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SOURCES OF ARCHAEOLOGICAL OBSIDIAN IN THE GREATER AMERICAN SOUTHWEST: AN UPDATE AND QUANTITATIVE ANALYSIS

M. Steven Shackley

Obsidian studies in the greater American Southwest have come of age. No longer does the region lag behind other adjoining regions both in the understanding of source provenance and the integration of obsidian source studies into regional designs. Most of the archaeological obsidian sources discussed here were originally presented in semi-quantitative form in this journal in 1988 (Shackley 1988a). The purpose here is to present that same data in broadly useable quantitative form calibrated to international standards, update the source descriptions when appropriate, and, finally, present data on a few new sources recently located. This is a necessary step to continue the momentum of obsidian studies in the region and make the information available to all. Finally, some discussion is directed toward the archaeological utility of obsidian studies in the region.

Los estudios sobre obsidiana en el gran Suroeste Americano han madurado. La región ya no se encuentra detrás de adyacentes tanto en la comprensión de fuentes de proveniencia, como en la integración de los estudios de fuentes de obsidiana detron de un diseño regional. La mayoría de los yacimientos arqueológicos de obsidiana discutiós aquí fueron originalmente presentados de forma semicuantitativa para esta publicación en 1988 (Shackley 1988a). El propósito aquí es, presentar estos mismos datos de una forma cuantitativa ampliamente utilizada en los estándars internacionales de calibración, actualizar la descripcion del yacimiento cuando sea apropriado, y finalmente, presentar datos actualizados de algunos yacimientos neuvos recientemente localizados. Este es un paso necesario para continuar la momento de los estudios obsidiana en la región y hacer la información disponible a todos. Finalmente, alguna discusión se dirige hacia la utilidad arqueológica de el estudios de obsidiana en la región.

Until the late 1980s, an awareness of the location and character of obsidian sources in the American Southwest was virtually nil. In a region heavily dominated by interpretation of the prehistoric record through ceramic analysis, obsidian studies lagged significantly behind other surrounding regions. Indeed, because they little understood the usefulness of obsidian studies and did not work in this area, most prehistorians who even acknowledged the presence of obsidian in archaeological context assumed that the obsidian was derived from either the Government Mountain source in northern Arizona, the Superior (Picketpost Mountain) source in central Arizona, one of the sources in northern New Mexico, or some unknown (but exotic) source in Mesoamerica. These assumptions were partly justified since the major work on obsidian before 1980 focused on only a few well-known sources (Boyer and Robinson 1956; Jack 1971; Schreiber and Breed 1971; see Shackley 1988a, 1990). While prehistorians in the greater American Southwest have only recently realized the potential utility of obsidian studies, mainly driven by cultural resource management studies, great strides have been made in the location and description of glass sources in the region (Baugh and Nelson 1987; Hughes 1988a; Lesko 1989; LeTourneau 1994; Newman and Nielsen 1985; Sanders et al. 1982; Shackley 1988a, 1990, 1991, 1992a; Stevenson and Klimkiewicz 1990). The results of recent obsidian studies, particularly in Classic period contexts, have begun to modify some of the long-held assumptions of the complexity of exchange and interaction primarily based on ceramic design studies and limited use of other data sets (Doyel 1994; Mitchell and Shackley 1995; Peterson et al. 1994).

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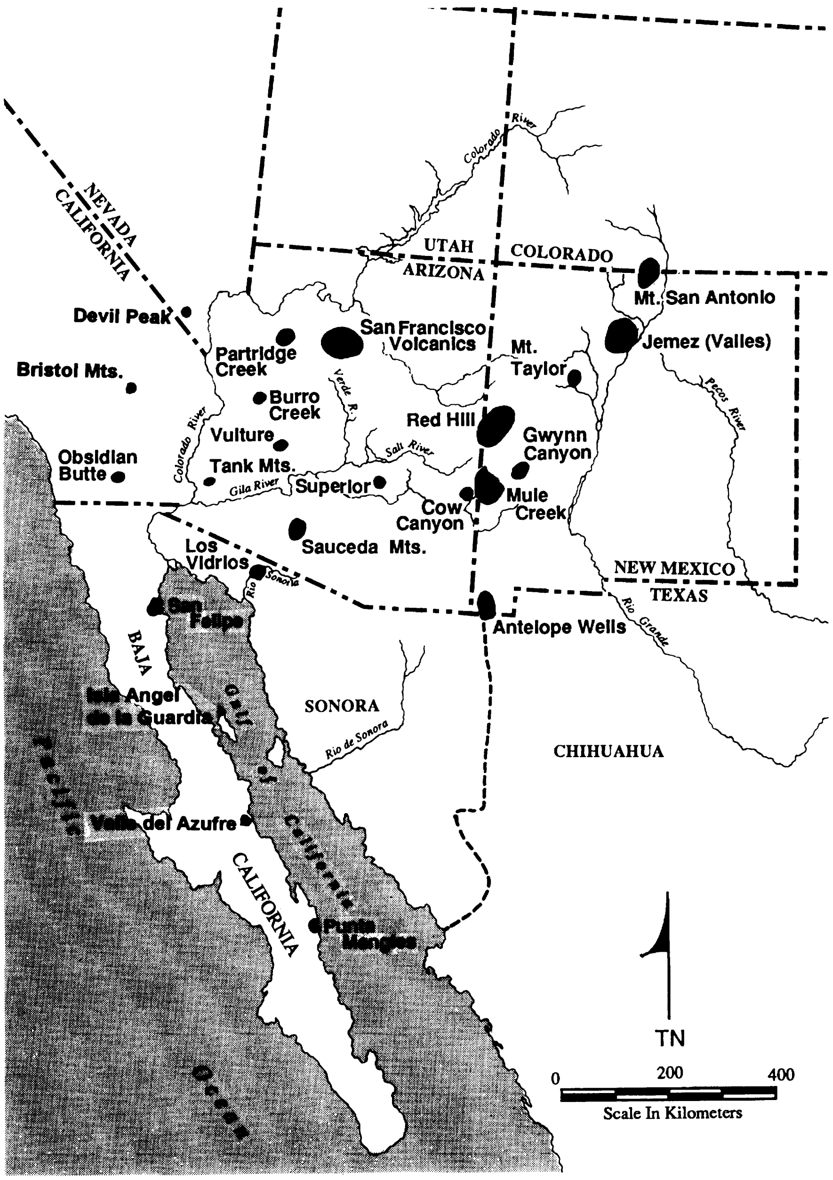

Figure 1. General location of archaeological obsidian sources in the greater American Southwest. The San Francisco River flows into the Gila River just east of the Cow Canyon source. The Blue River flows into the San Francisco River from the north under the dot used for the location of the Cow Canyon source. Obsidian Butte, the northern New Mexico, and Baja California sources are not discussed here.

To be effective, however, the obsidian source standard data must be available to all interested archaeologists and archaeometrists and be presented in a form internally valid as well as reliable (see Bishop et al. 1990 and Hughes and Smith 1993). The original study of 18 glass sources presented in this journal in 1988 (Shackley 1988a) was a result of a semi-quantitative analysis, internally consistent but not replicable and useful to other researchers. The primary purpose here is to present that same data in quantitative form, calibrated to international standards, update the source descriptions when appropriate, present data on a few sources recently located, and briefly discuss some of the implications these data bring to regional prehistory. For a discussion of the geological landscape and environment of southwestern obsidian sources, refer to Baugh and Nelson (1987) and Shackley (1988a, 1990, 1992a), as well as Reynolds et al. (1986).

Updated Geological, Geographical, and Archaeological Descriptive Data

In the seven years since the original paper (Shackley 1988a), five entirely new sources north of the international border have been discovered, and many more have been reevaluated based on further fieldwork and laboratory analysis (Shackley 1991, 1992a; Figure 1 here). Some of these have been and will be reported more fully elsewhere, but basic descriptive and geochemical data will be presented. In many cases the secondary depositional context of known sources was found to be more extensive than believed, and the chemical variability greater than previously detected. Both of these factors can greatly affect the archaeological and archaeometric character of a source (Hughes 1994; Hughes and Smith 1993; Shackley 1992a). The format of this presentation is, as much as practicable, the same as the original presentation (Shackley 1988a).

A Word About the Northern Mexican Region

A number of new and re-investigated sources of archaeological obsidian are currently being examined in a continuing project between the University of California, Berkeley, and the Instituto Nacional de Antropología e Historia (INAH)/FONDO Nacional Arquelógico of Mexico (Shackley 1993b, 1994a). By agreement with INAH, these sources will be reported separately in detail. Other than the San Felipe Tertiary source in the far northern part of the peninsula, and Los Vidrios in northern Sonora, none of these obsidians has appeared in archaeological contexts north of the border. Additionally, obsidian research in the neighboring Mexican states of Chihuahua and Sonora still is rudimentary, but work is progressing. Recent analyses of artifact obsidian from sites along the eastern edge of the Sierra Madre in Chihuahua in the Hearst Museum collections indicates at least five as yet unlocated sources in the region besides the Antelope Wells source in the northern part of this state and New Mexico. This study will be reported elsewhere as the work matures.

Southeastern California and Southern Nevada

This region was not covered in the earlier study, but these sources on the periphery of the Southwest merit some attention. The two sources reported here have been discussed in detail in Shackley (1994b). Obsidian Butte glass has been analyzed quantitatively by Ericson (1977) and Hughes (1986) elsewhere and will not be reported here. My analyses of Obsidian Butte source standards and archaeological obsidian from the region are comparable (Shackley 1993c).

Bristol Mountains (Bagdad), California

This source is located in the Bristol Mountains, San Bernardino County, California, in Quaternary alluvium consisting predominately of rhyolite, tuff, and marekanites (Apache Tears). The primary context of this late Tertiary (probably Miocene) source appears to be located in rhyolite domes of the Bristol Mountains on the Siberia 7.5' Provisional Quad (1985) in the northeast quarter, particularly in Sections 7 and 18 T7N R11E, and Sections 12 and 13 T7N R10 E (see also Bagdad 15' 1956). The domes of this Tertiary source are so eroded that the obsidian zone has apparently completely moved into the alluvium, not unusual in the Southwest (Shackley 1988a, 1990). Secondary deposits continue down Siberia and unnamed washes to Lavic and Bristol dry lakes approximately 15 to 20 km south. This is an interior drainage basin and so further downstream deposition is impossible.

The density of nodules near the primary context is up to 10 per 2 m^2 with nodule sizes up to 72 mm, although most are 40 to 50 mm. Ten km downstream the nodule density declines to less than 1 per 500 m^2 and nodule sizes are generally near 20 mm or less. In the desert pavements the cortex is generally reddish-brown eroding to black after entering the washes. The glass is typically translucent gray, sometimes banded, and an excellent medium for tool production. Few modified cores or bipolar flakes were noted in two days of survey, although these artifact forms have been recovered from archaeological contexts in the area (Shackley 1994b).

This source was first located by Philip Wilke in the 1980s (Shackley 1994b). Wilke and others noticed the presence of nodules in the alluvium near Bagdad and the source was colloquially called Bagdad. It is more properly called Bristol Mountains obsidian because the glass is derived from the Miocene rhyolite in the mountains. There is no known geologic publication on this source other than Dibblee (1966) for the adjacent Broadwell Lake 15' Quad.

Devil Peak, Clark County, Nevada

This source in extreme southern Nevada was discovered independently by Shackley (1988b) and Philip Wilke. Devil Peak is a series of coalesced rhyolite domes of Tertiary age that have extruded through the Paleozoic Monte Cristo Limestones of the Spring Mountains (Longwell et al. 1965). Devil Peak is located on Stateline Pass 7.5' Provisional Quad 1985 near the center of the sheet. Here nodules are found in situ in a perlite matrix on both the east and west sides of the peak eroding into either the interior drainage basins of Mesquite Lake on the west or Roach Lake on the east. Historic perlite mining on both sides of the peak has destroyed any evidence of prehistoric production. Some tool-manufacturing debris was noted in the alluvium east of the peak toward Roach Lake (Shackley 1988b, 1994b). The archaeological context of the eastern locus is now designated site 26-CK-3865 (Shackley 1988b).

Perlite matrix with in situ marekanites is located on the west near the Umpire Perlite Mines between UTM 3952000 and 3951000/637000 and 639000 (no sections on map). Perlite matrix with in situ marekanites is also located on a series of very small rhyolite domes on the east flank of the Spring Mountains between UTM 3953000 and 3951000/642000 and 644000 all on the Stateline Pass 7.5 Provisional Quad 1985. The density of nodules in both areas in the perlite is up to 100 per m^2, although most of the marekanites are less than 30 mm in diameter. Nodules up to 100 mm in diameter have been recovered, but most are less than 40 mm. The density of nodules on the east shoreline of Mesquite Lake is about 1 per 20 m^2, and about 1 per 100 m^2 on the shoreline of Roach Lake to the east. Significant chemical differences in some trace elements exist between obsidian from the east and west sides of Devil Peak. The nodules on the west side are generally superior media for tool production than those on the east. The "western" marekanites are generally more translucent and brittle, while the "eastern" nodules tend to be less vitreous and opaque and contain some plagioclase or sanidine phenocrysts. This may be due to wall rock reactions with the limestone during eruptive events on the east with the small dome structures. Bipolar cores and flakes occurred rarely, in part no doubt due to the perlite mining in the area. The only published references known are Longwell et al. (1965) and Shackley (1988b).

Eastern Arizona/Western New Mexico

One of the more striking developments in obsidian studies in this area of the Southwest is related to the problem of understanding the secondary deposition of obsidian from some of the large Tertiary sources, and the discovery of significant geochemical variability in what was originally known as the Mule Creek source (Shackley 1992a). In the first case, Mule Creek and Cow Canyon marekanites were found to be eroding into the San Francisco and Gila rivers at least 50 km and possibly 100 km from the primary sources. The Cow Canyon and Mule Creek marekanites are mixed in the Gila River alluvium near Safford, Arizona, in an approximate 3:1 ratio (Shackley 1992a). In this region—where in the Classic period, Hohokam, Salado, and Mogollon "boundaries" abutted—the closeness of boundary can cause considerable problems in dealing with issues of exchange and interaction when only the primary deposits are considered the "source" (see Figure 1).

Cow Canyon

It appears that the secondary depositional extent of this source is much greater than originally mapped (Shackley 1988a). This Tertiary source is eroding east into the Blue River, south into the San Francisco River, and west into the Gila River as originally noted, but also erodes in much higher density into Eagle Creek west of the Blue River, south into the Gila River, and up to 20 km south into the San Simon River valley. A number of "pockets" of Cow Canyon glass have been located in the San Simon River valley in Pliocene/Pleistocene sediments—the result of considerably higher sedimentation rates during these periods. The density of nodules at Eagle Creek, approximately 15 km west of the primary contexts at Cow Canyon, is up to 1 per 10 m^2 and less than 100 times lower in the Gila River (Shackley 1992a). Again, these nodules are mixed with the Mule Creek marekanites in the alluvium.

Mule Creek Source Area

One of the most startling recent discoveries is the chemical variability in the Mule Creek obsidian. In the earlier study, I noted two "outliers" collected at Mule Creek with significantly higher rubidium concentration values (Shackley 1988a:767). These outliers have now been identified as a distinct chemical group, often mixed in the regional Gila conglomerate with three other chemical groups. The geology in the area is complex and has been studied by Ratté and others for some time (Brooks and Ratté 1985; Ratté 1982; Ratté and Brooks 1983, 1989; Ratté and Hedlund 1981; Rhodes and Smith 1972). Primary in situ perlite localities for three of the chemical groups have been located.

At least four distinct chemical groups are evident, distinguished by rubidium (Rb), yttrium (Y), niobium (Nb), and barium (Ba), and, to a lesser extent, strontium (Sr) and zirconium (Zr) concentration values, and are named after the localities where marekanites have been found in perlitic lava: Antelope Creek, Mule Mountains, and Mule Creek/North Sawmill Creek, all in New Mexico (see Table 1 and Figures 2 and 3). Additionally, during the 1994 field season, a fourth subgroup was discovered in the San Francisco River alluvium near Clifton, Arizona, and in older alluvium between Highway 191 and Eagle Creek in eastern Arizona north of Clifton. While in situ nodules have not yet been found, they are certainly located somewhere west of Blue River and north and west of the San Francisco River, since none of this "low zirconium" subgroup was discovered in alluvium upstream from the juncture of the Blue and San Francisco rivers. The genetic relationship is apparent in the trace element matrix plot (Figure 2) and signifies the very complex nature of the Mule Creek silicic geology, with subsequent depositional mixing in the Gila conglomerate. Glass at other Tertiary sources in the Southwest, such as the Sauceda Mountains and Antelope Wells, also appears to exhibit more than one chemical mode, although not as distinct as that at Mule Creek (LeTourneau 1994; Shackley 1988a, 1990). The Mule Creek case is unusual because the chemical groups are not always spatially discrete, and they occur together in the extensive Gila conglomerate, which is mainly composed of Mule Creek rhyolite and tuffs in the area where the marekanites do occur (see Ratté and Brooks 1989).

Gwynn Canyon

In the earlier study (Shackley 1988a), this source was not personally mapped or surveyed. My survey in 1993 indicated that marekanites were directly associated with glassy, perlitic rhyolite in Ewe Canyon to the south, although this stream system erodes into Gwynn Canyon. These coalesced domes, shown as Feathery Hill on the quadrangle map, exhibit nodule densities in the regolith up to 200 per m^2. This source is located in Sections 19 and 20 T9S R16W Telephone Canyon 7.5' Quad 1963, Catron County, New Mexico. Unmodified marekanites on the domes have maximum diameters near 50 mm, although the vast majority ($\geq$ 95 percent) are 30 mm and smaller. Bipolar cores and flakes were found on and near Feathery Hill, but in low densities (< 1 per 100 m^2).

As noted above, marekanites are eroding into the Gwynn Canyon system and possibly the upper San Francisco River, although no nodules were noted in the San Francisco River alluvium as far north as Alma, New Mexico. Published references for the geology of this source include Findlow and Bolognese (1982:56), the regional geology map by Weber and Willard (1959), and Ratté et al. (1984).

The Gwynn Canyon and two of the Mule Creek groups (Antelope Creek and Mule

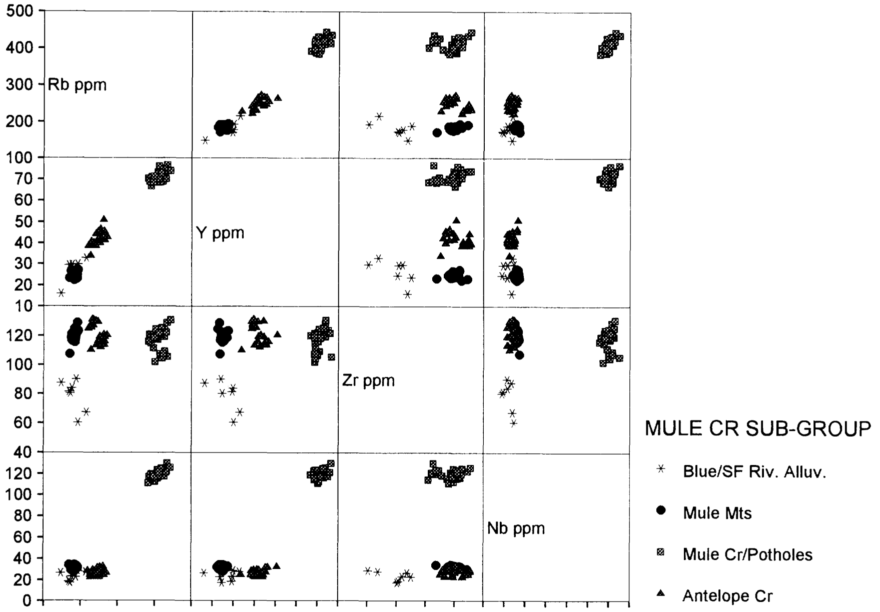

Figure 2. Matrix of Rb, Y, Zr, and Nb bivariate plots for the four Mule Creek chemical subsources. The four groups are most readily discriminated on Rb, Y, and Zr.

Mountains) are very similar in trace element composition (see Table 1). Zr plotted against Nb, Y, and/or Ba is the best method to discriminate these sources using energy dispersive X-ray fluorescence (EDXRF). This can be an important issue in western New Mexico late prehistory because these sources are located in very different environments that may have had cultural significance in prehistory. It is possible that in the late period Gwynn Canyon obsidian could have been controlled by the Cibola branch of the Mogollon, while the Mule Creek sources could have been controlled by the Mimbres branch. This may or may not influence the spatial distribution of these obsidian sources in the region, and confident source assignment can become crucial. Again, the secondary distribution of Mule Creek is quite extensive to the west through the San Francisco and Gila River systems, and the presence of Mule Creek glass in archaeological contexts to the west may not necessarily indicate that it was procured in the highlands, but could have been procured from the Gila River alluvium.

Antelope Wells

In the original study, geologic investigations were hampered by land closures at the source (Shackley 1988a, 1990). An important observation then: contrary to the Findlow and Bolognese (1982) study, no artifact quality marekanites could be located in the Peloncillo Mountains, and there was considerable secondary dispersion of the nodules in the area (Shackley 1990:201–202). A significant new study of this source by LeTourneau (1994) amplifies this observation and provides useful insight. LeTourneau's intensive study of the geology and petrology, with access to the OK Bar conglomerate and Deer Creek, indicates that this is a rather typical Tertiary peralkaline glass source with a probable rhyolite formation origin and attendant secondary deposition (LeTourneau 1994). LeTourneau did find marekanites in situ in tuff and conglomerates, and volcaniclastics of Culberson Ranch (1994:4). No nodules were located in perlitic lava. Nodule sizes, however, located by LeTourneau are about the same size as those reported in my original survey (up to 6 cm), but the extent of the deposit is much greater. LeTourneau (1994) notes a number of geological studies in the area including Erb (1979), as well as Alper (1961), and Zeller (1962).

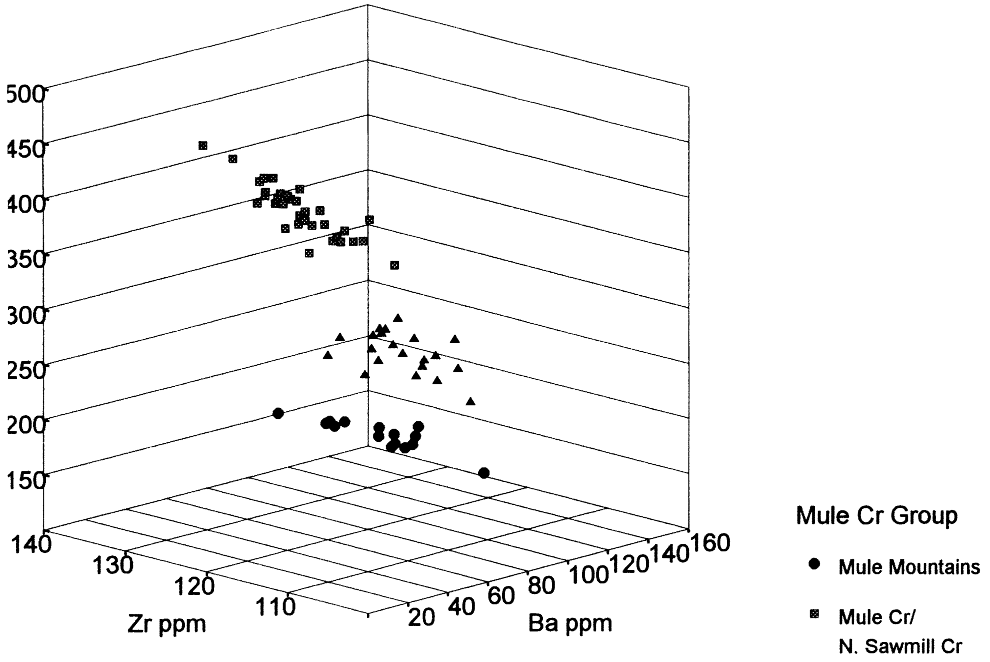

Figure 3. Three-dimensional plot of Rb, Zr, and Ba for the three Mule Creek source groups with in situ marekanites.

Northern Arizona

Two newly discovered sources of glass have been reported in the Mount Floyd Volcanic Field in association with the Partridge Creek locality west of the San Francisco Volcanic Field (Lesko 1989). The Partridge Creek (Round Mountain) source still remains as originally described (Shackley 1988a:754–755). Two new sources reported by Lesko (1989:389–390) have not been recognized in archaeological contexts outside northern Arizona, but were used prehistorically in that region (Lesko 1989).

Presley Wash

This is a gray and black glassy and subvitreous rhyolite most often opaque gray to gray-green to black. Sanidine or plagioclase phenocrysts (not quartz as stated by Lesko 1989:389) are common in the matrix, hampering control during knapping. The black variety is generally subvitreous, rarely with phenocrysts, and not well suited to the production of small bifaces. There are no chemical differences between these two varieties, and they occur together in Presley Wash east of Round Mountain (Table 1). After the juncture of Partridge Creek running east from Round Mountain and Presley Wash, all varieties of obsidian are found in the alluvium (see Lesko 1989:389).

Black Tank

I have not visited this source, but received samples from David Nealy (U.S. Geological Survey, Flagstaff, Arizona) in 1987. Lesko describes the source, also known as Rose Well obsidian, as located in the Black Tank area north of Round Mountain (1989:389–390). It occurs as small (< 5 cm diameter) black or black and mahogany nodules in an area disturbed by cattle tank construction. The black material is nearly identical megascopically to Partridge Creek glass but exhibits a very different chemistry (Table 1). Lesko describes the source as "small and the material not abundant" (1989:390).

Unknown Sources

Particularly in later prehistoric period contexts, a small proportion of obsidian assemblages exhibit artifacts portraying chemical signatures that do not match any known North or Central American

Table 1. Mean and Central Tendency Data for Archaeological Sources of Obsidian in the Southwest.

Element	Mean	S.D.	Minimum	Maximum	N
Eastern Arizona/Western New Mexico[a]					
Cow Canyon, Arizona					
Ti	1067.20	226.80	819.97	1898.13	23
Mn	519.02	73.20	329.67	633.34	23
Fe	9468.41	932.25	7725.69	11937.85	23
Rb	141.95	10.3	112.19	160.94	23
Sr	109.95	10.56	84.05	128.52	23
Y	23.68	1.76	20.02	26.25	23
Zr	139.18	11.04	98.83	153.50	23
Nb	19.39	1.91	15.32	22.22	23
Ba	867.58	46.12	796.16	1001.13	17
Mule Creek Source Region, Arizona and New Mexico					
Antelope Creek Group					
Ti	679.27	109.11	470.91	849.27	14
Mn	352.17	39.97	285.92	425.05	14
Fe	9686.14	401.87	8880.69	10386.48	14
Rb	239.63	12.97	220.89	271.99	14
Sr	17.22	.93	15.95	19.21	14
Y	40.68	3.03	33.72	45.35	14
Zr	123.71	7.55	110.37	131.34	14
Nb	26.51	2.66	22.50	31.49	14
Ba	115.57	20.91	85.09	146.61	14
Mule Creek/North Sawmill Creek Group					
Ti	613.62	189.49	305.48	1276.39	34
Mn	575.36	41.04	503.21	671.58	34
Fe	8423.30	564.44	7602.84	11022.36	34
Rb	411.31	14.61	383.73	444.04	34
Sr	5.52	1.70	1.27	10.47	34
Y	70.93	2.36	66.64	76.70	34
Zr	118.15	7.22	102.09	131.22	34
Nb	119.85	4.00	110.96	130.15	34
Ba	45.34	1.72	43.01	49.52	26
Mule Mountains Group					
Ti	720.45	105.29	614.11	992.83	12
Mn	439.02	43.33	357.05	520.26	12
Fe	8058.51	578.32	7446.45	9252.74	12
Rb	193.10	31.09	170.63	262.91	12
Sr	10.87	1.28	7.85	13.15	12
Y	28.39	9.57	22.30	50.76	12
Zr	118.35	4.16	107.59	125.01	12
Nb	32.14	1.93	28.29	34.38	12
Ba	86.14	11.16	64.13	99.88	12
Blue/San Francisco River Alluvium					
Ti	663.63	187.81	448.91	1023.15	7
Mn	490.15	144.74	303.37	726.46	7
Fe	7262.97	504.97	6444.17	8051.88	7
Rb	180.36	21.27	147.22	215.23	7
Sr	14.21	6.40	6.65	22.60	7
Y	26.58	5.60	16.12	32.85	7
Zr	78.73	10.87	60.38	90.03	7
Nb	23.53	4.43	17.29	28.86	7

Table 1 Continued.

Element	Mean	S.D.	Minimum	Maximum	N
Ba[b]	119.84	66.12	66.01	212.51	7
Red Hill, New Mexico					
Ti	360.84	43.16	274.8	417.1	14
Mn	631.15	107.50	445.2	819.5	14
Fe	6970.98	600.67	5986.3	8239.7	14
Rb	176.19	21.16	138.2	221.5	14
Sr	11.33	2.84	5.2	14.6	14
Y	38.24	4.59	31.6	48.5	14
Zr	68.52	3.67	60.8	74.4	14
Nb	50.46	6.51	39.8	65.7	14
Ba	50.59	3.24	43.4	56.4	14
Gwynn Canyon, New Mexico					
Ti	765.93	110.79	587.38	1066.40	20
Mn	429.02	42.35	327.95	507.84	20
Fe	8511.58	538.92	7368.46	9734.20	20
Rb	226.45	12.95	196.38	244.23	20
Sr	19.27	1.81	15.81	23.19	20
Y	30.99	2.19	26.89	35.95	20
Zr	155.57	7.42	137.30	167.13	20
Nb	21.56	2.73	15.25	27.16	20
Ba	85.55	7.00	77.15	107.50	20
Antelope Wells, New Mexico and Chihuahua					
Ti	1383.03	121.83	1190.1	1705.7	25
Mn	982.96	97.09	770.2	1184.5	25
Fe	22520.54	1913.95	18125.6	25988.6	25
Rb	347.99	22.11	303.5	391.5	25
Sr	7.13	1.23	5.1	9.3	25
Y	127.74	6.28	118.9	143.3	25
Zr	1255.13	46.83	1178.5	1356.8	25
Nb	97.10	5.15	89.9	109.1	25
Ba	45.45	2.43	41.3	52.2	17
West and Central Arizona/Northern Sonora Region					
Tank Mountains, Arizona					
Ti	663.65	176.99	527.0	1249.7	15
Mn	429.94	36.60	381.9	512.2	15
Fe	10756.54	467.78	10255.6	11915.1	15
Rb	165.41	7.58	152.3	180.6	15
Sr	148.93	5.40	141.7	160.1	15
Y	24.55	1.79	21.5	27.7	15
Zr	124.09	3.75	118.5	130.2	15
Nb	20.33	2.73	15.1	26.4	15
Ba	887.87	83.94	711.5	1028.1	15
Vulture, Arizona[c]					
Ti	978.52	115.22	744.5	1076.2	10
Mn	346.90	23.00	318.9	389.6	10
Fe	8528.30	407.88	7706.2	8925.0	10
Rb	142.41	8.88	126.4	151.3	10
Sr	40.48	2.26	35.8	42.8	10
Y	19.58	1.90	16.8	22.9	10
Zr	134.53	6.23	122.5	141.1	10

Table 1 Continued.

Element	Mean	S.D.	Minimum	Maximum	N
Nb	25.03	2.66	20.1	29.3	10
Ba	430.85	10.81	406.9	442.3	10
Superior (Picketpost Mountain), Arizona[c]					
Ti	831.84	148.94	708.9	1298.1	13
Mn	489.01	19.63	455.8	536.6	13
Fe	7873.22	163.89	7518.1	8175.4	13
Rb	130.23	2.74	125.7	136.3	13
Sr	19.09	2.03	15.9	21.7	13
Y	25.26	2.13	20.5	28.7	13
Zr	99.83	2.64	94.5	104.9	13
Nb	32.51	1.79	29.3	35.4	13
Ba	243.73	5.57	237.0	254.6	13
Sauceda Mountains, Arizona					
Ti	1545.80	118.77	1324.5	1828.1	17
Mn	295.98	40.84	253.5	389.7	17
Fe	11626.93	461.98	10606.4	12575.4	17
Rb	172.83	7.53	160.6	191.8	17
Sr	104.21	11.12	78.2	113.8	17
Y	28.97	4.12	23.4	40.9	17
Zr	197.91	12.05	183.8	227.0	17
Nb	21.91	2.33	17.9	27.3	17
Ba	923.29	44.58	858.2	1026.3	17
Los Vidrios, Sonora					
Ti	784.23	85.64	657.8	893.3	10
Mn	208.17	15.71	178.9	231.5	10
Fe	13085.70	686.78	11743.4	13803.6	10
Rb	260.11	12.91	236.0	271.1	10
Sr	13.96	1.28	12.2	16.5	10
Y	74.60	4.23	67.8	79.9	10
Zr	235.25	8.50	217.1	242.2	10
Nb	32.47	2.19	29.0	35.0	10
Ba	81.67	3.19	75.4	86.3	10
Burro Creek, Arizona					
Ti	410.66	86.59	223.8	510.5	13
Mn	493.74	38.48	438.9	555.1	13
Fe	9146.95	429.73	8299.7	9641.0	13
Rb	367.94	19.00	333.6	397.4	13
Sr	5.62	1.63	0.0	7.7	13
Y	75.91	4.58	68.4	82.5	13
Zr	101.22	4.37	92.7	106.9	13
Nb	48.06	3.56	40.3	54.1	13
Ba	41.96	1.63	39.4	45.1	13
Unknown A[d]					
Ti	2265.22	163.20	2074.1	2613.8	10
Mn	565.62	70.32	429.5	658.6	10
Rb	140.94	9.14	121.7	148.8	10
Sr	18.03	1.73	15.9	21.5	10
Y	79.35	4.13	72.6	86.4	10
Zr	712.79	40.23	643.5	755.0	10
Nb	46.96	5.77	35.9	52.8	10

Table 1 Continued.

Element	Mean	S.D.	Minimum	Maximum	N
Northern Arizona Region (San Francisco Volcanic Field)					
Government Mountain, Arizona[e]					
Ti	273.09	41.89	198.0	325.5	10
Mn	543.91	42.20	468.0	602.6	10
Fe	8622.39	372.11	7955.4	9187.9	10
Rb	108.92	3.20	104.5	115.6	10
Sr	78.75	2.38	75.4	84.3	10
Y	19.70	1.25	18.3	22.0	10
Zr	81.69	2.01	77.7	84.2	10
Nb	52.71	2.12	47.9	54.8	10
Ba	357.89	10.36	344.5	374.5	10
O'Leary Peak, Arizona					
Ti	798.50	97.54	728.3	963.7	5
Mn	677.93	86.20	560.4	752.4	5
Fe	18543.05	1867.69	16203.8	20540.2	5
Rb	74.42	5.49	68.5	82.5	5
Sr	165.76	8.07	153.6	175.8	5
Y	31.56	1.97	29.4	33.6	5
Zr	244.23	12.84	228.4	259.4	5
Nb	48.91	5.23	43.0	55.4	5
Ba	1588.37	65.33	1519.4	1688.2	5
San Francisco Peak, Arizona					
Ti	662.28	49.47	598.4	704.8	5
Mn	468.01	23.39	441.0	502.6	5
Fe	17650.99	506.19	16968.8	18181.1	5
Rb	137.52	5.58	128.7	142.1	5
Sr	4.40	2.51	0	6.1	5
Y	81.16	4.52	75.2	87.5	5
Zr	752.72	26.69	728.6	793.8	5
Nb	142.49	5.21	134.9	149.4	5
Ba	43.62	2.14	39.9	45.1	5
RS Hill, Arizona					
Ti	348.52	114.16	210.4	507.1	11
Mn	422.95	29.06	354.0	476.4	11
Fe	10023.96	456.98	9335.3	10722.6	11
Rb	408.66	10.44	387.6	423.8	11
Sr	5.29	2.95	0	8.6	11
Y	90.05	5.07	81.9	99.7	11
Zr	175.90	3.75	168.0	181.1	11
Nb	263.91	4.84	255.8	272.0	11
Ba	43.93	1.66	41.2	46.7	11
Sitgreaves Peak, Arizona					
Ti	337.22	81.00	275.8	529.2	10
Mn	423.01	32.68	374.0	462.4	10
Fe	9572.15	453.33	8827.3	10335.2	10
Rb	395.51	11.76	375.8	409.8	10
Sr	6.63	1.46	4.4	8.5	10
Y	88.12	3.85	83.3	94.9	10
Zr	174.36	5.40	164.6	182.8	10
Nb	257.55	7.02	245.6	269.1	10
Ba	43.79	2.34	40.5	48.0	10

Table 1 Continued.

Element	Mean	S.D.	Minimum	Maximum	N
Slate Mountain (Wallace Tank), Arizona					
Ti	649.86	72.71	553.2	773.9	10
Mn	446.30	24.69	424.8	501.0	10
Fe	11617.40	450.53	11178.6	12643.1	10
Rb	115.26	3.91	109.9	122.9	10
Sr	67.38	10.07	61.1	94.8	10
Y	21.90	1.89	18.2	24.7	10
Zr	143.16	4.49	134.5	149.4	10
Nb	45.84	2.51	40.6	48.9	10
Ba	753.62	24.94	716.9	792.4	9
Kendrick Peak, Arizona					
Ti	282.51	44.54	218.6	382.3	10
Mn	542.96	49.51	469.2	647.6	10
Fe	10395.85	482.57	9778.9	11355.8	10
Rb	121.57	3.52	117.3	127.1	10
Sr	10.99	1.30	8.4	12.4	10
Y	29.08	1.78	26.7	31.2	10
Zr	142.18	3.44	135.4	147.0	10
Nb	70.99	2.39	68.2	76.9	10
Ba	105.46	3.49	98.7	110.8	10
Northern Arizona Region (Mount Floyd Volcanic Field)					
Partridge Creek (Round Mountain), Arizona[f]					
Ti	321.35	44.94	247.8	382.0	15
Mn	483.76	38.65	412.7	551.1	15
Fe	8562.98	395.26	7985.6	9118.1	15
Rb	256.07	10.50	241.5	275.7	15
Sr	5.51	1.82	0	8.2	15
Y	39.28	1.55	36.6	42.2	15
Zr	97.95	3.40	92.9	103.4	15
Nb	54.66	1.74	51.2	58.0	15
Ba	45.71	2.34	41.8	51.5	15
Presley Wash, Arizona					
Ti	2279.92	1016.89	1527.3	4672.5	9
Mn	399.69	67.25	339.5	557.3	9
Fe	18645.18	5119.43	14256.9	30743.3	9
Rb	87.42	6.82	74.4	95.3	9
Sr	209.22	26.52	186.9	272.7	9
Y	15.75	1.92	13.2	19.0	9
Zr	139.83	3.66	134.6	146.2	9
Nb	20.76	2.22	17.4	23.9	9
Ba	1296.35	88.27	1107.1	1401.1	9
Black Tank, Arizona					
Ti	1212.87	141.57	1063.6	1345.3	3
Mn	519.17	24.59	498.8	546.5	3
Fe	14193.31	635.78	13471.8	14671.4	3
Rb	132.44	4.37	128.0	136.7	3
Sr	125.91	7.29	117.6	131.0	3
Y	22.88	1.92	20.9	24.7	3
Zr	97.52	2.89	94.2	99.7	3
Nb	28.49	2.31	25.9	30.3	3
Ba	922.59	62.09	859.8	984.0	3

Table 1 Continued.

Element	Mean	S.D.	Minimum	Maximum	N
Southeastern California/Southern Nevada Region					
Bristol Mountains (Bagdad), California					
Ti	884.73	43.70	806.86	979.29	20
Mn	399.69	37.99	346.24	527.79	20
Fe	9177.64	376.32	8486.44	9863.25	20
Rb	188.00	8.02	167.48	198.84	20
Sr	141.81	5.28	128.86	149.08	20
Y	20.56	1.61	17.12	23.42	20
Zr	129.00	3.98	119.65	138.01	20
Nb	22.26	2.52	17.20	27.44	20
Ba	924.73	136.74	831.63	1416.14	20
La	69.62	11.04	58.07	107.37	20
Ce	117.89	18.06	102.25	182.12	20
Devil Peak Source Group, Nevada					
Devil Peak East					
Ti	629.96	70.83	502.49	798.52	46
Mn	592.00	56.07	532.69	809.03	46
Fe	8465.21	538.47	7622.81	10409.65	46
Rb	201.03	10.61	182.98	240.90	46
Sr	110.12	10.80	100.17	163.29	46
Y	29.28	2.71	23.26	34.90	46
Zr	108.43	5.44	101.85	133.09	46
Nb	25.75	2.53	19.84	32.51	46
Ba	347.35	51.91	234.27	504.92	24
Devil Peak West					
Ti	815.25	100.82	605.27	989.53	15
Mn	538.18	50.30	412.66	612.25	15
Fe	9975.72	617.37	8660.73	10852.72	15
Rb	178.50	9.88	157.56	193.62	15
Sr	251.40	9.81	230.05	266.04	15
Y	25.90	1.68	22.78	28.98	15
Zr	155.37	5.92	144.97	166.62	15
Nb	23.04	1.88	19.65	26.36	15
Ba	876.13	124.18	744.77	1193.47	15
La	86.59	11.76	73.28	105.92	10
Ce	163.45	18.29	144.04	204.49	10

Note: S.D. = 1st standard deviation. All measurements in parts per million (ppm). Fe^T can be converted to $Fe_2O_3^T$ with a multiplier of $1.4297(10^{-4})$ (see also Glascock 1991).

a. Northern New Mexico sources are not covered here. Refer to the two excellent works on this region and the attendant quantitative analyses (Baugh and Nelson 1987; Newman and Nielson 1985; see also Stevenson and Klimkiewicz 1990 for an analysis of some of these sources).

b. The barium data appears to be quite variable (66.01–212.51 ppm). With the alluvial and small sample here it is difficult to determine whether this is intrasource variability or two sources mixed in the alluvium; probably the former.

c. Zirconium and barium most effectively separate Vulture and Superior sources (see text).

d. Data from Organ Pipe Cactus National Monument, Arizona; archaeological obsidian.

e. Cow Canyon and Government Mountain exhibit similar chemistry in a number of elements. They are megascopically distinctive, and Ti, Zr, Nb, and Ba effectively separate these two sources.

f. One of the source standard samples exhibited significantly different chemistry that the other 15. These data, following, were not included in the statistical analysis here: Ti 583.59; Mn 254.99; Fe 12356.14; Rb 251.90; Sr 12.519; Y 65.378; Zr 236.99; Nb 30.27; Ba 89.31.

obsidians. In some cases, as evident in the discussions above, this phenomenon could be due to the variability of known sources where that variability has not been shown in source standard analyses. In other cases, a very real source is evident but as yet unlocated, as in the case of "Unknown A," relatively common in Hohokam contexts in central and southern Arizona. This source is represented in artifact assemblages from the Gatlin Site (Gila Bend, Arizona) and Pueblo Grande (Phoenix, Arizona), as well as from sites in Organ Pipe Cactus National Monument (Arizona-Sonora border near Sonoita, Mexico). In a recent study at Organ Pipe the source was more common than at Los Vidrios, and the next most common source after the Sauceda Mountains, the closest known source (Shackley 1992b; Figure 1 here). Presence of core fragments and cortex suggests that the source is relatively nearby, somewhere in the Papagueria, and probably in the rhyolites on the western edge of the Tohono O'odahm reservation abutting the Organ Pipe Cactus National Monument. Permission to pass on the reservation could not be secured. No other unknown source has been recovered in any of my analyses in the Southwest in any quantity.

Elemental Data Analysis

Table 1 exhibits the quantitative analysis of the source standards. The table is annotated to discuss pertinent characteristics, and particularly elements, that adequately separate any two chemically similar obsidian sources (see Doyel 1994; Mitchell and Shackley 1995; Shackley 1994b).

Analytical Methods

All samples were analyzed whole and were washed in distilled water before analysis. Nodules were split using bipolar percussion to produce a fresh, relatively flat surface. 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 interinstrument comparison with a predictable degree of certainty (Hampel 1984).

The trace element analyses were performed in the Department of Geology and Geophysics, University of California, Berkeley, using a Spectrace™ 400 (United Scientific Corporation) energy dispersive X-ray fluorescence spectrometer. The spectrometer is equipped with a Rh X-ray tube, a 50 kV X-ray generator, with a Tracor X-ray (Spectrace™) TX 6100 X-ray analyzer using an IBM PC-based microprocessor and Tracor reduction software. The X-ray tube was operated at 30 kV, .20 mA, using a .127 mm Rh primary beam filter in a vacuum path at 250 seconds livetime to generate X-ray intensity Kα-line data for elements titanium (Ti), manganese (Mn), total iron (as Fe^T), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb). Weight percent iron ($Fe_2O_3{}^T$) can be derived by multiplying ppm estimates by $1.4297(10^{-4})$. X-ray intensity Kα-line data for barium (Ba), lanthanum (La), and cerium (Ce) were determined by using a ^{241}Am gamma ray source for 500 seconds livetime in an air path. Trace element intensities were converted to concentration estimates by employing a least-squares calibration line established for each element from the analysis of international rock standards certified by the National Institute of Standards and Technology (NIST), the U.S. Geological Survey, Canadian Centre for Mineral and Energy Technology, and the Centre de Recherches Pétrographiques et Géochimiques in France (Govindaraju 1989). Further details concerning the petrological choice of these elements in Southwest obsidians is available in Shackley (1988a, 1990, 1992a; also Hughes and Smith 1993; Mahood and Hildreth 1983; and Mahood and Stimac 1990). Specific standards used in calibration for the measurements presented here, and the practical detection limits for the elements of interest, are presented in the Appendix.

The data from the Tracor software were translated directly into Quattro Pro for Windows software for manipulation and 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. Table 2 shows a com-

Table 2. X-ray Fluorescence Concentrations for Selected Trace Elements of Three International Rock Standards.

Sample	Ti	Mn	Fe	Rb	Sr	Y	Zr	Nb	Ba
RGM-1 (Govindaraju 1989)	1600	279	12998	149	108	25	219	8.9	807
RGM-1 (Glascock and Anderson 1993)	1079±120	323±7	863±210	145±3	120±10	N.R.	150±7	N.R.	826±31
RGM-1 (This study)	1516±58	259±19	13991±143	152±3	108±2	24±1	226±4	10±1	806±12
SRM-278 (Govindaraju 1989)	1469	402	14256	127.5	63.5	41	295	N.R.	1140
SRM-278 (Glascock and Anderson 1993)	875±162	428±8	9932±210	128±4	61±15	N.R.	208±20	N.R.	891±39
SRM-278 (This study)	1376±96	372±17	15229±399	129±2	68±2	42±2	290±3	17±2	1090±38
JR-2 (Govindaraju 1989)[a]	540	852	6015	297	8	51	98.5	19.2	39
JR-2 (This study)	343±51	680±17	7358±65	300±5	10±1	49±3	94±2	16±2	34±6

Note: N.R. = no report. Values of ± represent first standard deviation computations for the group of measurements. All values are in parts per million (ppm) as reported in Govindaraju (1989) and this study. RGM-1 is a U.S. Geological Survey rhyolite standard, NBS (SRM)-278 is a National Institute of Standards and Technology obsidian standard, and JR-2 is a Geological Survey of Japan rhyolite standard. Fe^T can be converted to $Fe_2O_3^T$ with a multiplier of $1.4297(10^{-4})$ (see also Glascock 1991).

parison between values recommended for three international obsidian and rhyolite rock standards, RGM-1, NBS(SRM)-278, and JR-2. One of these standards is analyzed during each sample run to check machine calibration. The results shown in Table 2 indicate that the machine accuracy is quite high, particularly for the mid-Z elements, and other instruments with comparable precision should yield comparable results.

Trace element data exhibited in Tables 1 and 2 are reported in parts per million (ppm), a quantitative measure by weight. Table 2 exhibits the trace element concentrations for the source standards.

Recent Archaeological Applications and a Statement of Relevance

I recently argued that archaeometrists involved in the analysis of archaeological obsidian and archaeologists are not communicating as well as they might (Shackley 1993a). In many cases there appears to be a rather extreme lack of communication (or even co-interest) between what southwestern archaeologists who study stone tools think and do and what archaeometrists who are interested in rocks think and do. This, of course, is changing slowly. Now some researchers discuss their sampling strategies with archaeometrists before the fieldwork begins. Consequently, the quantity and quality of insight into what obsidian geochemistry can do for our concept of prehistory in the region is increasing.

In some ways, this problem is being addressed more efficiently in the chemical characterization of ceramics (see Bishop and Neff 1989; Bishop et al. 1990; Burton and Simon 1993; Neff 1992). Bishop et al.'s (1990) recent discussion of sensitivity, precision, and accuracy in the compositional analysis of ceramic pastes has real import for obsidian geochemical studies particularly in the discussion of the level of precision of neutron activation analysis (NAA) and X-ray fluorescence spectrometry (XRF) and use of international standards. An important difference here is that pottery is essentially a heterogeneous substance rather than a nearly homogeneous substance like the aphyric obsidians. Additionally, while NAA as claimed by Bishop et al. is more sensitive in the analysis of many elements, XRF is just as sensitive in the analysis of the heavier mid-Z incompatibles most useful in the discrimination of archaeological sources of obsidian, and comparisons of analyses between the two methods have been favorable (see Hughes 1988b; Shackley 1995b). Indeed, XRF can be more sensitive in the analysis of Ba and Sr, two important incompatibles in the analysis of silicic glasses (Hughes and Smith 1993; Mahood and Hildreth 1983; Shackley 1988a, 1990, 1995b).

Rarely discussed are the methods used to assign artifacts to sources. A method favored by a number of researchers, particularly those using NAA data yielding a relatively large number of elemental and compound data, is multivariate statistical analysis based on Mahalanobis distance measures to indicate group (source) provenance (Glascock 1992, 1994; Harbottle 1976). While this is convenient, it is important to remember that if the number of cases is not two to three times the number of variables (elements measured) ($p > 3n$), then the group assignments based on the sum of squares in the cross-products matrix (SSCP) can often yield spurious results due to zero cells in the matrix, and misclassifications can occur without knowledge (Baxter 1994a, 1994b; Johnson and Wichern 1982). More important, of course, is that group assignments based on multivariate statistical measurement do not necessarily represent groupings based on what is occurring in the field. The best procedure in my opinion is to combine multivariate analyses (i.e., cluster or discrimanant analysis), if one must use them, with graphic displays similar to those used here (Figures 2 and 3). If the multivariate group assignments do not agree with that observed in the graphic displays (bivariate or trivariate), then it would be advisable to carefully assign the artifacts to sources. One of the reviewers suggested "normalizing" the data by employing log transformations. In one sense this would produce "normaloid" data from generally nonnormal geochemical data. While this has some utility, it often dissolves the very variability (normal or otherwise) that allows one to discriminate sources. While any statistical analysis of the data requiring normality (i.e., many classification analyses) would be enhanced, the sacrifice of variability needed to discriminate may be too great. It appears that a rule of thumb agreed to by most involved with archaeological obsidian geochemistry is to use the fewest variables necessary to discriminate without modifying the data (Harbottle 1982).

Another important factor to consider is the region of interest. As the region of interest increases, the potential for error correspondingly increases, because, while silicic glass geochemistry is generally source specific, the level of variability that can occur is limited by what can be produced in silicic melts (Bouška 1993; Hughes and Smith 1993; Macdonald et al. 1992). While it is tempting to assume that one can determine the provenance of obsidian anywhere on earth, it is simply not possible without defining the region. Furthermore, nothing is better than experience with the source geology and chemistry. The use of international standards by all of the labs analyzing obsidian in North America allows us to directly compare data from one lab to another regardless of whether the analysis is by NAA or XRF (Shackley 1995b). But frankly, many source assignments are made both by multivariate analyses and graphic displays, as well as the experience of the analyst with obsidian from that region.

In response to the growing use of obsidian geochemistry in the service of understanding prehistory, for the first time a panel discussion on the subject involving international participants was organized by the International Association for Obsidian Studies (IAOS) at the annual meeting of the Society for American Archaeology in 1994 in Anaheim (IAOS 1994). Many of these issues were discussed and all agreed that: (1) all labs should freely share source data and publish often; (2) international standards should be employed for calibration statistics and analyzed routinely for comparison and adjustment; and (3) source standard data will be submitted to Ronald L. Bishop at the Smithsonian Institution's Conservation Analytical Laboratory (SARCAR) from which researchers from all over the world will ultimately be able to access the data through Internet.

Obsidian studies in archaeology are maturing and becoming an important part of problem designs and analysis. Although all the major laboratories in North America freely share data and calibrate to the same international standards ensuring comparable accurate analyses, there is still room for improvement.

Archaeology and Obsidian in the Southwest

While it is true that obsidian studies in the Southwest lag somewhat behind other adjoining regions in the New World, it has recently gained momentum in a number of important domains, in some cases challenging current ideas and in other cases reinforcing prevailing thought. Much of this is occurring in large cultural resource management (CRM) studies, but long-term research projects are beginning to integrate obsidian studies into planning and analysis at a regular rate (Doyel 1994; Mitchell and Shackley 1995; Peterson et al. 1994; Shackley 1990, 1995a). A few brief examples of recent studies will serve to outline the growing potential of obsidian geochemical research in southwestern archaeology.

Obsidian in Hohokam Studies

Due mainly to the spate of CRM work in Hohokam contexts in central Arizona, a number of important CRM studies serve to illustrate the potential for inference based on obsidian analyses. Most of this has been focused on Classic period sites, with one important Sedentary period study at Gila Bend (Doyel 1994). It appears that with few exceptions, obsidian is most common in Classic contexts and rather rare in earlier periods (Mitchell and Shackley 1995). This could be due to a number of factors including increases in the number of specialists and, possibly connected to this, interest in obsidian as well as other "exotics" by members of platform mound communities (see Peterson et al. 1994).

At Pueblo Grande, a Classic platform mound complex in the Phoenix Valley, obsidian was common in a number of domestic and communal contexts (Peterson et al. 1994). While the vast majority of the obsidian was derived from regional Sonoran Desert sources (Sauceda Mountains, Vulture, and Los Vidrios), glass sources likely under control of the Hohokam, a significant proportion was derived from the Colorado Plateau (Government Mountain and Partridge Creek), and some from Superior (Peterson et al. 1994:163–164). The analysis indicated that much of the obsidian from greater distances was likely procured as finished tools while obsidian from Sauceda and Vulture was used as raw material at the site.

What is perhaps more important during the Classic is the near absence of Superior obsidian even at sites such as Escalante Ruin near the source (Mitchell and Shackley 1995). Indeed, the vast majority of obsidian at Escalante was from the Sauceda Mountains source near Gila Bend, a much greater distance west, but apparently a source in the Hohokam territory or procurement range (Mitchell and Shackley 1995). Following this, Sonoran Desert sources are absent at Classic sites in the Tonto Basin, which are dominated by Superior and Colorado Plateau obsidian (Mitchell and Shackley 1995). There certainly appears to be a boundary between the Hohokam and Salado through which obsidian rarely penetrated, although both groups had access to the Colorado Plateau glass sources.

In both the Classic Tonto Basin contexts, and Classic Hohokam contexts to the south, obsidian is often most common in the platform compounds apparently controlled by the members of that group. While obsidian occurs throughout these sites, it is often cached in rooms within the platform mound complexes where nodule reduction and artifact production activities also occurred (Mitchell and Shackley 1995). This does imply a certain value for this raw material, and, given the absence of obsidian from the other major cultural group (Hohokam versus Salado) in these sites, it suggests a level of importance beyond other flaked lithic raw materials. If ceramics and other items are exchanged over this same boundary, then the group or individuals knapping obsidian experienced different relationships. This may have been "gender" based and associated with higher status individuals. The Pueblo Grande study suggested that some "higher status" individuals may have had access to obsidian sources that other individuals did not, but the sample size is really not large enough to derive confident conclusions (Mitchell 1992; Peterson et al. 1994).

Sauceda Mountains obsidian is the most common glass found in Classic Hohokam contexts thus far analyzed in both the Phoenix Valley and Tucson Basin (Mitchell and Shackley 1995). It appears that all Hohokam groups had equal access and/or were involved in the same exchange relations. This has nothing to do with intersource raw material or nodule size variability, because all the Sonoran Desert sources are equal in these attributes (Shackley 1988a, 1990). Given this, obsidian becomes a very real indicator of exchange relationships that may have been gender and/or social group based. Much more work needs to be done, but at least southwesternists are looking at the possibilities. The data are becoming available to compare the acquisition and distribution of this high-quality raw material against other data sets such as ceramics, shell, and other nonlocal stones. This could not be done 10 or even five years ago.

Conclusion

The title to this section is, in many ways, a misnomer. Given the relatively immature character of obsidian studies in the American Southwest, and the presence of unlocated sources obvious in archaeological obsidian assemblages, a conclusion to this work may not be possible for many years. What we do know now is that most of the obsidian sources used prehistorically in the U.S. portion of the American Southwest are known, and confident inferences concerning exchange, interaction, and procurement ranges based on obsidian provenance are possible with a great degree of certainty. This study has certainly been worthwhile in that regard. The presentation of the quantitative data here should help to disseminate the important source data so that it is available to all and continues to increase our knowledge of prehistory in the greater American Southwest.

Recent archaeological obsidian projects in the region have indicated that they can indicate more complex exchange and interaction in the late period than can be discerned with many other data sets alone, or they can bolster those models based on less confident source or regional assignments (Doyel 1994; Mitchell and Shackley 1995; Peterson et al. 1994; Shackley 1995a).

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Appendix

Specific standards used for the best-fit regression calibration for elements Ti through Nb include G-2 (basalt), AGV-1 (andesite), GSP-1 and SY-2 (syenite), BHVO-1 (hawaiite), STM-1 (syenite), QLM-1 (quartz latite), RGM-1 (obsidian), W-2 (diabase), BIR-1 (basalt), SDC-1 (mica schist), TLM-1 (tonalite), SCO-1 (shale), all U.S. Geological Survey standards, and BR-N (basalt) from the Centre de Recherches Pétrographiques et Géochimiques in France (Govindaraju 1989). Barium calibration standards include G-2 (basalt), BCR-1 (basalt) AGV-1 (andesite), GSP-1 (syenite), BHVO-1 (hawaiite), STM-1 (syenite), RGM-1 (obsidian), W-2 (diabase), SY-2 (syenite), MRG-1 (gabbro), all U.S. Geological Survey standards; NBS or SRM-278 (obsidian) from the NIST; and JA-2 (andesite), JB-2 (basalt), and JR-2 (rhyolite) from the Geological Survey of Japan (Govindaraju 1989). In addition to the reported values here, Ni, Cu, Zn, Ga, Th, La, Ce, Pr, Nd, and Sm were measured, but these are not consistently useful in discriminating these glass sources and are not generally reported. These data are available on disk by request.

The approximate practical detection limits of the elements of interest that include error imposed by interelement interference are as follows: Ti 23 ppm; Mn 40 ppm; Fe 10 ppm; Pb 8 ppm; Rb 5 ppm; Sr 3.5 ppm; Y 7 ppm; Zr 7 ppm; Nb 8 ppm; Ba 20 ppm; La 20 ppm; Ce 20 ppm. These are the smallest amounts that can be quantitatively measured, defined as a signal which is six standard deviation units above background (6Σ).

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