

NEUTRON ACTIVATION ANALYSIS AND THE OBSIDIAN TRADE
IN LOWER SNAKE RIVER REGION PREHISTORY

By

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To the Faculty of Washington State University:

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ABSTRACT

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Washington State University, 1975

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Results of neutron activation analysis of obsidian from several geological sources and three archaeological sites are presented. Trace and major element concentrations determined by activation analysis for both samples are compared. Methodological and interpretive considerations are examined in light of previous attempts to characterize obsidian. Analysis of element data suggests a common source for one variety of obsidian found at all three archaeological sites.

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THE PROBLEM

The occurrence of non-local raw material in archaeological sites offers the prehistorian a unique opportunity to investigate past trade networks and relationships. Instrumental analyses of lithic materials have proven especially fruitful in isolating patterns of trade, particularly in the trade of and for obsidian. The volcanic glass obsidian, by virtue of its wide use prehistorically, limited distribution geographically, and internal componential homogeneity, is a significant indicator of past trade relations amenable to characterization by various methods of instrumental analyses (Griffin, Gordus, and Wright 1969; Renfrew 1969; Stevenson, Stross, and Heizer 1971; Nelson, D'Auria, and Bennett 1975). Previous investigations of the obsidian trade utilizing the neutron activation method have clearly indicated the usefulness of this analytical technique in characterizing, or "fingerprinting," both source and artifact obsidians (Gordus et al. 1967; Frison et al. 1968; Wright 1969; Griffin, Gordus, and Wright 1969).

The purpose of the present study is threefold: (1) to provide, by means of neutron activation analysis, selected trace and major element compositions of obsidian artifacts from three archaeological sites (Windust Caves, Marmes Rockshelter, and Granite Point), and geologic samples from two source areas, Glass Buttes and Burns, in central Oregon (Fig. 1); (2) to

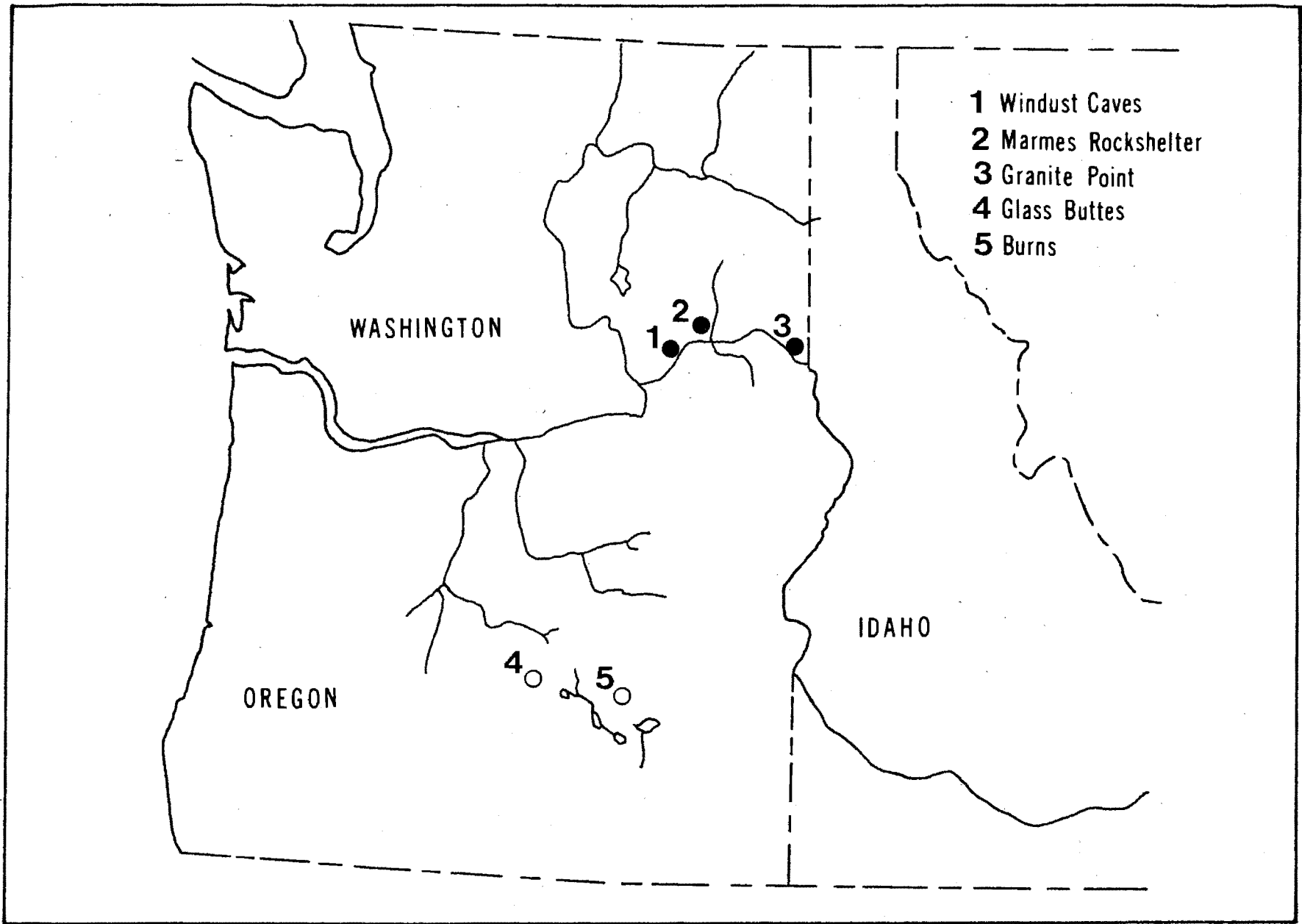


Fig. 1.-- Map Showing the Location of the Archaeological Sites and Geologic Source Areas From Which Obsidian Samples Have Been Analyzed.

interpret compositional data within and between samples; and (3) to consider the results of this research in terms of pre-historic trade networks in the southern Columbia Plateau.

The primary objective of activation analyses, such as the one presented here, is to provide a quick and accurate method of sourcing artifact obsidian. For this reason, every attempt has been made to present all methodological considerations in order that the full scope of this analysis might be reproduced.

There are a number of factors which must be considered in conducting this type of analysis. First, regarding the collection of geologic samples, it is important to distinguish between a source area and individual flows. The obvious concern here is identifying exactly what area or obsidian source is being characterized, and, thus, the proof that differences in elemental composition are greater between flows than within them (cf. Parks and Tieh 1966). Detailed geologic and geomorphic maps are, therefore, advantageous in collecting source samples. In view of the absence of this information for the source areas considered in the present study it was necessary to rely on tight geologic sampling techniques and the interpretation of activation results for separating flow material.

A further caution must be sounded regarding the issue of what constitutes an adequate sample. In the case of the artifacts analyzed we are certainly working with a representative sample in that it incorporates virtually all of the obsidian recovered from the respective sites. The geologic, or source

area, sample will need to be enlarged, however, in order to provide an inclusive characterization of obsidian from these locales. The necessity of working with representative samples has been underscored recently by research indicating the problem of intra-flow variation (cf. Bowman, Asaro, and Perlman 1973). Problems relating to the number of samples analyzed stem, in part, from a poor understanding of consistent methods of characterizing obsidian. The geologic samples that have been analyzed in the present work are, thus, intended to be a preliminary assessment of those source areas, and are subject to modification with the compilation of additional data.

A final consideration relates to the archaeological sample and, specifically, to the amount or percentage of obsidian being utilized prehistorically. In the case of the three sites included in this study, obsidian constituted an extremely small percentage of the total raw material types represented. This is particularly true of the earliest components at these sites (D. G. Rice 1972:137). This fact alone provides valuable insights regarding the trade for and use of obsidian. In any case, it is a point that must be borne in mind when evaluating the results of this study.

A central focus of the present paper, then, is on the application of the neutron activation method. More analyses of this type will certainly be needed to provide a definitive understanding of prehistoric trade patterns in the southern Plateau. Nevertheless, it is the primary intent of this study to present a first assessment of intra- and inter-site relationships and

the possible correspondences between artifacts and source areas,
as reflected by the scope and direction of the obsidian trade.

THE OBSIDIAN SAMPLE

As noted earlier, obsidian artifacts included for analysis were selected from three archaeological sites in the southern Columbia Plateau. Materials were chosen from these sites on the basis of the following considerations. First, all three sites evidence long-term cultural sequences, with limited amounts of obsidian represented, stratigraphically, throughout. Second, the length of cultural occupations at the three locales combined with their geographic proximity provide an excellent opportunity to test for variation in obsidian type (intra- and inter-site) and, hence, differential patterns of trade over time and space. Finally, obsidian had to be transported to these sites, either from source areas to the south (central Oregon, southern Idaho) or north (British Columbia). Identification of the direction of this trade would indeed enhance the clarification of trade and communication patterns in the southern Plateau.

The geologic samples analyzed herein were selected for three fundamental reasons: (1) both the Glass Buttes and Burns source areas are extensive and easily accessible, suggesting that they would have been known and possibly exploited prehistorically; (2) obsidian at both locales occurs as eroded cobbles, thereby easily lending itself to trading activities; and (3) the central Oregon location of these sources makes this an ideal

area to test for possible Basin-Plateau relationships, that is, in terms of an obsidian trade network.

Following is a discussion of the above samples incorporating relevant locational and descriptive data.

The Archaeological Sample

The Windust Caves (45FR46) (H. S. Rice 1965), Marmes Rockshelter (45FR50) (Fryxell and others 1968), and Granite Point (45WT41) (Leonhardy 1970) archaeological sites are located in the lower Snake River region of southeastern Washington (Fig. 1). All three sites contain components attributable to the Windust Phase, which at present is the oldest documented cultural component (ca. 10,000-8,000 B.P.) in the lower Snake River region (D. G. Rice 1972:213-214). All three sites contained relatively complete cultural chronologies with obsidian dispersed in limited quantities throughout. Only the Windust Caves Site did not have obsidian occurring in the early component, although it is present at this locale by about 2500 B.C. (H. S. Rice 1965, Table 1). Data presented on the obsidian samples in Table 1 and Figures 2-4 indicate the vertical distribution of the materials selected from each site for analysis.

Obsidian analyzed in this study from Windust Caves was located in Cave C, which hereafter will be referred to as Windust Cave.

The obsidian sample from Marmes Rockshelter was recovered from the floodplain as well as rockshelter deposits. It should be noted in passing that while a number of projectile

TABLE 1.-- Provenience and Descriptive Data: Windust Caves (WC), Marmes Rockshelter (M), and Granite Point (GP) Obsidian Samples

CATALOGUE NO.	MAX. DIMENSIONS (mm)			PROVENIENCE	DESCRIPTION
	L	W	TH		
WC-1	2.62	2.84	.60	surface	flake; bluish-grey
2	1.14	.76	.12	65-70 W; 91.50-91.00	distal fragment (flake); bluish-grey
3	.96	.95	.25	35-40 W; 93.00-92.50	flake; bluish-grey
4	1.17	.87	.22	"	flake; bluish-grey
5	2.00	1.20	.85	"	shatter; bluish-grey
6	2.18	.93	.67	"	shatter; brownish-green
7	2.85	.99	.14	35-40 W; 87.00-top stratum E	flake; bluish-grey
8	.95	1.37	.34	70-75 W; 90.00-89.50	flake; greenish tint
9	1.65	1.45	.30	35-40 W; 87.00-top stratum E	flake; bluish-grey
10	1.43	1.60	.31	"	flake; bluish-grey
M- 1	1.25	.79	.10	90-95 N/10-15 W; Len 2, 6c	flake; brownish-green
2	1.87	.83	.12	"	flake; grey
3	3.76	2.59	.55	30 N/5 W; Marmes A/1	bifacial fragment; bluish-grey
4	3.12	1.72	.29	85-90 N-90-95 N/10-15 W; 15 W face	flake; brownish-green
5	1.92	1.90	.31	90-95 N/10-15 W; 86.85-85.85, 6c	flake; brownish-green

TABLE 1.-- (continued)

CATALOGUE NO.	MAX. DIMENSIONS (mm)			PROVENIENCE	DESCRIPTION
	L	W	TH		
M- 6	1.31	.92	.17	90-95 N/10-15 W; 86.35-85.85, 6c	flake; grey
7	.62	.76	.12	"	flake; grey
8	1.52	.74	.16	90-95 N/10-15 W; Len 3, 3c	flake; grey
9	1.00	.63	.14	"	flake; grey
10	.90	.85	.17	"	flake; grey
GP-1	1.22	1.35	.19	12-14 S/16-18 W; 96.00-95.80	flake; bluish-grey
2	1.15	1.21	.15	"	flake; greenish tint
3	.90	.84	.15	"	flake; brownish-green
4	.77	.84	.12	12-14 S/16-18 W; 95.20-95.00	flake; brownish-green
5	.88	1.07	.15	"	flake; greenish tint
6	1.08	.95	.18	"	flake; greenish tint
7	1.62	1.45	.25	12-16 S/14-18 W; 95.60-95.40	flake; brownish-green
8	1.65	1.20	.25	"	flake; greenish tint
9	1.40	2.35	.16	10-12 S/18-20 W; 95.40-95.20	flake; greenish tint
10	.81	1.17	.17	10-12 S/18-20 W; 95.60-95.40	flake; bluish-grey

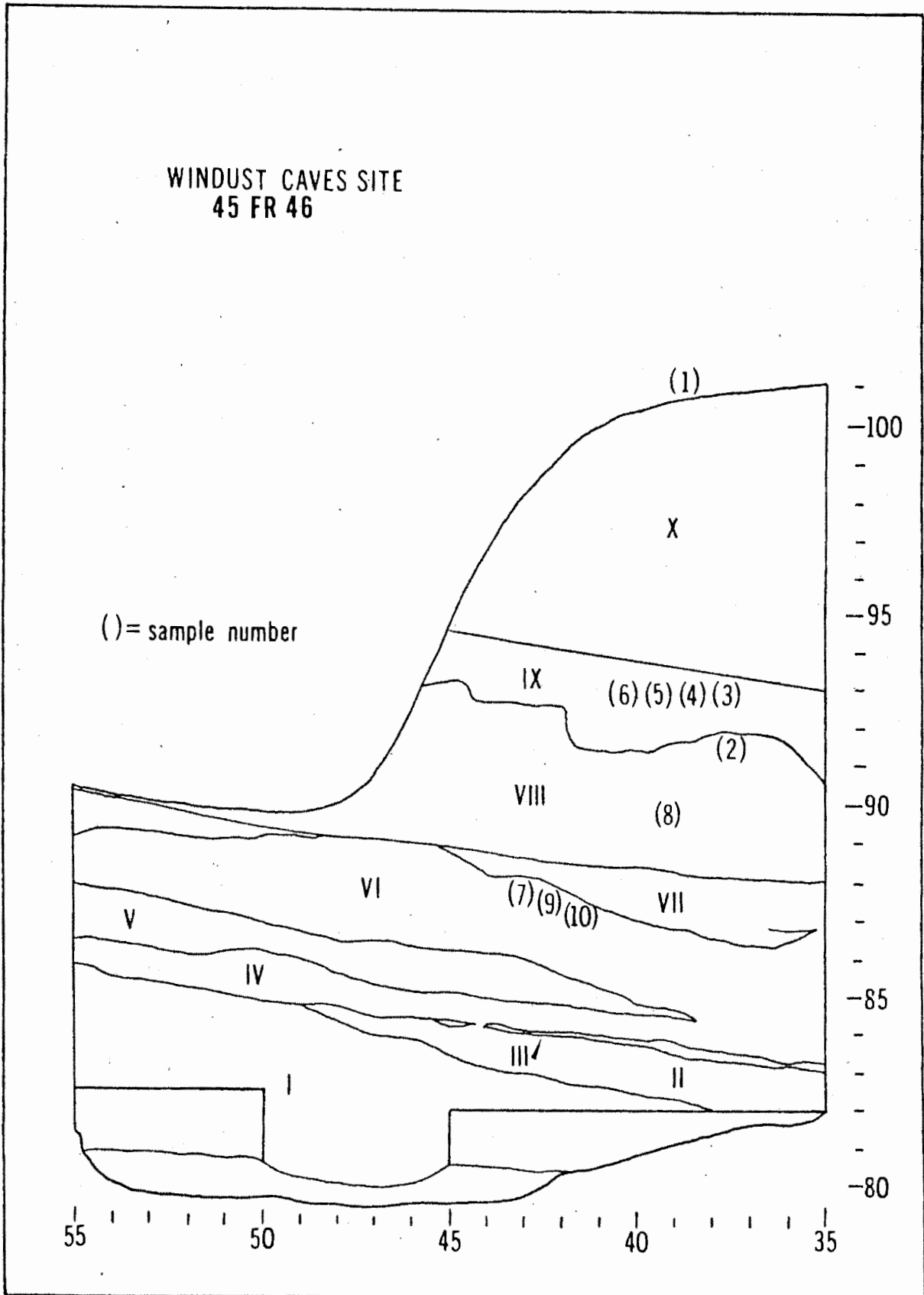


Fig. 2.-- Schematic Representation Showing Stratigraphic Distribution of Windust Cave Obsidian (WC). (Adapted from H.S. Rice 1965)

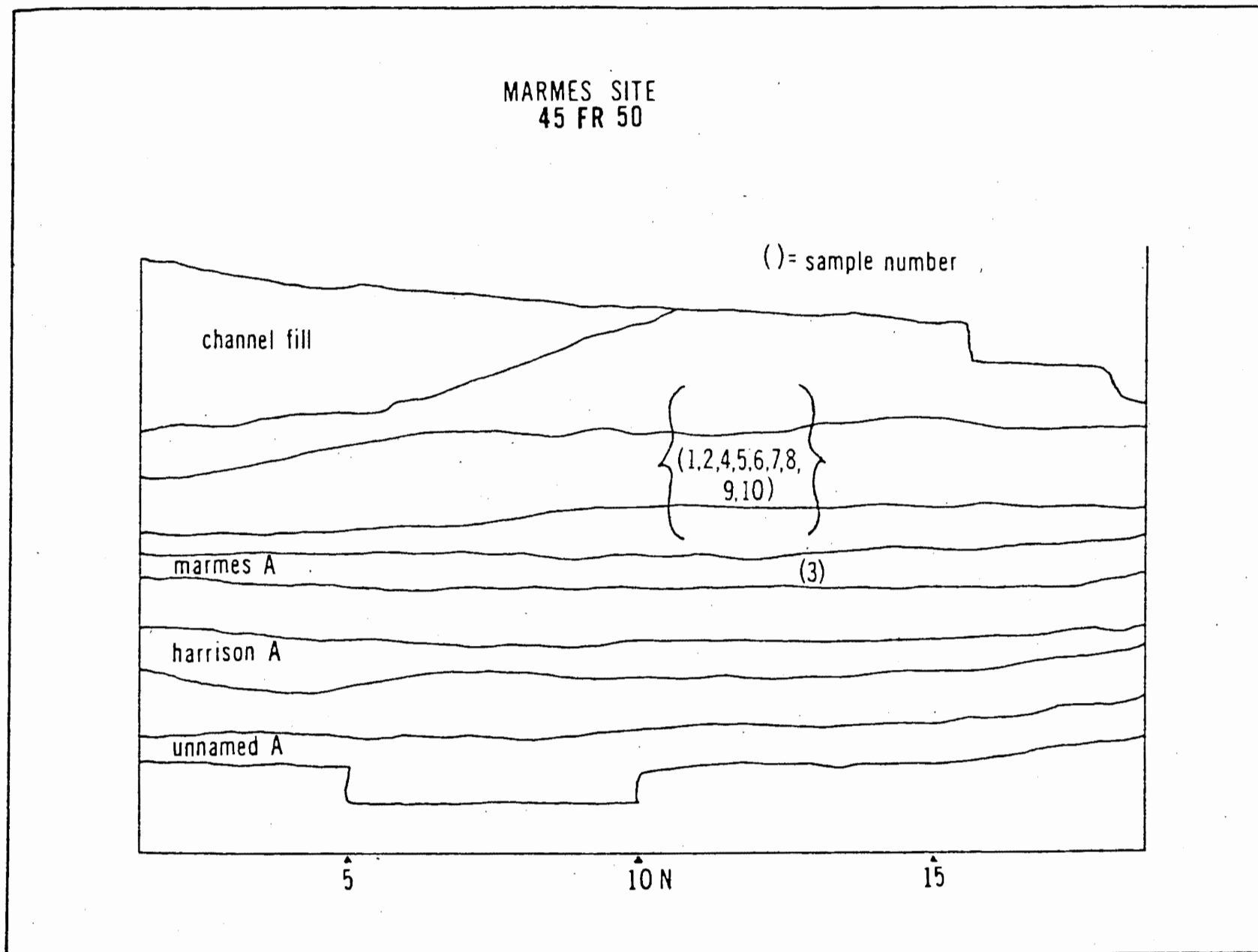


Fig. 3.-- Schematic Representation Showing Stratigraphic Distribution of Marmes Floodplain and Rockshelter Obsidian (M). (Adapted from C.E. Gustafson 1972)

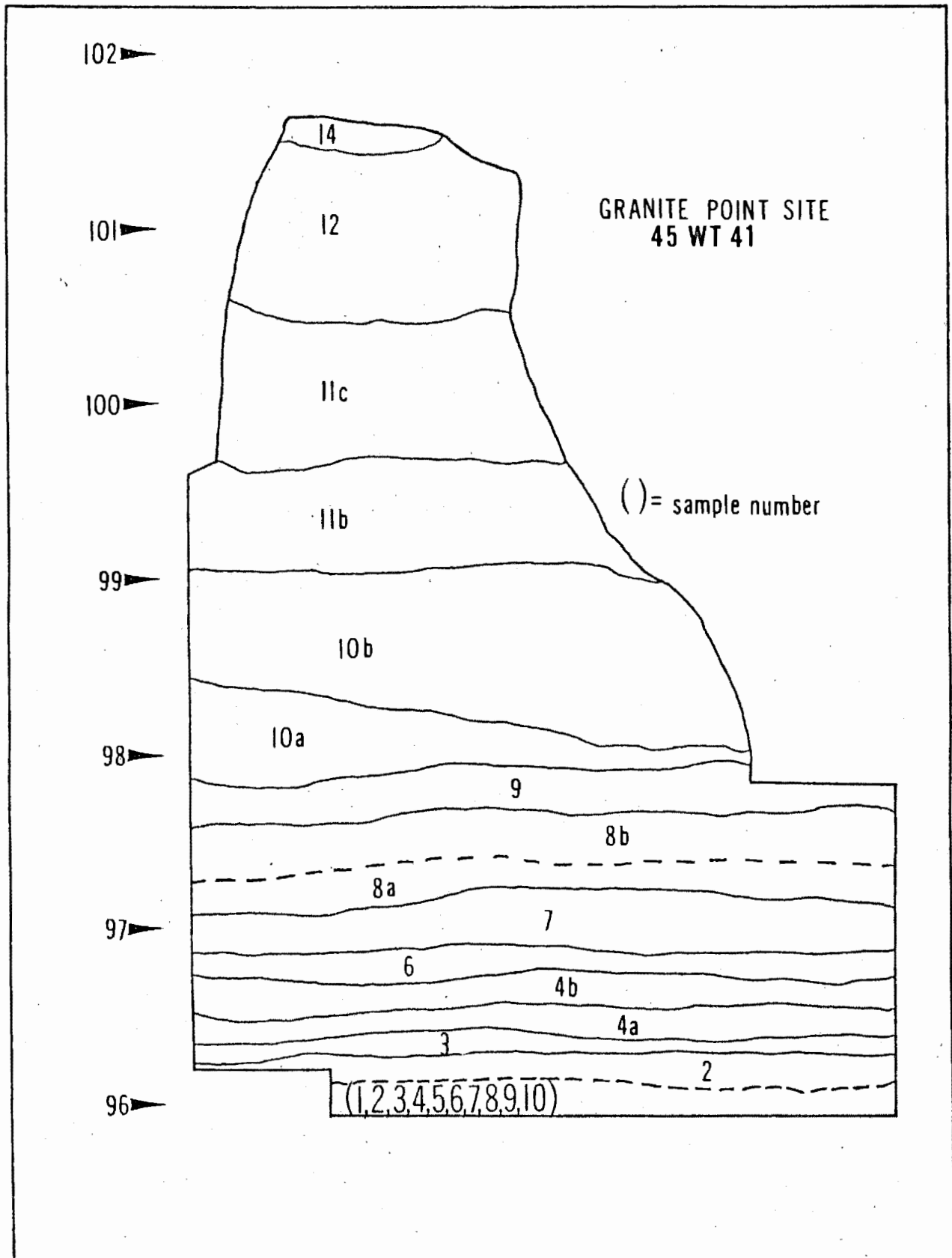


Fig. 4.-- Schematic Representation Showing Stratigraphic Distribution of Granite Point Obsidian (GP). (Adapted from F.C. Leonhardy 1970)

points from this site were not included for analysis those artifacts share virtually identical visual properties with the sample examined.

The obsidian sample obtained from Granite Point is predominantly from Area B of the site, although several specimens from Area C excavations were included for analysis (cf. Leonhardy 1970, Fig. 2, 16, 25).

The Geologic Sample

Obsidian samples were collected from the Glass Buttes and Burns, Oregon, source areas by the author during the spring of 1974. Sample collection at both areas was hindered in part by the lack of suitable topographic maps for this region of central Oregon. Both source areas are located in the south-central portion of the geomorphic region known as the High Lava Plains (Baldwin 1964), an area of extensive volcanic activity.

A total of three samples were collected from the two source areas, one from Burns and the remaining two from Glass Buttes. Provenience and descriptive data for each of the three samples are provided below. In view of the problem of accurately separating obsidian flows alluded to earlier, it was deemed necessary to collect sample sets within tightly restricted areas, thus reducing the possibility of mixing flow materials. Furthermore, spatial and topographic separation were maintained between sample groups, likewise enhancing the probability of collecting separate flow samples. Neither source area presented a problem in regard to collection techniques. Flow outcroppings

were located at the Burns source and samples were collected within and immediately above a single exposure. At Glass Buttes two geographically separated (2 miles; 3.21 kilometers) and visually distinctive obsidian sources provided the samples for this analysis. The samples obtained from Glass Buttes are very similar to those described by Waters (1927) in his study of this area.

In summary then, we can reasonably conclude that the three samples described below are, in fact, representative of separate flows and are, thus, amenable to individual characterization. As we will see later, data obtained from this analysis indeed support this interpretation.

Glass Buttes

Obsidian from the Glass Buttes source is characterized by a wide variety of visual "types," including such well-known names as mahogany, burgundy, and banded chocolate. At present it is not known exactly how many separate flows containing obsidian there are at this source area.

Collecting locality #1.--Obsidian from this locality is characterized by its occurrence as medium to well rounded cobbles, ranging from about 5-7 inches (12.7-17.78 cm) maximum in diameter on downward in size. Cortex thicknesses vary from 1/32 to 1/64 inch, with brown to grey-brown surface colors predominating. This obsidian is jet-black in color and extremely homogeneous in composition. The source area is located in the valley northeast of Glass Buttes proper (cf. Waters 1927:443), approximately 1 mile south of Highway 20 (Fig. 5 and 6).



Fig. 5.-- View to the Southwest Showing Glass Butte Proper in the Upper Center of Photograph, Taken From Collecting Locality #1. Arrow indicates the Approximate Location of Collecting Locality #2.



Fig. 6.-- View to the South From Collecting Locality #2 Showing the Glass Buttes Range in the Distance.

Collecting locality #2.--Located approximately 2 miles (3.21 kilometers) southwest of locality #1, locality #2 obsidian is characterized by a wide variety of color combinations. This variegated type of obsidian occurs as slightly eroded cobbles, angular to sub-angular rounded in shape. Much of the obsidian from this area show signs of recent breakage, and cortex development is minimal even on the most weathered of specimens. Cobble sizes cluster around 10-12 inches (25.4-30.48 cm) in diameter, although even larger pieces are not hard to find. An alternating red and black banded obsidian is the most common variety recorded at this locality. The visual varieties examined in this analysis are recorded by sample number in Table 2. Obsidian is much more abundant in this area than at locality #1.

Burns

The Burns source area (Fig. 7) is located approximately 45 miles east of the Glass Buttes Range. Obsidian occurring here is jet-black in color but has a much duller luster than either of the Glass Buttes samples. Obsidian here is obtainable as a flow outcrop and at ground surface in the form of angular to sub-angular cobbles. Cobble sizes range up to a 6-8 inch (15.24-20.32 cm) diameter maximum. All specimens exhibit minimal cortex development. Moderate numbers of phenocrysts were contained within the samples examined (quartz?).

TABLE 2.-- Visual Description of Glass Buttes Obsidian Samples (Collecting Locality #2: GB2)

CATALOGUE NO.	DESCRIPTION
GB ² -1	Alternating red and brown banded; homogeneous
2	Black (clear); homogeneous
3	Black (clear); phenocrysts
4	Red-brown mottled; homogeneous
5	Black (clear) with red bands; phenocrysts
6	Alternating black and brown banded; homogeneous
7	Black-grey mottled; homogeneous
8	Red-brown mottled; homogeneous
9	Black-grey mottled; homogeneous
10	Black (clear) with red bands; homogeneous
11	Red-brown mottled; phenocrysts
12	Red-brown mottled; phenocrysts
13	Red-brown mottled; homogeneous
14	Black (clear) with red bands; phenocrysts
15	Black (clear) with red bands; phenocrysts



Fig. 7.-- View to the Northeast at the Burns Source Area. The Road Extending the Full Length of the Photograph is National Forest Road 19.

METHOD OF ANALYSIS

The method of neutron activation analysis has been described in detail elsewhere and need only be reviewed here (cf. Gordus et al. 1967; Fite et al. 1971; Aitken 1961). In simplest terms, activation analysis involves three basic steps: (1) sample preparation; (2) irradiation of the sample to the desired radioactivity; and (3) counting, or measurement of the emitted radiations (Fite et al. 1971:320). A fourth step, of course, is the interpretation of the resulting data (quantitative and qualitative), a concern which will be dealt with in a following section of this paper.

Of particular interest is a recounting of the methods employed in preparing samples for irradiation. This entire procedure can be completed by the investigator prior to submitting the obsidian samples for analysis. It is necessary in all stages of the preparation procedure to avoid the possible contamination of the sample through the addition of foreign elemental components. There are indeed a myriad of ways in which obsidian can be contaminated prior to irradiation. Contamination of the geologic sample was avoided by obtaining interior sections of each specimen to be analyzed. The archaeological sample posed a slightly more difficult problem, however, due to the fact that there was the added danger of depositional matrices having remained on the surface of these materials. The following

cleaning procedure was, therefore, devised for the archaeological sample as a means of both avoiding and eliminating surface contamination.

First, each specimen was washed with a brush and distilled water. The samples were then placed in a 13% hydrochloric acid solution for a period of one hour, after which they were thoroughly rinsed in distilled water. Each sample was dried with acetone upon removal from the water and immediately sealed in a clean polyethylene bag. Plastic tongs and sterile polyethylene gloves were used whenever handling the obsidian in order to avoid direct contact and, hence, possible contamination.

As noted above, processing the geologic sample was somewhat easier as it simply involved obtaining interior pieces from each cobble. Again, care was taken to avoid direct contact with the obsidian when breaking or handling individual samples. Interior samples weighing a minimum of 10-15 mg (preferably, 50-100 mg) were then sealed in polyethylene bags.

All samples were crushed to a fine powder to produce a homogeneous surface geometry. A uniform surface geometry was desirable in that it facilitated consistent irradiation and counting of the samples. A tungsten-carbide disc-mill was used for crushing the obsidian, which unavoidably added contaminants to the powdered samples. However, the degree and type of contamination produced were not considered detrimental to this analysis in that the elements involved have not proven to be crucial in previous chemical characterizations of obsidian.

Having completed the preparation process, the samples are then irradiated and element half-lives counted. Irradiation and counting of the samples were conducted at the Nuclear Radiation Center, Washington State University, under the supervision of Dr. Royston Filby. The U.S.G.S. rock standards, GSP-1 (granite) and BCR-1 (basalt), were used as calibration standards. The results of the activation analysis are presented in an appendix.

Prior to the actual irradiation of the samples, it was necessary to determine what elements to look for in these materials. Determining what elements will satisfactorily cluster obsidian of similar origin and differentiate among materials of varying derivation is perhaps the most crucial, yet poorly understood, aspect of activation analysis.

A determination of all the elements in a sample would be both expensive and time consuming, and, therefore, of limited practical value. Variation in the elemental composition of obsidian throughout the world has led investigators to devise a wide range of methodological and interpretive strategies. Indeed, a cursory review of pertinent literature suggests that a definitive suite of elements of universal applicability, if such a set does in fact exist, has not yet been found.

A total of 18 elements was counted in this analysis, the list of which is presented on each sample print-out contained in the appendix. This set of elements represents a combination of both trace and major elements and provides a wide variety in terms of the number and type of chemical components occurring in

obsidian. While this list of elements was not formulated on a completely arbitrary basis, an attempt was made to consider those members easily detected by the activation method.

INTERPRETING THE RESULTS

The large amount of quantitative data made available by activation analysis facilitated the determination of a technique for characterizing the various obsidian samples. In evaluating these data it should be pointed out that the number recorded for each element on the print-outs represents an actual count rather than a mean value. The standard deviation (\pm) provided below each value is, thus, a function of the intensity of individual peaks obtained in the counting procedure; that is, weak peaks produce large standard deviations, and stronger peaks yield relatively smaller values. Statistical manipulation of these data is, therefore, confined by the necessity of considering standard deviations and central values obtained.

Examination of source and artifact data sets indicates that previously utilized interpretive methods are unsatisfactory for characterizing these obsidian samples. It will be noted that Na and Mn counts were not obtained in this analysis, thus ruling out the interpretive method of Griffin, Gordus, and Wright (1969). While this method is relatively fast, it does have the disadvantage of being cumbersome when dealing with a large number of samples (cf. Ward 1974:42). A second method, involving the use of strontium (Sr)-rubidium (Rb)-zirconium (Zr) quantities, was found to be unsatisfactory for this analysis as the elements Sr and Zr were often below detection limits of the

counting apparatus. The absence of quantitative data for these elements, thus, severely limited comparisons between and within sample sets.

Perhaps the most unique feature of the source data is the wide range of variation recorded for the majority of the elements counted. As a check for variation within a source, powdered samples from Glass Buttes locality #1 (GB) and Burns (B) were divided and irradiated separately. Sample numbers B-14 and -15 were taken from samples 3 and 5 respectively, and samples GB-14 and -15 were split from numbers GB-9 and -12. Review of the element counts recorded for these samples indicates substantial fluctuation and, indeed, well reflects the range of variation obtained for the entire sample from each source area. Source sample variation was most extreme for the Glass Buttes locality #2 (GB2) obsidian. While some of the range in element counts can be attributed to one or two samples, we must conclude that, in general, parts per million (ppm) fluctuations are indicative of discreet intra-flow variation. Recognition of the pattern of element distributions within each data set is, then, the primary task in characterizing these source materials.

Inspection of the various data sets revealed major differences in the concentrations of certain elements. In analyzing source area data it was found that five elements, cerium (Ce), barium (Ba), terbium (Tb), iron (Fe) and europium (Eu), provided a consistent method of characterizing these flows, both in terms of internal homogeneity and sample heterogeneity. Sample means (\bar{x}) and ranges (r) of these elements are presented

for each source area in Table 3. It was decided to test this interpretive technique on the archaeological samples to see if equally consistent results could be obtained.

Three major classes of obsidian were recognized in the combined archaeological sample on the basis of visual properties prior to activation analysis. These three categories, brownish-green (Munsell: 2.5Y 4/6-3/4), bluish-grey (grey) (Munsell: 10B 4/2-4/1), and greenish tint (Munsell: 7.5Y 7/8-6/8), if indicative of separate sources, should reveal compositional differences in the five elements being considered. Comparison of mean and range data presented in Table 4 indicates a wide separation of the brownish-green and bluish-grey obsidian, particularly among the elements Ce, Fe, and Eu. However, it can be seen that there is substantial overlap of all five elements between the bluish-grey and greenish tint categories and, in several instances, between the latter material and the brownish-green obsidian. The seven brownish-green specimens form a rather distinct cluster, as do 16 of the 17 samples designated as bluish-grey or grey. Sample GP (Granite Point)-10 did not fit this pattern and, in fact, is quite different in terms of the five elements compared. The remaining six, greenish tint, samples were easily incorporated into the brownish-green or bluish-grey categories (hereafter referred to as green and grey) with the exception of sample GP-9. Like GP-10, GP-9 is unique, showing some overlap with both major categories but remaining quite distinct. Also, samples GP-9 and -10 cannot be combined; Ce and Fe counts show clear separation of the two samples.

TABLE 3.-- Mean (\bar{X}) and Range (R) Values for Source Area Samples.

	Glass Buttes #1 (n=13)		Glass Buttes #2 (n=13)		Burns (n=15)	
	\bar{X}	R	\bar{X}	R	\bar{X}	R
Ce	31.39	29.00-35.28	59.60	41.05-91.37	71.38	63.52-101.87
Ba	257.33	102.92-919.38	1044.49	69.21-1396.32	713.58	627.99-820.98
Tb	1.69	1.12-2.17	.76**	.35-1.28	1.09	.67-1.43
Fe	4550.02	4046.76-5104.14	6419.62	4976.77-11,381.69	10,991.70	9646.82-13,578.65
Eu	.34*	.28-.47	.57	.17-.95	.39	.30-.50

*n=11

**n=12

NOTE: Range= \pm 1 s.d.

TABLE 4.-- Mean (\bar{X}) and Range (R) Values for Artifact Samples (By Color).

	Green (n=7)		Grey (n=16)		Greenish Tint (n=5)	
	\bar{X}	R	\bar{X}	R	\bar{X}	R
Ce	72.10	61.52-88.68	42.60	31.39-51.25	64.30	48.83-76.69
Ba	1516.06	1306.82-1715.57	1555.50	957.92-2137.89	1648.45	1397.64-2064.17
Tb	1.39	.67-1.78	.64*	n.d.-.90	1.25	.74-1.65
Fe	14,483.12	12,627.17-15,915.34	6975.83	5161.47-8235.39	12,149.03	5825.24-17,065.52
Eu	1.24	1.13-1.37	.51	.19-.83	1.02	.44-1.37

*n=14

n.d.= not detected

NOTE: Range= \pm 1 s.d.

Samples GP-9 (Greenish Tint), and GP-10 (Grey) not included

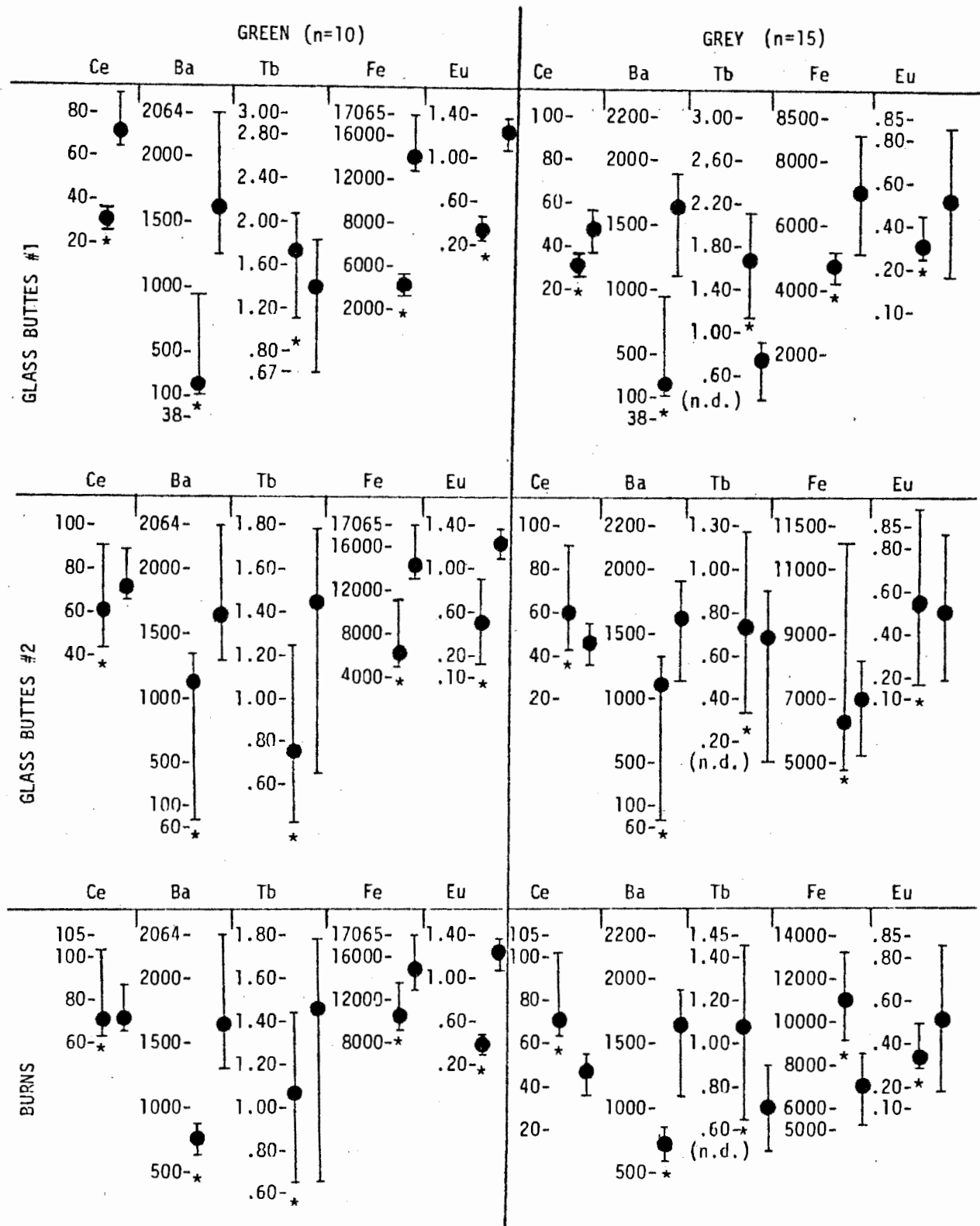
Attempts to separate obsidian by site using this method did not prove fruitful. Comparison of mean and range data for all color types, by site, clearly warranted lumping the archaeological samples.

In summary, a comparison of the suite of five elements suggests that the artifact obsidian can be divided into four distinct categories, clearly dominated by two major color groups, green and grey. The fact that the greenish tinted obsidian revealed no unique features may simply be a function of the transparent, and, hence, poorly definable, nature of this sample.

In returning to Table 1, we see that both the green and grey varieties occur in all three archaeological sites. They are also occurring in a common stratigraphic context within each site, although the temporal placement of this occurrence varies between sites. The fact that both the green and grey obsidian are most likely being obtained contemporaneously may be significant in evaluating possible sources of this material.

Having characterized the source and artifact obsidian, it is now possible to compare the two samples. A comparison of the source and archaeological samples is presented in Figure 8. No consistent overlap in element composition was found between the green, GP-9, or GP-10 artifact categories and the three source samples. Certain correspondences are apparent, however, between the grey and GB2 samples. Significant correlation can be seen in the ranges of all five elements, with the possible exception of barium (Ba). The artifact sample shows both a larger mean value and range for this element, although ranges do overlap.

Fig. 8.-- Comparison of Source and Artifact Compositional Data (ppm).



Note: Samples GP-9,10 and WC-1,7,10 not included; GP-8 and WC-8 included in Grey category; GP-2,5,6 in Green category.

*= source sample

n.d.= not detected

It will be noted that Ba content in the artifact sample is easily separated from the two other sources, occurring in the grey sample as a much larger proportion of the total composition.

Individual values included in the grey obsidian category were checked as a final test of the interpretive method to see if all samples compared favorably with GB2 data. Excluding the afore-mentioned differences in Ba counts, a total of three samples, WC-1, -7, and -10, were found to have lower values for Ce than the GB2 obsidian. The significance of the differences in Ce and Ba counts cannot be determined at this time, although it must be emphasized that all samples in question compare favorably to the GB2 source material in terms of the other elements considered. The problem of where to place samples, WC-1, -7, and -10, therefore, cannot be resolved with the data at hand, so for our purposes, these numbers can be excluded from further discussion.

On the basis of this comparative analysis we may tentatively conclude that the grey artifact sample was derived from locality #2 at Glass Buttes. In echoing an earlier statement, it should be remembered that the interpretation presented above is a first assessment of activation results. Continuing application of the neutron activation method and the analysis of additional obsidian samples will no doubt determine the usefulness of the characterization technique employed herein.

The foregoing interpretation of activation results can be summarized as follows:

1. Five elements, cerium (Ce), barium (Ba), terbium (Tb), iron (Fe), and europium (Eu), were found to provide an inclusive yet distinctive characterization of both source and archaeological samples.
2. An initial separation (intra- and inter-site) of the artifactual sample into three color categories was expanded to at least four categories on the basis of activation data. Two categories, green and grey, clearly dominate the artifact samples tested.
3. Assignment of the grey artifact sample to the Glass Buttes locality #2 source is proposed, based on a comparison of the suite of elements noted above.

DISCUSSION

The full implications of the preceding analysis are, at present, unclear. While the source of one group of artifact obsidian has tentatively been identified, the remaining samples have not been assigned to a geographical origin. Certainly, the results of this study go part way in providing evidence for long-standing Basin-Plateau relationships. There are, of course, other obsidian sources to the south that may hold answers to the question of the origin of the unidentified samples analyzed in this study. The alternative speculation that obsidian was being obtained from sources to the north, likewise cannot be ruled out. Thus, as Wright has pointed out, in the final analysis we have solved nothing (1969:4). An attempt has been made to apply new techniques and data to old problems and, in doing so, to indicate possible directions for future research. The problem of sourcing artifact obsidian will, therefore, require the analysis of additional samples, from the south and north, until concise characterizations are obtained.

A far more difficult question to answer, however, relates to the definition of trade patterns and relationships. Simply stated, does the occurrence of limited numbers of obsidian implements and debitage in archaeological sites reflect the maintenance of viable trade systems? Certainly, there can be no easy solution to this question. As noted earlier, obsidian does not

occur in large quantities within the three sites analyzed. It could be somewhat misleading to infer that the mere presence of obsidian in this instance reflects viable patterns of communication and trade. In considering this problem, Wright has suggested that weights rather than counts (frequency) of obsidian materials should be determined, thus indicating the actual amounts of material being transported (Wright 1969:48). Also, assignment of other exotic materials to their place of origin will aid in the clarification of trade routes and relationships. Both suggestions go some way toward what is required, but, nevertheless, it will be necessary to incorporate data from an even wider range of resources before we can begin to address this problem in a manner that will promote its solution. The ability to source artifact obsidian by the neutron activation method, or any other technique for that matter, is certainly an important first step in this process. In concert with other forms of data, activation analyses do, indeed, hold great potential for an in-depth study of prehistoric systems of trade and communication.

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APPENDIX, NEUTRON ACTIVATION RESULTS

The following print-outs contain all the element counts obtained by activation analysis. The headings across the top of each page refer to the sample name and number (e.g., WC-1: Windust Caves, sample #1). The element names are listed down the left margin. The letters employed to designate the obsidian sample are the same as those used throughout the text. When spaces occur in a line, they should be read as "not detected." This is not to imply that this element is completely absent in the sample, but merely that it produced an insufficient signal. The GSP samples are the U.S.G.S. rock standards.

*** OBSIDIAN SET 2 LONG-CORRECTED WC SERIES APRIL 1975

ELEMENT	ANALYSIS A									
	WC-1	WC-2	WC-3	WC-4	WC-5	WC-6	WC-7	WC-8	WC-9	WC-10
1 CE (PPM)	31.565 ± 0.1743	45.827 ± 0.3182	43.234 ± 0.3224	46.566 ± 0.1527	43.920 ± 0.1201	76.016 ± 0.2530	36.217 ± 0.1641	49.024 ± 0.1919	44.783 ± 0.2795	38.682 ± 0.2208
2 TH (PPM)	4.471 ± 0.0339	10.616 ± 0.0780	9.872 ± 0.0823	10.631 ± 0.0397	10.263 ± 0.0297	9.277 ± 0.0435	7.827 ± 0.0390	10.182 ± 0.0426	10.407 ± 0.0703	8.082 ± 0.0513
3 CR (PPM)	0.751 ± 0.2057	4.446 ± 0.4169		1.487 ± 0.1528	2.109 ± 0.1652	1.411 ± 0.2274	1.286 ± 0.2128	3.014 ± 0.2961		0.751 ± 0.1652
4 FF (PPM)	3.071 ± 0.0389	4.851 ± 0.0798	4.531 ± 0.0764	4.462 ± 0.0418	4.296 ± 0.0323	8.881 ± 0.0782	3.563 ± 0.0405	4.061 ± 0.0422	4.564 ± 0.0653	3.661 ± 0.0509
5 BA (PPM)	2102.728 ± 35.1758	1854.555 ± 49.7698	1575.250 ± 53.4659	1775.411 ± 26.3458	1687.769 ± 23.2377	1649.846 ± 28.1798	1011.862 ± 26.0307	1605.708 ± 27.2590	1716.496 ± 48.1114	985.494 ± 27.5710
6 SR (PPM)	129.205 ± 10.4883		182.866 ± 30.2106	179.027 ± 18.1483	131.853 ± 9.6730	285.965 ± 21.0225	114.779 ± 9.5057	71.757 ± 10.9129	79.377 ± 13.4153	105.212 ± 12.0944
7 ZR (PPM)	134.581 ± 13.8175	195.957 ± 32.7838	173.717 ± 26.3571	146.757 ± 12.4728	151.034 ± 9.9997	263.686 ± 21.6428	89.135 ± 11.0061	104.561 ± 11.3465	153.670 ± 19.5921	116.433 ± 15.8212
8 CS (PPM)	2.926 ± 0.0432	5.523 ± 0.0947	5.056 ± 0.0889	5.527 ± 0.0530	5.276 ± 0.0356	3.972 ± 0.0456	2.643 ± 0.0364	5.756 ± 0.0549	5.358 ± 0.0702	2.899 ± 0.0542
9 NI (PPM)										
10 SC (PPM)	2.738 ± 0.0156	4.060 ± 0.0239	3.756 ± 0.0227	3.800 ± 0.0203	3.839 ± 0.0192	4.025 ± 0.0195	1.900 ± 0.0102	3.743 ± 0.0202	3.999 ± 0.0222	2.037 ± 0.0126
11 TB (PPM)	0.556 ± 0.0258	0.691 ± 0.0472	0.573 ± 0.0469	0.873 ± 0.0268	0.804 ± 0.0183	1.562 ± 0.0272	0.419 ± 0.0205	0.767 ± 0.0276	0.730 ± 0.0360	0.428 ± 0.0285
12 RB (PPM)	85.928 ± 3.1514	158.250 ± 6.1727	133.526 ± 5.8658	161.834 ± 3.9755	122.863 ± 2.8280	124.728 ± 3.0535	101.260 ± 3.1228	155.927 ± 3.9005	144.258 ± 4.8685	108.000 ± 3.5905
13 FE (PPM)	6132.020 ± 89.0638	7746.543 ± 144.6420	8084.039 ± 151.3667	7222.141 ± 100.3665	7526.516 ± 97.7054	15300.586 ± 236.1799	7003.844 ± 112.4099	5910.473 ± 85.2319	7387.137 ± 128.8568	7580.594 ± 128.4453
14 TA (PPM)	7.985 ± 0.3889	12.009 ± 0.6348	10.447 ± 0.5546	3.527 ± 0.1760	7.775 ± 0.3749	8.401 ± 0.4390	7.823 ± 0.4092	9.741 ± 0.4728	5.638 ± 0.3015	7.042 ± 0.3724
15 CC (PPM)	26.928 ± 0.1641	55.102 ± 0.3707	46.316 ± 0.3257	12.738 ± 0.0970	23.576 ± 0.1227	25.908 ± 0.1604	32.664 ± 0.1952	35.420 ± 0.2019	18.942 ± 0.1532	26.632 ± 0.1985
16 EU (PPM)	0.616 ± 0.0134	0.531 ± 0.0190	0.529 ± 0.0191	0.502 ± 0.0139	0.547 ± 0.0094	1.265 ± 0.0186	0.408 ± 0.0089	0.455 ± 0.0122	0.540 ± 0.0160	0.455 ± 0.0135
17 U (PPM)	5.209 ± 0.7729	6.039 ± 0.8702	5.276 ± 1.0077	5.934 ± 0.5732	4.431 ± 0.4534	5.062 ± 0.4186	4.560 ± 0.4546	5.566 ± 0.5149	8.377 ± 1.0920	3.382 ± 0.4051
18 SB (PPM)	0.969 ± 0.0751	0.522 ± 0.0458	0.321 ± 0.0390	0.787 ± 0.0636	1.050 ± 0.0577	0.304 ± 0.0200	0.133 ± 0.0163	1.051 ± 0.0759	0.359 ± 0.0318	0.124 ± 0.0191

** OBSIDIAN SET 2 SERIES M CORRECTED APRIL 30 1975 ****

ANALYSIS A										
ELEMENT	M-1	M-2	M-3	M-4	M-5	M-6	M-7	M-8	M-9	M-10
1 CE (PPM)	69.252 ± 0.8375	43.963 ± 0.4102	43.898 ± 0.3800	74.454 ± 0.2814	68.989 ± 0.3271	46.193 ± 0.3281	40.273 ± 1.5101	50.744 ± 0.5154	43.145 ± 1.0380	44.448 ± 0.4073
2 TH (PPM)	7.827 ± 0.1797	9.533 ± 0.1031	9.772 ± 0.0919	8.950 ± 0.0532	8.086 ± 0.0633	9.457 ± 0.0727	7.277 ± 0.2669	11.036 ± 0.1298	9.517 ± 0.2490	9.550 ± 0.0973
3 CR (PPM)	18.137 ± 1.2833	7.343 ± 0.8361	3.475 ± 0.6554	2.365 ± 0.3220	2.562 ± 0.3615	6.565 ± 0.7263	32.290 ± 2.6580	5.868 ± 0.8665		4.653 ± 0.8339
4 HF (PPM)	7.507 ± 0.1984	4.214 ± 0.0965	4.553 ± 0.0911	8.750 ± 0.0820	7.888 ± 0.0879	4.389 ± 0.0757	2.975 ± 0.2676	3.667 ± 0.1112	4.385 ± 0.2649	4.404 ± 0.0975
5 BA (PPM)	1417.784 ± 110.9608	1626.223 ± 82.2668	1531.073 ± 49.3606	1489.693 ± 39.5481	1382.414 ± 38.8021	1589.815 ± 55.2339	1329.359 ± 215.0226	1141.239 ± 88.3045	1484.147 ± 143.8621	1583.747 ± 79.7638
6 SR (PPM)		145.320 ± 28.8390	121.785 ± 23.8470		131.937 ± 22.2440					
7 ZR (PPM)	271.054 ± 58.3433	127.109 ± 36.5748	88.495 ± 25.4420	269.722 ± 24.9849	271.930 ± 29.2767	131.236 ± 30.4613				142.446 ± 30.6434
8 CS (PPM)	3.124 ± 0.2684	5.082 ± 0.1210	5.005 ± 0.1124	4.014 ± 0.0512	3.698 ± 0.0774	5.322 ± 0.1043	3.792 ± 0.3885	5.575 ± 0.1522	4.621 ± 0.3623	4.992 ± 0.1280
9 NT (PPM)									135.113 ± 36.9766	
10 SC (PPM)	3.689 ± 0.0394	3.759 ± 0.0247	3.786 ± 0.0254	3.981 ± 0.0199	3.679 ± 0.0206	3.997 ± 0.0254	2.801 ± 0.0498	3.320 ± 0.0290	3.514 ± 0.0507	3.910 ± 0.0285
11 TR (PPM)	0.826 ± 0.1531	0.520 ± 0.0737	0.537 ± 0.0596	1.474 ± 0.0322	1.236 ± 0.0456	0.765 ± 0.0672		0.694 ± 0.0893		0.820 ± 0.0812
12 RB (PPM)	181.830 ± 23.0990	140.820 ± 10.6608	123.067 ± 5.7648	110.777 ± 3.8593	97.922 ± 4.5297	151.673 ± 8.0707	76.610 ± 21.4501	142.806 ± 10.6065	115.189 ± 23.6486	57.937 ± 8.1263
13 FE (PPM)	12954.039 ± 326.8662	7326.891 ± 161.4669	7877.770 ± 154.1966	15670.234 ± 245.1121	14033.414 ± 229.4628	7146.895 ± 130.9073	5520.543 ± 359.0796	5624.871 ± 159.4817	6291.523 ± 297.4009	6543.379 ± 149.1594
14 TA (PPM)	42.549 ± 2.2570	27.276 ± 1.4296	11.620 ± 0.6211	11.428 ± 0.5972	17.563 ± 0.9194	36.256 ± 1.7521	40.325 ± 2.0924	27.958 ± 1.4747	28.366 ± 1.5848	22.315 ± 1.0988
15 CC (PPM)	254.653 ± 1.6901	154.585 ± 0.9137	49.312 ± 0.3783	36.740 ± 0.2227	68.152 ± 0.4162	155.246 ± 0.7995	188.089 ± 1.6809	128.353 ± 0.8404	143.220 ± 1.3783	90.461 ± 0.5978
16 EU (PPM)	1.320 ± 0.0648	0.545 ± 0.0228	0.566 ± 0.0246	1.244 ± 0.0198	1.166 ± 0.0243	0.547 ± 0.0219	0.250 ± 0.0622	0.408 ± 0.0251	0.754 ± 0.0870	0.534 ± 0.0322
17 U (PPM)		7.520 ± 1.5842	6.333 ± 0.9598	7.025 ± 0.7883	5.986 ± 0.8146			7.143 ± 1.4704		
18 SB (PPM)	0.401 ± 0.1168	0.472 ± 0.0540	0.460 ± 0.0543	0.282 ± 0.0224	0.278 ± 0.0299	1.032 ± 0.1399	2.968 ± 0.8142	0.389 ± 0.0630		1.006 ± 0.1850

*** OBSIDIAN SET 3 LONG CORRECTED NO 1, SERIES GP **** MAY 11

ELEMENT	ANALYSIS A									
	GP-1	GP-2	GP-3	GP-4	GP-5	GP-6	GP-7	GP-8	GP-9	GP-10
1 CE (PPM)	38.182 ± 0.1919	60.712 ± 0.2784	88.345 ± 0.3458	62.189 ± 0.6613	70.086 ± 0.3039	76.405 ± 0.2988	65.473 ± 0.2884	56.289 ± 0.2734	112.142 ± 0.2547	16.348 ± 0.3352
2 TH (PPM)	9.606 ± 0.0448	9.200 ± 0.0529	9.455 ± 0.0550	7.706 ± 0.1267	8.603 ± 0.0548	9.248 ± 0.0540	7.918 ± 0.0527	13.146 ± 0.0627	10.077 ± 0.0301	14.101 ± 0.1108
3 CR (PPM)	2.933 ± 0.2761	10.782 ± 0.4210	8.914 ± 0.3612	13.049 ± 0.9852	11.801 ± 0.4179	8.561 ± 0.4172	3.232 ± 0.3576	2.810 ± 0.4322	5.237 ± 0.1533	3.908 ± 0.7343
4 HF (PPM)			83.020 ± 0.7609	89.837 ± 1.9084	90.490 ± 0.8737	85.703 ± 0.7929	75.467 ± 0.7412	46.971 ± 0.5918	131.186 ± 0.9240	33.835 ± 0.9069
5 BA (PPM)	1892.873 ± 17.2845	2042.703 ± 21.4785	1690.411 ± 17.1677	1465.539 ± 43.6121	1582.401 ± 18.8202	1595.377 ± 18.3067	1504.784 ± 18.4613	1416.102 ± 18.4619	46.496 ± 6.0175	63.211 ± 15.6521
6 SP (PPM)	288.604 ± 29.1859		119.932 ± 18.2862				116.093 ± 22.4674			
7 ZR (PPM)	147.827 ± 19.5901	201.537 ± 25.5191	276.887 ± 26.4407	355.539 ± 68.4519	303.605 ± 30.4345	268.652 ± 27.7340	207.550 ± 23.4360	174.901 ± 25.3377	402.249 ± 23.8706	
8 CS (PPM)	5.392 ± 0.0843	3.862 ± 0.0974	4.321 ± 0.0873	3.521 ± 0.2806	4.210 ± 0.1047	4.178 ± 0.0982	3.684 ± 0.0536	5.707 ± 0.1044	2.720 ± 0.0358	5.205 ± 0.1932
9 NI (PPM)										
10 SC (PPM)	3.375 ± 0.0190	3.727 ± 0.0213	4.004 ± 0.0233	3.422 ± 0.0370	3.746 ± 0.0223	3.826 ± 0.0219	3.390 ± 0.0203	4.313 ± 0.0247	0.620 ± 0.0043	5.277 ± 0.0370
11 TP (PPM)	0.620 ± 0.0361	1.449 ± 0.0545	1.741 ± 0.0450	1.528 ± 0.1376	1.605 ± 0.0539	1.580 ± 0.0511	1.408 ± 0.0484	0.852 ± 0.0455	1.867 ± 0.0228	1.031 ± 0.0966
12 RB (PPM)	129.029 ± 2.6757	101.532 ± 3.0149	112.170 ± 2.5280	102.480 ± 8.2785	102.072 ± 3.1640	120.580 ± 3.4140	95.812 ± 2.9528	169.794 ± 3.7157	126.605 ± 1.9630	221.767 ± 7.0926
13 FE (PPM)	6798.648 ± 98.7332	13842.113 ± 186.3428	15456.789 ± 205.5792	13945.539 ± 288.7363	15949.203 ± 216.5787	16841.523 ± 224.0077	14021.277 ± 192.2918	8201.940 ± 123.7688	14480.305 ± 178.5209	4551.691 ± 134.6283
14 TA (PPM)	13.072 ± 0.7145	38.073 ± 2.0679	3.324 ± 0.1923	19.839 ± 1.1351	22.114 ± 1.2065	26.655 ± 1.4511	17.612 ± 0.9633	16.087 ± 0.8810	11.926 ± 0.6478	20.440 ± 1.1361
15 CC (PPM)	80.213 ± 0.4748	172.035 ± 0.5428	15.348 ± 0.1574	134.543 ± 1.1653	104.158 ± 0.6245	118.166 ± 0.6789	69.597 ± 0.4482	66.746 ± 0.4373	39.635 ± 0.2227	113.340 ± 0.8425
16 EU (PPM)	0.483 ± 0.0174	1.310 ± 0.0290	1.345 ± 0.0320	1.206 ± 0.0707	1.291 ± 0.0307	1.309 ± 0.0285	1.152 ± 0.0281	0.734 ± 0.0225	0.264 ± 0.0072	0.256 ± 0.0271
17 U (PPM)										
18 SB (PPM)	0.387 ± 0.0283	0.648 ± 0.0449	0.612 ± 0.0399	1.778 ± 0.1641	0.598 ± 0.0401	0.388 ± 0.0295	0.278 ± 0.0333	0.239 ± 0.0293	0.387 ± 0.0151	0.663 ± 0.0774

** OBSIDIAN SET 1 LCAG CORRECTED GB SERIES MAY 6 1975 ***

ELEMENT	ANALYSIS A														
	GB-1	GB-2	GB-4	GB-6	GB-7	GB-8	GB-9	GB-10	GB-11	GB-12	GB-13	GB-14	GB-15		
1 CE (PPM)	21.243 ± 0.1604	25.280 ± 0.2195	29.485 ± 0.1790	29.156 ± 0.1566	33.056 ± 0.2356	30.563 ± 0.1809	29.909 ± 0.1942	33.392 ± 0.1397	35.139 ± 0.1597	33.064 ± 0.1456	25.454 ± 0.2211	22.432 ± 0.2164	31.407 ± 0.1502		
2 TH (PPM)	12.655 ± 0.0512	11.451 ± 0.0653	11.032 ± 0.0570	11.636 ± 0.0504	12.994 ± 0.0998	12.211 ± 0.0576	11.508 ± 0.0598	10.802 ± 0.0407	14.131 ± 0.0498	12.931 ± 0.0460	11.728 ± 0.0528	10.910 ± 0.0684	12.438 ± 0.0456		
3 CR (PPM)	24.005 ± 0.2502	20.608 ± 0.4255	20.353 ± 0.3397	29.549 ± 0.3426	48.059 ± 1.0774	38.990 ± 0.4704	40.244 ± 0.5030	36.781 ± 0.3460	22.914 ± 0.3141	61.606 ± 0.4701	37.657 ± 0.6853	37.135 ± 0.5400	38.979 ± 0.3619		
4 HF (PPM)	4.118 ± 0.0413	3.848 ± 0.0527	3.636 ± 0.0430	3.721 ± 0.0394	4.148 ± 0.0650	4.141 ± 0.0470		3.628 ± 0.0347	4.594 ± 0.0432	4.327 ± 0.0402	3.773 ± 0.0557	4.565 ± 0.0543	4.053 ± 0.0403		
5 EA (PPM)	214.255 ± 27.6006	150.565 ± 37.0645	161.342 ± 29.0948	145.320 ± 26.3836	219.742 ± 179.6417	103.008 ± 25.0496	207.538 ± 38.0426	332.748 ± 22.9431	166.479 ± 18.8276	174.377 ± 18.7644	327.557 ± 54.7055	161.503 ± 23.3660	221.117 ± 29.0024		
6 SF (PPM)											35.156 ± 5.4055	25.576 ± 7.6155			
7 CS (PPM)	5.055 ± 0.0433	4.502 ± 0.0511	4.043 ± 0.0528	4.548 ± 0.0413	5.096 ± 0.0542	4.842 ± 0.0503	4.779 ± 0.0561	4.174 ± 0.0346	5.604 ± 0.0463	5.148 ± 0.0411	4.652 ± 0.0543	5.152 ± 0.0566	4.912 ± 0.0421		
8 V1 (PPM)	25.658 ± 4.7044	18.500 ± 5.3824	19.265 ± 5.7197	22.510 ± 3.9736	20.643 ± 4.6692	16.971 ± 4.9432	39.285 ± 7.4684	21.875 ± 3.7213		30.894 ± 4.5396	20.010 ± 5.5373		26.775 ± 5.4706		
9 TB (PPM)	1.258 ± 0.0266	1.763 ± 0.0407		1.688 ± 0.0296	1.315 ± 0.0389	1.965 ± 0.0357	1.753 ± 0.0366	1.144 ± 0.0213	2.149 ± 0.0319	2.027 ± 0.0294	1.072 ± 0.0377		1.258 ± 0.0256		
10 SC (PPM)	7.022 ± 0.0410	7.066 ± 0.0358	7.294 ± 0.0401	7.042 ± 0.0381	7.919 ± 0.0488	7.554 ± 0.0413	7.147 ± 0.0397	6.554 ± 0.0353	8.637 ± 0.0461	8.957 ± 0.0430	7.164 ± 0.0445	7.826 ± 0.0434	7.401 ± 0.0370		
11 R9 (PPM)	155.272 ± 3.7055	141.766 ± 4.4118	145.295 ± 3.7600	141.276 ± 3.4981	154.870 ± 7.7767	145.001 ± 3.7520	146.035 ± 3.8983	131.440 ± 2.9993	173.563 ± 3.7356	159.292 ± 3.4873	135.491 ± 6.6765	155.071 ± 4.3748	158.727 ± 7.5863		
12 FE (PPM)	4655.152 ± 58.7522	4217.660 ± 63.1475	4471.602 ± 61.6279	4100.031 ± 53.2749	4667.215 ± 121.0019	4402.973 ± 59.5789	4563.262 ± 64.0822	4358.566 ± 53.7850	5042.078 ± 62.0768	4827.008 ± 58.9432	4448.034 ± 118.1774	4231.035 ± 65.7370	4755.727 ± 59.3534		
13 ZN (PPM)															
14 TA (PPM)	1.216 ± 0.0678	1.125 ± 0.0671	1.147 ± 0.0663	1.218 ± 0.0683	1.273 ± 0.0759	1.169 ± 0.0670	1.196 ± 0.0698	1.062 ± 0.0590	1.452 ± 0.0804	1.286 ± 0.0712	1.177 ± 0.0708	1.340 ± 0.0777	1.210 ± 0.0674		
15 CO (PPM)	0.256 ± 0.0115	0.177 ± 0.0143	0.195 ± 0.0132	0.278 ± 0.0116	0.407 ± 0.0163	0.281 ± 0.0148	0.281 ± 0.0151	0.258 ± 0.0103	0.235 ± 0.0121	0.437 ± 0.0130	0.265 ± 0.0180	0.315 ± 0.0165	0.370 ± 0.0120		
16 EU (PPM)	0.355 ± 0.0128	0.335 ± 0.0177	0.320 ± 0.0149	0.308 ± 0.0117		0.304 ± 0.0140	0.297 ± 0.0147	0.464 ± 0.0121	0.376 ± 0.0134	0.331 ± 0.0114		0.378 ± 0.0173	0.315 ± 0.0113		
17 J (PPM)	1.452 ± 0.3260	1.286 ± 0.3105	1.209 ± 0.2731	1.341 ± 0.2998		1.340 ± 0.3027	1.187 ± 0.2705	1.147 ± 0.2457	1.580 ± 0.3393	1.552 ± 0.3368		1.427 ± 0.3325	1.435 ± 0.3132		
18 SB (PPM)	0.306 ± 0.0157	0.257 ± 0.0267	0.401 ± 0.0264	0.250 ± 0.0176	0.326 ± 0.0288	0.310 ± 0.0223	0.278 ± 0.0249	0.717 ± 0.0223	0.333 ± 0.0186	0.280 ± 0.0165	0.252 ± 0.0255	0.282 ± 0.0238	0.286 ± 0.0202		

** OBSIDIAN SET 3 LONG CORRECTED SERIES GB-2 NO U MAY 11 1975 ***

ELEMENT	ANALYSIS A									
	GB2-1	GP2-2	GB2-3	GB2-4	GB2-5	GB2-6	GB2-7	GB2-8	GB2-9	GB2-10
1 CE (PPM)	48.816 ± 0.1801 ±	46.671 0.1075 ±	50.616 0.1209 ±	90.284 0.2037 ±	46.617 0.1209 ±	73.618 0.2206 ±	62.920 0.4442 ±	54.330 0.1713 ±	79.953 0.1661 ±	42.315 0.1750 ±
2 TH (PPM)	9.331 ± 0.0358 ±	8.941 0.0209 ±	10.238 0.0248 ±	9.474 0.0216 ±	9.011 0.0239 ±	9.553 0.0294 ±	12.921 0.0724 ±	5.496 0.0265 ±	11.457 0.0276 ±	9.393 0.0403 ±
3 CR (PPM)	126.701 ± 0.6591 ±	83.411 0.3850 ±	81.747 0.3926 ±	60.058 0.2883 ±	64.648 0.3259 ±	98.144 0.4941 ±		3.730 0.2117 ±	100.206 0.4723 ±	3.490 0.2372 ±
4 HF (PPM)	38.338 ± 0.3705 ±	35.505 0.2346 ±	37.020 0.2515 ±	36.481 0.2399 ±	37.373 0.2665 ±	40.786 0.3345 ±	52.015 0.7962 ±	61.873 0.4699 ±	81.822 0.4706 ±	36.404 0.3399 ±
5 BA (PPM)	1152.789 ± 10.6119 ±	1075.180 6.7982 ±	1151.401 7.7348 ±	1204.184 7.5952 ±	1085.753 7.7278 ±	1255.228 10.3458 ±	89.075 19.8608 ±	1186.782 11.3475 ±	651.063 6.2483 ±	1073.208 13.0279 ±
6 SF (PPM)	88.645 ± 11.4752 ±	80.847 6.9304 ±		75.929 ± 6.1764 ±	65.703 7.8458 ±			106.056 ± 13.7588 ±		123.899 ± 21.0674 ±
7 ZR (PPM)	125.239 ± 13.2560 ±	111.140 7.4581 ±	127.639 7.0234 ±	108.415 7.6740 ±	117.780 8.7281 ±	81.019 8.1366 ±	94.495 25.6538 ±	196.091 16.1139 ±	220.549 12.0733 ±	101.579 16.3452 ±
8 CS (PPM)	4.494 ± 0.0655 ±	3.913 0.0704 ±	4.126 0.0334 ±	3.855 0.0303 ±	3.932 0.0358 ±	3.950 0.0426 ±	4.774 0.1138 ±	3.035 0.0539 ±	3.396 0.0325 ±	4.043 0.0670 ±
9 NT (PPM)	102.288 ± 6.1984 ±	52.796 2.5661 ±	44.746 2.8077 ±	8.901 1.3260 ±	38.070 3.0575 ±	65.244 4.1300 ±			49.937 ± 3.2019 ±	
10 SC (PPM)	3.244 ± 0.0156 ±	3.133 0.0126 ±	3.386 0.0137 ±	3.140 0.0126 ±	3.194 0.0132 ±	3.122 0.0132 ±	6.848 0.0326 ±	2.746 0.0129 ±	4.108 0.0164 ±	3.173 0.0153 ±
11 TE (PPM)	0.646 ± 0.0240 ±	0.717 0.0120 ±	0.753 0.0135 ±	0.359 0.0096 ±	0.701 0.0145 ±	0.940 0.0185 ±		1.265 0.0297 ±	1.181 0.0165 ±	0.668 0.0304 ±
12 RB (PPM)	116.861 ± 1.8542 ±	117.054 1.7587 ±	128.714 1.4059 ±	124.943 1.3596 ±	122.316 1.4559 ±	109.235 1.3921 ±	124.370 3.3157 ±	75.662 1.7761 ±	140.594 1.5697 ±	114.084 2.2251 ±
13 FF (PPM)	5919.371 ± 75.5017 ±	5634.605 61.7869 ±	6174.762 68.1181 ±	6158.969 67.6570 ±	5419.746 61.3729 ±	5208.848 60.0236 ±	5050.563 88.6451 ±	9780.801 ± 112.1121 ±	11261.414 ± 120.2892 ±	5261.051 ± 72.4134 ±
14 TA (PPM)	0.919 ± 0.0595 ±	0.853 0.0472 ±	0.920 0.0510 ±	0.929 0.0514 ±	0.870 0.0492 ±	0.851 0.0489 ±	8.159 0.4422 ±	12.405 0.6632 ±	2.305 0.1229 ±	14.675 0.7736 ±
15 CC (PPM)	1.163 ± 0.0413 ±	0.840 0.0172 ±	0.820 0.0179 ±	0.747 0.0174 ±	0.808 0.0212 ±	0.966 0.0214 ±	42.844 0.3324 ±	61.532 0.3383 ±	1.542 0.0227 ±	60.279 0.3535 ±
16 EU (PPM)	0.670 ± 0.0205 ±	0.574 0.0109 ±	0.605 0.0109 ±	0.615 0.0109 ±	0.582 0.0116 ±	0.532 0.0113 ±	0.188 0.0195 ±	0.948 0.0189 ±	0.443 0.0090 ±	0.613 0.0187 ±
17 U (PPM)										
18 SB (PPM)	1.735 ± 0.2153 ±	1.522 0.1053 ±	1.310 0.1046 ±	1.252 0.1305 ±	0.749 0.1175 ±	1.419 0.1260 ±	2.409 0.5017 ±	2.450 0.2299 ±	4.486 0.1670 ±	1.729 0.2363 ±

** OBSIDIAN SET 3 LONG CORRECTED SERIES GB-2

ELEMENT	GB2-11	GB2-12	GSP-12	GSP-12	GB2-15
1 CE (PPM)	91.065 ± 0.3162	41.249 ± 0.1939	394.000 ± 0.7990	394.000 ± 0.9868	46.475 ± 0.2014
2 TH (PPM)	10.323 ± 0.0373	9.936 ± 0.0453	104.000 ± 0.1995	104.000 ± 0.2396	11.473 ± 0.0517
3 CR (PPM)	3.521 ± 0.2305	2.265 ± 0.2565	17.821 ± 0.3766	16.666 ± 0.5048	2.007 ± 0.2444
4 HF (PPM)	41.157 ± 0.4017	35.273 ± 0.4093	159.000 ± 1.1050	159.000 ± 1.3010	4.611 ± 0.0521
5 BA (PPM)	1218.298 ± 12.2413	1047.802 ± 13.5500	1294.684 ± 16.8643	1300.032 ± 22.0825	1387.682 ± 30.0279
6 SF (PPM)	93.655 ± 16.2800	68.330 ± 15.0465	281.854 ± 23.5089	328.529 ± 36.8974	40.396 ± 10.0186
7 ZR (PPM)	86.405 ± 14.2926	125.197 ± 15.8055	500.000 ± 31.8800	500.000 ± 38.9700	146.133 ± 17.8189
8 CS (PPM)	4.018 ± 0.0695	3.955 ± 0.0695	1.739 ± 0.1191	1.145 ± 0.0985	4.315 ± 0.0489
9 NI (PPM)				40.021 ± 11.8086	
10 SC (PPM)	3.244 ± 0.0155	3.130 ± 0.0159	5.761 ± 0.0270	6.105 ± 0.0346	3.906 ± 0.0194
11 TR (PPM)	0.668 ± 0.0316	0.717 ± 0.0301	0.756 ± 0.0369	1.353 ± 0.0556	0.672 ± 0.0253
12 RB (PPM)	117.555 ± 2.3317	110.523 ± 2.7610	289.805 ± 4.1448	305.417 ± 5.3509	138.748 ± 3.3836
13 FE (PPM)	6103.980 ± 82.2885	5047.594 ± 70.8241	26506.203 ± 295.5764	30063.238 ± 389.2871	6433.320 ± 105.7938
14 TA (PPM)	12.350 ± 0.6523	8.441 ± 0.4494	1.000 ± 0.0738	1.000 ± 0.0765	7.234 ± 0.3796
15 CC (PPM)	50.922 ± 0.3113	39.722 ± 0.2682	6.955 ± 0.1151	6.540 ± 0.1108	31.310 ± 0.1936
16 EU (PPM)	0.602 ± 0.0200	0.546 ± 0.0187	2.287 ± 0.0459	2.245 ± 0.0463	0.605 ± 0.0125
17 U (PPM)					7.259 ± 0.5980
18 SB (PPM)	1.236 ± 0.2064		16.305 ± 0.6670	1.722 ± 0.0718	0.154 ± 0.0168

** OBSIDIAN SET 2, APRIL 30, 75, CORRECTED **

ELEMENT	ANALYSIS A									
	B-1	B-2	B-3	B-4	B-5	B-6	B-8	B-9	B-10	
1 CE (PPM)	63.522 ± 0.3724	65.647 ± 0.1918	80.214 ± 0.3807	82.956 ± 0.3409	75.160 ± 0.1947	66.038 ± 0.2303	28.728 ± 0.1093	71.911 ± 0.2599	93.146 ± 0.3751	
2 TH (PPM)	11.350 ± 0.0861	9.680 ± 0.0363	13.877 ± 0.0850	10.941 ± 0.0599	10.982 ± 0.0353	11.940 ± 0.0496	4.863 ± 0.0237	12.693 ± 0.0560	11.281 ± 0.0642	
3 CR (PPM)		1.188 ± 0.2411	1.207 ± 0.3466	1.883 ± 0.3361	2.122 ± 0.2091	1.443 ± 0.2541	1.653 ± 0.2430	0.900 ± 0.2016	0.752 ± 0.2109	
4 FF (PPM)	7.761 ± 0.0960	7.688 ± 0.0552	10.187 ± 0.1081	7.640 ± 0.0688	9.119 ± 0.0616	7.936 ± 0.0711	3.646 ± 0.0336	9.205 ± 0.0832	7.865 ± 0.0779	
5 EA (PPM)	627.994 ± 45.9191	701.830 ± 29.0659	758.821 ± 38.4825	701.930 ± 39.3697	766.763 ± 19.4362	690.683 ± 25.0664	301.204 ± 16.2616	727.053 ± 25.9198	817.974 ± 47.2331	
6 SR (PPM)				55.736 ± 11.7000		67.077 ± 11.3125	38.302 ± 11.3675		52.294 ± 13.6092	
7 ZR (PPM)	209.813 ± 24.1220	163.626 ± 10.4969	301.073 ± 30.9016	216.601 ± 16.6435	254.505 ± 14.7938	221.043 ± 19.5226	108.235 ± 10.1638	252.916 ± 22.2448	196.678 ± 22.1109	
8 CS (PPM)	3.087 ± 0.0766	3.117 ± 0.0345	3.777 ± 0.0757	2.893 ± 0.0565	3.420 ± 0.0384	3.233 ± 0.0425	2.950 ± 0.0437	3.264 ± 0.0490	3.419 ± 0.0867	
9 NI (PPM)										
10 SC (PPM)	3.769 ± 0.0225	3.760 ± 0.0193	4.974 ± 0.0270	3.854 ± 0.0220	4.320 ± 0.0219	3.938 ± 0.0187	4.123 ± 0.0203	4.327 ± 0.0213	3.525 ± 0.0243	
11 TB (PPM)	0.956 ± 0.0486	1.046 ± 0.0218	1.239 ± 0.0457	1.181 ± 0.0377	0.671 ± 0.0186	1.008 ± 0.0249	1.009 ± 0.0294	1.060 ± 0.0294	1.269 ± 0.0554	
12 RB (PPM)	131.565 ± 5.5695	130.564 ± 3.5060	176.869 ± 5.4081	132.502 ± 5.1730	153.555 ± 3.6571	144.527 ± 3.3561	141.350 ± 4.2193	161.558 ± 4.0219	131.533 ± 6.2404	
13 FE (PPM)	9646.828 ± 169.6229	9910.559 ± 129.3103	13578.652 ± 223.6855	10474.758 ± 151.0804	12715.414 ± 162.9437	9750.588 ± 153.5310	10328.590 ± 163.8492	10988.541 ± 173.6554	10440.566 ± 162.3074	
14 TA (PPM)	10.527 ± 0.5577	6.484 ± 0.3144	7.761 ± 0.4125	6.989 ± 0.3450	8.332 ± 0.4028	7.198 ± 0.3770	3.749 ± 0.1962	11.068 ± 0.5792	8.270 ± 0.4133	
15 CO (PPM)	42.746 ± 0.3025	30.718 ± 0.1629	41.492 ± 0.2842	44.749 ± 0.2673	63.577 ± 0.3077	40.839 ± 0.2385	51.749 ± 0.2979	45.436 ± 0.2669	32.211 ± 0.2430	
16 EU (PPM)	0.349 ± 0.0153	0.303 ± 0.0077	0.527 ± 0.0168	0.351 ± 0.0136	0.418 ± 0.0094	0.361 ± 0.0099	0.400 ± 0.0096	0.431 ± 0.0104	0.480 ± 0.0234	
17 U (PPM)	5.271 ± 0.9578	5.335 ± 0.5967	5.166 ± 0.8204	4.311 ± 0.7773	6.254 ± 0.5437	6.144 ± 0.4738	7.197 ± 0.7337	7.284 ± 0.5758	9.596 ± 1.7182	
18 SE (PPM)	0.452 ± 0.0410	1.305 ± 0.0718	0.554 ± 0.0448	1.122 ± 0.1125	1.449 ± 0.0711	0.477 ± 0.0228	0.568 ± 0.0290	0.476 ± 0.0257	1.262 ± 0.0553	

** OBSIDIAN SET 2, APRIL 30, 75, CORRECTED **

ELEMENT	B-11	B-12	B-13	B-14	B-15	B-15
1 CE (PPM)	73.500 ± 0.2643 ±	65.908 0.3717 ±	101.874 0.2372 ±	64.654 0.2352 ±	68.259 0.1512 ±	69.304 0.3034
2 TH (PPM)	12.223 ± 0.0583 ±	11.503 0.0860 ±	10.996 0.0310 ±	10.575 0.0535 ±	10.229 0.0271 ±	11.901 0.0680
3 CR (PPM)	1.829 + 0.4157 ±	1.211 0.3409 ±	2.261 0.2068 ±	1.801 0.2977 ±	3.015 0.1937 ±	2.001 0.4102
4 FF (PPM)	9.003 ± 0.0752 ±	8.492 0.1016 ±	8.657 0.0557 ±	8.080 0.0680 ±	8.387 0.0521 ±	8.563 0.0868
5 BA (PPM)	738.605 ± 32.3600 ±	820.986 57.4765 ±	648.716 19.4795 ±	819.480 37.1552 ±	793.118 19.2593 ±	788.599 52.2268
6 SR (PPM)			43.357 ± 6.5971			
7 ZR (PPM)	217.538 + 19.8694 ±	266.571 29.8055 ±	197.106 10.9022 ±	205.105 17.2771 ±	193.935 9.9744 ±	275.846 27.7936
8 CS (PPM)	3.433 ± 0.0672 ±	3.016 0.0739 ±	3.428 0.0284 ±	3.181 0.0613 ±	3.216 0.0249 ±	3.081 0.0548
9 NI (PPM)						
10 SC (PPM)	4.453 ± 0.0247 ±	4.006 0.0233 ±	4.140 0.0204 ±	3.961 0.0220 ±	4.067 0.0199 ±	4.076 0.0211
11 TB (PPM)	1.439 + 0.0447 ±	1.025 0.0494 ±	1.113 0.0181 ±	1.127 0.0388 ±	1.211 0.0160 ±	1.027 0.0375
12 RB (PPM)	160.675 ± 5.8473 ±	146.577 6.8331 ±	162.251 3.6275 ±	134.382 5.0647 ±	144.014 3.0621 ±	139.455 5.4796
13 FE (PPM)	12753.223 ± 178.6333 ±	10195.508 ± 177.3528 ±	11316.594 ± 142.6546 ±	11164.340 ± 156.3234 ±	11266.922 ± 140.8223 ±	10343.684 ± 169.9441
14 TA (PPM)	8.058 ± 0.3964 ±	9.184 0.4879 ±	11.927 0.5732 ±	8.746 0.4278 ±	14.566 0.6996 ±	14.501 0.7577
15 CO (PPM)	87.269 + 0.4586 ±	53.451 0.3578 ±	55.726 0.2604 ±	85.884 0.4417 ±	61.549 0.2819 ±	61.207 0.3607
16 EU (PPM)	0.399 ± 0.0151 ±	0.353 0.0148 ±	0.374 0.0068 ±	0.352 0.0132 ±	0.365 0.0058 ±	0.378 0.0113
17 U (PPM)	2.997 ± 0.7303 ±	5.139 0.9090 ±	5.614 0.5755 ±	6.030 0.9153 ±	5.615 0.3989 ±	7.357 1.0634
18 SB (PPM)	1.151 ± 0.1283 ±	0.524 0.0445 ±	1.290 0.0521 ±	1.068 0.1139 ±	1.380 0.0420 ±	0.614 0.0360

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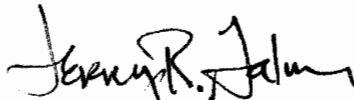
Mr. Craig Skinner
Dept. of Anthropology
University of Oregon
Eugene, Oregon 97403

Dear Craig:

Enclosed please find a copy of my Master's paper. I hope it is of some help although as you can see, the results were rather inconclusive. Running a "Goodness of fit" type analysis on these data would no doubt help since so much new data are now available.

Best of luck with your research - I would enjoy seeing your results.

Sincerely,



Jerry R. Galm, Ph.D.
Program Director

JRG:slp

Enclosure