# AN ENERGY DISPERSIVE X-RAY FLUORESCENCE (EDXRF) ANALYSIS OF OBSIDIAN ARTIFACTS FROM TWO PREHISTORIC SITES IN THE LAGUNA MOUNTAIN RECREATION AREA, SAN DIEGO COUNTY, CALIFORNIA

by

M. Steven Shackley
Phoebe Hearst Museum of Anthropology
University of California at Berkeley

for

Affinis
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## INTRODUCTION

Obsidian studies in the Laguna Mountain area have generally focused on hydration analysis rather than provenance (Graham 1981). The geochemical analysis here of five obsidian artifacts from SDI-5848 and SDI-8556 indicated that four of the specimens were produced from glass derived from the Obsidian Butte source in Imperial County, approximately 70 km northeast, and one specimen was derived from the San Felipe (Arroyo Matomí) source in northern Baja California, over 300 km south. The presence of San Felipe obsidian at SDI-8556 calls into question previous hydration analyses performed in the absence of chemical characterization.

## ANALYSIS AND INSTRUMENTATION

All samples were analyzed whole, and were washed in distilled water before analysis. 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).

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, 0.20 mA, using a 0.127 mm Rh primary beam filter in a vacuum path at 250 seconds livetime to generate x-ray intensity $K\alpha$-line data for elements titanium (Ti), manganese (Mn), 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 0.00014297. 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 US. Geological Survey (USGS), 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 continental margin obsidians is available in Shackley (1988, 1990, 1992, 1994a; also Mahood and Stimac 1991; 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 US Geological Survey standards, and BR-N (basalt) from the Centre de Recherches Pétrographiques et Géochimiques in France (Govindaraju 1989). In addition to the reported values here, Pb, Ni, Cu, Zn, Ga, and Th were measured, but these are rarely useful in discriminating Tertiary glass sources and are not generally 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 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. Table 1 shows a comparison 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 1 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 archaeological specimens.

## DISCUSSION

Obsidian is generally common in Late Prehistoric sites in the northern Peninsular Ranges (Graham 1981; Shackley 1981). Unfortunately, little of this obsidian has been subjected to instrumental chemical analysis to determine the source. This is vexing in the light of the many attempts to model exchange and procurement range for Late Prehistoric contexts (Christenson 1980; Graham 1981; Shackley 1981; c.f. Christenson 1990; Pigniolo 1992). While this is changing, there has been a general assumption that most if not all of the obsidian artifacts recovered in San Diego County sites was procured from Obsidian Butte in Imperial County:

> If Obsidian Butte was the primary source of obsidian in the San Diego County area, and all available evidence suggests it was...(Christenson 1980:206).

While it is impossible to control for the results in the gray literature, using only my own work it is apparent that a significant amount of obsidian is derived from sources other than Obsidian Butte, including Casa Diablo and Coso to the north, and San Felipe to the south (Shackley 1984 1993a, 1993b, 1994b).

The most important caveat here is that any obsidian hydration based chronology can be seriously flawed without provenance studies (see Hughes 1988, 1994). Furthermore, it is hazardous to compare an assemblage that has received a chemical analysis to one that has not for all the reasons discussed above.

**The San Felipe (Arroyo Matomí) Source, Baja California.**

This Tertiary source of obsidian on the eastern scarp of the Peninsular Ranges has been discussed in some detail elsewhere (Banks 1971; Bouey 1984; Douglas 1981). The source has only recently been analyzed quantitatively, a plot of that data is provided in Figure 1. In my studies I have detected obsidian artifacts produced from this source in sites in Otay Mesa (SDI-11,952), Santee (SDI-9243), Indian Hill (SDI-2537), and Bahia de los Angeles in Baja California (Shackley 1993a, 1993b, 1994c). The source has been detected in a number of other contexts in San Diego County, even though it is over 300 airline kilometers south of the Laguna Mountains (Don Laylander: personal communication 1992). Typical of many Tertiary sources, the primary source for San Felipe in the Peninsular Ranges is eroding to the Gulf of California producing a relatively large procurement area (Banks 1971; Douglas 1981; see Shackley 1992). The source does appear to be variable in some mid-Z elements as shown in Figure 1.

The particular artifact that was made from the San Felipe obsidian is a straight-based, side notched arrowpoint, typical of the Desert Side-notch series (Holmer 1986; Thomas 1981). This form is rather common in San Diego County as well as northern Baja California, so no specific ties to the south can be drawn (Ritter 1994).

**Conclusion**

The mix of Obsidian Butte and San Felipe obsidian in these two sites appears to be typical of assemblages in the southern part of San Diego County. This small study coupled with the obsidian hydration analysis should begin to provide a baseline for other research in the Peninsular Ranges.

It is always relatively easy to determine the source provenance of obsidian artifacts and relatively difficult to determine how it arrived in archaeological context. It seems reasonable that the Late Prehistoric inhabitants in the Laguna Mountains were in contact with other Yuman speaking groups to the south, in this case probably Kiliwa (see Shackley 1981; Christenson 1990). Given the distance to the San Felipe source it seems sensible that exchange was the likely method of procurement, while at least some of the Obsidian Butte material could have been procured directly or by contact with groups living at some time of the year in the desert. There is ample ethnographic evidence to suggest that rather large ranges were occupied by the ancestors of the Tipai including desert, mountain, and coastal environments (Bolton 1930; Cline 1979; Coues 1900; Hicks 1963; Spier 1923). Therefore, the Obsidian Butte obsidian could have been procured directly or from relatives visiting the mountains in the fall (Graham 1981; Shackley 1981). The strong presence of San Felipe obsidian at Indian Hill in the late contexts suggests continued contact with groups to the south (Shackley 1993b). It is certainly possible that much of the San Felipe obsidian was transported into the mountains through one of the many passes from the Imperial Valley (Cline 1979; Graham 1981; Shackley 1981).

Regardless of the methods used to transport obsidian and other non-local materials into the mountains, this small study provides some important information. It is not sufficient to assume that all obsidian was procured from Obsidian Butte in the Late Prehistoric period.

Comparisons of chemically characterized obsidian assemblages to those that have not been characterized are hazardous, since there is little chance that Obsidian Butte and San Felipe glass hydrate at the same rate. This study, as well as a number of others indicate that there were important contacts into what is now Baja California, at least up to several hundred kilometers.

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Table 1. X-ray fluorescence concentrations for selected trace elements of three international rock standards. ± 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, 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 0.00014297 (see also Glascock 1991).

| 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.[a] | 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[b] |
| 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)[b] | 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 |

[a] n.r. = no report; n.m.=not measured

[b] values proposed not recommended

Table 2. X-ray fluorescence concentrations for archaeological specimens. All measurements in parts per million (ppm).

| SAMPLE | Ti | Mn | Fe | Rb | Sr | Y | Zr | Nb | Source |
|---|---|---|---|---|---|---|---|---|---|
| SDI-5846 | | | | | | | | | |
| 412 | 1478.79 | 333.27 | 18736.13 | 140.79 | 27.31 | 112.97 | 331.04 | 18.95 | Obsidian Butte |
| 419 | 1517.74 | 370.38 | 18879.14 | 138.60 | 28.89 | 110.25 | 331.47 | 24.38 | Obsidian Butte |
| 523 | 1409.51 | 381.31 | 19462.98 | 140.20 | 32.69 | 116.86 | 352.58 | 26.77 | Obsidian Butte |
| SDI-8556 | | | | | | | | | |
| 53 | 776.45 | 312.99 | 14805.47 | 129.95 | 12.28 | 123.80 | 275.61 | 31.19 | Obsidian Butte |
| 93 | 630.88 | 232.42 | 11062.18 | 136.77 | 51.64 | 33.15 | 118.64 | 5.46 | San Felipe, BC |

Figure 1.  Three dimensional plot of Y, Rb, and Zr for archaeological specimens.