GEOARCHAEOLOGICAL XRF LAB

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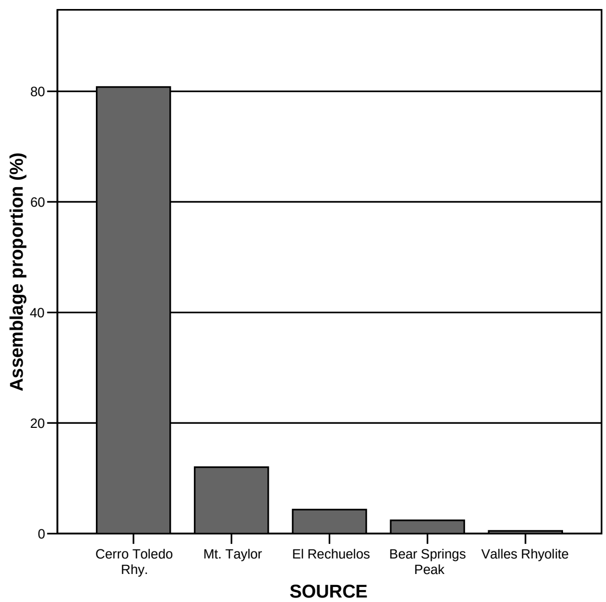
SOURCE PROVENANCE AND SECONDARY DEPOSITIONAL DISCUSSION OF A BIPOLAR OBSIDIAN ASSEMBLAGE FROM MAINLY PALEOARCHAIC SITES ON FORT BLISS, DOÑA ANA COUNTY, NEW MEXICO



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INTRODUCTION

The analysis here of 209 mostly bipolar reduced obsidian artifacts from Paleoarchaic contexts at Fort Bliss in Doña Ana County, New Mexico is one of the largest single assemblages most likely procured from Quaternary Rio Grande sediments thus far analyzed. The source provenance of these water eroded bipolar core fragments and debitage indicate sources and proportions of those sources similar to an intensive study of lithic secondary deposits by Church just west of the study area (2000). This compositional analysis here is also a study of procurement from the Rio Grande secondary stone deposits.

LABORATORY SAMPLING, ANALYSIS AND INSTRUMENTATION

All 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 200 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 but Fe where a derivative fitting is used to improve the fit for iron and thus for all the other elements. When barium (Ba) is analyzed in the High Zb condition, the Rh tube is operated at 50 kV and up to 1.0 mA, ratioed to the bremsstrahlung region (see Davis 2011; Shackley 2011). Further details concerning the petrological choice of these elements in Southwest obsidians is available in Shackley (1988, 1995, 2005, 2011b; also Mahood and Stimac 1991). 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 rhyolite obsidian standard is analyzed during each run. The values, reported in Table 1 indicate high resolution and international inter-instrument comparability (Govindaraju 1994; see also Tables 2 and 3 and Figures 1 and 2 here).

DISCUSSION

Secondary Distribution of Obsidian in the Rio Grande Quaternary Alluvium

The secondary distribution and prehistoric procurement of archaeological obsidian in the Southwest has been a subject of study for some time (Church 2000; Shackley 1990, 1992, 1998, 2012). During the Paleoindian and Archaic periods (called Paleoarchaic here) in the Southwest, obsidian marekanites, generally from Tertiary Period sources were reduced through bipolar technology to produce mainly non-formal tools such as utilized flakes, but at times bifaces and projectile points (Shackley 1990, 1996, 2005; see Figure 3 here). Clovis knappers in what is now Arizona and New Mexico used bipolar technology, often from secondarily deposited obsidian nodules to produce small Clovis points (Shackley 1990, 2007, 2012). This strategy appears to be the case with this Fort Bliss Paleoarchaic assemblage, although biface production seems to be absent.

The UC, Berkeley Field Practice in Archaeological Petrology Field School has been sampling the Rio Grande Quaternary alluvium from Española to San Antonito, New Mexico for a number of years (Shackley 2012). The proportion of sources in the alluvium is similar to Church's study in the southern portion of New Mexico with a dominance of Cerro Toledo

Rhyolite (called Obsidian Ridge by Church), with minor proportions of El Rechuelos (called Polvadera by Church), Bear Springs Peak (called Canovas Canyon by Church), and one of the two Mount Taylor sources that enters the Rio Grande from the Rio Puerco just north of Socorro (Church 2000, Shackley 2012; see Tables 4 and 5, and Figure 4 here). What is somewhat different is that there is a higher proportion of Cerro Toledo Rhyolite nodules and flakes a result most likely of reduction from nodule to artifact (Tables 4 and 5).

Volcanic Petrology and Structural Geology. A word about the volcanic petrology and structural geology with regard to secondary deposition is worthwhile here (see Shackley 2005). The first caldera event that produced the Bandelier Tuff in the Jemez Mountains was the Cerro Toledo event between 1.6 and 1.23 mya (Gardner and Goff 1996; Gardner et al. 2007; Heiken et al. 1986; Shackley 2005). This caldera collapse created an ash flow tuff eruption 100s of times larger than the recent Mt. Saint Helens eruption and covered much of northern New Mexico, including the proto-Rio Grande with rhyolitic ash including quenched rhyolite glass (obsidian). Megatons of material was thrown into the proto-Rio Grande, and this material including obsidian nodules has been eroding into the river ever since. The second caldera collapse, the Valles Rhyolite event, was a much smaller and less dynamic event, and consequently Valles Rhyolite is rare in the Rio Grande alluvium and appears to be totally absent south of Albuquerque (Shackley 2012).

Pre-caldera rhyolite eruptive events including the Canovas Canyon Rhyolite (obsidian outcropping at Bear Springs Peak) at about 8.7 mya, and El Rechuelos domes that are about 2.4 million years old have been eroding into the Rio Grande for a longer period of time. The details of these sedimentary events are not important here, but were significant to prehistoric knappers who took advantage of the readily available obsidian. With the quantity of secondarily deposited obsidian seen in archaeological contexts of all time periods in sites along the Rio Grande it could be argued that this was not just an encounter strategy, but planned and perhaps embedded into annual or more frequent movements (see Miller and Shackley 1998, Shackley 1990, 2005).

One interesting exception here is artifact 22-24 from Site FB 19605 that is a flake produced from the Valles Rhyolite source in the Jemez Mountains, northern New Mexico, as mentioned above is not seen in lower Rio Grande Quaternary alluvium (Table 2 and Figure 2; see Shackley 2012). There is a small portion of somewhat angular cortex left on the flake suggesting procurement at the primary source, or nearer the source such as Albuquerque or above. It is possible that a nodule of Valles Rhyolite made it all the way down to the lower river alluvium, but the very few Valles Rhyolite pieces recovered from Rio Grande alluvium thus far are all less than 20 mm in diameter and found at Albuquerque (Tijeras Wash) or above, and this flake would have had to have come from a relatively large core (Shackley 2012). Unfortunately the flake is nearly an interior flake and the original origin of the raw material will probably not be resolved.

CONCLUSION

Procurement of secondary deposited high quality raw material is typical of the Southwest in all time periods. The lithic assemblage here is a prime example of Paleoarchaic knappers taking advantage of a local source of obsidian nodules for the production of non-formal tools. Nearer the primary sources, in Arizona and New Mexico with larger nodule sizes, biface production is more common, of course, but these early knappers did produce bifaces and projectile points from small nodules of obsidian particularly in lithic resource poor regions (Shackley 2005, 2012).

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Table 1. Mean and central tendency for 11 analyses of USGS RGM-1 obsidian standard for this project. ± = 1 standard deviation

SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb
RGM-1 (Govindaraju 1994)	1600	279	12998	149	108	25	219	8.9
RGM-1 (USGS recommended)[1]	1619±120	279±50	13010±210	150±8	110±10	25[2]	220±20	8.9±0.6
RGM-1, pressed powder (this study, n=11)	1580±44	283±8	13777±17	150±2	107±2	23±2	217±2	9±2

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

SITE/SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	SOURCE
FB 562									
132	639	492	12054	210	10	65	174	95	Cerro Toledo Rhy.
17	713	562	12972	226	8	64	183	104	Cerro Toledo Rhy.
127	609	540	12410	207	8	64	170	93	Cerro Toledo Rhy.
99	551	592	12035	505	14	93	136	235	Mt. Taylor (Horace Mesa)
49	573	522	12460	209	8	71	177	100	Cerro Toledo Rhy.
52	530	425	11413	188	8	64	164	92	Cerro Toledo Rhy.
FB 330									
18-1	716	494	12068	211	11	62	169	94	Cerro Toledo Rhy.
18-2	629	464	11961	204	8	64	166	97	Cerro Toledo Rhy.
51	707	566	12054	522	11	94	132	226	Mt. Taylor (Horace Mesa)
330-52	535	505	11998	212	8	63	169	98	Cerro Toledo Rhy.
FB 1455									
73	314	664	10766	527	12	78	107	188	Mt. Taylor (E. Grants Ridge)
13	790	413	10611	121	46	21	104	56	Bear Springs Peak
31	811	598	13206	232	11	69	189	110	Cerro Toledo Rhy.
34	686	491	12274	209	10	65	177	103	Cerro Toledo Rhy.
FB 19605/Fea. 7									
6-1	610	466	11866	201	13	60	168	89	Cerro Toledo Rhy.
10	977	593	1340	22	13	67	179	102	Cerro Toledo Rhy.

			9	2					
14	547	436	11935	201	8	61	170	99	Cerro Toledo Rhy.
212	540	498	12233	211	8	65	180	103	Cerro Toledo Rhy.
6-2	550	446	11879	197	10	61	176	96	Cerro Toledo Rhy.
306	786	568	13097	230	9	70	175	102	Cerro Toledo Rhy.
2-1	608	502	12182	207	10	60	171	93	Cerro Toledo Rhy.
30	781	392	10484	111	40	20	96	51	Bear Springs Peak
218	904	463	13089	202	10	59	166	89	Cerro Toledo Rhy.
219	861	637	14204	256	8	73	185	108	Cerro Toledo Rhy.
331	550	493	12017	199	11	61	168	98	Cerro Toledo Rhy.
7-1	638	493	12166	203	8	64	169	97	Cerro Toledo Rhy.
26	631	460	12091	200	8	61	165	94	Cerro Toledo Rhy.
14-2	583	501	12260	217	8	67	172	98	Cerro Toledo Rhy.
SITE/SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	SOURCE
21	664	464	11978	196	11	63	166	90	Cerro Toledo Rhy.
14-1	589	498	12040	205	11	64	170	96	Cerro Toledo Rhy.
38	1050	623	13400	218	9	58	165	88	Cerro Toledo Rhy.
45	525	511	12196	215	10	64	176	97	Cerro Toledo Rhy.
22-1	854	519	12525	214	10	67	180	96	Cerro Toledo Rhy.
29	435	517	11632	508	12	90	134	225	Mt. Taylor (Horace Mesa)
23	605	519	12320	213	8	63	178	98	Cerro Toledo Rhy.
24	812	550	13109	236	10	66	175	100	Cerro Toledo Rhy.
25	596	485	12127	213	8	64	176	97	Cerro Toledo Rhy.
143	664	500	12305	208	10	62	179	99	Cerro Toledo Rhy.
18	653	489	12446	209	11	61	172	98	Cerro Toledo Rhy.
220	1031	499	13650	219	13	66	177	94	Cerro Toledo Rhy.
19	622	509	12658	217	11	65	178	101	Cerro Toledo Rhy.
FB 19605									
243	834	516	12473	203	9	61	162	91	Cerro Toledo Rhy.
209	653	528	12482	218	8	64	185	89	Cerro Toledo Rhy.

67-1	775	419	10615	119	42	21	100	48	Bear Springs Peak
67-3	575	465	11750	203	10	62	171	103	Cerro Toledo Rhy.
192	703	361	10527	151	14	24	72	47	El Rechuelos
71	659	495	12202	207	9	62	168	94	Cerro Toledo Rhy.
95-1	568	470	12170	208	11	65	170	101	Cerro Toledo Rhy.
95-2	597	409	11604	194	8	67	166	99	Cerro Toledo Rhy.
95-3	572	479	11968	197	8	62	168	99	Cerro Toledo Rhy.
95-4	652	505	12147	199	8	63	174	94	Cerro Toledo Rhy.
95-5	552	499	12301	218	9	67	176	98	Cerro Toledo Rhy.
208-1	701	526	12616	211	11	63	174	98	Cerro Toledo Rhy.
208-2	633	461	12007	204	10	62	171	95	Cerro Toledo Rhy.
267-1	495	671	11207	525	9	77	116	191	Mt. Taylor (E. Grants Ridge)
267-2	611	478	12200	208	10	60	173	97	Cerro Toledo Rhy.
84	631	525	12277	213	11	64	175	97	Cerro Toledo Rhy.
126	612	436	11848	200	8	62	168	96	Cerro Toledo Rhy.
110-1	704	553	12726	222	8	70	181	105	Cerro Toledo Rhy.
110-2	487	689	11280	543	12	78	115	198	Mt. Taylor (E. Grants Ridge)
110-3	581	478	11876	209	8	65	172	95	Cerro Toledo Rhy.
110-4	608	441	11953	201	8	59	174	94	Cerro Toledo Rhy.
110-5	593	495	12234	224	12	66	183	97	Cerro Toledo Rhy.
108	578	462	11942	203	8	62	169	96	Cerro Toledo Rhy.
76-1	570	433	11980	195	8	62	164	96	Cerro Toledo Rhy.
76-2	747	490	12726	204	11	60	162	95	Cerro Toledo Rhy.
76-3	589	463	11844	210	8	65	174	92	Cerro Toledo Rhy.
321-1	690	433	10543	159	11	26	73	46	El Rechuelos
321-2	646	497	12282	208	10	63	171	95	Cerro Toledo Rhy.
321-3	528	451	11829	204	8	67	175	99	Cerro Toledo Rhy.
321-4	664	492	12336	216	10	65	176	101	Cerro Toledo Rhy.
223-1	576	561	1223	50	11	94	137	234	Mt. Taylor (Horace Mesa)

			6	9					
223-2	1045	400	11062	116	61	21	108	38	Bear Springs Peak
223-3	950	502	12993	211	8	63	171	98	Cerro Toledo Rhy.
122	765	409	10650	156	12	23	71	50	El Rechuelos
330	576	476	11995	197	10	64	168	93	Cerro Toledo Rhy.
SITE/SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	SOURCE
137	580	446	11945	204	8	63	168	95	Cerro Toledo Rhy.
141-1	630	518	12235	208	9	65	171	101	Cerro Toledo Rhy.
141-2	662	524	12566	226	8	65	174	106	Cerro Toledo Rhy.
141-3	611	497	12337	221	8	64	180	99	Cerro Toledo Rhy.
266	761	499	12720	213	9	59	174	91	Cerro Toledo Rhy.
66	508	478	12032	210	13	59	168	97	Cerro Toledo Rhy.
155-1	704	501	12488	206	9	66	171	100	Cerro Toledo Rhy.
155-2	652	351	10217	138	13	22	67	45	El Rechuelos
134	621	488	12025	207	9	63	172	98	Cerro Toledo Rhy.
224-1	689	508	12446	211	8	63	171	96	Cerro Toledo Rhy.
224-2	740	484	12527	208	8	62	165	95	Cerro Toledo Rhy.
138-1	600	448	12018	193	9	59	166	90	Cerro Toledo Rhy.
138-2	877	499	12863	221	8	62	172	87	Cerro Toledo Rhy.
138-3	588	477	12236	207	8	62	172	95	Cerro Toledo Rhy.
93-1	589	470	11944	207	8	64	176	93	Cerro Toledo Rhy.
93-2	750	536	13027	218	12	67	183	98	Cerro Toledo Rhy.
130-1	612	519	12347	207	8	63	171	98	Cerro Toledo Rhy.
130-2	650	472	12244	211	11	63	172	97	Cerro Toledo Rhy.
145	846	486	12849	207	12	62	172	101	Cerro Toledo Rhy.
140-1	624	478	12284	210	11	67	173	97	Cerro Toledo Rhy.
140-2	678	452	11997	196	11	65	172	94	Cerro Toledo Rhy.
86	564	494	12084	205	8	66	167	95	Cerro Toledo Rhy.
128-1	860	505	12857	214	13	67	175	99	Cerro Toledo Rhy.
128-2	699	405	1053	15	10	24	72	48	El Rechuelos

			4	5					
85	802	423	10677	116	47	23	103	53	Bear Springs Peak
68	654	421	11811	188	8	58	156	91	Cerro Toledo Rhy.
250	677	525	12273	206	11	69	173	96	Cerro Toledo Rhy.
99-1	518	537	12478	219	9	66	177	98	Cerro Toledo Rhy.
99-2	656	513	12278	209	9	60	170	98	Cerro Toledo Rhy.
147-1	803	518	12507	210	8	65	176	91	Cerro Toledo Rhy.
147-2	705	518	12522	222	11	67	176	102	Cerro Toledo Rhy.
144-1	819	535	13047	209	11	65	176	99	Cerro Toledo Rhy.
144-2	887	484	11234	169	12	22	68	45	El Rechuelos
144-3	781	554	12967	227	10	64	179	99	Cerro Toledo Rhy.
144-4	688	425	11790	193	10	67	162	95	Cerro Toledo Rhy.
83	633	539	12646	224	12	66	178	97	Cerro Toledo Rhy.
124	638	472	12127	204	8	62	176	97	Cerro Toledo Rhy.
96	633	506	12285	208	8	62	172	95	Cerro Toledo Rhy.
90	664	500	12426	212	11	68	168	93	Cerro Toledo Rhy.
1-1	631	500	12196	205	8	67	172	96	Cerro Toledo Rhy.
1-2	731	512	12543	206	10	63	177	100	Cerro Toledo Rhy.
1-3	628	442	11906	204	10	61	168	99	Cerro Toledo Rhy.
1-4	661	466	11985	200	11	62	173	95	Cerro Toledo Rhy.
1-5	489	728	11314	554	10	76	112	190	Mt. Taylor (E. Grants Ridge)
1-6	611	551	12522	220	10	66	176	103	Cerro Toledo Rhy.
1-7	650	515	12770	211	12	61	166	94	Cerro Toledo Rhy.
6	597	522	12523	227	9	67	177	96	Cerro Toledo Rhy.
14	610	505	12279	218	10	66	175	99	Cerro Toledo Rhy.
12-1	642	483	12280	198	8	57	170	97	Cerro Toledo Rhy.
SITE/SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	SOURCE
12-2	587	364	11171	172	13	60	150	95	Cerro Toledo Rhy.
2	749	464	12325	204	9	62	171	95	Cerro Toledo Rhy.
8	874	514	1280	21	11	66	174	98	Cerro Toledo Rhy.

			6	1					
13	723	429	11914	183	9	60	156	84	Cerro Toledo Rhy.
42	710	484	12381	203	10	66	171	98	Cerro Toledo Rhy.
62-1	623	505	12190	212	10	65	174	100	Cerro Toledo Rhy.
62-2	432	716	11021	543	10	77	110	192	Mt. Taylor (E. Grants Ridge)
16	571	499	12197	211	11	68	171	98	Cerro Toledo Rhy.
11-1	690	461	11943	199	9	58	167	96	Cerro Toledo Rhy.
11-2	879	570	13391	221	11	62	173	89	Cerro Toledo Rhy.
17-1	718	495	12580	200	8	62	171	96	Cerro Toledo Rhy.
17-2	559	474	11866	200	9	62	176	94	Cerro Toledo Rhy.
5-1	662	580	12833	230	9	65	187	100	Cerro Toledo Rhy.
5-2	568	545	12064	490	11	88	126	226	Mt. Taylor (Horace Mesa)
15-1	604	484	12118	209	8	66	174	97	Cerro Toledo Rhy.
15-2	650	504	12393	215	8	63	174	99	Cerro Toledo Rhy.
40-1	392	732	11053	538	11	82	119	192	Mt. Taylor (E. Grants Ridge)
40-2	564	500	12270	215	10	62	177	95	Cerro Toledo Rhy.
40-3	620	488	12142	207	11	63	171	93	Cerro Toledo Rhy.
35-1	492	430	11427	185	10	62	160	84	Cerro Toledo Rhy.
35-2	816	546	13133	224	8	62	176	98	Cerro Toledo Rhy.
35-3	600	472	12112	204	9	63	176	101	Cerro Toledo Rhy.
36-1	348	742	11073	558	12	78	106	197	Mt. Taylor (E. Grants Ridge)
36-2	515	441	11686	204	12	63	171	97	Cerro Toledo Rhy.
52	453	799	11537	583	9	81	115	195	Mt. Taylor (E. Grants Ridge)
28	644	533	12531	218	10	67	187	99	Cerro Toledo Rhy.
31	770	553	12725	218	8	67	181	105	Cerro Toledo Rhy.
41-1	441	503	11457	477	11	85	127	224	Mt. Taylor (Horace Mesa)
41-2	812	515	12668	204	9	63	170	95	Cerro Toledo Rhy.
41-3	511	860	11761	605	11	82	117	197	Mt. Taylor (E. Grants Ridge)
41-4	659	491	12143	202	9	66	171	93	Cerro Toledo Rhy.

41-5	343	128	8554	2	28	1	16	3	not obsidian
41-6	542	476	12002	209	9	66	171	97	Cerro Toledo Rhy.
41-7	519	502	12124	215	9	69	177	97	Cerro Toledo Rhy.
41-8	643	647	12624	536	11	92	139	238	Mt. Taylor (Horace Mesa)
26-1	627	471	11990	194	9	59	171	96	Cerro Toledo Rhy.
26-2	762	579	12826	224	10	67	178	97	Cerro Toledo Rhy.
26-3	397	767	11497	587	14	84	117	204	Mt. Taylor (E. Grants Ridge)
49	615	489	12187	205	8	64	174	100	Cerro Toledo Rhy.
67-1	713	479	11995	195	10	58	165	88	Cerro Toledo Rhy.
67-2	554	467	11919	204	8	64	168	92	Cerro Toledo Rhy.
47-1	624	439	11969	204	9	65	171	97	Cerro Toledo Rhy.
47-2	573	457	11796	201	8	65	171	100	Cerro Toledo Rhy.
20-1	573	512	12053	206	9	60	180	97	Cerro Toledo Rhy.
20-2	663	486	12267	213	10	63	182	96	Cerro Toledo Rhy.
20-3	571	481	11891	204	10	64	166	93	Cerro Toledo Rhy.
22-1	607	512	12437	215	10	65	172	99	Cerro Toledo Rhy.
22-2	779	510	12712	214	8	66	184	100	Cerro Toledo Rhy.
22-3	629	470	11904	194	8	61	168	92	Cerro Toledo Rhy.
SITE/SAMPLE	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	SOURCE
22-4	782	400	10682	155	14	23	73	45	El Rechuelos
22-5	675	420	10457	168	14	22	73	51	El Rechuelos
22-6	684	477	12129	206	9	61	165	91	Cerro Toledo Rhy.
22-7	707	516	12579	215	9	63	169	99	Cerro Toledo Rhy.
22-8	930	561	12254	190	9	59	155	84	Cerro Toledo Rhy.
22-9	644	484	11910	203	9	63	168	96	Cerro Toledo Rhy.
22-10	842	499	12334	217	9	61	165	92	Cerro Toledo Rhy.
22-11	663	547	12675	228	11	69	177	103	Cerro Toledo Rhy.
22-12	663	712	11225	540	13	75	108	183	Mt. Taylor (E. Grants Ridge)
22-13	400	603	12031	554	11	86	138	225	Mt. Taylor (E. Grants Ridge)
22-14	634	444	1175	20	8	62	161	92	Cerro Toledo Rhy.

			2	1					
22-15	629	382	11225	172	8	58	158	87	Cerro Toledo Rhy.
22-16	525	689	12613	561	12	95	140	231	Mt. Taylor (Horace Mesa)
22-17	620	758	11468	557	12	80	117	190	Mt. Taylor (E. Grants Ridge)
22-18	794	437	10979	158	11	21	71	49	El Rechuelos
22-19	515	461	11819	204	9	66	169	98	Cerro Toledo Rhy.
22-20	522	596	12027	530	13	92	143	248	Mt. Taylor (Horace Mesa)
22-21	381	742	11317	554	11	77	111	197	Mt. Taylor (E. Grants Ridge)
22-22	554	459	11949	200	8	62	169	97	Cerro Toledo Rhy.
22-23	450	771	11138	544	11	77	115	194	Mt. Taylor (E. Grants Ridge)
22-24	789	395	12372	168	15	46	162	58	Valles Rhyolite
22-25	436	624	10668	511	9	76	106	193	Mt. Taylor (E. Grants Ridge)
22-26	728	536	12620	214	8	66	172	95	Cerro Toledo Rhy.
22-27	534	523	12384	215	10	66	175	96	Cerro Toledo Rhy.
21-1	576	476	12244	210	10	59	174	93	Cerro Toledo Rhy.
21-2	695	559	12900	222	9	62	179	94	Cerro Toledo Rhy.
21-3	656	514	12204	195	8	61	160	94	Cerro Toledo Rhy.
44-1	549	478	12034	206	8	64	172	100	Cerro Toledo Rhy.
44-2	557	473	11842	202	9	63	166	94	Cerro Toledo Rhy.
44-3	600	462	11783	193	8	62	163	86	Cerro Toledo Rhy.
64	568	422	11725	195	8	60	168	95	Cerro Toledo Rhy.
66	550	459	11769	193	10	60	167	98	Cerro Toledo Rhy.
74	553	440	11733	199	8	65	168	92	Cerro Toledo Rhy.
73	580	482	11996	211	9	64	167	96	Cerro Toledo Rhy.
68	630	475	12199	210	9	66	174	101	Cerro Toledo Rhy.

Table 3. Crosstabulation of source by site.

			SOURCE					
			Cerro Toledo Rhy.	Bear Springs Peak	El Rechuelos	Valles Rhyolite	Mt. Taylor	Total
Site	FB 1455	Count	2	1	0	0	1	4
		% within Site	50.0%	25.0%	.0%	.0%	25.0%	100.0%
		% within SOURCE	1.2%	20.0%	.0%	.0%	4.0%	1.9%
		% of Total	1.0%	.5%	.0%	.0%	.5%	1.9%
	FB 19605	Count	87	4	6	0	4	101
		% within Site	86.1%	4.0%	5.9%	.0%	4.0%	100.0%
		% within SOURCE	51.8%	80.0%	66.7%	.0%	16.0%	48.6%
		% of Total	41.8%	1.9%	2.9%	.0%	1.9%	48.6%
	FB 562	Count	8	0	0	0	2	10
		% within Site	80.0%	.0%	.0%	.0%	20.0%	100.0%
		% within SOURCE	4.8%	.0%	.0%	.0%	8.0%	4.8%
		% of Total	3.8%	.0%	.0%	.0%	1.0%	4.8%
	FB 70	Count	71	0	3	1	18	93
		% within Site	76.3%	.0%	3.2%	1.1%	19.4%	100.0%
		% within SOURCE	42.3%	.0%	33.3%	100.0%	72.0%	44.7%
		% of Total	34.1%	.0%	1.4%	.5%	8.7%	44.7%
Total		Count	168	5	9	1	25	208
		% within Site	80.8%	2.4%	4.3%	.5%	12.0%	100.0%
		% within SOURCE	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	80.8%	2.4%	4.3%	.5%	12.0%	100.0%

Table 4. The distribution of sources in Church's (2000) Rio Grande alluvium study. His Obsidian Ridge is Cerro Toledo Rhyolite here; Canovas Canyon, Bear Springs Peak here; and Polvadera, El Rechuelos here.

Table V. Obsidian sources represented in the Rio Grande gravels.

	Fillmore Pass Collection Area		Rincon Arroyo Collection Area		Tortugas Mountain Collection area		Vado Collection area		Totals	
									#	%
Obsidian Ridge (random)	7	10.29	0		1	1.47	15	22.06	23	33.82
Obsidian Ridge (selected)	3	4.41	0		5	7.35	12	17.65	20	29.41
Canovas Canyon (random)	0		0		0	0	2	2.94	2	2.94
Canovas Canyon (selected)	0		0		0	0	0		0	
Grants Ridge (random)	3	4.41	0		1	1.47	4	5.88	8	11.76
Grants Ridge (selected)	1	1.47	0		0	0	2	2.94	3	4.41
No Agua (random)	0		0		0	0	1	1.47	1	1.47
No Agua (selected)	0		0		0	0	0		0	
Paliza Canyon ? (random)	0		0		0	0	1	1.47	1	1.47
Paliza Canyon (selected)	0		0		0	0	0		0	
Polvardera (random)	0		2	2.94	1	1.47	0		3	4.41
Polvadera (selected)	0		3	4.41	1	1.47	1	1.47	5	7.35
Unknown (random)	0		0	0	0	0	2	2.94	2	2.94
Unknown (selected)	0		0	0	0	0	0		0	
Total random	10	14.71	2	2.94	3	4.41	25	36.76	40	58.82
Total selected	4	5.88	3	4.41	6	8.82	15	22.06	28	41.18
Total	14	20.59	5	7.35	9	13.24	40	58.82	68[a]	100

[a] Two specimens were determined not to be obsidian and are not included in these tabulations.

Table 5. Frequency distribution of source provenance from all sites.

		Frequency	Percent
Source	Cerro Toledo Rhy.	168	80.8
	Bear Springs Peak	5	2.4
	El Rechuelos	9	4.3
	Mt. Taylor	25	12.0
	Valles Rhyolite	1	.5
	Total	208	100.0

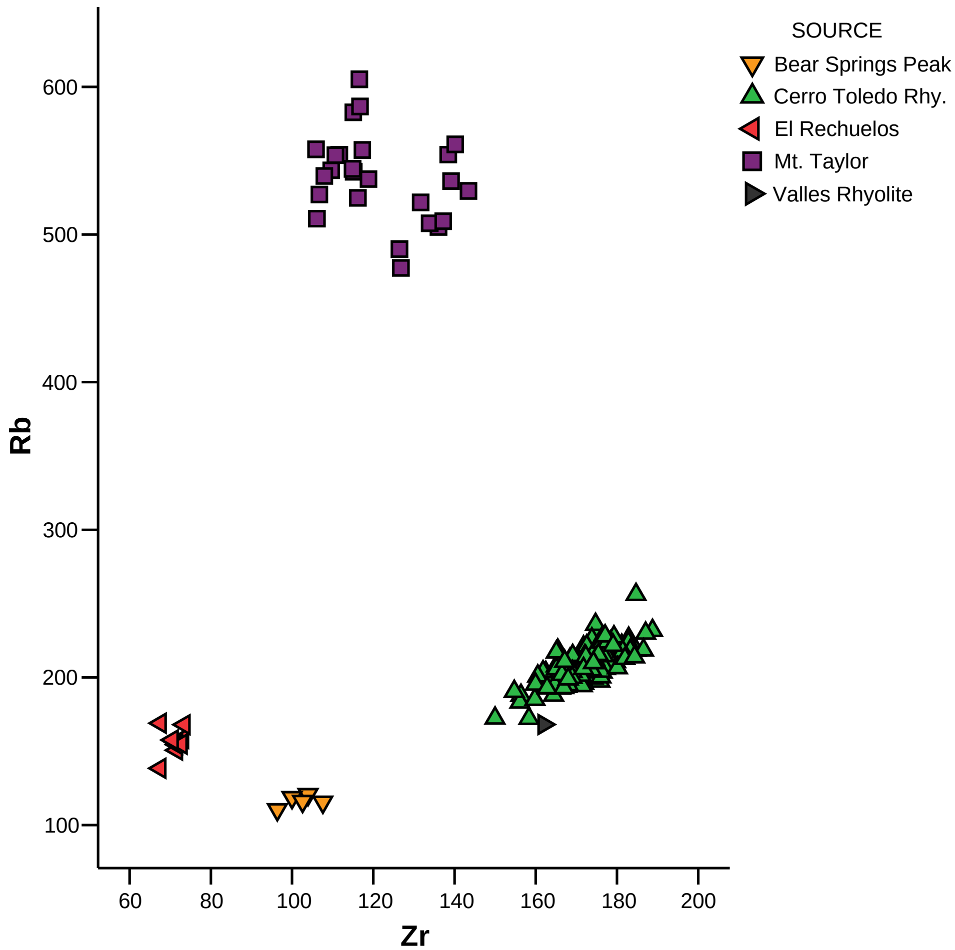

Figure 1. Zr versus Rb bivariate plot of all samples from all sites.

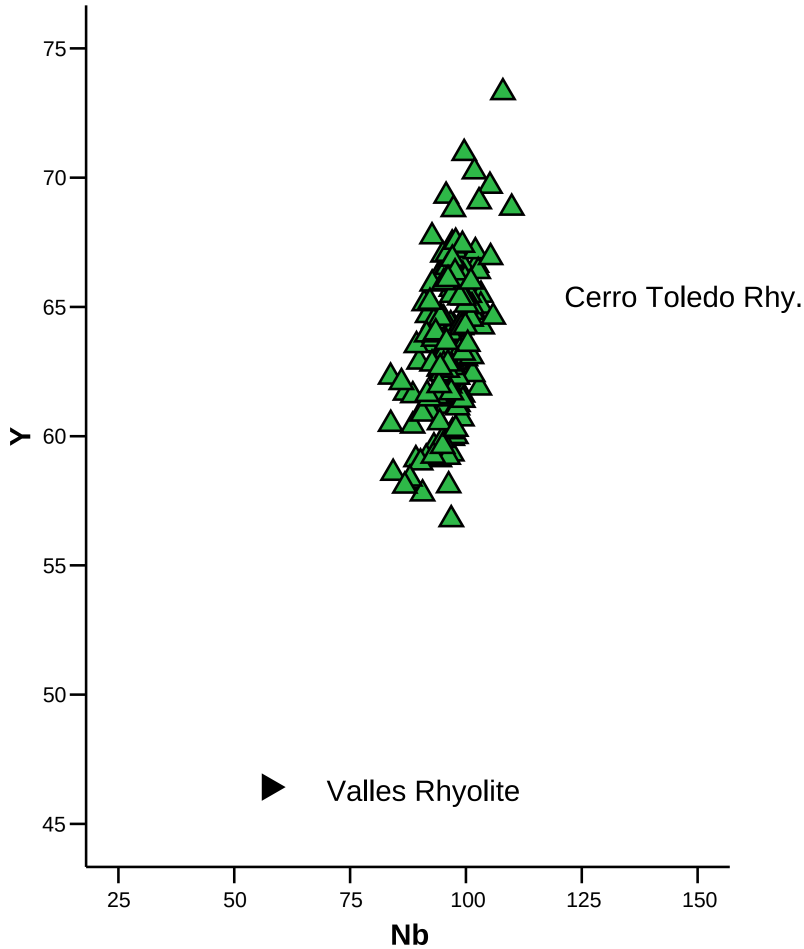

Figure 2. Nb versus Y bivariate plot discriminating the Cerro Toledo Rhyolite and Valles Rhyolite assigned artifacts (see Shackley 2005).

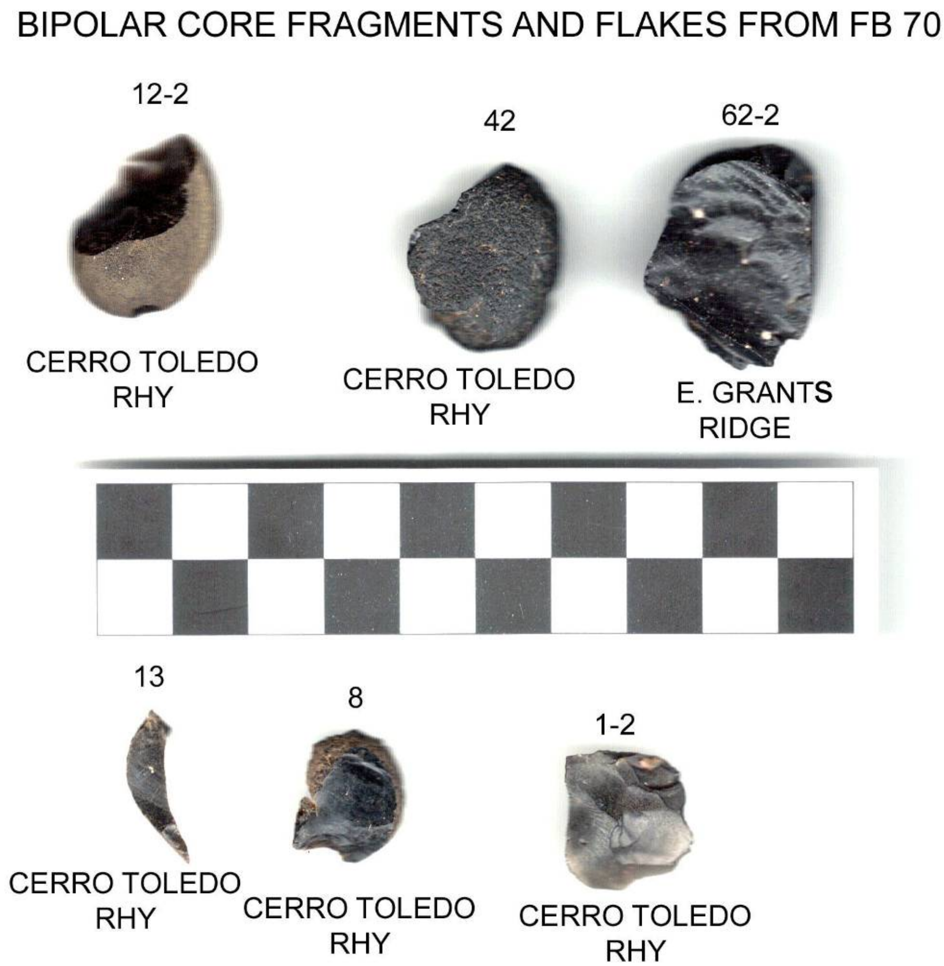

Figure 3. A sample of bipolar core fragments and "orange slice" flakes typical of bipolar reduction from site FB 70. Core fragments top row, flakes bottom row.

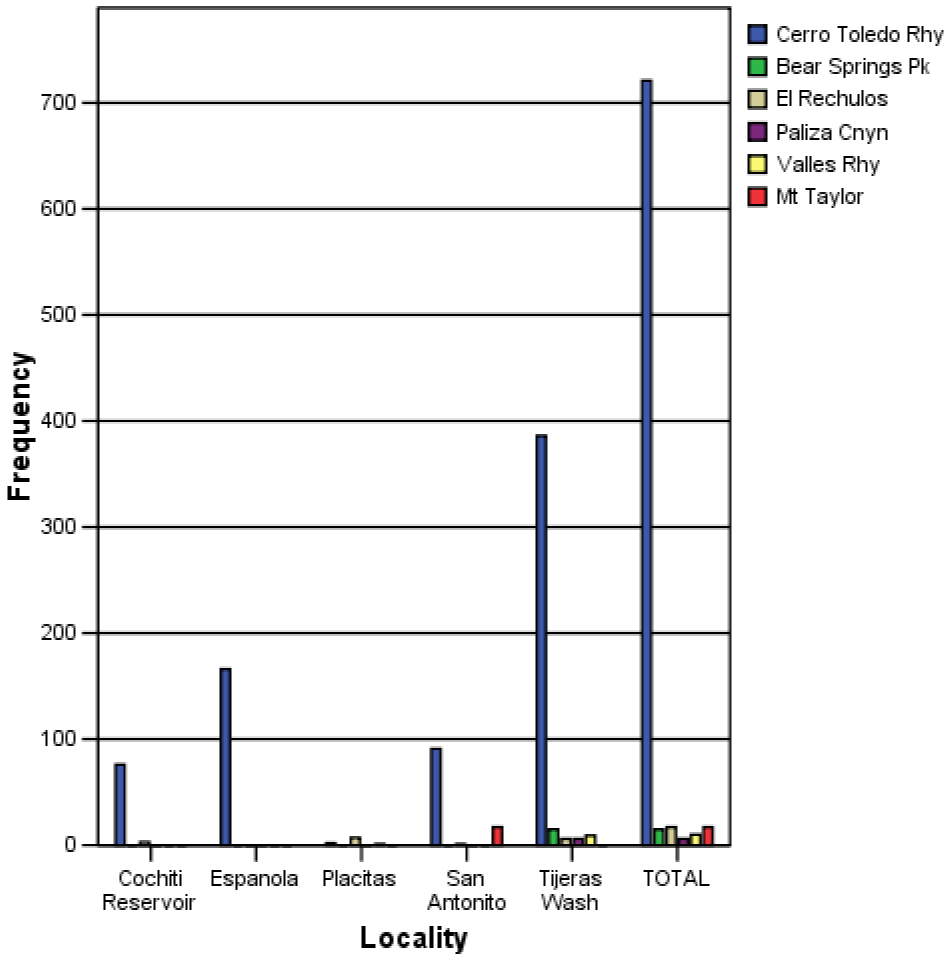

Figure 4. Frequency distribution of sources at four localities along the Rio Grande (from Shackley 2012).