2005). In the North American Southwest I have, through some research, recognized that when mobility is great, the diversity of sources expected is correspondingly great (Shackley 1990, 1996a, 2005; see also Eerkens et al. 2007). This is, perhaps, an overgeneralization. If a given residentially mobile hunter-gatherer group inhabits a site near a source, often that source, all things being equal, dominates the assemblage - most often. However, even in early hominid contexts in East Africa where mobility was certainly high, this is not always the case and another source from a greater distance may be more common depending on any number of social processes (Shackley and Sahle 2017). With sedentism as a result of agricultural adoption or intensification, the dynamic can be very different than the residentially mobile pattern (see Railey 2010). This was especially evident in the recent social network project on Late Classic contexts in the Southwest where social relations played a major part in the exchange of obsidian rather than simple distance decay, and thus its presence in the archeological record was a product of social relations writ large (Mills et al. 2013a, 2013b). Was this also the case at Los Pozos, or was some or all the obsidian procured directly in concert with some members of the group that were more mobile than others (Binford 1977; Cashdan 1983; Hewlett et al. 1982; Shackley 1990, 1996a)? Interestingly here is that the obsidian sources in the assemblage were derived from sources in all Cardinal directions, dominated by the nearest Sonoran Desert sources (especially Sauceda Mountains), but also Cow Canyon from the Arizona Uplands near to what is now the New Mexico state line (see cover image). Additionally, the obsidian sources in northwest Mexico, actually also Sonoran and Chihuahuan Desert sources suggests contact or movement toward the Sea of Cortez and the Sierra Madre Occidental, and the possibility of procurement of marine resources and social networks that could include other early agricultural groups to the south and southeast (the rest of the artifact assemblage will be key here in this regard). In any case, the diverse obsidian provenance assemblage indicates a relationship over a territory with a radius of over 250 km in all directions. This in itself would be significant, but given that few or no other Cienega Phase sites have this kind of diversity, another layer of explanation is required. Did Los Pozos act as a distribution center for obsidian raw material to other Cienega Phase sites, or did the inhabitants of the other sites just not have the kin relations (social network) as diverse or were just not interested in obsidian as a stone raw material?

Los Pozos Obsidian Cienega Projectile Points

Most, if not all, the projectile points would be classified as Cienega or Cienega Stemmed projectile points common in contemporaneous contexts in many areas of the southern Southwest (Sliva, personal communication, 2021; Shackley 1996b, 2005; Sliva 1999, 2015). The distribution of obsidian source diversity in the projectile points was similar to the debitage (general distribution not frequency), and given the dominance of obsidian biface thinning and rejuvenation flakes in the obsidian assemblage, not surprising (Table 3 and Figures 2 and 3). The projectile point assemblage is a very "active" assemblage indicating some production, but more in-haft rejuvenation of fractured points, although many fractured points (blade portions) seem to have been de-hafted and rejected or were embedded in various game and entered the archaeological record in that manner (see Figure 3). Again, given that the obsidian provenance assemblage is so extensive here it does seem that obsidian as a raw material had some import at Los Pozos. Whether this was a difference in desired prey species selection at Los Pozos (obsidian versus other raw materials) than other Cienega Phase sites, or some other social reason is not clear (see Shackley 2018, 2019 for a Late Prehistoric example in southeastern California). Projectile point design can be significant functionally as well as socially (Cattelain 1997; Christenson 1997; Griffin 1997; Shackley 2018, 2019; Whittaker 1984). Whether either of these concepts drove the greater production and use of obsidian Cienega Phase points at Los Pozos remains a mystery.

And again, Los Pozos will continue as the "type site" for discussions of obsidian source provenance, obsidian projectile point design and function, and social networks during the Cienega Phase for some time to come. This study is just a beginning.

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

SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th
RGM-1 (Govindaraju 1994)	1600	279	12998	149	108	25	219	8.9	807	24	15.1
RGM-1 (USGS recommended)[1]	1619±120	279±50	13010±210	150±8	110±10	25[2]	220±20	8.9±.6	810±46	24±3	15±1.3
RGM-1, pressed powder standard (this study, n=9)	1553±47	313±16	13182±193	147±3	109±3	25±2	218±4	9±2	796±13	20±3	17±3

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

Table 2. Elemental concentrations and source assignments for the archaeological specimens. All measurements in parts per million (ppm).

FN #	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th	Source
78	1258	289	13328	86	135	76	35	228	19	976	20	31	Sauceda Mtns
115	1641	733	32915	322	268	15	110	1405	105	5	44	23	Antelope Wells (El Berrendo)
165A	918	464	8065	56	116	21	24	96	34	235	21	19	Superior (Picketpost Mtn)
165B	1230	326	14275	117	135	77	38	232	24	871	20	22	Sauceda Mtns
206	932	246	11625	113	235	16	67	213	26	53	31	26	Los Vidrios
213	1171	579	8968	136	136	26	23	100	28	171	27	17	Superior (Picketpost Mtn)
319	1195	296	13875	96	136	80	39	230	25	880	20	21	Sauceda Mtns
320	1330	506	10084	87	138	114	25	135	22	895	24	19	Sauceda Mtns
328A	1641	285	14355	160	135	80	34	221	17	852	19	14	Sauceda Mtns
328B	1470	464	10111	79	144	130	21	124	13	1190	27	19	Cow Canyon
350	948	264	13128	162	267	19	65	224	34	12	33	27	Los Vidrios
351	1023	281	13533	126	120	73	32	212	14	959	18	20	Sauceda Mtns
364A	1053	407	11209	72	137	131	18	121	18	1413	19	10	Cow Canyon
364B	1281	469	19401	190	134	20	75	668	49	120	21	17	Los Sitios del Agua
372	1073	290	13736	82	125	74	35	230	22	963	13	19	Sauceda Mtns
373	1339	433	9593	64	139	134	21	126	15	1384	24	20	Cow Canyon
490	792	275	13470	154	238	16	63	213	30	7	25	36	Los Vidrios
551	1455	493	12279	146	140	126	19	123	12	1280	20	13	Cow Canyon
691	1624	311	14239	211	130	78	37	219	20	840	22	14	Sauceda Mtns
693	1279	274	13548	132	126	76	36	224	16	881	18	19	Sauceda Mtns

FN #	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th	Source
761	1150	397	9235	60	132	126	20	122	21	1332	20	12	Cow Canyon
794	998	270	12946	138	248	18	67	224	28	38	30	42	Los Vidrios
813A	1434	514	10670	107	152	138	16	131	14	1255	24	11	Cow Canyon
813B	618	1430	8824	34	-1	60	1	19	2	888	7	7	not obsidian
815A	1423	431	10106	96	144	134	20	123	13	1240	24	16	Cow Canyon
815B	1422	358	8993	107	120	110	18	112	8	1223	20	9	Cow Canyon
815C	687	262	13184	170	243	19	65	209	27	0	28	29	Los Vidrios
815D	1432	337	15480	150	138	83	38	235	22	791	24	29	Sauceda Mtns
815E	1218	275	14145	177	268	16	72	228	29	29	24	32	Los Vidrios
815F	965	229	12082	171	237	16	68	209	31	0	27	25	Los Vidrios
815G	704	267	13777	149	265	18	68	223	38	0	26	24	Los Vidrios
822	1248	290	13627	95	122	75	36	232	16	974	18	18	Sauceda Mtns
824	1004	484	8399	74	121	20	30	102	28	227	18	11	Superior (Picketpost Mtn)
830	1335	458	25543	205	150	20	85	716	51	99	21	19	Los Sitios del Agua
831	1316	312	14333	101	129	79	36	237	17	938	16	18	Sauceda Mtns
862A	770	287	13667	138	252	18	66	222	27	0	27	29	Los Vidrios
862B	1587	443	10385	105	147	135	26	129	5	1122	22	14	Cow Canyon
862C	1153	315	14191	83	129	78	35	232	24	982	16	20	Sauceda Mtns
862D	1209	287	13058	80	132	76	31	222	15	922	20	16	Sauceda Mtns
862E	1428	337	14941	150	140	81	30	224	18	814	25	19	Sauceda Mtns
862F	1357	460	11931	82	144	138	16	123	10	1378	20	15	Cow Canyon
912	993	302	15058	179	297	16	71	233	30	28	36	28	Los Vidrios
915	753	927	5234	54	0	37	4	19	1	426	30	4	not obsidian
920A	1299	437	9849	56	141	135	21	126	16	1311	19	15	Cow Canyon
920B	1218	474	8632	97	131	22	30	106	33	199	26	21	Superior (Picketpost Mtn)
920C	865	248	12067	115	243	12	67	217	27	51	22	21	Los Vidrios
920D	1489	340	15601	168	142	81	35	229	17	772	23	9	Sauceda Mtns
925A	1658	363	12192	89	166	109	28	184	18	918	26	35	Sauceda Mtns
925B	1325	549	10086	69	142	114	28	131	20	939	22	16	Sauceda Mtns
975A	1457	297	14341	127	135	79	31	219	20	773	14	18	Sauceda Mtns
975B	766	464	10416	80	117	26	26	97	32	132	21	19	Superior (Picketpost Mtn)
987	1023	284	13074	140	138	149	44	120	16	145	29	23	Cow Canyon?
987B	1416	590	11228	139	170	127	26	141	20	777	26	13	Sauceda Mtns
987C	1475	523	25777	212	150	19	80	721	53	88	25	19	Los Sitios del Agua

FN #	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th	Source
990	1317	448	9645	113	140	132	23	120	17	1245	19	13	Cow Canyon
993	993	259	12303	138	243	18	66	214	30	42	25	34	Los Vidrios
995-1	1352	289	14197	127	137	80	37	231	18	889	17	21	Los Sitios del Agua
995-2	1397	492	24097	270	142	16	75	662	48	123	18	16	Los Sitios del Agua
996	1264	425	9498	63	140	138	23	125	16	1319	21	12	Cow Canyon
997	1367	447	9872	80	140	132	20	126	11	1219	21	13	Cow Canyon
998	1237	284	12994	86	124	75	35	227	24	904	19	28	Sauceda Mtns
999	1259	443	9662	139	132	125	22	115	11	1188	21	23	Cow Canyon
5000	1265	296	13959	89	134	82	36	234	22	956	21	10	Sauceda Mtns
5001	964	264	12939	128	258	17	66	231	34	28	30	27	Los Vidrios
5002	1026	238	12341	111	249	16	72	220	34	101	26	32	Los Vidrios
5003	1249	426	9545	64	143	129	23	122	14	1273	17	19	Cow Canyon
5016	1413	497	11870	87	146	145	22	126	17	1227	21	23	Cow Canyon
5016A	1409	475	23939	184	147	10	86	702	50	111	20	14	Los Sitios del Agua
5016B	1225	283	13029	80	128	76	40	231	16	869	20	19	Sauceda Mtns
5016C	1245	333	14719	115	140	80	35	241	23	928	24	25	Sauceda Mtns
5016E	1352	470	10154	78	148	140	22	133	20	1283	19	18	Cow Canyon
5016F	1100	281	12748	51	120	72	36	225	18	968	14	21	Sauceda Mtns
5016G	1021	310	14704	119	287	22	76	236	32	24	27	40	Los Vidrios
5017	708	479	10662	75	126	26	19	97	27	234	24	16	Superior (Picketpost Mtn)
5020	1449	446	10208	92	145	136	19	134	17	1297	23	19	Cow Canyon
5021	1302	293	13386	111	129	76	31	218	18	835	17	6	Sauceda Mtns
5022	1237	283	13687	92	132	77	39	228	16	962	23	21	Sauceda Mtns
5023	1278	468	23898	198	146	16	78	686	51	106	24	23	Los Sitios del Agua
5024	1324	446	9877	79	139	138	23	127	20	1302	20	14	Cow Canyon
5025	1335	470	23867	188	141	18	82	685	46	117	17	25	Los Sitios del Agua
5033	1233	299	14095	113	132	85	33	231	13	969	18	22	Sauceda Mtns
5033	1471	505	24940	214	146	18	83	704	43	108	24	15	Los Sitios del Agua
5038	1249	284	12528	58	122	69	37	231	21	951	19	19	Sauceda Mtns
5041	1283	290	13852	88	132	79	33	230	20	978	16	18	Sauceda Mtns
5042	1498	493	10729	117	150	141	18	130	18	1255	27	18	Cow Canyon
5043	1450	311	14963	98	135	81	40	234	19	952	20	22	Sauceda Mtns
5048A	1256	430	9844	67	142	132	14	128	13	1314	25	24	Cow Canyon
5048B	1385	466	10286	99	147	144	18	132	17	1297	25	18	Cow Canyon

FN #	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th	Source
5048C	1261	514	9852	95	144	117	25	139	20	849	21	12	Sauceda Mtns
5048D	1085	534	12232	127	171	18	40	253	31	52	27	27	Sand Tanks
5048E	1239	371	8861	45	131	124	18	120	11	1328	17	7	Cow Canyon
5053	1284	282	13640	108	130	78	33	227	23	929	14	12	Sauceda Mtns
5061	1789	352	17738	161	153	86	35	231	21	725	22	11	Sauceda Mtns
5062	1180	270	12971	66	124	82	31	218	20	916	16	16	Sauceda Mtns
5075	1298	453	21887	187	131	16	75	661	45	96	15	17	Los Sitios del Agua
5109A	1106	516	8491	135	124	24	26	95	28	238	28	9	Superior (Picketpost Mtn)
5109B	1442	510	25770	234	145	12	82	695	44	107	18	16	Los Sitios del Agua
5238A	1269	301	13442	104	142	83	36	235	24	870	22	21	Sauceda Mtns
5238B	1180	253	12620	80	117	72	32	217	22	948	14	13	Sauceda Mtns
5245	700	261	13016	104	237	18	70	223	31	0	25	19	Los Vidrios
5246B	1239	439	11338	85	131	127	21	117	15	1359	18	16	Cow Canyon
5246C	1194	283	12839	80	121	70	31	220	24	932	19	21	Sauceda Mtns
5246D	1271	439	11532	81	142	134	18	125	20	1370	15	14	Cow Canyon
5246E	1351	369	8942	118	128	126	21	119	13	1201	24	12	Cow Canyon
5246F	1438	285	13418	138	123	77	31	213	17	818	15	33	Sauceda Mtns
5246G	1020	313	13363	70	126	73	33	225	17	994	18	17	Sauceda Mtns
5258	1300	423	9754	70	136	135	18	128	18	1271	23	12	Cow Canyon
5326	1427	478	24105	187	140	16	79	666	49	116	20	10	Los Sitios del Agua
5329	1014	502	8514	90	131	21	28	104	33	229	29	18	Superior (Picketpost Mtn)
5335	1179	494	9725	65	135	112	31	138	18	892	19	6	Sauceda Mtns
5338	1317	320	13995	120	131	84	32	231	19	845	20	20	Sauceda Mtns
5342	1211	294	13734	77	135	82	35	236	26	940	14	22	Sauceda Mtns
5343	874	264	12469	121	257	19	67	222	32	19	22	29	Los Vidrios
5345	1192	550	8716	98	134	23	24	99	33	244	21	18	Superior (Picketpost Mtn)
5346A	944	279	13145	133	267	17	67	225	30	68	32	36	Los Vidrios
5346B	1036	308	13797	66	125	76	33	230	20	1017	20	19	Sauceda Mtns
5348	1364	461	10112	90	145	131	17	125	16	1238	20	16	Cow Canyon
5354	1273	448	9727	68	139	135	17	121	18	1272	20	11	Cow Canyon
5359	1348	318	14426	83	125	77	36	228	21	1095	24	18	Sauceda Mtns
5474B	1756	454	10597	195	143	137	21	117	14	1072	23	17	Cow Canyon
5482-1	1650	337	16775	226	137	75	35	210	20	624	26	18	Sauceda Mtns
5482-2	1544	518	10760	121	159	147	21	128	19	1116	26	9	Cow Canyon

FN #	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th	Source
5483	1291	282	13645	88	128	77	37	229	19	964	17	14	Sauceda Mtns
5484	1222	290	13922	87	127	76	34	224	25	939	19	17	Sauceda Mtns
5559	1268	494	11986	111	153	147	18	132	14	1211	25	35	Cow Canyon
5563	1445	795	33279	278	282	12	112	1456	110	0	40	38	Antelope Wells (El Berrendo)
5575	1242	291	13355	84	124	76	39	232	23	987	20	14	Sauceda Mtns
5687	1645	563	28105	252	157	12	82	713	43	78	28	13	Los Sitios del Agua
5698A	1437	553	27166	247	156	17	85	726	47	93	26	19	Los Sitios del Agua
5698B	708	279	13495	161	242	17	70	215	30	5	26	28	Los Vidrios
5719	1448	479	25089	177	149	19	84	712	54	118	20	25	Los Sitios del Agua
5721-1	1601	338	11848	111	165	112	23	187	20	916	26	28	Sauceda Mtns
5721-2	1618	519	27256	295	152	20	77	676	42	109	24	15	Los Sitios del Agua
5868	1222	417	9171	52	137	125	21	132	14	1314	17	12	Cow Canyon
5771A	1384	291	10603	44	157	106	30	186	21	1191	15	24	Sauceda Mtns
5771B	1201	337	14993	80	137	86	37	236	19	936	19	24	Sauceda Mtns
5873	1433	483	25133	196	143	17	82	700	49	171	30	28	Los Sitios del Agua
5874A	1262	466	22191	161	135	16	75	694	51	103	19	22	Los Sitios del Agua
5874B	1480	350	12888	51	166	113	30	187	21	1027	17	26	Sauceda Mtns
5918	894	232	12511	164	245	14	66	220	34	52	23	26	Los Vidrios
5945	1547	327	11953	102	172	110	31	183	15	907	23	28	Sauceda Mtns
5976A	958	256	12149	128	242	18	70	211	26	64	28	37	Los Vidrios
5976B	1528	511	24596	208	141	14	71	680	46	95	16	18	Los Sitios del Agua
6006A	1262	303	13579	92	134	77	36	228	18	950	20	19	Sauceda Mtns
6006B	1179	283	13572	194	259	16	68	224	31	35	28	26	Los Vidrios
6084A	1286	451	9853	94	153	141	21	127	9	1187	26	20	Cow Canyon
6084B	933	291	15041	202	299	19	70	223	29	33	30	33	Los Vidrios
6084C	1025	336	15470	217	292	17	74	229	31	0	30	35	Los Vidrios
6084D	1879	379	16971	187	146	84	35	233	24	806	31	30	Sauceda Mtns
6098	992	409	10973	55	124	127	21	122	14	1335	21	18	Cow Canyon
6099	1246	286	13430	114	124	74	33	211	13	964	16	14	Sauceda Mtns
6102	1120	278	13219	146	256	15	64	221	28	47	28	31	Los Vidrios
6108	1802	500	11007	147	147	139	20	124	13	1125	29	18	Cow Canyon
6145	1014	482	8552	101	125	26	26	101	31	228	24	21	Superior (Picketpost Mtn)
6237A	1329	463	10272	98	148	137	19	122	8	1221	25	22	Cow Canyon

6237B	1172	287	13563	121	126	75	30	234	20	969	20	15	Sauceda Mtns
FN #	Ti	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th	Source
6237C	1406	303	14238	136	134	73	35	222	24	880	20	18	Sauceda Mtns
6253	657	258	12808	131	238	17	75	210	31	19	24	24	Los Vidrios
6256A	1023	565	11344	124	133	21	30	95	28	115	28	5	Superior (Picketpost Mtn)
6256B	1312	316	14657	131	140	79	34	229	27	923	19	22	Sauceda Mtns
6256C	1103	543	9002	83	131	22	29	105	27	226	24	22	Superior (Picketpost Mtn)
6268B	698	257	12852	94	236	15	68	208	28	4	20	31	Los Vidrios
6268C	1230	484	11622	111	131	130	28	125	10	1223	20	20	Cow Canyon
6289	1486	359	15772	140	150	81	36	245	20	919	26	27	Sauceda Mtns
6298	912	239	12916	208	246	12	63	200	28	20	23	26	Los Vidrios
6301	1359	441	9963	111	135	128	22	115	14	1083	21	15	Cow Canyon
6309	613	268	13391	151	246	20	69	219	32	0	30	40	Los Vidrios
6366	1086	227	12396	221	233	15	59	200	30	46	22	29	Los Vidrios
6546A	1186	275	12783	79	123	76	36	231	20	994	16	17	Sauceda Mtns
6546B	1398	312	14845	144	131	81	35	227	17	837	18	23	Sauceda Mtns
6546C	1606	305	16056	135	144	77	32	234	22	826	23	27	Sauceda Mtns
6546D	1474	337	15869	158	147	84	41	231	13	728	18	14	Sauceda Mtns
6563	1389	518	10687	85	156	152	20	125	16	1213	23	19	Cow Canyon
6612	1050	259	12492	135	240	17	63	205	32	33	27	26	Los Vidrios
6828A	935	581	11040	105	146	23	22	97	27	169	23	22	Superior (Picketpost Mtn)
6828B	1501	526	10748	133	153	143	16	122	12	1211	19	18	Cow Canyon
6923	1312	400	8834	46	132	128	20	123	15	1403	20	12	Cow Canyon
6943	1735	441	10033	201	140	124	16	115	15	951	23	21	Cow Canyon
7037	944	273	13324	161	259	18	71	221	34	75	29	36	Los Vidrios

Table 3. Crosstabulation of artifact type (debitage and points/bifaces) versus source. Non-obsidian samples excluded.

			Artifact Type		
			DEBITAGE	POINT/BIFACE	Total
Source	Sauceda Mtns	Count	49	16	65
		% within Source	75.4%	24.6%	100.0%
		% within Artifact Type	35.5%	41.0%	36.7%
		% of Total	27.7%	9.0%	36.7%
	Sand Tanks	Count	1	0	1
		% within Source	100.0%	0.0%	100.0%
		% within Artifact Type	0.7%	0.0%	0.6%
		% of Total	0.6%	0.0%	0.6%
	Superior (Picketpost Mtn)	Count	12	1	13
		% within Source	92.3%	7.7%	100.0%
		% within Artifact Type	8.7%	2.6%	7.3%
		% of Total	6.8%	0.6%	7.3%
	Cow Canyon	Count	34	11	45
		% within Source	75.6%	24.4%	100.0%
		% within Artifact Type	24.6%	28.2%	25.4%
		% of Total	19.2%	6.2%	25.4%
	Los Vidrios	Count	28	4	32
		% within Source	87.5%	12.5%	100.0%
		% within Artifact Type	20.3%	10.3%	18.1%
		% of Total	15.8%	2.3%	18.1%
	Los Sitios del Agua	Count	12	7	19
		% within Source	63.2%	36.8%	100.0%
		% within Artifact Type	8.7%	17.9%	10.7%
		% of Total	6.8%	4.0%	10.7%
	Antelope Wells (El Berrendo)	Count	2	0	2
		% within Source	100.0%	0.0%	100.0%
		% within Artifact Type	1.4%	0.0%	1.1%
		% of Total	1.1%	0.0%	1.1%
Total		Count	138	39	177
		% within Source	78.0%	22.0%	100.0%
		% within Artifact Type	100.0%	100.0%	100.0%
		% of Total	78.0%	22.0%	100.0%

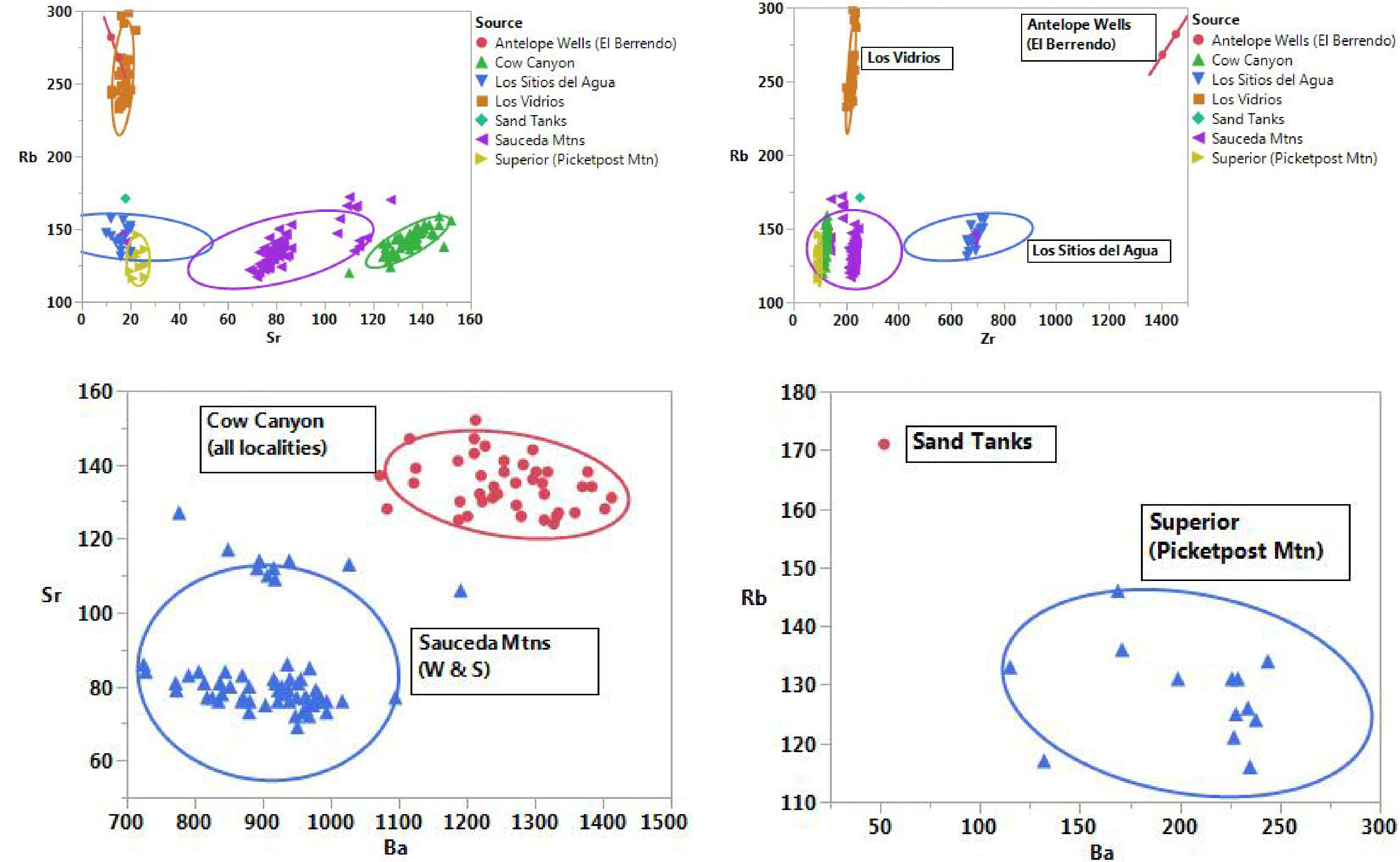

Figure 1. Plotting/discrimination trajectory of obsidian source assignment (confidence ellipses at 90%). Upper left Sr/Rb all samples; upper right Zr/Rb aiding discrimination of Antelope Wells, Los Sitios del Agua, and Los Vidrios; lower left Ba/Rb plot aiding in the discrimination of Sauceda Mountains (both chemical groups) and Cow Canyon (all localities); lower right Ba/Rb plot discriminating Sand Tanks, and Superior (Picketpost Mountain).

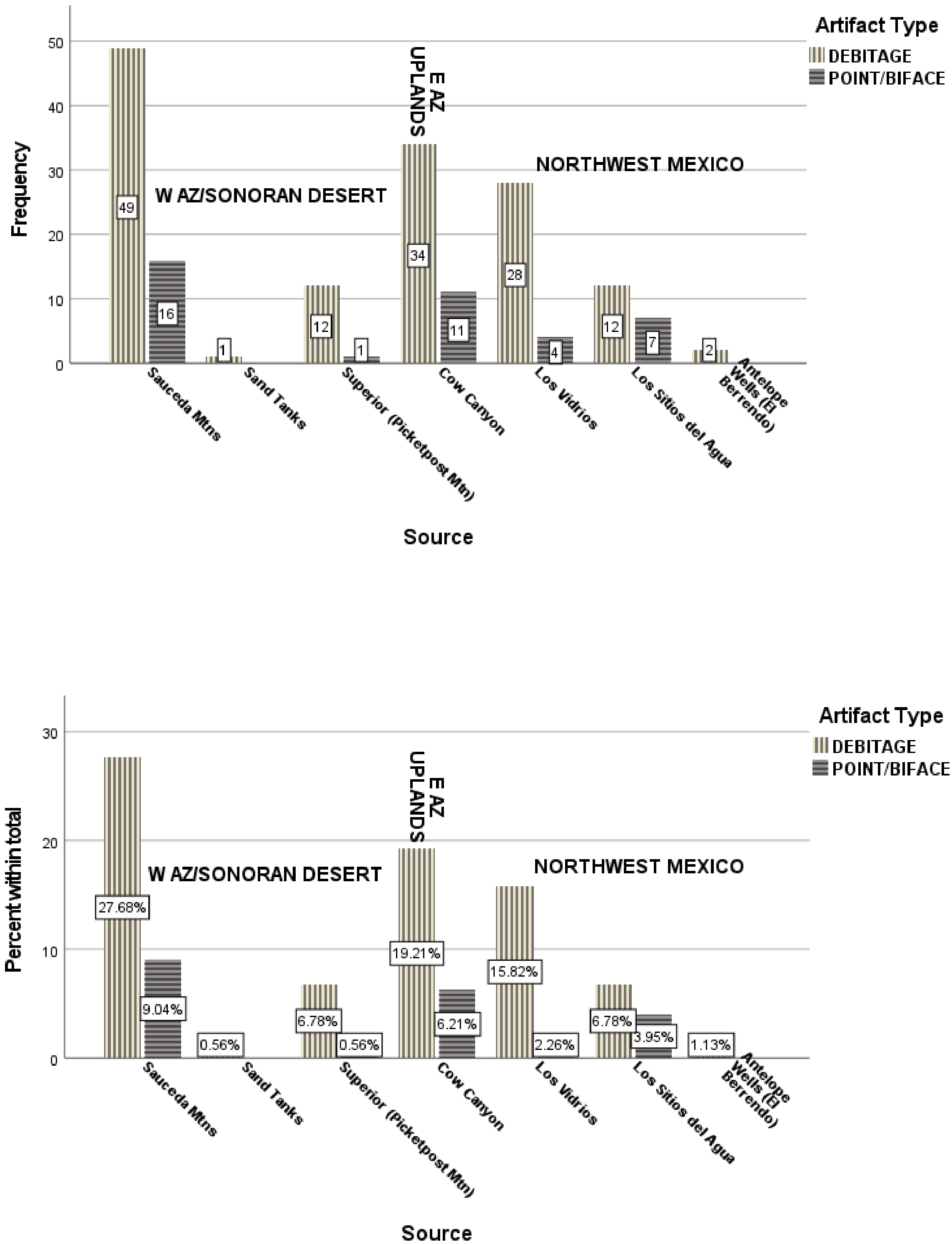

Figure 2. Frequency histograms (count and proportion) of obsidian source by artifact type (see Tables 2 and 3).

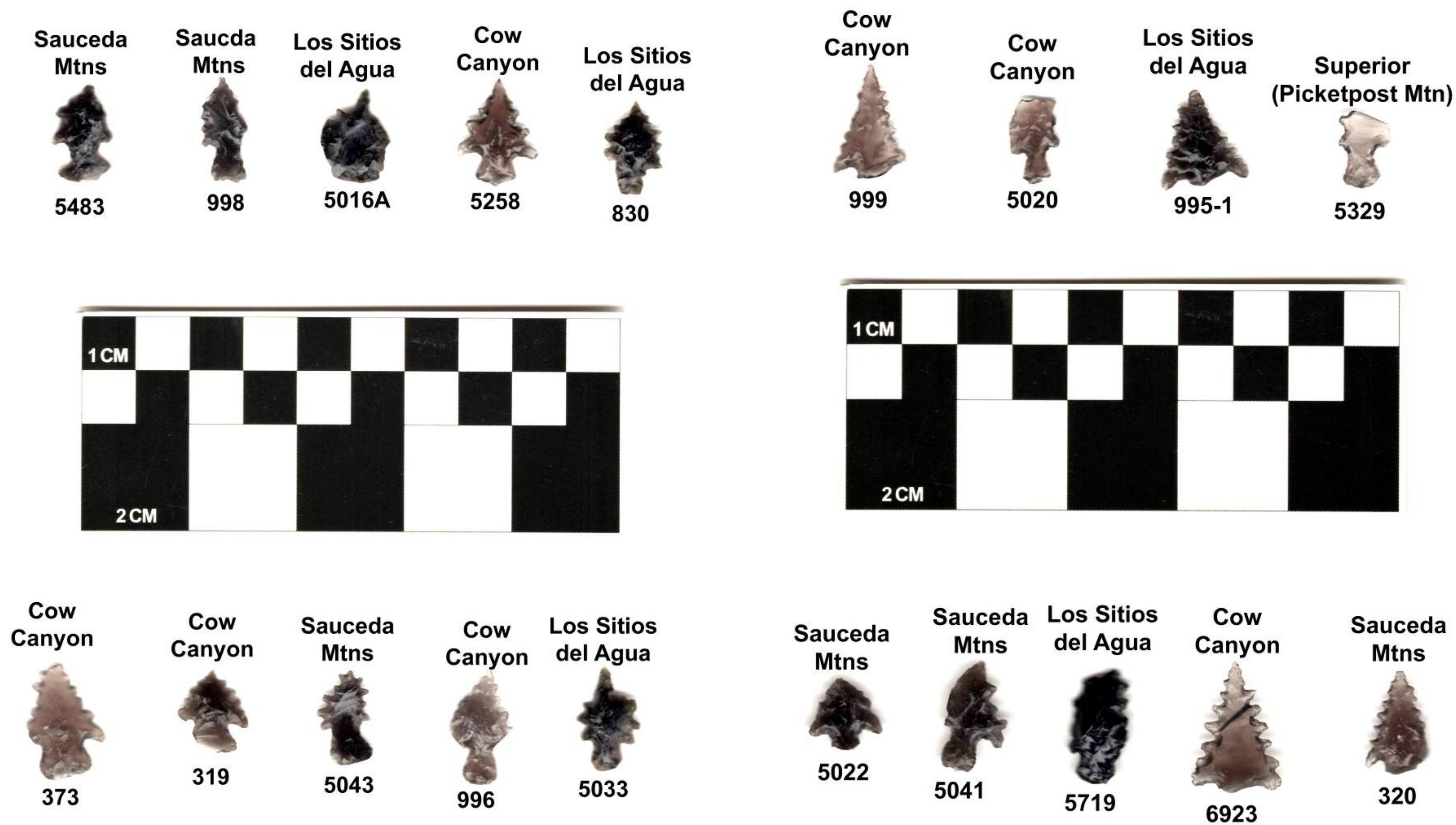

Figure 3. Selected Cienega (formerly Cienega Stemmed) projectile points and obsidian source assignments from Los Pozos (see Table 3). "Complete" projectile points (left), and impact/in-haft fractured points (right). Some of the "complete" points could certainly be in-haft rejuvenated specimens (i.e. #319, see text). The execution (quality) of the production (i.e. notching and serration symmetry) does not appear to be source specific (see Cow Canyon #6923 and Los Sitios del Agua #995-1).