

REPORT

Intersource and Intrasource Geochemical Variability in Two Newly Discovered Archaeological Obsidian Sources in the Southern Great Basin

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Two newly discovered sources of archaeological obsidian in the southern Great Basin (Devil Peak, Nevada, and Bristol Mountains, California) are described. Geological, geochemical, and archaeological data are presented on these sources in an effort to aid in the elimination of spurious source assignments in regional archaeological contexts.

THE location and chemical composition of Tertiary period sources of archaeological obsidian in southern Nevada and southeastern California remain essentially unknown and unreported (see Wilke and Schroth 1989). Indeed, with a few exceptions, obsidian studies in the southern Nevada and extreme southeastern California region have generally remained ignored. This is partially due to the small number of development projects initiating large scale archaeological efforts, as well as a corresponding lack of interest in the region by archaeometrists (see Hughes 1986). Reported here are two sources of archaeological obsidian: Bristol Mountains, California, and Devil Peak, Nevada. While these sources are not completely unknown, they had not yet been examined geochemically. The Devil Peak source group exhibits unique internal variability and there is some chemical similarity between Devil Peak and Bristol Mountains, although they are separated by over 130 km. of basin and range geology (Fig. 1). Both sources are Tertiary in

age, and both have been assigned to the Miocene based on relative geology, although neither has been radiometrically dated. The geology and archaeology of these sources are quite similar to other Tertiary marekanite (Apache tear) sources in the greater American Southwest (Shackley 1988a, 1990, 1991a, 1992).

BRISTOL MOUNTAINS (BAGDAD), SAN BERNARDINO COUNTY, CALIFORNIA

This source is located in the northern portion of the northwest/southeast trending Bristol Mountains in San Bernardino County, California. The primary context of this late Tertiary (probably Miocene) source appears to be located in extensively weathered rhyolite domes of the Bristol Mountains as shown on the 1985 USGS Siberia, California 7.5' series map (provisional), particularly in sections 7 and 18, T. 7 N., R. 11 E., and sections 12 and 13, T. 7 N., R. 10 E. (see also the 1956 Bagdad, California 15' series map). The domes of this Tertiary source are so eroded that the obsidian zone has apparently completely moved into the alluvium, or was originally composed mainly of ash flow tuffs, not unusual in the Southwest (Shackley 1988a, 1990; see also Hughes and Smith 1993). No marekanites were located within a perlitic or vitrophyric matrix, although some of the nodules near the rhyolite dome remnants exhibited tuff coatings. Marekanites are, however, firmly embedded in the local pavements, particularly near the dome structures. 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, so further downstream deposition is impossible (see Fig. 1).

The density of nodules near the primary context is up to 10 per 2 m.² with nodule sizes

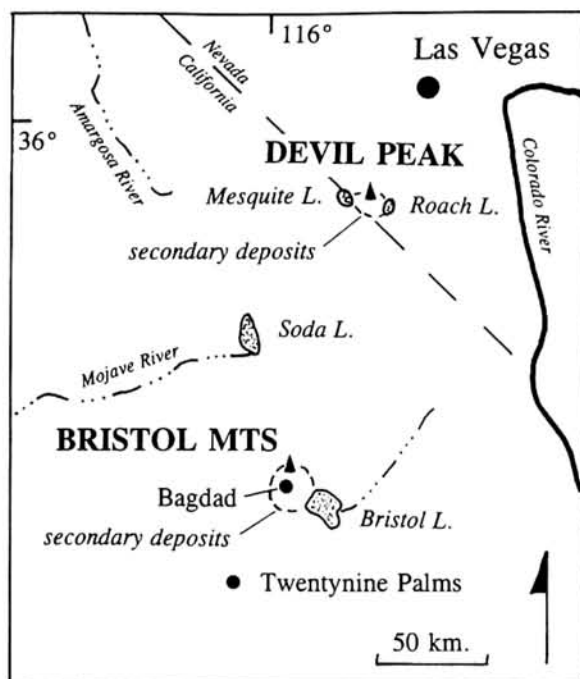


Fig. 1. Location of the Bristol Mountains and Devil Peak obsidian sources in the southwestern Great Basin. Solid triangles designate primary source locations.

up to 72 mm., although most are 40 to 50 mm. Ten kilometers downstream the nodule density declines to less than one per 500 m.², and nodule sizes are generally near 20 mm. or less. In the desert pavements, the cortex is generally reddish-brown that erodes to black after entering the washes. The glass is generally translucent to nearly transparent gray, sometimes banded, and an excellent medium for tool production. Fewer than ten modified cores or bipolar flakes were noted in two days of survey, although they have been recovered from archaeological contexts in the area to the south (Shackley 1991b; Jerry Schaefer, personal communication 1992).

This source was first located in the 1980s by Philip Wilke (personal communication, 1993). Wilke and others noticed the presence of nodules in the alluvium near the Bagdad railroad siding, and the source was colloquially called Bagdad (Shackley 1991b). It is more properly called Bristol Mountains obsidian since the glass is derived from the Miocene rhyolite in the moun-

tains. There is no known geologic publication on the source other than Dibblee (1966) for the adjacent Broadwell Lake, California 15' series map.

Geochemistry

The trace element chemistry suggests a mildly peraluminous liquid with relatively high strontium and barium relative to zirconium, rather typical for Tertiary volcanic arcs (Cox et al. 1979; Table 1). The chemistry is somewhat distinctive for the region but, as discussed below, similar to the other source reported here. While most of the samples fell near the mean of 924.73 for barium, one sample exhibited a higher level of 1416.14 (Table 1). On all other elements, the variability appears to be typical of most Tertiary rhyolites. Analytical methods are discussed in the notes.¹

DEVIL PEAK, CLARK COUNTY, NEVADA

This source in extreme southern Nevada was discovered independently by Shackley (1988b) and Wilke in the 1980s. The Devil Peak source group is composed of a series of coalesced rhyolite domes of Tertiary age that have extruded through the Paleozoic Monte Cristo limestone on both the west and east sides of the Spring Mountains southwest of Las Vegas in Clark County, Nevada (Longwell et al. 1965). The geological region is characterized by an abundance of carbonate rocks of Precambrian and Permian age, particularly Monte Cristo limestone. A number of Tertiary intrusive and extrusive bodies occurs along fault lines in the region. The largest is the subcircular rhyolite neck called Devil Peak, also the largest silicic volcanic body in the region (Longwell et al. 1965). Other extrusives include andesitic flows, such as Table Mountain to the northeast (southwest of Goodsprings, Nevada, not shown in Fig. 1). The primary source itself (Devil Peak) consists of rhyolite tuff-breccias and perlite/vitrophyre deposits.

Table 1
MEAN AND CENTRAL TENDENCY STATISTICS FOR BRISTOL MOUNTAINS AND DEVIL PEAK SOURCE STANDARDS. MEAN, MINIMUM, AND MAXIMUM IN PARTS PER MILLION (PPM)

Element	Mean	SE Mean ^a	Std. Dev. ^b	Minimum	Maximum	N ^c
Bristol Mountains, San Bernardino County, California						
Ti	884.73	9.77	43.70	806.86	979.29	20
Mn	399.69	8.50	37.99	346.24	527.79	20
Fe	9177.64	84.15	376.32	8486.44	9863.25	20
Pb	26.98	0.39	1.76	23.46	30.04	20
Rb	188.00	1.79	8.02	167.48	198.84	20
Sr	141.81	1.18	5.28	128.86	149.08	20
Y	20.56	0.36	1.61	17.12	23.42	20
Zr	129.00	0.89	3.98	119.65	138.01	20
Nb	22.26	0.56	2.52	17.20	27.44	20
Ba	924.73	30.58	136.74	831.63	1416.14	20
Ce	117.89	4.04	18.06	102.25	182.12	20
La	69.62	2.47	11.04	58.07	107.37	20
Devil Peak East, Clark County, Nevada						
Ti	629.96	10.44	70.83	502.49	798.52	46
Mn	592.00	8.27	56.07	532.69	809.03	46
Fe	8465.21	79.39	538.47	7622.81	10409.65	46
Pb	40.19	0.87	4.93	29.41	52.31	32
Rb	201.03	1.56	10.61	182.98	240.90	46
Sr	110.12	1.59	10.80	100.17	163.29	46
Y	29.28	0.40	2.71	23.26	34.90	46
Zr	108.43	0.80	5.44	101.85	133.09	46
Nb	25.75	0.37	2.53	19.84	32.51	46
Ba	347.35	10.60	51.91	234.27	504.92	24
Ce	113.16	4.22	13.34	101.45	141.54	10
La	59.56	2.54	8.02	49.56	73.02	10
Devil Peak West, Clark County, Nevada						
Ti	815.25	26.03	100.82	605.27	989.53	15
Mn	538.18	12.99	50.30	412.66	612.25	15
Fe	9975.72	159.40	617.37	8660.73	10852.72	15
Pb	40.65	1.26	3.99	34.57	45.24	10
Rb	178.50	2.55	9.88	157.56	193.62	15
Sr	251.40	2.53	9.81	230.05	266.04	15
Y	25.90	0.43	1.68	22.78	28.98	15
Zr	155.37	1.53	5.92	144.97	166.62	15
Nb	23.04	0.49	1.88	19.65	26.36	15
Ba	876.13	32.06	124.18	744.77	1193.47	15
Ce	163.45	5.79	18.29	144.04	204.49	10
La	86.59	3.72	11.76	73.28	105.92	10

^a standard error of mean; ^b 1 standard deviation; ^c sample size

The primary source domes and most of the secondary deposits are 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 Spring Mountains, eroding into either the interior drainage basins of Mesquite Lake on the west or Roach Lake on the east. The primary contexts of these loci are only 5 km. distant. On both sides, historic perlite mining has essentially destroyed any evidence of prehistoric production that may have existed. Some bipolar reduction was noted in the alluvium east of the peak toward Roach Lake (Shackley 1988b; Philip Wilke, personal communication 1993). The archaeological context on the east side of the Spring Mountains is now designated site 26CK 3865 (Shackley 1988b). The west and east loci are separable both spatially and chemically, and will be treated individually.

West Locus (Umpire and Picture Rock Perlite)

Perlite deposits with *in situ* marekanites are located on the west near the Umpire Perlite Mines between UTM 11 3952000 and 3951000/637000 and 639000 (no sections on map). These historic perlite mines continue to be used for commercial rhyolite (picture rhyolite) and perlite.

The density of nodules in both areas of the perlite matrix is up to 100 per m.² Most of the marekanites are less than 30 mm. in diameter but some up to 100 mm. in diameter have been recovered. The marekanites have eroded into the Mesquite Lake interior drainage basin, where the density of nodules on the east shoreline is about one per 20 m.² On the east shore, bipolar cores and flakes, as well as rhyolite debitage, are relatively common in lithic scatters among the mesquite dunes.

Besides the significant chemical differences in some trace elements, the nodules on the west side are generally superior for tool production to those on the east. Similar to the Bristol Mountains glass, 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, although both loci exhibit nodules indistinguishable from the other. The only published references known are Longwell et al. (1965) and Shackley (1988b).

East Locus

The east locus of the source is a group of small, coalesced, rhyolite domes on the east flank of the Spring Mountains. It appears that these domes were produced from vents pushed through the Precambrian base during the Miocene.

Secondary deposits extend at least 5 km. east to Interstate 15 (I-15), and probably to the Roach Lake shoreline, with nodule sizes decreasing as the distance from Devil Peak increases. Specifically, the secondary deposit is located in at least sections 7, 8, 9, 17, 18, and adjacent unnumbered sections to the west (in T. 26 S., R. 59 E., of the 1985 USGS Stateline Pass, California 7.5' series map [provisional]). The coalesced domes with perlite deposits and *in situ* marekanites are located on the west side of Section 7 and the adjacent unnumbered area between UTM 11 3953000 and 3951000/642000 and 644000. The perlite mine adjacent to the northwestern edge of Section 7 is designated as "X Prospect." As in the west locus, marekanites occur in perlitic and vitrophyric matrix up to 100 per m.²

Nodule sizes range from approximately pea size to two centimeters in diameter near I-15, up to a size of 53 mm. found near the perlite mine. Most of the larger nodules are between two and three centimeters in diameter. The density of unreduced nodules in alluvium varies from one per 50 m.² near I-15 to five per 25 m.² near Devil Peak.

The fabric and character of the nodules vary from aphyric, subvitreous, gray rhyolite to nearly transparent glass. Some of the translucent vitreous specimens exhibit mahogany-red colored banding, but these are quite rare. Many of the nodules are a steel-gray, subvitreous rhyolite that

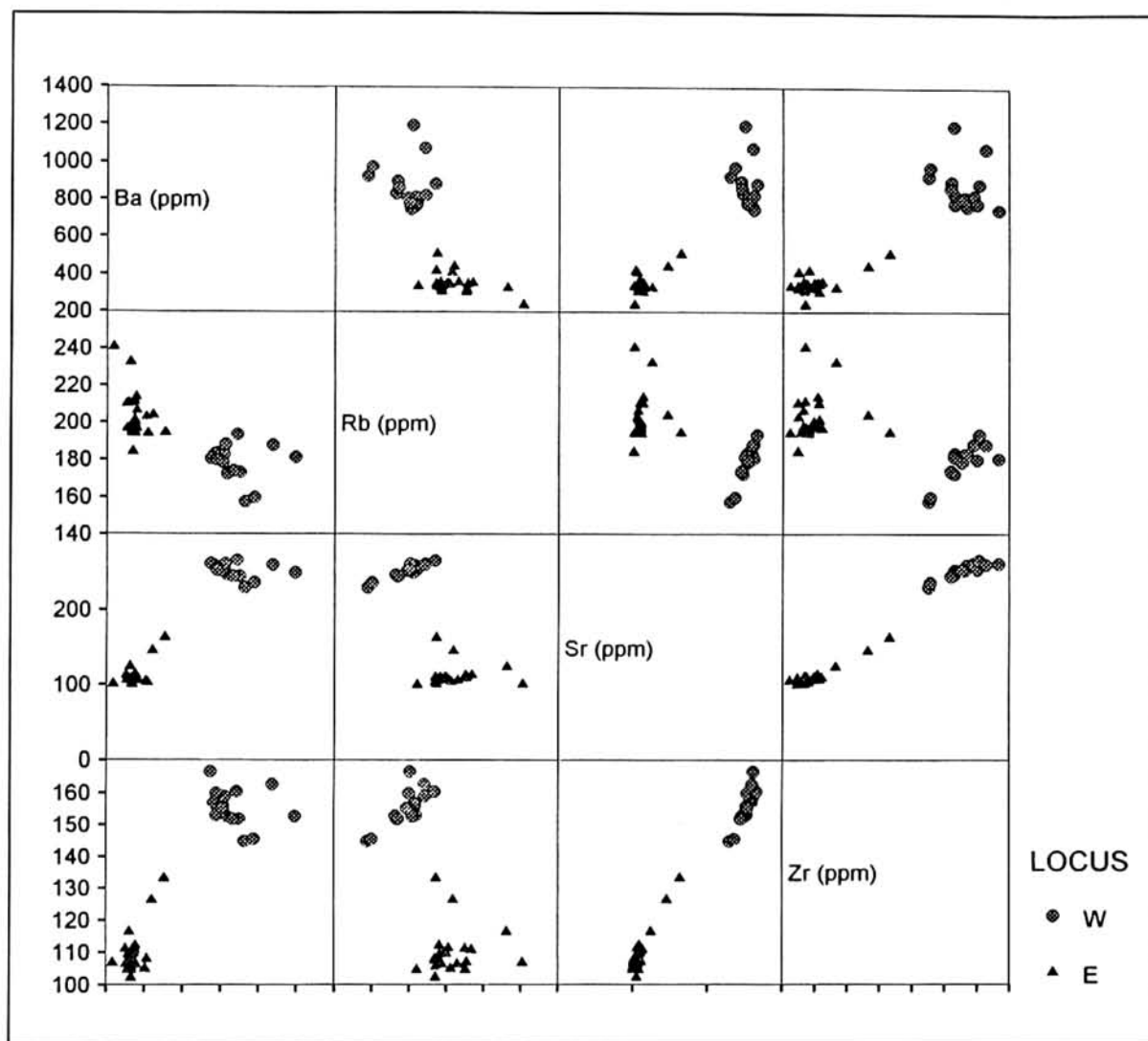


Fig. 2. Matrix plot of Ba, Rb, Sr, and Zr trace element concentrations for Devil Peak East and West obsidian.

is significantly harder and less brittle than the brown-black translucent glass more common on the west side. There appears to be a relationship between vitreous character and nodule size. Most of the translucent and vitreous glass is smaller (<20 mm.), while the largest nodules are often subvitreous, opaque, and may exhibit sanidine or plagioclase phenocrysts. Most of the nodules have weathered, velvet-like cortex, and some still exhibit remnant tuff or perlite coating from the eruption and subsequent emplacement.

No finished artifacts or formed tools were

noted in the area surveyed. Bipolar cores and flakes were relatively common, especially near the domes. The highest density of artifacts reached five per 25 m.² in Section 7 and the area to the west. The density of reduced nodules and debitage naturally followed the density of nodules in the alluvium.

Geochemistry

As mentioned earlier, the chemistry of these two loci differs rather markedly on barium and strontium and to a lesser extent on zirconium

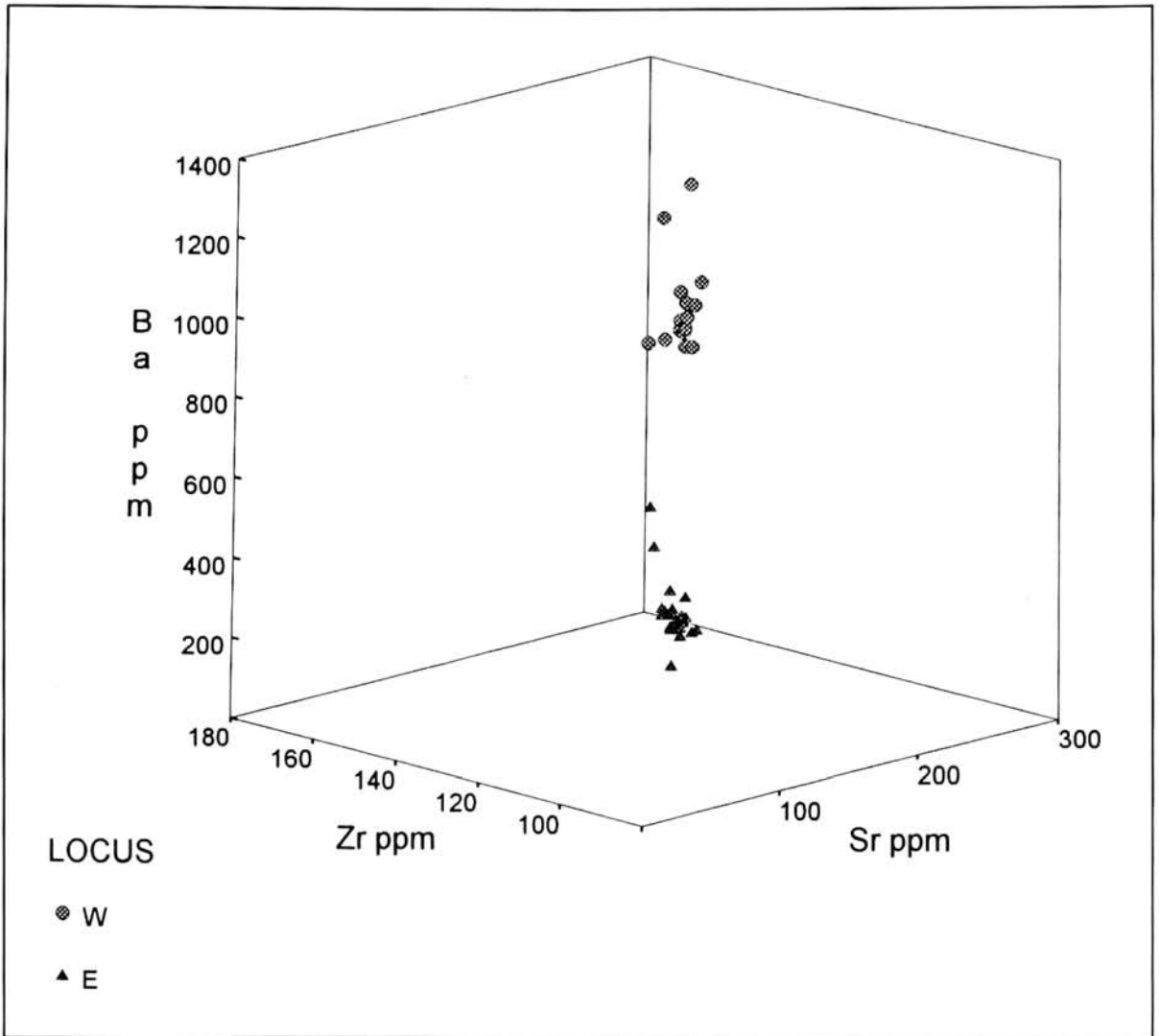


Fig. 3. Ba, Zr, Sr trace element 3-D concentration plot for Devil Peak East and West obsidian.

(Table 1; Figs. 2 and 3). Figure 2 displays a matrix plot of barium, rubidium, strontium, and zirconium from the two loci. Based on trace elements, the west locus exhibits an incompatible element chemistry relatively unique in rhyolite obsidians (MacDonald and Bailey 1973; Mahood and Hildreth 1983). Note especially that the west locus is particularly high in strontium (230.05 to 266.04 ppm), unusual for rhyolite obsidians and likely a result of the remelting characteristics of, and "contamination" by, the carbonates of the Spring Mountains.

Recently, the issue of intrasource variability has found its way into the archaeometric literature, for good reason (Hughes 1988, 1989, 1994; Shackley 1990, 1992; Hughes and Smith 1993). Most of these cases suggest small but significant variability, much less than the Devil Peak data. While the Devil Peak obsidian is certainly a single "geological entity" as defined by Hughes and Smith (1993), it exhibits elemental signatures that in many circumstances would cause the two chemical groups to be easily mistaken for different sources, particularly

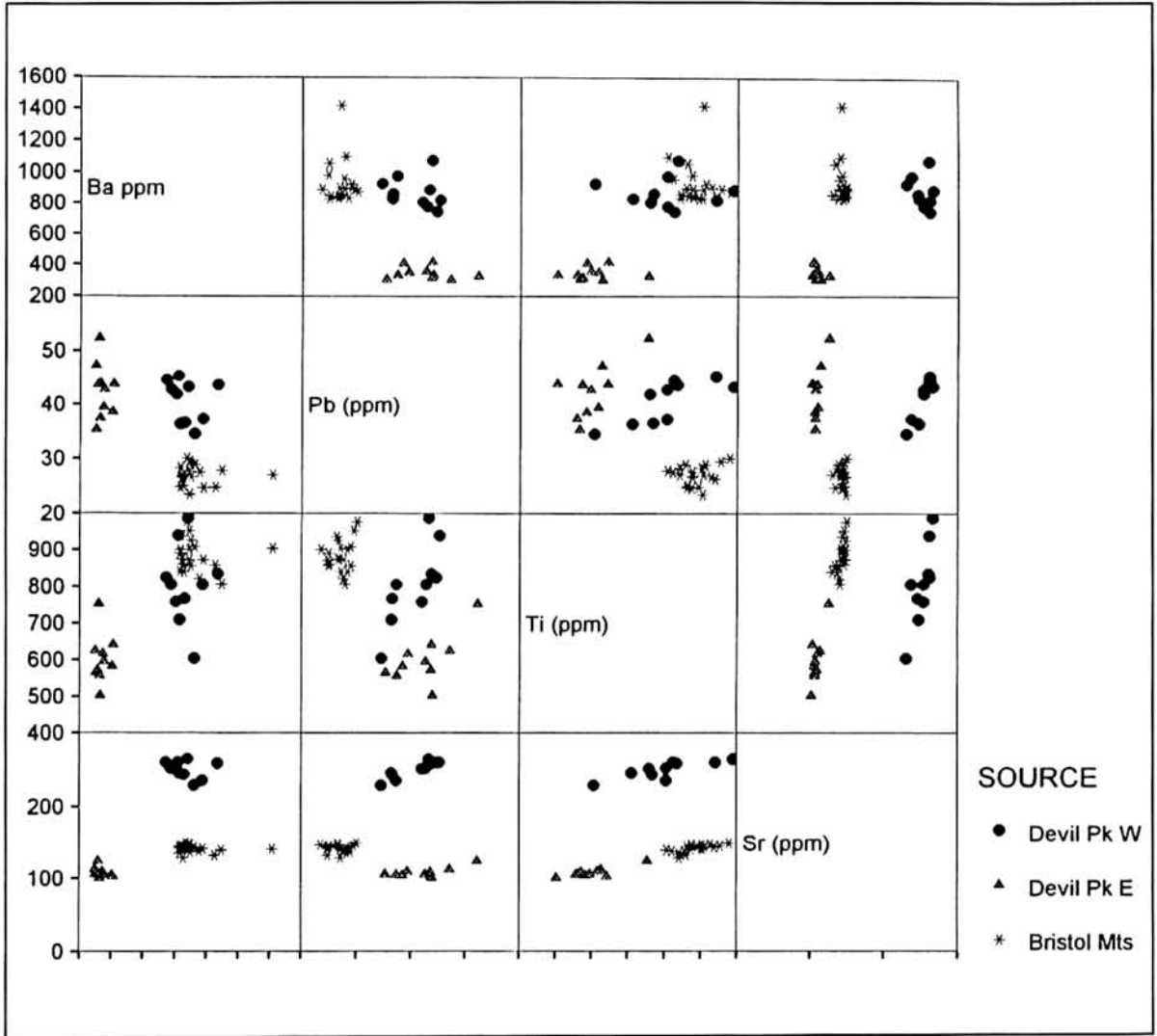


Fig. 4. Matrix plot of Ba, Pb, Ti, and Sr trace element concentrations for Devil Peak and Bristol Mountains obsidian source standards.

if it was only known from archaeological contexts. For the two Devil Peak chemical groups, the most diagnostic elements are Ba, Rb, Sr, and Zr, particularly Sr and Ba. These are readily obtainable with current instrumental technology.

DISCRIMINATION PROBLEMS OF THE BRISTOL MOUNTAINS AND DEVIL PEAK SOURCES

Careful inspection of the source standard data in Table 1 suggests a potential discrimi-

nation problem between the Bristol Mountains and Devil Peak sources. The similarity between Bristol Mountains and Devil Peak East is striking, given the differing parent magma (see Figs. 4 and 5). Although an argument could be made for a similar chronology or melting of similar crustal rock, this is neither empirically demonstrated nor necessarily causative (Cullers et al. 1981; MacDonald et al. 1987). However, it does appear that a Ba, Sr, Rb plot separates the sources well (Fig. 5). Additionally, Pb and Ti

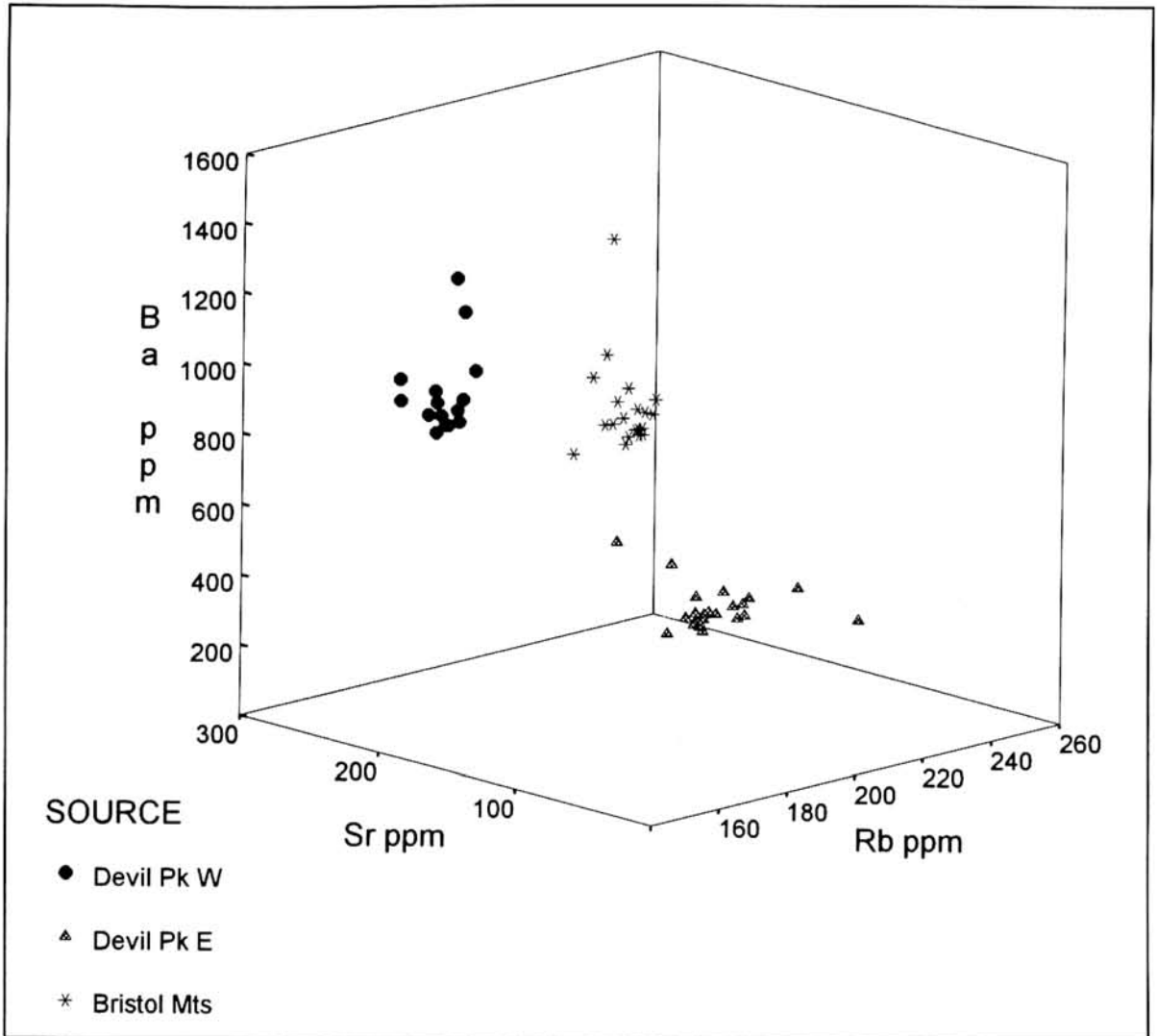


Fig. 5. Ba, Sr, Rb trace element 3-D concentration plot for Devil Peak and Bristol Mountains obsidian source standards.

appear to be useful discriminating elements. Ti, Pb, Sr, and Rb are all easily obtainable on the Ti-Nb or Ni-Nb analytical procedures employed with the EDXRF Tracor software commonly used in western North American obsidian studies, as well as wavelength XRF and INAA.

DISCUSSION AND CONCLUSION

The Devil Peak and Bristol Mountains source data presented here may help solve some of the "unknown" obsidian assignments in

regional archaeological contexts. Perhaps most importantly for archaeology, the two Devil Peak chemical groups would likely have been designated as two separate glass sources if only archaeological data were available. This would mean that any models of exchange, interaction, or procurement range would be seriously flawed by assuming that two sources were present in archaeological context when both groups actually were derived from the same locality. While it is true that this is a relatively extreme case of

intrasource chemical differentiation, it appears that this phenomenon is much more common than originally thought. Furthermore, the level of chemical differentiation within geological sources of obsidian can vary from something as small as that similar to instrument detection limit error to that seen at Devil Peak or Casa Diablo, California (Hughes 1994). Archaeologists need to know that this level of intrasource variability occurs, and that cursory source assignment can seriously flaw our designs.

These two sources reported here, unlike many in the Southwest, are characterized by relatively small areas of secondary deposition due to erosion into surrounding interior drainage basins. While the quality of the glass at Bristol Mountains and Devil Peak West is high, this phenomenon may be responsible for its relative rarity in archaeological contexts in the region outside the immediate area. Other sources reported in Lanfair Valley in San Bernardino County and at Juan (26CK3849) in Clark County to the east may also exhibit similar limited distribution (Wilke and Schroth 1989; Philip Wilke, personal communication 1993). It cannot be reasonably argued that the small nodule size limited its use, since marekanite bipolar technology is very common in all periods in the Southwest and the Great Basin, providing utilized flakes in all periods, and projectile point raw material in the late periods (Shackley n.d., 1990). Further archaeological and archaeometric studies will certainly shed some light on the problem.

NOTES

1. All samples were analyzed whole, and were washed in distilled water before analysis. Nodules were split with a bipolar technique 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 (Schamber 1977; McCarthy and Schamber 1981). More essentially, through the analysis of international rock

standards, these data allow for inter-instrument 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 an 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, 0.20 mA, using a 0.127 mm. Rh primary beam filter in a vacuum path at 250 seconds live time to generate x-ray intensity $K\alpha$ -line data for elements titanium (Ti), manganese (Mn), iron (as Fe^T), lead (Pb), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb). Weight percent iron ($Fe=Fe_2O_3^T$) can be derived by multiplying ppm estimates by 1.4297. X-ray intensity $K\alpha$ -line data for barium (Ba), lanthanum (La), and cerium (Ce) were determined by using a ^{241}Am gamma ray source for 500 seconds live time 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 U.S. Bureau of Standards, 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 detail concerning the petrological choice of these elements in Southwest obsidians is available in Shackley (1988, 1990, 1992; also Mahood and Stimac 1990; and Hughes and Smith 1993). 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 U.S. National Institute of Standards, 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 herein, Ni, Cu, Zn, Ga, Th, Pr, Nd, and Sm were measured, but these are rarely useful in discriminating Tertiary glass

sources and are not reported. These data are available on disk by request.

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 comparison between values recommended for two international obsidian and rhyolite rock standards, RGM-1, and NBS-278. 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 for the mid-Z incompatibles, and other instruments with comparable precision should yield comparable results.

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

ACKNOWLEDGEMENTS

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REFERENCES

- Cox, K. G., J. D. Bell, and R. J. Pankhurst
1979 *The Interpretation of Igneous Rocks*. London: George Allen and Unwin.
- Cullers, R. L., R. J. Kock, and M. E. Bickford
1981 Chemical Evolution of Magmas in the Proterozoic Terrane of the St. Francois Mountains, Southeastern Missouri, 2, Trace Element Data. *Journal of Geophysical Research* 86(B11):10388-10401.
- Dibblee, T. W., Jr.
1966 *Geologic Map of the Broadwell Lake Quadrangle, San Bernardino County, California, Miscellaneous Geologic Investigations*, U.S. Geological Survey and California Division of Mines and Geology, Map I-478.
- Glascok, Michael D.
1991 *Tables for Neutron Activation Analysis (3rd Ed.)*. Research Reactor Facility, University of Missouri, Columbia.
- Govindaraju, K.
1989 *Compilation of Working Values and Sample Description for 272 Geostandards*. *Geostandards Newsletter* 13 (special issue).
- Hampel, Joachim H.
1984 *Technical Considerations in X-ray Fluorescence Analysis of Obsidian*. In: *Obsidian Studies in the Great Basin*, Richard E. Hughes, ed., pp. 21-25. Berkeley: Contributions of the University of California Archaeological Research Facility No. 45.
- Hughes, Richard E.
1986 *Trace Element Composition of Obsidian Butte, Imperial County, California*. *Bulletin of the Southern California Academy of Sciences* 85(1):35-45.
1988 *The Coso Volcanic Field Reexamined: Implications for Obsidian Sourcing and Hydration Dating Research*. *Geoarchaeology* 3(4):253-265.
1989 *A New Look at Mono Basin Obsidians*. In: *Current Directions in California Obsidian Studies*, Richard E. Hughes, ed., pp. 1-12. Contributions of the University of California Archaeological Research Facility No. 48.
1994 *Intrasource Separation of Artifact-Quality Obsidians from the Casa Diablo Area, California*. *Journal of Archaeological Science* 21(2):263-271.
- Hughes, Richard E., and Robert L. Smith
1993 *Archaeology, Geology, and Geochemistry in Obsidian Provenance Studies*. In: *Scale on Archaeological and Geoscientific Perspectives*, J. K. Stein and A. R. Linse, eds., pp. 79-91. Geological Society of America Special Paper 283.

Table 2
X-RAY FLUORESCENCE CONCENTRATIONS FOR SELECTED TRACE ELEMENTS
OF TWO INTERNATIONAL ROCK STANDARDS²

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 (this study)	1516±58	259±19	13991±143	152±3	108±2	24±1	226±4	10±1	806±12
NBS-278 (Govindaraju 1989)	1468	402	14256	127.5	63.5	41	295	n.r. ^b	1140
NBS-278 (this study)	1373±101	374±17	15246±417	130±2	69±2	42±2	290±3	18±2	n.m. ^c

* ± values 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, and NBS (SRM)-278 is a National Institute of Standards obsidian standard. Fe's can be converted to Fe₂SO₃'s with a multiplier of 1.4297 (see also Glascock 1991).

^b no report

^c not measured

Longwell, C. R., E. H. Pampeyan, Ben Bowyer, and R. G. Roberts

1965 *Geology and Mineral Deposits of Clark County, Nevada*. Nevada Bureau of Mines and Geology Bulletin 62.

MacDonald, Ray, and D. K. Bailey

1973 *The Chemistry of Peralkaline Oversaturated Obsidians*. Chemistry of Igneous Rocks. In: *Data of Geochemistry*, M. Fleischer, ed., Chapter N. U.S. Geological Survey Professional Paper 440-N-1.

MacDonald, R., G. R. Davies, C. M. Bliss, P. T. Leat, D. K. Bailey, and R. L. Smith

1987 *Geochemistry of High-Silica Peralkaline Rhyolites, Naivasha, Kenya Rift Valley*. *Journal of Petrology* 28(6):979-1008.

Mahood, Gail A., and Wes Hildreth

1983 *Large Partition Coefficients for Trace Elements in High-Silica Rhyolites*. *Geochimica et Cosmochimica Acta* 47:11-30.

Mahood, Gail A., and James A. Stimac

1990 *Trace-Element Partitioning in Pantellerites and Trachytes*. *Geochimica et Cosmochimica Acta* 54:2257-2276.

McCarthy, J. J., and F. H. Schamber

1981 *Least-Squares Fit with Digital Filter: A Status Report*. In: *Energy Dispersive X-ray Spectrometry*, K. F. J. Heinrich, D.

E. Newbury, R. L. Myklebust, and E. Fiori, eds., pp. 273-296. Washington: National Bureau of Standards Special Publication 604.

Schamber, F. H.

1977 *A Modification of the Linear Least-Squares Fitting Method Which Provides Continuum Suppression*. In: *X-ray Fluorescence Analysis of Environmental Samples*, T. G. Dzubay, ed., pp. 241-257. Ann Arbor: Ann Arbor Science Publishers.

Shackley, M. Steven

n.d. *Range and Mobility in the Early Hunter-Gatherer Southwest*. In: *Early Formative Adaptations in the Southern Southwest*, Barbara Roth, ed. Madison: Prehistory Press (in press).

1988a *Sources of Archaeological Obsidian in the Southwest: An Archaeological, Petrological, and Geochemical Study*. *American Antiquity* 53(4):752-772.

1988b *Archaeology*. In: *Cultural and Paleontological Resources Survey and Subsurface Evaluation, US Sprint Fiber Optic Cable Project, Rialto, California to Las Vegas Nevada*, C. M. Woods, ed., pp. 11-43. Report on file at the Information Center, San Bernardino County Museum.

- 1990 Early Hunter-Gatherer Procurement Ranges in the Southwest: Evidence from Obsidian Geochemistry and Lithic Technology. Ph.D. dissertation, Arizona State University.
- 1991a Tank Mountains Obsidian: A Newly Discovered Archaeological Obsidian Source in East-Central Yuma County, Arizona. *Kiva* 57(1):17-25.
- 1991b Prehistoric Hunter-Gatherer Land Use on the Northeastern Portion of the Marine Corps Air Ground Combat Center (MCAGCC), Twentynine Palms, California. Report on file at the U. S. Army Corps of Engineers, Los Angeles District, Los Angeles.
- 1992 The Upper Gila River Gravels as an Archaeological Obsidian Source Region: Implications for Models of Exchange and Interaction. *Geoarchaeology* 7(4):315-326.
- Wilke, Philip J., and Adella B. Schroth
1989 Lithic Raw Material Prospects in the Mojave Desert, California. *Journal of California and Great Basin Anthropology* 11(2):146-174.

