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COMPOSITION VARIATIONS IN OBSIDIAN SOURCES AND ARCHAEOLOGICAL IMPLICATIONS*

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ABSTRACT

An obsidian source can exhibit considerable variations in chemical composition. One such flow at Borax Lake in Lake County, California has been carefully investigated by neutron activation analysis of specimens from a number of different loci. It was found that the variable elements were completely coherent, and thus judgments concerning provenience could be just as definitive as with extremely homogeneous materials.

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The chemical compositions of obsidian artifacts have been used by a number of investigators to "finger-print" them and thereby locate the sources of some of man's early implements (Cann and Renfrew 1964, Stevenson et al. 1971, Griffin et al. 1969). Although obsidian artifacts are found widely, the possible sources of volcanic glass are comparatively few. The evidence is good that obsidian was an article of commerce and there is some incentive in establishing specific trade patterns or to deduce what other circumstances resulted in the appearance of artifacts away from obsidian sources.

Technically, obsidian has some advantages for "finger-printing" over other materials as pottery. Firstly, the sources are relatively few and discrete so it should be possible to obtain samples from all possible sources of interest to establish absolute provenience. Secondly, in fashioning artifacts,

the material remains unaltered in chemical composition. Neither of these attributes apply as well in attempting to relate pottery to clays of an area.

It is implicit in this chemical approach to provenience studies that one determines the composition of obsidian from specific sources. A group of samples from one place will, of course, show some dispersion introduced by error of measurement even if the obsidian flow is very homogeneous. Beyond this, the source material may be intrinsically inhomogeneous. In such a case, provenience of artifacts can still be established if differences in composition between different sources are sufficiently great.

The present communication is based largely upon a geochemical study to be published elsewhere and stresses two points which are pertinent to archaeological problems: (1) An obsidian flow or source can show considerable variation in composition. (2) In the case studied, the coherence in variation of the elements is extraordinary, so much so, that the judgment of provenience is just as definitive as it would be if the flow were extremely homogeneous.

Analytical data presented here pertain to a small volcanic flow at Borax Lake in Lake County, Northern California. It has been described (Anderson 1936) as a thin layer of dacite (15-25 ft.) overlain by a thicker layer of obsidian (40-50 ft.). Thirty-three samples of "obsidian" and ten samples of "dacite" were analyzed and, for reasons to be explained, the results have been grouped according to the iron content. The procedure employed was neutron activation analysis as described in some detail in an earlier publication (Perlman and Asaro 1969). This system of analysis emphasizes the trace elements and, in all, some 40 elements are determined including a considerable number for which the precision is high.

Figure 1 shows the variation of six of the trace elements relative to iron and embraces the whole range of obsidians and dacites. (It will be noted that only 14 data points are shown whereas 43 samples were analyzed. In order to avoid congestion, those samples with identical compositions have been grouped and represented by single points.) Other elements also show linear relationships and only add to the picture in demonstrating that this behavior is common to all of the elements. Each line which has been entered is the result of a least-squares-fit to the data points. The use of iron as the reference element is arbitrary, as any other element measured with high precision would serve as well.

There is no sharp line of demarcation between specimens classified as obsidians and those called dacites but, as a rough guide, one may consider the break at the composition corresponding with an iron content of about 2%. The dacite data are of no archaeological consequence and are included here only to emphasize the extent of the coherent compositional pattern (Fig. 1).

Numerical information for one of the elements, scandium, is presented in Table 1. It is seen here that the root-mean-square deviation of the data points from the straight line is little more than the precision of determining scandium--a number better than 1%. The existence of a single sequence embracing a considerable range of composition and different rock types is of geological interest and has been taken as evidence for magmatic mixing.

The data of Fig. 1 are displayed in Fig. 2 with some modifications in format. The range is confined to those specimens which can be classed as obsidian and the zones, each defined by a pair of lines, represent $\pm$ to the least-squares-fit line (not shown). Statistically, two out of three data points would lie within the zone shown. If one wishes to know whether an

artifact was made from Borax Lake obsidian one simply enters the data points on this diagram. Selecting, say, 21 elements chosen to display a variety of chemical behavior, about 14 of these should lie within the zones. This analysis provides extremely fine discrimination between different flows even where there is a large range in composition, provided it is proved that the variations are coherent as found here.

The data points displayed in Fig. 2 were obtained from the analysis of five obsidian artifacts found at Borax Lake (Harrington 1948). Considering that these were found at a site with a ready source of obsidian, there was hardly any question of their provenience, consequently our interest in these was of a more microscopic nature. It is seen from Fig. 2 that all five have compositions near one extreme of the range, corresponding to the most silicic material; but artifacts made from any local material should fit as well. In terms of sampling locus, obsidian of this composition was obtained at one end of the flow locally termed "the gravel pit" in deference to alluvial deposits of small rocks in this area.

There is some evidence that inhabitants of this site used obsidian covering a wider range of compositions than that encountered in the five specimens analyzed by us. Stevenson, Stross, and Heizer analyzed a considerable number of artifacts from Borax Lake using the x-ray fluorescence technique and found a variation in composition. We shall only be concerned with their iron and manganese data because only with these do we have possible intercomparisons. They presented their data in arbitrary units so that comparisons cannot be made directly. However, they also analyzed obsidian from another flow (Mt. Konocti) found by us to be sufficiently uniform in composition that conversion of their arbitrary units to absolute numbers was possible. In our measurements of 37

randomly-selected pieces of obsidian from Mt. Konocti the RMS deviations for iron and manganese were respectively 5% and 6% of the mean values.

One group of 7 Borax Lake artifacts (Stevenson et al. 1971) proved to have an iron content of $0.65 \pm 0.05\%$ which agrees well with the 5 artifacts analyzed by us (see Fig. 2). Another group showed $Fe = 1.04 \pm 0.07\%$. The corresponding manganese values for these two groups are 118 ± 15 and 186 ± 24 ppm respectively. These two groups are significantly different from each other and both will be found to fit well on the Mn vs Fe plot in Fig. 2.

Of interest to the archaeologist is the question of whether the Borax Lake compositional picture is singular or should one expect to encounter this situation elsewhere and commonly. There can be no unequivocal answer at this point but we are inclined to the view that this picture may be common but will vary in degree. A sampling from a fairly large flow in Napa County, California showed the obsidian to be fantastically homogeneous; at Mt. Konocti (like Borax Lake, in Lake County) a variational pattern was seen, but of lower order than that from Borax Lake. Where the variation in composition is small, all artifacts from that source will show essentially the same composition; where variations are severe, artifacts from the same source could prove difficult to interpret unless the pattern of source obsidians has been determined. Finally, it is possible that one area may have different flows which have different geochemical histories. We have some fragmentary experimental evidence from the Medicine Lake region in the far north-east of California that we are confronted with just such a situation. The geological complexity of this region of volcanism is well known (Anderson 1941) and, even without our experimental results, should serve as a warning of what might be encountered in provenience studies.

Finally, some further identification might be provided for the particular artifacts from Borax Lake that were analyzed. All of these were fluted points typologically attributed to an early culture dating back some 10,000 years (Harrington 1948). Results from hydration-layer dating (Meighan and Haynes 1970) were not unequivocal but were nevertheless consistent with this date, and even earlier, for occupation at Borax Lake.

We gratefully acknowledge the continued help of Mr. Duane Mosier, Mrs. Helen V. Michel, Miss Susanne Halvorsen, Mr. Edward Minasian, Mr. Edward Arnold, and Mr. Wally Chin. The arduous job of changing samples in the after hours was done by the Safety Services Department, and the reactor irradiations were made in the Berkeley Triga Reactor. We would like to thank C. W. Meighan for obtaining the artifacts for us and the Southwest Museum of Los Angeles for allowing us to analyze these important specimens.

Table 1. Coherence of Sc variation relative to Fe in
Borax Lake obsidians and dacites

	<u>Scandium</u>
Range	4.71 - 24.77 ppm
{ Precision of meas.	0.035 - 0.12 ppm
{ % Precision	0.7 - 0.5 %
* { RMS Dev. (σ)	0.11 ppm
{ σ , % of range median	0.8 %

* The root-mean-square deviation was obtained from the scatter of the data points from the least-squares-fit line. The value " σ , %" is a rough indication of σ on a percentage basis (percent of the mean of the range) to be compared with the precision of a single measurement.

FOOTNOTES AND REFERENCES

* Work performed under the auspices of the U. S. Atomic Energy Commission.

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FIGURE CAPTIONS

Fig. 1. The chemical variation diagrams for scandium, manganese, cobalt, uranium, cesium, and thorium plotted against total iron content for obsidian and dacite from the Borax Lake source area.

Fig. 2. The comparison of the elemental composition of obsidian implements (excavated at Borax Lake, Calif.) with the chemically variable obsidian from the same area. The two lines for each element are the RMS deviations obtained from the analysis of obsidian and dacite samples from the source area.

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Fig. 1

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Fig. 2

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