V. "FINGER-PRINTING" OF SOME MESOAMERICAN OBSIDIAN ARTIFACTS

Robert N. Jack and Robert F. Heizer

ABSTRACT

A total of 176 obsidian samples are here reported on. These include 151 samples of Mesoamerican obsidian collected in January-February, 1968, from the surface of the Olmec site of La Venta, Tabasco, Mexico, 12 excavated samples of obsidian from La Venta, 10 obsidian pieces from the Olmec site of Tres Zapotes, Veracruz, 2 samples from the Aztec site of Tlatelolco, and one from the Maya site of Comalcalco. The obsidian samples have been analyzed by non-destructive x-ray fluorescence rapid scan technique for the elements rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb). This method has been successful in characterizing 163 of the 176 samples (92.6%) into five chemically distinct groups. Examination of the samples in hand specimen has revealed consistent, although usually subtle, visual characteristics of each of these five chemical groups, confirming that they are mutually distinct volcanic glasses. A geologic source has been established for only one of these obsidian types, indicating a need for further geologic and archaeologic sampling to identify the sources and determine the time, mechanisms, and extent of distribution of particular obsidians in Mesoamerica in prehistoric times.

INTRODUCTION

In addition to providing precise quantitative chemical analyses, the x-ray fluorescence technique can provide very rapid semi-quantitative determinations of many elements in low concentrations in a variety of samples. It has been shown (Jack, Carmichael and Lajoie 1967) that natural (volcanic) glasses (obsidians and pumices) from various volcanic centers in California, western Nevada, and southern Oregon may be characterized chemically by their minor and trace element compositions. In that study the concentrations of 19 elements were reported; however, for the purpose of the characterization of obsidians from a limited geographical area, it is often sufficient to make a rapid semi-quantitative determination of only a few elements. In order to test the feasibility of this method as applied to Mesoamerican obsidians, 151 obsidian fragments collected in 1968 from the surface of the La Venta site, plus another 25 pieces of obsidian collected in the course of archaeological investigations of the La Venta and other Mesoamerican sites, were analyzed by x-ray fluorescence rapid scan technique. The purpose of this note is to summarize the results of the reconnaissance study.

ANALYTICAL METHOD

For very rapid semi-quantitative comparative determination of the chemical compositions of a large number of samples by x-ray fluorescence analysis, the most satisfactory technique is often a rapid scan over the spectral region of the elements of interest, the data being presented on a chart recorder. One of the most convenient spectral regions for such determinations of trace element compositions of natural glasses (obsidians) includes the x-ray emission lines Nb $K\alpha$, Zr $K\alpha$, Sr $K\alpha$, Rb $K\alpha$, Th $L\alpha$, and Pb $L\beta$ (0.74 angstrom to 0.99 angstrom) in which the relative Zr $K\alpha$, Sr $K\alpha$, and Rb $K\alpha$ intensities are particularly useful for plotting obsidian compositions. The sample (up to 1¼" in diameter for the currently used sample cup) is placed in the cup in the form of a flake or artifact (obsidian), rock chip (pumice, rhyolite, etc.), loose grains or powder, or in the form of a specially prepared pellet usable also for precise quantitative analyses. In spite of variations in the effective sample surface of randomly broken pieces or loosely packed grains, relative intensities of the various spectral lines over a narrow wavelength region may be very precisely determined. Quite precise "absolute" concentrations may also be obtained in many analytical situations by using the primary beam (continuum plus characteristic radiation of the target material) scattered from the sample to standardize the effective intensities (chart recorder deflection) from sample to sample by varying the spectrograph tube current (Ma).

The technique utilized for this study allows the recording of the required spectral scan of one sample in approximately 7 minutes, or, including sample changes and resetting the instrument, at least 6 samples per hour. No sample preparation is required other than a washing in water if the obsidian flake is coated with soil, and trimming or breaking of the specimen to fit the sample cup if it exceeds 1¼" in length. After setting the counting rate at the starting angle of the scan to a standard value (2000 counts per second for these analyses) by adjusting the spectrograph tube current, the spectrograph scans automatically. The measurements of the amplitude of the spectral peaks on the chart, the computation of the corrections for spectral interferences, and the calculation of the relative intensities of the spectral lines for each sample can be made while other samples are being scanned.

These analyses were made in the Department of Geology and Geophysics, University of California, Berkeley, on a Norelco (Philips) Universal Vacuum X-ray Spectrograph using a tungsten tube, LiF {220} analyzing crystal, scintillation detector with pulse height discrimination, and an air path. The scans were made at 2 degrees (two-theta) per minute.

RESULTS OF THE ANALYSES

The results of the x-ray fluorescence scans of the La Venta surface obsidian samples are plotted in Figure 1 as relative x-ray emission line intensities of Rb Kα, Sr Kα, and Zr Kα for each of 150 samples. One sample only (No. 1) is not plotted as it yielded no measurable spectral output for these elements and may in fact be non-igneous (e.g. flint). From the plotted data in Figure 1 it is clear that there are three distinct chemical groups represented by the surface samples from La Venta, each presumably representing a separate geologic source rock. These have been designated types A, B, and C. Also identifiable are two other types, here designated as types D and E, based in part upon scans of the samples from Tres Zapotes (type D) and inspection of the obsidians in hand specimen (types D and E). Of the 151 surface samples from La Venta, 142 fall within these 5 groups. Average values of the two scans are plotted for samples numbered 3, 52, 75, 78, and 89 since they are particularly small or irregular in shape.

On Figure 2 are plotted the analyses of the 12 excavated samples from La Venta and 13 samples from Tres Zapotes, Comalcalco, and Tlatelolco sites and the analyses of three potential geologic source obsidians (Pachuca, Hidalgo, Mexico; El Chayal, and Ixtepeque, Guatemala). It can be seen that 21 of these 25 archaeological samples fall within 4 of the same 5 chemical groups observed in the La Venta surface samples. The other 4 specimens group into two pairs of relative compositions intermediate to types C and E. The El Chayal geologic source sample plots near the group composed of samples numered VII (La Venta) and IX (Comalcalco) and La Venta surface samples numbered 70 and 117, perhaps indicating that El Chayal is the source of these obsidians. However, the present sampling is too small to clearly establish this statistically. The other two labeled samples, numbered XVI and XVII (from Tres Zapotes site), as well as La Venta surface sample number 54, group together, suggestive of another source type. The Ixtepeque geological source material likewise plots outside the five major groups recognized in the La Venta surface samples. La Venta surface samples numbered 4, 5, and 89 fall roughly into the same compositional area as the Ixtepeque sample, but again, any correlation based upon this small number of samples is quite uncertain. As expected, the Pachuca geologic source obsidian plots with the obsidians of type A, supporting the opinion that these distinctive green obsidians are from the Pachuca source.

Obsidians often are quite distinctive in appearance (e.g. the Pachuca green obsidian), no doubt contributing in many cases to their collection and distribution in prehistoric times. With the exception of the distinct green obsidians, cursory inspection of the obsidian samples as they were being prepared for analysis in the spectrograph did not reveal any notable

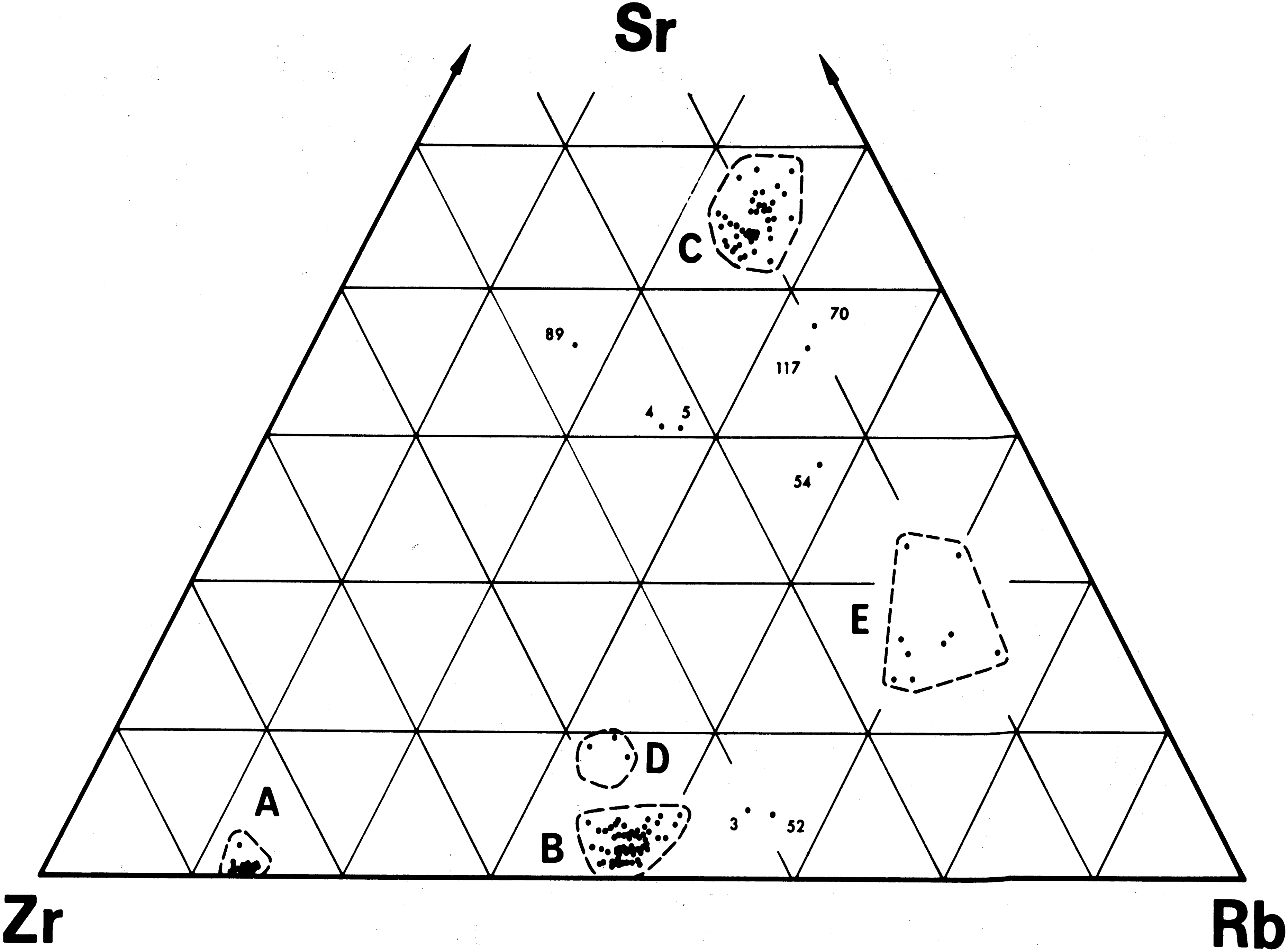

Fig. 1. Plot of La Venta surface samples

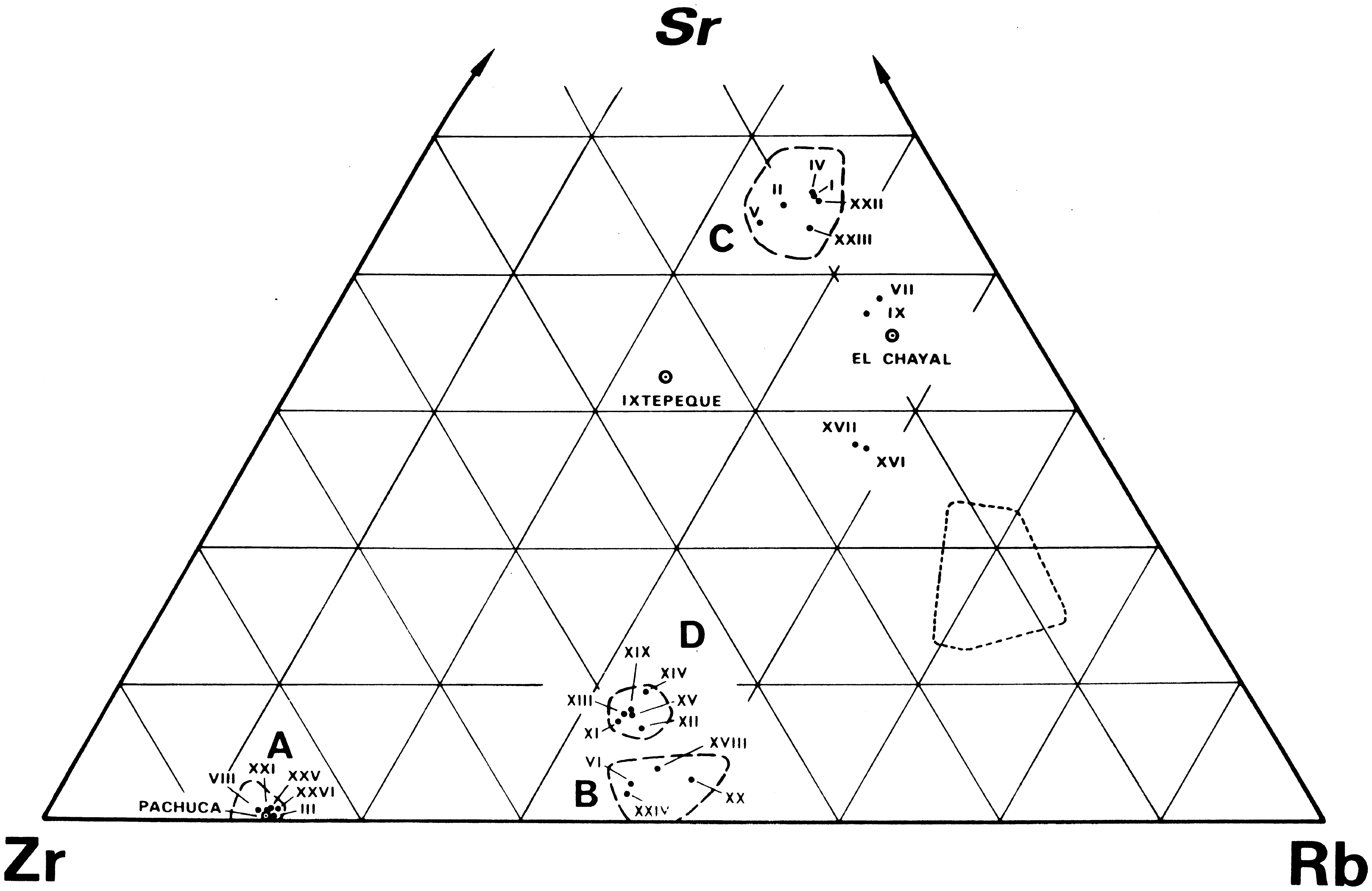

Fig. 2. Plot of obsidian samples (for identification see p. 90)

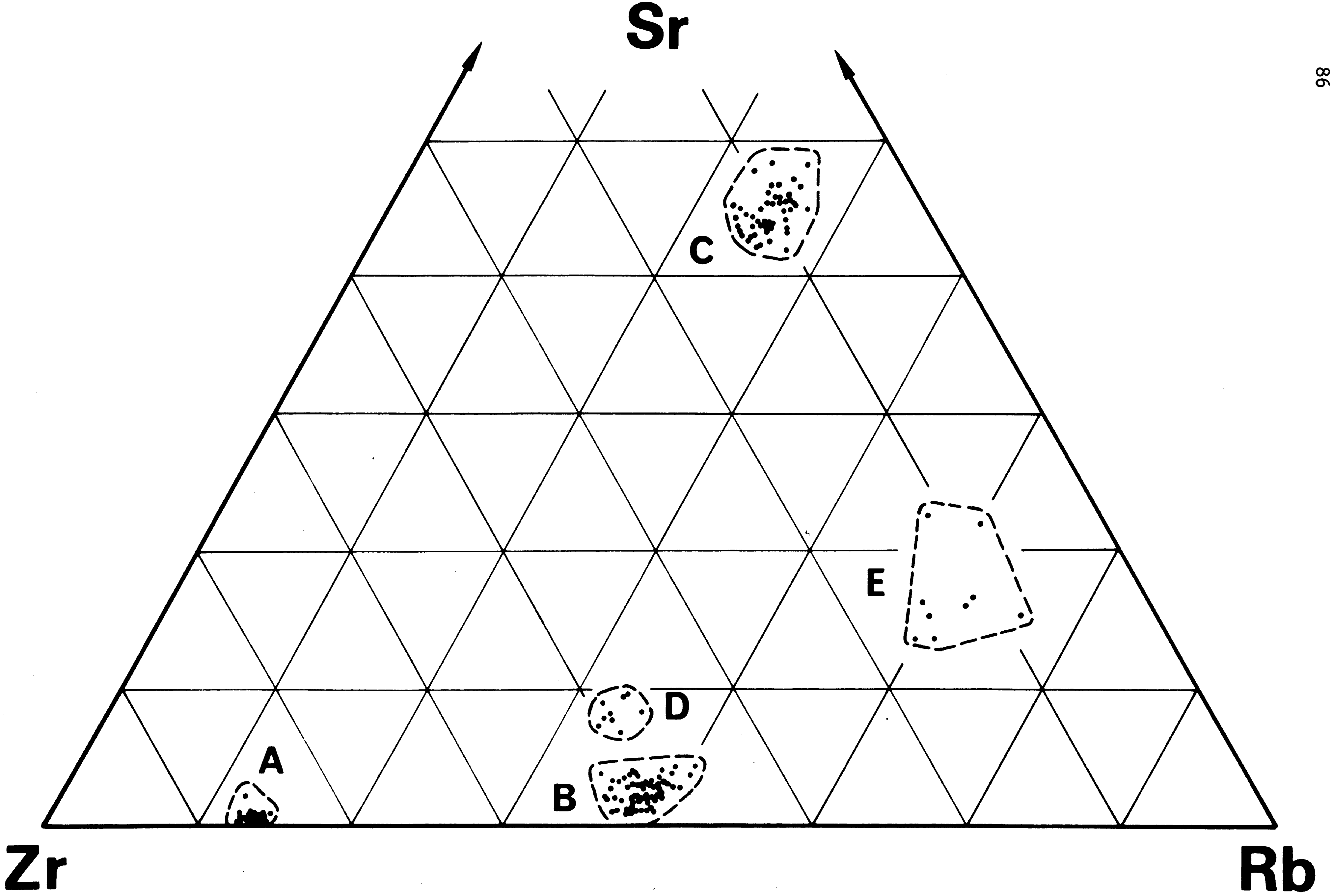

Fig. 3. Composite plot of all samples belonging to types A, B, C, D, E

differences in appearance which seemed trustworthy as criteria for sorting the samples. When it became clear, however, that the obsidians did fall into several distinct groups, based upon x-ray fluorescence analysis, a more detailed inspection of the samples in hand specimen was clearly advisable. Accordingly, the first 55 La Venta surface samples run on the spectrograph were examined under reflected artificial light and on a light table, and any pertinent observations recorded. In addition, all samples found by x-ray fluorescence to lie outside the compositional range of the three dominant (86% of the La Venta surface sample) groups A, B, and C, and all excavated samples catalogued with Roman numerals were examined in a similar manner. The results are summarized in Table 1. The three dominant types A, B, and C have consistent characters, type A being a distinctive green color, type B being a generally uniform smoky gray, and type C being light gray with a definite tan tint with a dense tan to black internal flecking. More significant, however, is the fact that type D samples have a darker, more irregular streaky (inhomogeneous?) appearance than type B, supporting the narrow distinction between the two types observed chemically, and the fact that samples belonging to the rather broad group designated type E have a consistent greenish-yellow tint to their light gray body color, supporting their identification as a valid obsidian type. Of the 12 samples (not including No. 1) not falling within one of the five major chemical types, numbers 54, XVI, and XVII in one group and numbers 70, 117, VII, and IX in another group, are most like type C obsidians in hand specimen, and numbers 3 and 52 are most like type B in hand specimen. Samples numbered 4, 5, and 89, although generally similar to each other in that they are dark gray and finely flow banded or mottled, do not have definite similarity to any other observed groups.

At this time any statistical statement regarding the obsidian types in Mesoamerica must be in terms of the La Venta surface samples or in terms of all samples analyzed (including the La Venta surface samples) since only thus is there a sufficiently large sampling. A summary of the finding of this study is given on page 88. It is notable that by means of the non-destructive x-ray fluorescence rapid scan method 94.0% of the available La Venta surface samples and 92.6% of all samples analyzed may be assigned to one of five major chemical types; 86.0% and 82.4%, respectively, belong to the three major types. Figure 3 is a summary plot of the samples belonging to the five major chemical groups. No chemical types were observed among the excavated samples which were not represented in the La Venta surface sampling; however, type E of the La Venta surface obsidians was not observed among the excavated samples. Both samples from Tlatelolco burials are of type A (Pachuca). Of the 10 Tres Zapotes samples, 6 are of type D, 2 of type B, and 2 are similar to La Venta surface sample 54 in composition. The single Comalcalco sample (No. IX) is similar in composition to La Venta sample VII and two La Venta surface samples, numbered 70 and 117. Sample VII is the only excavated La Venta sample not belonging to one of the three dominant types A, B, or C.

Obsidian Type	La Venta Surface Samples: No. of Samples	La Venta Surface Samples: Per cent of Total	All Samples: No. of Samples	All Samples: Per cent of Total
A	24	15.9	29	16.5
B	62	41.0	66	37.5
C	44	29.1	50	28.4
D	3	2.0	9	5.1
E	9	6.0	9	5.1
Other	9	6.0	13	7.4
Total	151	100.0	176	100.0

Tables 2 through 6 summarize the data for the 163 samples belonging to each of the five major obsidian groups, and Table 7 presents the same type of data for the remaining 13 samples and the 3 geologic samples (potential sources), generally similar samples being grouped for comparison. The units used are chart divisions measured from the spectrograph charts, one division being equivalent to a counting rate of 20 counts per second. The columns entitled Rb/Σ, Sr/Σ, and Zr/Σ are the values used to plot the composition of each sample on the ternary diagrams. The samples are identified by number in Appendix I, arabic numerals being used for La Venta surface samples and Roman numerals for the excavated La Venta samples and those from other localities. Included in each table are average values (in chart divisions) for Rb, Sr, Y, Sr, and Nb for that obsidian type, with an approximate value in parts per million (by weight) for each element based upon comparison with U.S. Geological Survey standard granite G-1. These values are uncorrected for matrix mass absorption, but are expected to be accurate within a few per cent of the amount present. Also included in Table 2 are measurements taken on green obsidians from northwesternmost Nevada (Hu X-1 and Hu X-2) which confirm their general similarity with the Pachucan green obsidians but also reveal significant differences in the Y, Zr, and Nb concentration levels.

In conclusion, it can be said that the x-ray fluorescence rapid scan technique holds great promise in characterizing Mesoamerican obsidians and thereby contributing to the solution of certain basic archaeological problems. In cases in which the rapid semi-quantitative determination of Rb, Sr, and Zr, plus Y and Nb, doesnot provide adequate resolution between obsidian types, measurement of the concentrations of other elements may be useful. The desirability of further sampling at a number of archaeological sites, and equally important, the collection of geologic source obsidian, is indicated in order to further define other obsidian chemical types and to establish the sources and distribution of Mesoamerican obsidians.

Initial work on Mesoamerican obsidians by Weaver and Stross (1965) was successful in demonstrating that obsidian from Pachuca (i.e. Cerro de Navajas, Hidalgo) was traded as far south as the La Venta site in the state of Tabasco, but the archaeological sample was collected from the surface and could not be dated. Excavations at La Venta in July, 1967, and January-February, 1968, produced 12 small obsidian blades ("razors"; samples Nos. I-VII, XXI-XXV). All of these, without exception, were recovered from refuse or constructions of the La Venta period (Middle Pre-Classic) and dated at this site in the time span 1000 B.C. - 600 B.C. (cf. Berger, Graham and Heizer 1967). Since three of these are of Type A obsidian from Pachuca, we can be certain of the fact that obsidian from the Mexican highland was being traded to southeastern Mexico in the Middle Pre-Classic. Drucker (1952:145) observes that he found no green obsidian in the test pits and stratigraphic trenches dug by him at La Venta in 1941. We do not know how to explain this, since several of our pits were in areas immediate to those where he had dug some twenty years earlier. Obsidian samples from highland Olmec sites such as Tlapacoya, Tlatilco, Las Bocas, Chalcatzingo, and others, when analyzed by the method employed here might provide us with information on the intensity of contacts between these various sites.

The Ixtepeque (Guatemala) source is apparently not represented at La Venta, unless we accept the general similarities of La Venta samples 4, 5, and 89 to Ixtepeque obsidian as supporting this. However, this is not surprising in view of the fact that these two spots lie 380 airline miles apart. At the same time, it is puzzling to find that the El Chayal source in Guatemala (Coe and Flannery 1964) may have provided the material for samples VII, 70, and 117 (from La Venta) and IX (from Comalcalco). In view of the Olmec presence in Salvador (Boggs 1950) and southeastern Quetzaltenango, Guatemala (Thompson 1943:III, fig. a), it would not be surprising to find some indication of material interchange between the Veracruz-Tabasco Olmec area and the Guatemala-Salvador region.

A single source, not now identified, supplied obsidian both to the La Venta and Tres Zapotes sites as judged from samples XVI and XVII (Tres Zapotes) and No. 54 (La Venta).

One obsidian type (E) known from surface artifacts at La Venta was not found in excavations. This obsidian may either date from post-La Venta phase times at the La Venta locality or, since it is represented by only 9 specimens, it may be a rare type which we did not encounter in our limited investigations of 1967 and 1968.

Of the five major source types identified (A,B,C,D,E) only type A is now locatable. Type B obsidian is the most abundant at La Venta, type C is next most common, and type A is in third place. The greatest need now is to have samples of source obsidians with which to correlate La Venta artifacts.

APPENDIX I

LOCALITY DESCRIPTIONS OF SAMPLES

1 through 151	Surface obsidian samples, mainly fragmentary flake blades, collected from La Venta site in February, 1968. Sequential numbers assigned as specimens were run on x-ray spectograph.
I.	From refuse deposits west of La Venta pyramid. Collected in July, 1967, by R. F. Heizer and P. Drucker. Test Pit No. 3, d. 8-16 in.
II.	Same as I.
III.	Same as I.
IV.	Stirling Group southeast of La Venta pyramid. Specimen found in gray gumbo packing of Drain No. 1. Collected February, 1968, by NGS-UC expedition.
V.	Same as IV.
VI.	Refuse deposits lying on top of large rectangular platform construction (shown on site map in this volume as "Great Platform") near southwest corner of the south platform of the La Venta pyramid. Test Pit No. 2, level 3 (d. 40-60 cm.). Dates from La Venta phase. Collected January, 1968, by NGS-UC expedition.
VII.	Same location as VI. Test Pit No. 1, level 8 (d. 140-160 cm.).
VIII.	Tlatelolco, Mexico. Flake blade found in mouth of Burial No. 1. Assignable to Aztec II-III period on basis of associated pottery. Collected by UC research group on February 15, 1968.
IX.	Comalcalco, Tab., Mexico. Surface obsidian chip collected February 7, 1967.
X.	Number not used.

XI - XX	Ten obsidian samples recovered by P. Drucker from a test pit excavated in the cutbank of the Arroyo Hueyapan at the locus of his earlier Trench 26. Sequential numbers assigned as run on x-ray spectograph.
XXI.	La Venta site. Test Pit 1968-1, level 6 (d. 100-120 cm.).
XXII.	La Venta site. Test Pit 1968-2, level 7 (d. 120-140 cm.).
XXIII.	La Venta site. Test pit 1968-2, level 8 (d. 140-160 cm.).
XXIV.	La Venta site. Test Pit 1968-2, level 5 (d. 80-100 cm.).
XXV.	La Venta site. Test Pit 1968-5, level 7 (d. 120-140 cm.).
XXVI.	Tlatelolco, Mexico. Flake blade found in mouth of Burial 2. Assignable to Aztec II period on basis of associated pottery. Collected by UC research group on February 14, 1968.

Table 1. Summary of the appearance of five major obsidian types (in hand specimen)

Type A	Distinct olive green body color (to greenish-black in thicker sections). Commonly shows golden internal reflections from parallel discontinuous planes (incipient cracks?). Occasionally golden reflections are on a very fine (powdery) scale. Generally smooth fracture surfaces of high lustre. Fine cracks often visible running in curves perpendicular to conchoidal fracture rings or undulations. Occasionally small tan spherules or trains of spherules are visible.
Type B	Light gray, dark gray, to nearly black body color. Clear uniform smoky-gray color generally characteristic. Occasional faint darker gray streaking visible in light gray body color. Surface highly lustrous to somewhat greasy; occasionally faintly irridescent. Diverging curved cracks observed occasionally. Occasional spots; vesicles rare.
Type C	Light gray with distinct tan tint, particularly in thicker sections. Dense flecking of fine tan, brown, to black spots is characteristic. Areas of shadowy gray streaking or banding due to concentration of fine spots is common, more obvious when viewed parallel to plane of spots. May be very light gray to clear in thinnest sections. Surface usually greasy in lustre due to roughness related to dense flecking. Lustrous surface only when flecking is on finest scale.
Type D	Dark gray to black with streaky appearance. Dense irregular mottling of dark gray in lighter gray background. Surface shiny to pitted (with a greasy lustre).
Type E	Light smoky-gray with greenish-yellow tint. Clear to greenish-gray in thinner sections. Faint banding on fine scale. Very fine spotting gives dusty internal appearance; occasional larger spots of rust coloring. Faint banding becomes more distinct on rotation of sample to certain orientations. Surface generally highly lustrous, occasionally pearly.

Table 2. Summary of Data for Obsidians of TYPE A
(1.0 equivalent to 20 counts per second)

Sample Number	Rb	Sr	Y	Zr	Nb	Σ(Rb,Sr,Zr)	Rb/Σ	Sr/Σ	Zr/Σ	Total
7	23.5	1.0	15.0	146.0	10.5	170.5	.138	.006	.856	1.000
8	24.0	0.5	17.5	146.5	13.0	171.0	.142	.003	.855	1.000
9	24.0	0.5	16.5	150.0	14.0	174.5	.137	.003	.860.	1.000
10	24.0	0.5	14.5	149.0	14.0	173.5	.138	.003	.859.	1.000
11	25.0	1.0	16.5	152.5	17.0	178.5	.140	.006	.854	1.000
12	25.5	1.0	14.5	151.5	14.5	178.0	.142	.007	.851	1.000
13	16.5	3.0	14.5	114.5	19.5	134.0	.122	.022	.857	1.001
14	21.0	0.5	14.5	146.5	17.5	168.0	.126	.005	.869	1.000
15	23.0	0.5	14.0	145.0	13.5	168.5	.136	.004	.860	1.000
16	21.0	0.5	15.0	144.0	12.5.	165.5	.128	.005	.867	1.000
17	24.5	0.5	15.5	151.5	13.0	176.5	.140	.003	.857	1.000
18	22.5	1.5	15.0	144.5	14.0	168.5	.134	.009	.858	1.000
19	23.0	0.5	16.0	144.0	13.0	167.5	.137	.003	.860	1.000
20	23.5	1.0	15.0	145.0	12.5	169.5	.139	.006	.855	1.000
21	23.0	0.5	15.0	146.5	14.0	170.0	.135	.003	.862	1.000
22	21.0	1.0	16.5	140.0	13.0	162.0	.130	.006	.864	1.000
23	23.5	0.5	15.0	145.0	13.0	169.0	.139	.003	.858	1.000
24	21.5	0.5	16.5	146.5	10.5	168.5	.128	.003	.869	1.000
25	22.0	0.5	17.5	152.5	13.5	175.0	.126	.003	.871	1.000
26	22.0	0.5	15.0	140.0	12.5	162.5	.135	.003	.862	1.000
27	22.0	1.0	15.0	140.0	12.5	163.0	.136	.003	.861	1.000
28	22.0	1.0	15.0	140.0	12.5	163.0	.135	.006	.859	1.000
29	23.0	0.5	15.0	139.0	11.5	162.5	.142	.003	.855	1.000
146	22.0	1.5	15.0	139.5	13.5	163.0	.135	.009	.856	1.000
III	25.5	0.5	15.5	150.5	15.5	176.5	.143	.003	.853	.999
VIII	23.0	1.0	16.0	147.5	15.0	171.5	.134	.006	.860	1.000
XXI	23.0	1.0	16.5	141.5	15.0	165.5	.139	.006	.855	1.000
XXV	23.0	1.0	16.0	140.0	13.5	164.0	.140	.006	.854	1.000
XXVI	24.5	1.5	15.0	142.5	15.0	168.5	.145	.009	.846	1.000
Average of 24	22.63	0.83	15.40	144.15	13.54	(La Venta surface samples)				
ppm	251	7	124	1164	109	Standard: G-1				

For comparison the following data are given for samples from northwest Nevada:

Hu X-1	23.0	0.5	11.0	85.0	5.5	108.5	.212	.005	.783	1.000
Hu X-2	24.0	0.5	12.5	90.0	5.5	114.5	.210	.004	.786	1.000

Table 3. Summary of Data for Obsidians of TYPE B
(1.0 equivalent to 20 counts per second)

Sample Number	Rb	Sr	Y	Zr	Nb	Σ(Rb,Sr,Zr)	Rb/Σ	Sr/Σ	Zr/Σ	Total
2	19.5	1.0	6.0	33.0	7.5	53.5	.364	.019	.617	1.000
30	19.0	1.0	7.0	30.5	7.5	50.5	.376	.020	.604	1.000
31	18.0	1.0	8.0	31.5	7.0	50.5	.356	.020	.624	1.000
34	18.5	2.0	10.0	33.0	6.5	53.5	.346	.038	.617	1.001
37	20.5	1.0	6.0	34.0	6.0	55.5	.369	.018	.613	1.000
42	20.5	1.0	6.0	32.0	8.5	53.5	.383	.019	.598	1.000
47	21.5	1.0	6.0	33.0	7.5	55.5	.387	.018	.595	1.000
49	20.5	1.0	8.0	32.5	8.0	54.0	.380	.019	.602	1.001
50	20.5	1.0	7.5	32.5	6.5	54.0	.380	.019	.602	1.001
53	23.0	0.5	7.0	34.5	8.5	58.0	.394	.010	.596	1.000
57	20.0	2.0	9.0	32.0	7.5	54.0	.370	.037	.593	1.000
58	20.0	1.0	9.0	32.5	7.0	53.5	.374	.019	.607	1.000
60	17.0	1.5	9.0	28.5	7.5	47.0	.362	.034	.603	.999
61	18.0	1.5	6.0	30.5	7.0	50.0	.355	.032	.613	1.000
63	20.5	1.5	9.0	31.0	6.5	53.0	.390	.024	.585	.999
64	20.0	0.5	7.0	31.0	6.5	51.5	.388	.010	.602	1.000
67	19.5	1.0	7.5	31.5	7.5	52.0	.375	.019	.606	1.000
71	21.5	0.5	7.5	32.5	8.5	54.5	.391	.011	.598	1.000
74	19.0	1.0	7.5	30.5	4.0	50.5	.376	.020	.604	1.000
79	19.0	0.5	8.0	32.0	7.0	51.5	.369	.010	.621	1.000
80	18.0	0.5	6.0	29.5	6.5	48.0	.375	.010	.615	1.000
81	20.5	1.0	8.0	31.0	6.5	52.5	.390	.019	.590	.999
82	19.5	1.5	5.5	29.5	6.5	50.5	.386	.030	.584	1.000
84	20.5	1.0	7.5	31.0	6.0	52.5	.390	.019	.590	.999
85	20.0	1.5	8.5	31.5	6.5	53.0	.377	.028	.594	.999
86	20.0	1.5	6.5	30.0	8.0	51.5	.388	.029	.583	1.000
87	19.0	1.5	8.0	30.5	7.0	51.0	.373	.029	.598	1.000
93	18.5	0.5	8.0	31.5	7.5	50.5	.366	.010	.624	1.000
94	19.0	0.5	7.5	31.0	7.0	50.5	.376	.010	.614	1.000
96	18.5	2.0	7.0	27.0	5.5	47.5	.389	.042	.568	.999
97	19.0	1.5	7.0	31.0	7.5	51.5	.369	.029	.602	1.000
98	19.0	1.5	8.0	30.0	7.0	50.5	.376	.030	.594	1.000
99	19.0	1.5	7.5	30.0	6.5	50.5	.376	.030	.594	1.000
100	17.0	1.5	6.5	29.0	6.0	47.5	.358	.032	.610	1.000
101	20.5	1.5	9.5	31.5	7.0	53.5	.383	.028	.589	1.000
102	20.5	1.5	7.0	31.0	8.5	53.0	.388	.031	.582	1.001
103	20.5	1.0	6.5	30.5	6.5	52.0	.394	.019	.587	1.000
106	19.0	1.0	6.0	31.0	7.5	51.0	.377	.016	.607	1.000
108	18.5	0.5	6.5	29.5	8.0	48.5	.381	.010	.608	.999
109	20.5	1.0	8.5	32.0	8.0	53.5	.383	.019	.598	1.000
110	22.0	2.0	8.0	30.5	6.5	54.5	.404	.037	.560	1.001
113	21.0	1.5	7.5	31.5	7.0	54.0	.389	.028	.583	1.000
114	19.5	1.0	7.0	31.0	7.5	51.5	.379	.019	.602	1.000
115	20.0	0.5	7.0	31.5	7.5	52.0	.385	.010	.606	1.001
116	19.0	0.5	6.5	30.5	6.5	50.0	.380	.010	.610	1.000
118	20.5	1.5	7.0	31.5	7.0	53.5	.381	.031	.588	1.000
120	20.0	1.0	7.5	30.0	6.5	51.0	.392	.020	.588	1.000
122	19.0	2.0	6.5	28.5	6.5	49.5	.384	.040	.576	1.000
124	19.0	1.5	8.0	31.0	5.5	51.5	.369	.029	.602	1.000
126	22.0	2.0	8.0	33.0	6.5	57.0	.386	.035	.579	1.000

Table 3. continued

Sample Number	Rb	Sr	Y	Zr	Nb	Σ(Rb, Sr, Zr)	Rb/Σ	Sr/Σ	Zr/Σ	Total
127	20.0	1.0	6.5	30.5	7.5	51.5	.388	.019	.592	.999
129	19.5	2.0	7.0	27.0	7.0	48.5	.403	.042	.556	1.001
131	21.0	0.5	6.5	34.0	8.5	55.5	.377	.009	.613	.999
133	19.0	1.5	7.5	30.0	7.0	50.5	.376	.030	.594	1.001
134	19.5	0.5	7.5	31.5	7.0	51.5	.379	.010	.612	1.001
135	19.5	2.0	8.0	32.0	7.0	53.5	.364	.037	.598	.999
142	19.0	2.0	9.0	31.0	7.0	52.0	.365	.038	.596	.999
143	22.0	1.0	9.0	34.0	6.5	57.0	.386	.018	.596	1.000
145	19.0	2.0	6.0	27.5	7.5	48.5	.392	.041	.567	1.000
147	21.0	1.5	7.0	30.5	7.0	53.0	.396	.028	.575	.999
148	19.5	1.5	7.5	30.5	7.5	51.5	.379	.029	.592	1.000
150	21.5	1.5	6.5	30.5	9.0	53.5	.402	.028	.570	1.000
VI	20.0	1.5	8 5	34.5	9.0	56.0	.357	.027	.616	1.000
XVIII	19.5	2.0	6.5	31.5	7.0	53.0	.368	.038	.594	1.000
XX	19.5	1.5	7.0	28.5	7.0	49.5	.394	.030	.576	1.000
XXIV	17.5	1.0	6.5	30.5	7.0	49.0	.357	.020	.622	.999
Average of 62	19.77	1.23	7.38	31.04	7.06					
ppm	220	11	60	251	57	Standard: G-1				

Table 4. Summary of Data for Obsidians of TYPE C
(1.0 equivalent to 20 counts per second)

Sample Number	Rb	Sr	Y	Zr	Nb	Σ(Rb,Sr,Zr)	Rb/Σ	Sr/Σ	Zr/Σ	Total
32	14.5	22.0	2.5	16.0	1.5	52.5	.276	.419	.305	1.000
33	13.5	24.5	3.5	15.5	015	53.5	.252	.458	.290	1.000
35	13.5	24.0	2.0	17.0	1.5	54.5	.248	.440	.312	1.000
36	14.0	24.0	1.5	16.5	1.0	54.5	.257	.440	.303	1.000
38	12.5	21.5	2.5	15.0	0.5	49.0	.255	.439	.306	1.000
39	14.0	26.0	3.5	14.0	0.0	54.0	.259	.481	.259	.999
40	13.5	23.0	2.0	15.0	3.0	51.5	.262	.447	.291	1.000
43	14.5	26.5	2.5	17.0	0.5	58.0	.250	.457	.293	1.000
44	14.5	26.0	2.0	16.0	0.5	56.5	.257	.460	.283	1.000
45	12.5	22.5	2.5	17.0	1.0	52.0	.240	.433	.327	1.000
46	14.0	24.0	1.5	18.0	2.0	56.0	.250	.429	.321	1.000
48	13.0	26.5	1.5	15.5	2.5	55.0	.236	.482	.282	1.000
51	12.0	24.0	4.0	17.0	0.5	53.0	.231	.451	.319	1.001
55	15.0	25.0	4.0	18.0	1.0	58.0	.255	.434	.311	1.000
59	12.5	25.5	4.0	18.0	1.5	56.0	.226	.452	.321	.999
62	13.5	22.0	1.5	19.0	3.5	54.5	.245	.404	.351	1.000
66	14.5	23.5	5.0	16.0	0.5	54.0	.269	.435	.296	1.000
68	13.0	24.5	2.5	16.0	2.0	53.5	.244	.462	.295	1.001
69	13.5	24.0	2.5	17.5	2.5	55.0	.245	.436	.318	.999
72	12.0	25.0	3.0	15.5	1.0	52.5	.127	.477	.295	.999
73	13.5	22.5	4.0	16.0	1.5	52.0	.256	.436	.308	1.000
76	13.0	24.0	3.0	17.0	3.0	54.0	.241	.444	.315	1.000
77	12.5	24.5	2.5	12.0	2.5	49.0	.256	.500	.244	1.000
91	13.5	25.5	2.0	18.0	2.5	57.0	.237	.447	.316	1.000
92	13.0	23.0	3.0	14.5	1.5	50.5	.257	.455	.287	.999
95	13.5	23.0	3.0	17.5	2.5	54.0	.250	.426	.324	1.000
104	13.0	24.0	2.0	14.0	2.0	51.0	.255	.471	.275	1.001
105	12.5	24.0	3.0	15.0	3.5	51.5	.243	.466	.291	1.000
107	13.0	21.0	2.5	15.5	2.0	49.5	.263	.424	.313	1.000
111	13.0	22.5	2.5	16.0	2.0	51.5	.252	.437	.311	1.000
112	13.0	23.5	2.5	15.5	2.5	52.0	.250	.452	.298	1.000
119	13.5	23.0	3.0	14.5	2.0	51.0	.264	.448	.287	.999
121	13.5	23.5	3.0	17.0	1.5	54.0	.252	.437	.311	1.000
125	13.0	23.0	3.5	17.5	2.5	53.5	.243	.430	.327	1.000
128	14.5	25.0	2.0	17.5	3.0	57.0	.254	.439	.307	1.000
130	13.5	24.0	3.0	14.0	2.0	51.5	.262	.466	.272	1.000
132	11.5	22.0	2.5	16.0	2.0	49.5	.232	.444	.323	.999
136	13.0	21.5	2.5	16.5	2.0	51.0	.255	.422	.324	1.001
137	12.0	22.0	1.0	14.5	2.5	48.5	.247	.454	.299	1.000
138	14.0	23.0	3.0	17.5	1.0	54.5	.257	.422	.321	1.000
139	13.0	24.5	3.5	15.0	2.5	52.5	.248	.467	.286	1.001
141	15.0	24.5	2.5	15.0	2.0	54.5	.275	.450	.275	1.000
144	12.5	21.5	2.5	16.0	2.0	50.0	.250	.430	.320	1.000
149	14.0	23.5	1.5	16.5	1.0	54.0	.259	.435	.306	1.000
I	14.0	25.0	0.5	15.5	2.5	54.5	.257	.459	.284	1.000
II	13.5	25.0	2.5	17.0	2.0	55.5	.243	.450	.306	.999
IV	15.0	26.5	3.0	16.5	2.5	58.0	.259	.457	.284	1.000
V	14.0	26.0	2.5	19.5	3.0	59.5	.235	.437	.328	1.000
XXII	14.0	24.0	2.5	15.0	1.5	53.0	.264	.453	.283	1.000
XXIII	14.0	22.5	1.5	15.5	2.0	52.0	.269	.433	.298	1.000
Average of 44	13.33	23.69	2.67	16.09	1.78					
ppm	148	212	22	130	14	Standard: G-1				

Table 5. Summary of Data for Obsidians of TYPE D
(1.0 equivalent to 20 counts per second)

Sample Number	Rb	Sr	Y	Zr	Nb	Σ(Rb,Sr,Zr)	Rb/Σ	Sr/Σ	Zr/Σ	Total
6	16.5	4.5	4.5	30.0	3.0	51.0	.324	.088	.588	1.000
56	16.5	4.5	5.0	27.5	2.0	48.5	.341	.088	.571	1.000
151	17.0	4.0	5.0	27.5	3.5	48.5	.350	.082	.567	.999
XI	15.5	3.5	4.0	28.5	5.0	47.5	.326	.074	.600	1.000
XII	17.5	3.5	3.0	30.0	3.0	51.0	.343	.069	.588	1.000
XIII	16.5	4.0	3.0	30.0	2.5	50.5	.327	.079	.594	1.000
XIV	17.0	5.0	5.0	29.0	4.0	51.0	.333	.095	.571	.999
XV	17.0	4.0	4.0	30.0	3.5	51.0	.333	.078	.588	.999
XIX	16.0	4.0	5.5	28.5	2.0	48.5	.330	.082	.588	1.000
Average of 3	16.65	4.33	4.83	28.33	2.83					
Average of all 9	16.61	4.11	4.33	29.00	3.17					
ppm	185	37	35	234	26					

Table 6. Summary of Data for Obsidians of TYPE E
(1.0 equivalent to 20 counts per second)

Sample Number	Rb	Sr	Y	Zr	Nb	Σ(Rb, Sr, Zr)	Rb/Σ	Sr/Σ	Zr/Σ	Total
41	12.5	3.5	3.0	8.0	2.0	24.0	.521	.146	.333	1.000
65	12.5	4.0	2.5	7.5	1.5	24.0	.521	.167	.313	1.001
75	12.5	6.0	2.0	8.0	2.5	26.5	.472	.226	.302	1.000
78	12.5	2.5	2.5	7.0	3.0	22.0	.568	.114	.318	1.000
83	11.5	3.5	1.5	8.0	4.0	23.0	.500	.152	.348	1.000
88	13.0	3.5	2.5	9,0	3.5	25.5	.510	.137	.353	1.000
90	12.5	5.5	2.0	7.0	5.0	25.0	.500	.220	.280	1.000
123	13.0	4.0	3.5	8.0	2.5	25.0	.520	.160	.320	1.000
140	12.0	4.0	2.5	8.5	2.5	24.5	.490	.163	.347	1.000
Average of 9	12.44	4.06	2.44	7.89	2.94					
ppm	138	36	20	64	24	Standard: G-1				

Table 7. Summary of Data for Obsidians Not Belonging to Five Dominant Types
(1.0 equivalent to 20 counts per seoond)

Sample Number	Rb	Sr	Y	Zr	Nb	Σ(RB,Sr,Zr)	Rb/Σ	Sr/Σ	Zr/Σ	Total
1	< 1	< 1	< 1	< 1	< 1	< 2				
54	11.5	9.5	1.5	11.0	3.0	32.0	.359	.297	.344	1.000
XVI	10.5	7.5	2.5	9.5	2.0	27.5	.382	.273	.345	1.000
XVII	15.0	11.0	3.5	14.0	2.0	40.0	.375	.275	.350	1.000
3	17.5	2.5	3.0	17.5	3.5	37.5	.467	.067	.467	1.001
52	17.5	3.0	4.0	18.5	3.5	39.0	.449	.077	.474	1.000
	(Cf El Chayal)									
70	16.5	19.0	3.0	15.0	3.5	50.5	.327	.376	.297	1.000
117	17.0	19.0	2.5	16.0	3.5	52.0	.330	.363	.308	1.001
VII	18.5	21.0	4.0	15.5	0.5	55.0	.336	.382	.282	1.000
IX	17.5	19.5	2.5	15.5	1.0	52.5	.333	.371	.295	.999
	(Cf Ixtepeque)									
4	14.0	16.0	3.0	20.5	1.5	50.5	.277	.317	.406	1.000
5	16.5	18.5	2.5	22.5	1.5	57.5	.287	.322	.391	1.000
89	11.5	22.5	3.5	31.0	3.0	65.0	.177	.346	.477	1.000
Pachuca (Cf Type A, Table 2)										
	22.5	0.5	15.5	137.5	12.5	160.5	.140	.003	.857	1.000
El Chayal										
	15.5	16.5	2.5	14.5	2.0	46.5	.333	.355	.312	1.000
Ixtepeque										
clear	12.5	17.5	3.0	24.0	1.5	54.0	.231	.324	.444	.999
flow-banded	13.0	21.5	2.5	24.5	1.0	59.0	.220	.364	.415	.999
U.S.G.S. Standard Granite G-1										
	19.5	27.0	2.0	25.5	1.0					
	20.0	29.0	1.5	27.5	4.5					
	20.0	28.0	2.5	25.0	2.5					
Average G-1	19.8	28.0	2.0	26.0	2.7					
ppm	220	250	13	210	20					

Bibliography

Berger, Rainer, J. A. Graham and R. F. Heizer
1967 A Reconsideration of the Age of the La Venta Site. Contributions of the University of California Archaeological Research Facility, No. 3:1-24, Berkeley.

Boggs, Stanley H.
1950 "Olmec" Pictographs in the Las Victorias Group, Chalchuapa Archaeological Zone, El Salvador. Carnegie Institute of Washington, Notes on Middle American Archaeology and Ethnology, 99:85-92, Washington, D.C.

Coe, M. D., and K. V. Flannery
1964 The Pre-Columbian Obsidian Industry of El Chayal, Guatemala. American Antiquity, 30: 1:43-49.

Drucker, Philip
1952 La Venta, Tabasco. A Study of Ceramics and Art. Bureau of American Ethnology, Bull. 153. Washington, D.C.

Jack, R. N., K. R. Lajoie and I. S. E. Carmichael
1967 "Finger-Printing" of Obsidian and Pumice from the Western United States. Proceedings 80th Annual Meeting Geological Society of America, New Orleans, La., Nov. 20-22, 1967 (p. 107).

Thompson, J. E. S.
1943 Some Sculptures from Southwestern Quetzaltenango, Guatemala. Carnegie Institute of Washington, Notes on Middle American Archaeology and Ethnology, No. 17, Washington, D.C.

Weaver, J. R. and F. H. Stross
1965 Analysis by X-Ray Fluorescence of Some American Obsidians. Contributions of the University of California Archaeological Research Facility, No. 1:89-103, Berkeley.