IV. ANALYSIS OF AMERICAN OBSIDIANS BY X-RAY FLUORESCENCE AND NEUTRON ACTIVATION ANALYSIS

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In recent years several studies have been published that were aimed at characterizing obsidian by analyzing for elements present in small or trace quantities. If obsidian rock can thus be characterized according to source, correlation of an obsidian artifact with its source becomes possible. Mediterranean and Afro-Asian obsidians have been studied by Castiglioni et al. (1963), Cann and Renfrew (1964), Renfrew, Cann and Dixon (1965), Renfrew, Dixon and Cann (1966), and Dixon, Cann and Renfrew (1968). Green, Brooks and Reeves (1967) have studied New Zealand obsidian types by emission spectroscopy. A similar though smaller study of American obsidians has been published by Weaver and Stross (1965) and Heizer, Williams and Graham (1965). The present paper is a continuation of the two latter studies.

Experimental

The samples reported here were analyzed by x-ray fluorescence using the same instrument and technique described in the earlier study (Weaver and Stross 1965). Values for the nine samples (with a few minor corrections) together with an additional fifty-seven samples analyzed in 1965 are shown in Table 1. The sample descriptions are given in Table 2. In addition to the analyses made by x-ray fluorescence, manganese was determined by neutron activation analysis. The x-ray values are in terms of counts-per-second-over-background and have no absolute quantitative significance; the manganese values are given in terms of parts per million by weight.

Aluminum, chromium, and manganese have been disregarded in the x-ray fluorescence determination. These can normally be measured, but they were judged to be of no value in this study for the following reasons: (1) the grinding device used to powder the samples was made of alumina and the samples were unquestionably contaminated with aluminum by the grinding operation; (2) the x-ray tube used had a chromium target which resulted in a very large background signal for chromium; (3) the small manganese peak,

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while detectable, was on the side of the large chromium peak, and hence measurement was unreliable. However, manganese is considered a good diagnostic element in this connection, and therefore we employed another technique for obtaining this analysis.

The x-ray fluorescence work was performed over an extended period of time, and it was necessary to adjust the conditions each time a lot of samples was analyzed to make all the data comparable with each other. Subsequent to the first lot, each time the instrument was used it was adjusted to give, as closely as possible, the same counts-per-second for each element in an arbitrarily chosen sample, namely sample 1-9. We include the data obtained on that sample at several points in Table 1 to illustrate the precision that was obtained in this process.

For the neutron activation determination of manganese, 20-mg samples were irradiated for 30 minutes in a thermal neutron flux of 10^{11} neutrons/cm^2/sec. in the Aerojet-General Nucleonics Industrial Reactor in San Ramon, California. Ten micrograms of gold was added to each sample and standard as an internal standard to compensate for flux variations. Gamma-ray spectra were recorded by means of a solid, 3-inch sodium iodide detector and a Nuclear Data, 512-channel analyzer. The only interference under these irradiation conditions was sodium. A computer program was used to remove the sodium interference by means of differences in the gamma-ray spectra and half-lives.

Results

Artifacts from Mexico, Guatemala, Honduras, and some from California and Nevada were analyzed. It has been suggested by Parks and Tieh (1966) that the strontium/rubidium ratio is characteristic of origin and age of the rock and could give an indication of its provenience. Among the other elements that showed the largest variation, the most useful for diagnostic purposes were considered to be zirconium, manganese, and iron. Data for these elements are displayed in a bar-graph (fig. 1) and in two ternary plots (Zr-Sr-Rb and Sr-Rb-Mn, figs. 2 and 3).

The graph and plots bring out the fact that the samples seem to fall into three groups:

Group "O", which comprises the greater part of source and site samples, is the group that clusters around the center of both of the ternary plots, and is characterized by approximately equal relative amounts of strontium, rubidium, zirconium, and manganese. This group, we believe, is inadequately differentiated; that is, there are probably several source types which are sufficiently similar to be included in this general group. On logical

grounds, the El Chayal and Ixtepeque (=Papalhuapa) sources in Guatemala may be suggested as providing the obsidian for most of the Maya site artifacts analyzed here (samples 1-5, 2-4 / 2-9, 2-14 / 2-19, 2-23 / 2-30, 2-32 / 2-48), and in addition, the Salvador sample (2-11) and those from Copán, Honduras (1-5, 1-13, 3-4). Stephens (1963:II:232), in the early eighteen-forties', may have been correct when he described a pottery jar from Kantunile, Yucatan, as "filled nearly to the top with arrow-heads, not of flint, but of obsidian; and as there are no volcanoes in Yucatan from which obsidian can be procured, the discovery of these proves intercourse with the volcanic regions of Mexico." The Otumba, Mexico, source (samples 2-20, 3-5A, 3-5B) probably provided the material for artifacts (2-21, 2-33) from Teotihuacán. The La Venta samples (2-1, 2-2) may have been derived from either the Guatemala highland, the Mexican highlands, or some as yet unknown source. The intermediate geographical position of La Venta, vis-à-vis Guatemala and Hidalgo, makes any guess based upon geographical proximity impossible. Only further artifact and source collecting and analysis will provide the data to differentiate Group O.

Group "2" is distinguished by a very low value for strontium, a high Zr/Rb ratio (4 to 6), and a high value for manganese. This group includes all "green" obsidians in the collection of samples analyzed. The only Mexican source represented in this group is the Pachuca quarry, Hildalgo (samples 1-3, 3-6A, 3-6B), which is well known for its green obsidian deposit and is thought to have supplied the raw material for most, perhaps all, of the green artifacts found in Mesoamerica. Sample 1-7 is a surface artifact from the La Venta site, and its age is therefore not determinable. In January-February 1968, excavations at La Venta in La Venta period refuse deposits yielded a number of obsidian blades of green color, and these may be presumed to have come from the Pachuca source. Drucker (1952:145) observed that he found no green obsidian in the test pits and trenches dug by him in 1942. It can now be said that the green obsidian from Pachuca was being traded as far south as La Venta in Middle Pre-Classic times, and as far as the Petén and highland Guatemala in Early Classic times.

It is remarkable that a blade found in Lovelock Cave, Nevada (sample 2-49) gave values that placed it clearly in Group 2; this specimen also seemed to have the greenish translucency that is characteristic of the Pachuca deposit. It is highly improbable that this artifact should have been traded the long distance from Pachuca to Lovelock, and consequently this finding is of special interest. The Department of Anthropology at Berkeley provided additional specimens (arrow points) of green obsidian which had been found at sites near Lovelock Cave. Eleven of these were analyzed and, without exception, gave analytical results that were consistent with the unusual analysis found for the first artifact. These analyses were compared with those obtained by the University of California (Berkeley)

Department of Geology (R. Jack, personal communication) for California and Nevada artifacts and sources. These included a few artifacts from Buckbrush Springs, Humboldt County, Nevada, which gave analyses similar to our Lovelock analyses. Since these two sites are not a great distance apart (about 65 airline miles), a common source of the obsidian is suggested. No deposit with the characteristic composition is now known, and it will be of interest to find the source from which the Lovelock Cave-Buckbrush Springs type green obsidian was obtained.

The remaining samples have been classed separately and are designated Group "1". They have in common a low strontium content and a much lower Zr/Rb ratio (approximately 1). The samples indeed appear as a generally homogeneous group in the ternary plot (Zr-Sr-Rb, fig. 2). This group includes the two samples from Napa County, California. Many obsidian samples from the same region have been analyzed independently by the Department of Geology (Jack, Le Joie and Carmichael 1967), and were found to give values on the Zr-Sr-Rb plot similar to those obtained on our samples. The latter, however, were further analyzed for manganese, and are distinguished by their very low manganese content, as is evident in Figures 1 and 3. Only one Mesoamerican sample (2-47, an artifact from Chichén Itzá) exhibits a similarly low manganese content. We have called this subgroup "1A." Here again, as in the Group 0 series, there must be at least two sources represented – one Californian and one Mesoamerican.

Four other Mesoamerican samples of Group 1 (samples 3-1, 3-2, 3-3, 2-10) have a manganese content intermediate between subgroup 1-A and most of Group 0, and are classed as subgroup 1-B. All of the subgroup 1-B samples date from the Pre-Classic. The source of the artifact material is not known, but we would guess that it will be found to exist in the Central Mexican highland. If there are two sources, one of which supplied Cuicuilco and the other southern Veracruz, both remain to be located.

The iron content generally varies with the groups (Group 0 has the lowest, Group 2 the highest iron content), but this does not seem, at least at the present time, to offer additional insight.

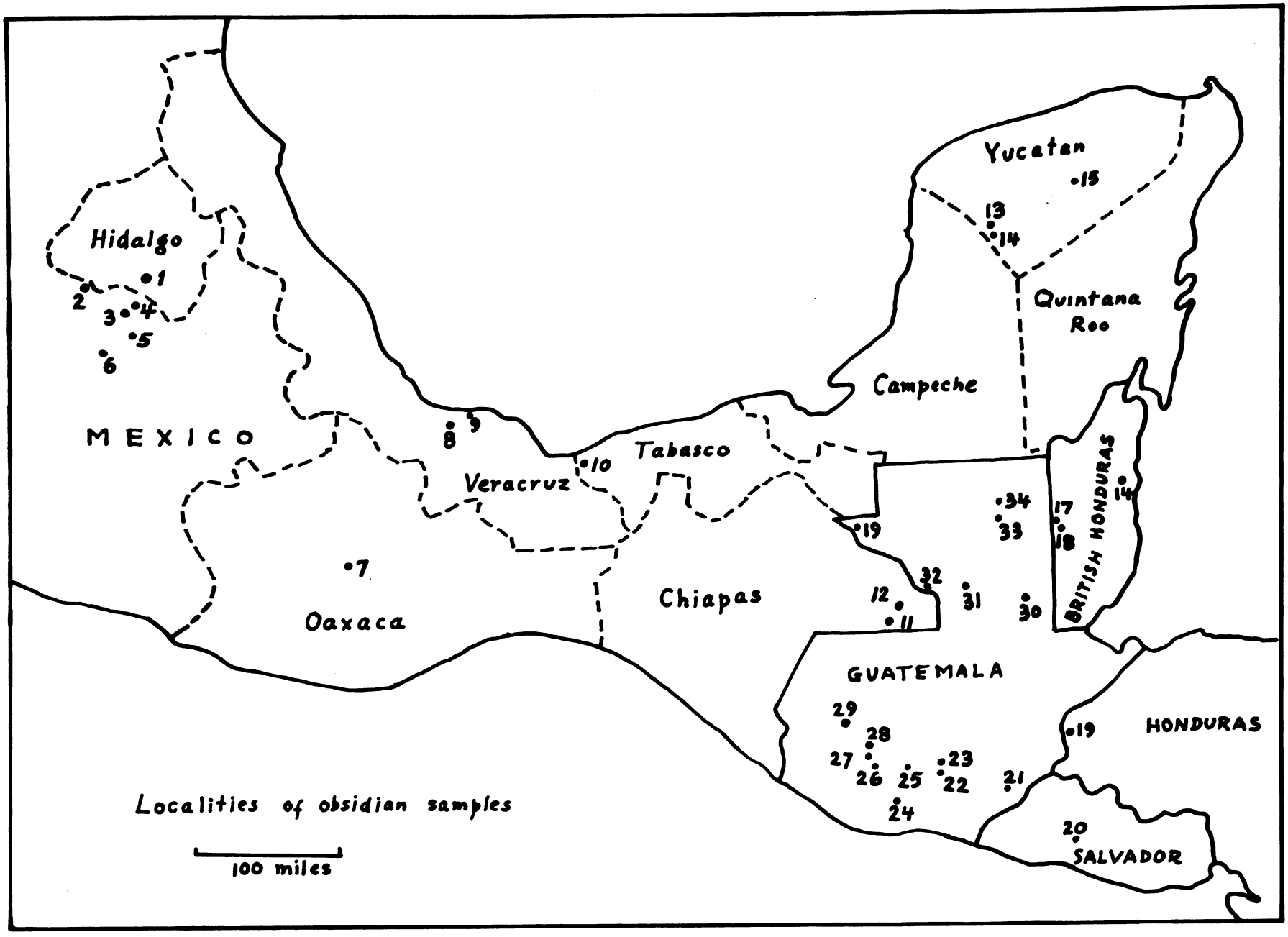
This study, in our opinion, serves mainly to point up the desirability of carrying out large scale studies of this kind, which, potentially at least, have been made possible by the efficient (but not inexpensive) analytical techniques developed in recent years. The crucial question concerning the divergence from source to source can be answered completely only be analyzing a sufficiently large number of samples from each of the individual sources. A substantial step in this direction has been made in the study already mentioned (Jack, Le Joie and Carmichael 1967), in which the similarity of composition (using the Zr-Sr-Rb ternary as criterion) within one lava flow was

found to be satisfactory. In our case, we can get information on this question from a few samples collected at the same sources at different instances. Thus, samples 1-4 and 1-8 are from the same source – the deposit at Papalhuapa, Guatemala. One sample is red, the other black. The analyses are seen to compare quite closely. Samples 1-3, 3-6A, and 3-6B are all from the Pachuca deposit (Group 2), and again give very similar analyses. Samples 1-9 (our reference sample for x-ray fluorescence) and 2-31 are from El Chayal, Guatemala, and they compare quite well with each other. Samples 2-20, 3-5A, and 3-5B are from the source deposit at Otumba, Mexico, and again the comparison is satisfactory. It should be noted, however, that of the four Mesoamerican sources only one (Pachuca) is different enough from the others to be clearly distinguishable. On the other hand, the samples in Group 1 are distinct from both Group 0 and Group 2; two of these samples are from California. No obsidian rock was found that corresponds to the Mesoamerican samples of Group 1, and it is thus not unlikely that these artifacts were made from obsidian obtained from at least one source as yet unknown to us.

The published literature on Mesoamerican obsidian working techniques, mining, and quarrying, and implement manufacturing techniques is large and scattered. We have not made any special effort to compile a bibliography on this subject, but have encountered some published data which we cite here in the hope that other workers may find them useful.

Stoll (1886:432-434) mentions the El Chayal source. It is also described by Holmes (1919:227) and by Coe and Flannery (1964). Thompson (1963:207) mentions a "vast deposit of obsidian" at Zacapa, Guatemala. We now know that this is in error, and that the obsidian seen along the railroad at this place is roadbed ballast carried there from El Chayal. Villacorta (1927) first mentions, although very casually, the obsidian at the site of Papalhuapa, Guatemala. This locality has been described geologically by Williams, McBirney and Dengo (1964).

The obsidian mines in southern Hidalgo, Mexico, were described by Holmes (1900,1919) and Breton (1902), and more recently by Spence and Parsons (1967) and Spence (1967). Breton (1902) also provides brief descriptions of obsidian workshop-quarry sites at Zinepecuaro, Michoacán, and near Guadalajara, Jalisco. Known or reported obsidian sources in Mexico are listed and mapped in Heizer, Williams and Graham (1965:98,map 5). The statement by Lunardi (1948:290) that obsidian is common in the vicinity of La Esperanza and Intibucá, Honduras, has not been verified, and judging from what is known of the geology of this area, the claim is probably incorrect. Hints of other Mesoamerican and Central American obsidian sources are contained in an article by Washington (1921).


Yucatan
15
13
14
Hidalgo
1
2
3
4
5
6
Quintana Roo
Campeche
MEXICO
8
9
10
Tabasco
Veracruz
19
34
33
17
18
14
BRITISH HONDURAS
7
Oaxaca
Chiapas
32
12
11
31
30
GUATEMALA
29
28
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23
22
21
19
HONDURAS
20
SALVADOR
Localities of obsidian samples
100 miles

Map 1

Table 1. RELATIVE ABUNDANCE OF ELEMENTS (COUNTS PER SECOND OVER BACKGROUND) IN SAMPLES

Sample	Si	Cl	K	Ca	Ba	Ti	Fe	Co	Ni	Cu	Zn	Rb	Sr	Zr	Nb	Mn(ppm)*
1-1	1480	10	2400	320	32	75	1130	0	18	135	25	140	0	210	30	150
2	1410	15	2450	335	25	60	1140	0	23	145	32	165	0	205	0	130
3	1360	20	2350	130	0	140	1880	0	25	135	78	140	0	720	85	1150
4	1440	9	2300	900	65	170	1080	0	15	150	15	80	110	160	0	500
5	1260	9	2400	960	60	150	1060	0	0	135	0	65	90	120	0	410
6	1380	18	2500	130	0	145	1900	0	25	135	85	160	20	600	60	1080
7	1290	15	2400	140	0	150	1940	0	25	160	75	150	0	800	70	1170
8	1460	4	2500	970	65	160	1180	15	20	135	20	80	140	150	0	510
9	1520	6	2350	810	50	120	780	15	25	145	25	120	110	110	0	650
9	1320	8	2200	730	45	100	880	5	20	150	35	130	150	160	0	
2-1	1220	7	2000	850	40	95	920	0	10	175	38	120	200	180	0	610
2	1140	5	1900	440	38	60	620	15	10	180	30	100	80	70	10	590
3	1240	19	2300	120	30	135	2250	20	30	170	118	230	0	910	160	1430
4	1120	8	1950	700	45	95	820	15	15	160	20	150	160	150	30	630
5	1090	8	2000	840	50	130	1220	0	5	165	25	90	150	210	0	450
6	1140	8	1850	690	50	90	860	0	10	165	20	150	180	160	0	580
7	1140	10	1900	710	45	75	820	10	15	175	20	150	160	130	0	620
8	1280	17	2600	190	25	200	1920	0	15	170	55	130	0	>>500	60	860
1-9	1360	10	2150	720												
2-9	1080	7	1800	720	35	85	800	0	15	160	20	120	130	100	0	560
10	1380	18	2650	300	25	100	1280	0	10	165	25	210	10	270	60	410
11	1340	9	2300	850	50	150	1320	15	10	165	30	100	170	210	10	440
12	1280	17	2275	120	20	135	2175	10	30	170	100	220	0	880	100	1210

(continued)

Table 1. (Contd-1)

Sample	Si	Cl	K	Ca	Ba	Ti	Fe	Co	Ni	Cu	Zn	Rb	Sr	Zr	Nb	Mn(ppm)*
1-9	1200	8	2050	720												
2-13	1160	9	2100	810	55	150	1320	0	10	165	25	100	150	210	10	720
14	1180	5	1700	600	45	90	840	10	15	175	15	170	180	170	0	600
15	940	9	1650	765	35	70	700	10	15	145	25	120	120	120	0	640
16	1140	6	1850	785	45	95	820	15	20	155	35	110	180	135	0	560
17	1240	6	2050	720	40	90	810	20	25	150	20	170	170	140	0	750
18	960	6	1700	720	60	85	700	10	15	160	25	100	170	135	0	440
19	1200	7	2150	830	50	130	1200	5	12	150	20	100	180	190	0	490
20	1240	5	2100	790	43	105	1140	10	15	155	25	100	150	185	15	440
1-9	1380	8	2200	800												
2-21	1260	6	2250	830	40	95	1130	23	25	145	35	140	120	180	0	440
22	1040	9	1900	740	35	85	970	20	15	160	30	120	120	150	0	300
23	1140	9	2000	750	43	80	740	10	10	145	20	150	150	130	0	590
24	1320	9	2200	750	40	78	780	5	15	125	30	130	150	120	0	900
25	1300	8	2150	890	48	90	840	20	15	135	15	125	190	150	0	550
26	1160	9	1950	800	40	80	640	10	15	110	10	140	170	150	0	600
27	1080	10	1900	840	40	95	620	15	10	120	20	90	170	140	0	530
28	880	17	1800	205	20	100	1600	10	20	115	55	140	30	640	50	920
29	1280	7	2200	760	50	90	650	0	10	120	20	140	130	125	0	720
30	1280	9	2250	875	50	135	940	0	15	115	15	120	170	210	0	530
1-9	1220	10	2100	750												
1-9	1320	9	2150	745												
2-31	1200	10	2050	720	45	90	610	10	25	115	25	140	140	140	15	700

Table 1. (Contd-2)

Sample	Si	Cl	K	Ca	Ba	Ti	Fe	Co	Ni	Cu	Zn	Rb	Sr	Zr	Nb	Mn(ppm)*
2-32	1220	11	2050	820	50	90	660	10	10	115	20	90	200	140	0	530
33	1180	9	1750	680	40	90	640	0	10	100	20	125	140	140	0	690
34	1260	8	2150	775	40	38	660	10	15	125	15	150	160	170	0	670
35	1260	11	2150	890	45	95	740	0	10	120	25	110	200	160	0	580
36	1100	7	1900	830	40	85	630	10	0	120	12	100	150	170	0	510
37	1300	11	2300	900	55	135	1000	0	0	100	15	100	180	210	0	510
38	1340	11	2150	870	43	100	700	10	5	110	15	120	190	130	0	560
39	1220	11	2100	720	41	75	630	0	10	110	15	100	120	120	0	740
40	1180	7	2150	740	43	83	620	0	10	130	23	150	150	135	0	640
41	1220	11	2100	740	40	85	660	0	10	110	25	115	150	130	0	650
42	1280	8	2150	860	45	95	660	0	15	115	5	120	190	130	0	570
43	1280	9	2100	730	40	93	660	0	7	110	20	140	140	150	0	730
44	1140	9	1950	720	38	85	620	15	0	115	20	140	120	115	0	620
1-9	1220	6	2000	700												
2-45	1120	23	2250	100	0	150	1740	0	25	110	80	180	0	1000	80	1350
46	940	20	2000	120	0	110	1520	0	23	110	65	175	0	830	60	940
47	740	9	1850	450	30	100	1270	20	20	115	20	205	10	160	0	100
48	1220	10	2000	720	43	90	660	10	10	100	25	140	150	170	0	640
49	**	12	1850	145	25	165	1400	8	15	110	45	140	0	520	0	1070
(3-1	1100	10	2100	350	40	120	1100	10	15	140	20	120	10	180	0)***	240
3-2	1220	9	2150	360	40	135	1180	20	10	165	20	140	20	180	0	270
3	1160	12	2100	340	40	135	1180	10	20	170	20	120	30	160	10	250
4	1240	9	2000	760	60	195	1160	20	10	165	15	80	120	160	20	500

Table 1. (Contd-3)

Sample	Si	Cl	K	Ca	Ba	Ti	Fe	Co	Ni	Cu	Zn	Rb	Sr	Zr	Nb	Mn(ppm)*
3-5A	1220	5	1900	720	55	160	1160	5	12	170	20	120	120	140	10	400
5B	1200	9	1850	700	50	165	1160	0	10	170	30	120	120	160	10	400
6A	1220	20	2000	80	10	195	2020	10	25	155	70	170	10	770	80	1250
6B	1160	16	2150	140	10	290	1780	20	25	155	55	100	30	580	50	1220

* The values for manganese were obtained by Neutron Activation Analysis and are given in parts per million.

** Not determined.

*** Approximate values.

Table 2

Sample Identification*
(Obsidians are black or gray unless otherwise noted)

Site No. on Map 1	Sample No.	Source Locality
	1-1	Glass Mt., near St. Helena, Napa Co., Calif. Sample from quarry. Collected by R. F. Heizer, 1959.
	1-2	Site CA-Sol-2, Solano Co., Calif. Artifact in Lowie Museum of Anthropology
1	1-3	Green obsidian. Pachuca, Hidalgo, Mex. Sample from quarry. Coll. by W. H. Holmes.
21	1-4	Papalhuapa, Depto. Jutiapa, Guatemala. Sample from quarry. Coll. by H. Williams, J. Graham, R. Heizer, 1964.
19	1-5	Copán. Artifact in Peabody Mus. Coll., Harvard University
3	1-6	Green obsidian. Teotihuacán, Mex. Surface artifact.
10	1-7	Green obsidian. La Venta, Tab. Surface artifact.
21	1-8	Red obsidian. Papalhuapa, Depto. Jutiapa, Guatemala. Sample from quarry.
23	1-9	El chayal, Depto. Guatemala, Guatemala. Sample from quarry.
10	2-1	La Venta, Tab. Surface artifact.
10	2-2	La Venta, Tab. Surface artifact.
5	2-3	Green obsidian. Texcoco, Valley of Mexico, Los Melones Md. Artifact in Peabody Mus. Coll., Harvard University.
12	2-4	Yaxun, Lower Lacantun R., Chiapas, Boco or Jimba Phase. Artifact in Peabody Mus. Coll., Harvard University.
13	2-5	Cave of Loltun, Yucatan. Entrance to Chamber 1. Artifact (c/1998) in Peabody Mus. Coll., Harvard University.
	2-6	Cave of Loltun, Yucatan, Sec. 1, Chamber 3. Artifact (c/2023) in Peabody Mus. Coll., Harvard University.
14	2-7	Labna, Yucatan, Md. 6 Late Classic Period. Artifact (c/2262) in Peabody Mus. Coll., Harvard University.
7	2-8	Green obsidian, Mitla, Oaxaca. Artifact (c/5917) in Peabody Mus. Coll., Harvard University.

Table 2 (cont'd.)

Site No. on Map 1	Sample No.	Source Locality
11	2-9	San Lorenzo, Lacantun R., Chiapas. Artifact in Peabody Mus. Coll., Harvard University.
6	2-10	Cuicuilco, D.F., Mexico. Tlalpan Phase (field cat. 769). University of California Collection.
20	2-11	"El Salvado." Artifact (30.0/2863) in Amer. Mus. Nat. Hist. Collection.
2	2-12	Green obsidian, Tula, Hidalgo. Mexico. Surface artifact. Artifact in Amer. Mus. Nat. Hist. Collection.
19	2-13	Copán, Honduras. Artifact in Peabody Mus. Coll., Harvard University.
34	2-14	Uaxaxtun, Depto. Petén, Guatemala. Stela A-7 cache, Late Classic Period. Artifact (33-99-20/3393) in Peabody Mus. Coll., Harvard University.
17	2-15	Benque Viejo, British Honduras. Artifact in Peabody Mus. Coll., Harvard University.
31	2-16	Seibal, Depto. Petén, Guatemala. Collected by J. Graham, 1965.
25	2-17	Iximche, Late Post Classic. Depto. Chimaltenango. Surface artifact collected by J. Graham and R. Heizer, 1965.
18	2-18	Nohoch Ek, Cayo Dist., British Honduras, Periods 4 and 5. Artifact in Peabody Mus. Coll., Harvard University.
14	2-19	Weston site 6, near Belize, British Honduras. Terminal Classic. Artifact (3-20232) in Peabody Museum Coll., Harvard University.
4	2-20	Obsidian source locality ("Mine") 2 km. NE of San Marcos, near Otumba, Estado de México. Collected by M. Spence, 1966.
3	2-21	Teotihuacán, Tlamimilolpa Phase. Site sector 21E:N5W1. Collected by J. Bennyhoff.
3	2-22	Teotihuacán, Tzacualli phase, Zona 5-9, Calle de los Muertos 0.199. Collected by Florencia Muller.
33	2-23	Tikal, Depto. Petén, Guatemala, Early Classic. Artifact (12C-408/29) in Univ. of Pennsylvania Mus. Collection.

Table 2 (cont'd.)

Site No. on Map 1	Sample No.	Source Locality
33	2-24	Tikal, Depto. Petén, Guatemala, Early Classic. Artifact (12K-164-18) in Univ. of Pennsylvania Mus. Collection.
33	2-25	Tikal, Depto. Petén, Guatemala, Late Preclassic. Artifact (12P-167/89) in Univ. of Pennsylvania Mus. Collection.
33	2-26	Tikal, Depto. Petén, Guatemala, Late Preclassic. Artifact (12P/138) in Univ. of Pennsylvania Mus. Collection.
33	2-27	Tikal, Depto. Petén, Guatemala, Middle Preclassic. Artifact (12P/152) in Univ. Penn. Mus. Collection.
33	2-28	Tikal, Depto. Petén, Guatemala, Early Classic. Artifact (127-226C/33) in Univ. Penn. Mus. Collection.
33	2-29	Tikal, Depto. Petén, Guatemala, Late Classic. Artifact (41F/2) in Univ. of Pennsylvania Mus. Collection.
33	2-30	Tikal, Depto. Petén, Guatemala, Early Post Classic. Artifact (98L/10) in Univ. Penn. Mus. Collection.
23	2-31	El Chayal, Depto. Guatemala, Guatemala. Sample from quarry.
24	2-31	Bilbao (Sta. Lucia Colzumahualpa), Depto. Escuintla, Guatemala. Surface artifact coll. by Graham, Heizer & Williams 1965.
34	2-33	Uaxactun, Tepeu phase, Depto. Petén, Guatemala. Artifact in Guatemala Museum of Archaeology Collection.
34	2-34	Uaxactun, Tepeu phase, Depto. Petén, Guatemala. Artifact in Guatemala Museum of Archaeology Collection.
28	2-35	Zacualpa, Depto. Quicha, Guatemala, Post Classic Period. Artifact in Peabody Mus. Coll., Harvard University.
28	2-36	Zacualpa, Depto. Quiche, Guatemala, Post Classic Period. Artifact in Guatemala Museum of Archaeology Collection.
30	2-37	Poptun, Depto. Petén, Guatemala. Late Classic Period. Artifact in Guatemala Museum of Archaeology Collection.
27	2-38	Utatlan, Depto. Quiche, Guatemala. Classic Period. Artifact in Peabody Mus. Coll., Harvard University.
29	2-39	Nebaj, Depto. Quiche, Guatemala. Classic Period. Artifact in Peabody Mus. Coll., Harvard University.

Table 2 (cont'd.)

Site No. on Map 1	Sample No.	Source Locality
32	2-40	Altar de Sacrificios, Depto. Petén, Guatemala. Artifact in Guatemala Museum of Archaeology Collection.
19	2-41	Piedras Negras, Depto. Petén, Guatemala. Classic Period. Artifact in Guatemala Museum of Archaeology Collection.
26	2-42	Agua Escondida, near lake, Depto. Solola, Guatemala. Artifact in Guatemala Museum of Archaeology Collection.
22	2-43	Kaminaljuyu, Depto. Guatemala, Guatemala. Artifact collected by R. Heizer and J. Graham, 1966.
22	2-45	Green obsidian, Kaminaljuyu, Depto. Guatemala, Guatemala. Early Classic (Tomb A-V). Artifact in Guatemala Museum of Archaeology Collection.
		Cenote of Sacrifice, Yucatan, Mexico. Artifact in Peabody Museum Collection, Harvard University.
15	2-46	Green obsidian, Chichén Itzá, Yucatan, Mexico. Artifact (c/5042) in Peabody Mus. Coll., Harvard University.
15	2-47	Chichén Itzá, Yucatan, Mexico. Artifact (c/5038) in Peabody Museum Collection, Harvard University.
15	2-48	Chichén Itzá, Yucatan, Mexico. Artifact (c/4919) in Peabody Museum Collection, Harvard University.
	2-49	Green obsidian, Lovelock Cave, Churchill Co., Nevada. Artifact (1-19208) in Univ. Calif. Lowie Mus. Collection.
8	3-1	Tres Zapotes, Veracruz, Mexico. Preclassic Period (?) (sub-ash cultural level Trench 26). Collected by P. Drucker and R. Heizer, 1967.
9	3-2	Site buried in sand dune near Roca Partida, Tuxtla Mts., Veracruz, Mexico. Probably Preclassic. Collected by J. Graham, R. Heizer, H. Williams, 1967.
9	3-3	Eroded site on beach near Punta Roca Partida, Tuxtla Mts., Veracruz, Mexico. Probably Preclassic.
19	3-4	Copán, Honduras. Classic Period. Surface artifact collected by R. Heizer, J. Graham, H. Williams, Feb. 1967.

Table 2 (cont'd.)

Site No. on Map 1	Sample	Source Locality
4	3-5A	Otumba, Estado de México, Mexico. Mine No. 1. Collected by Michael Spence, 1965.
4	3-5B	Otumba, Estado de México, Mexico. Mine No. 1. Collected by Michael Spence, 1965.
1	3-6A	Green obsidian, "Pachuca Mine No. 2," near Huasca, Hidalgo, Mexico. Collected by Michael Spence, 1965.
1	3-6B	Green obsidian, "Pachuca Mine No. 2," near Huasca, Hidalgo, Mexico. Collected by Michael Spence, 1965.

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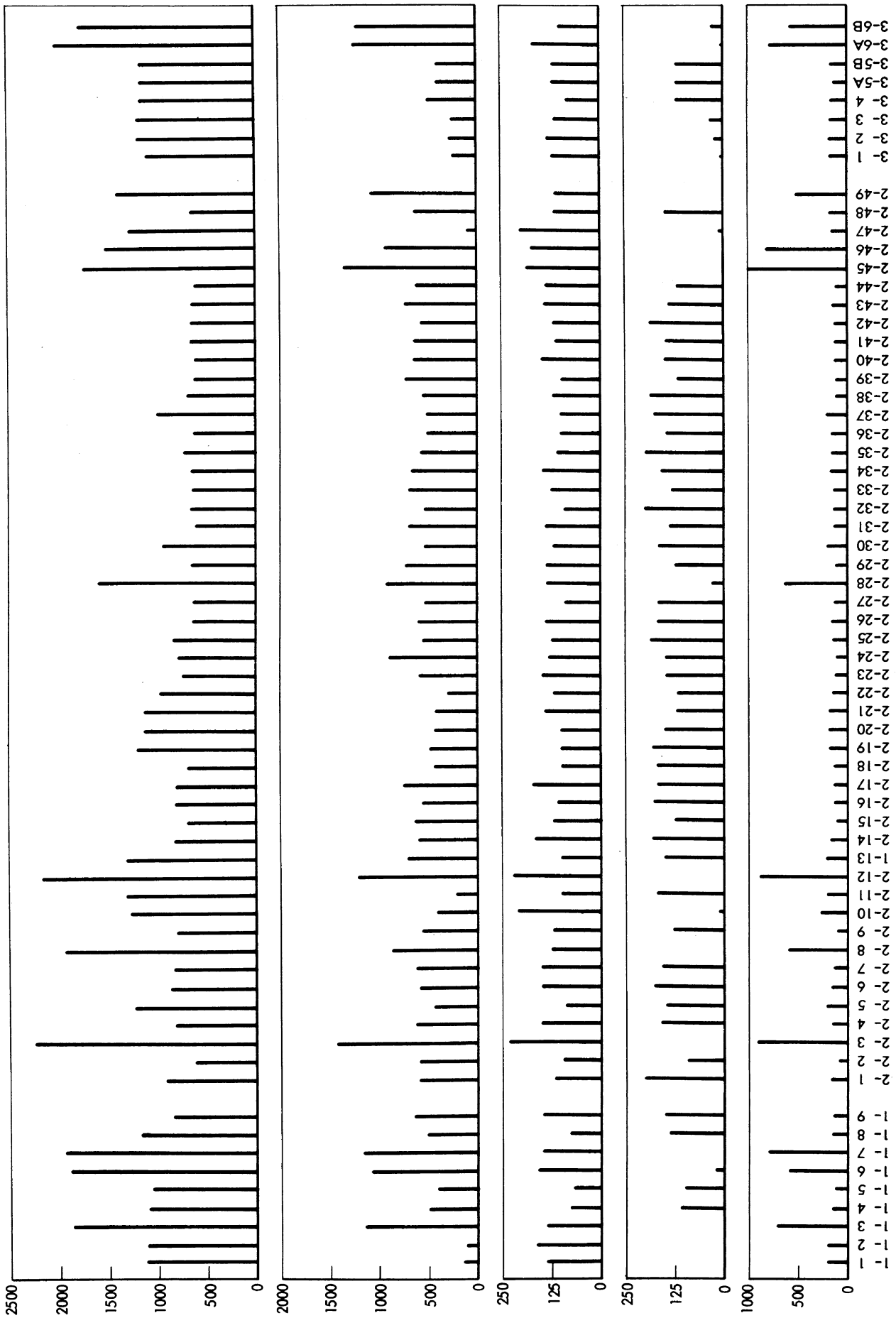

Figure 1. BAR GRAPH OF ANALYTICAL RESULTS

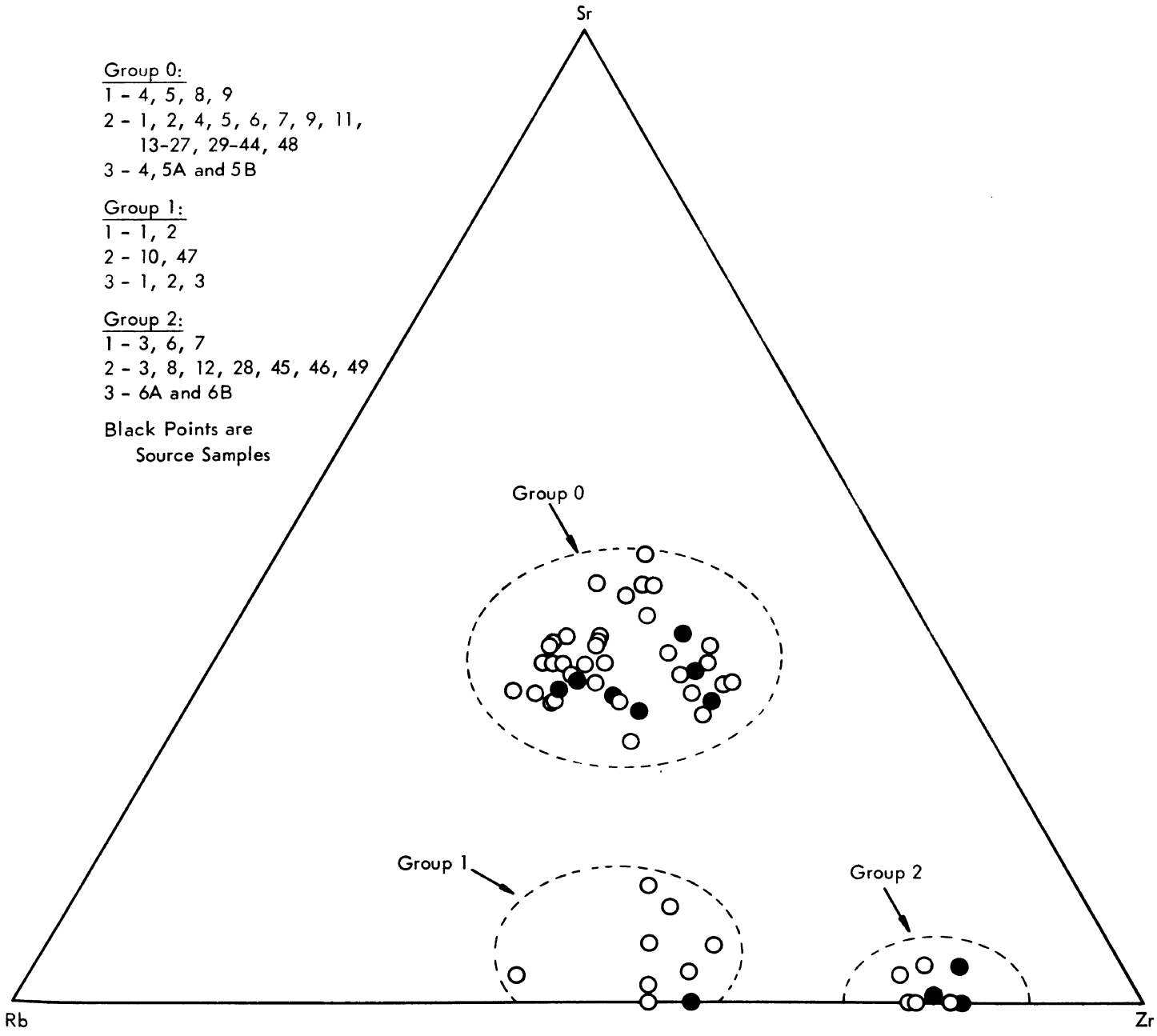

Figure 2. NORMALIZED RATIOS OF Zr-Sr-Rb

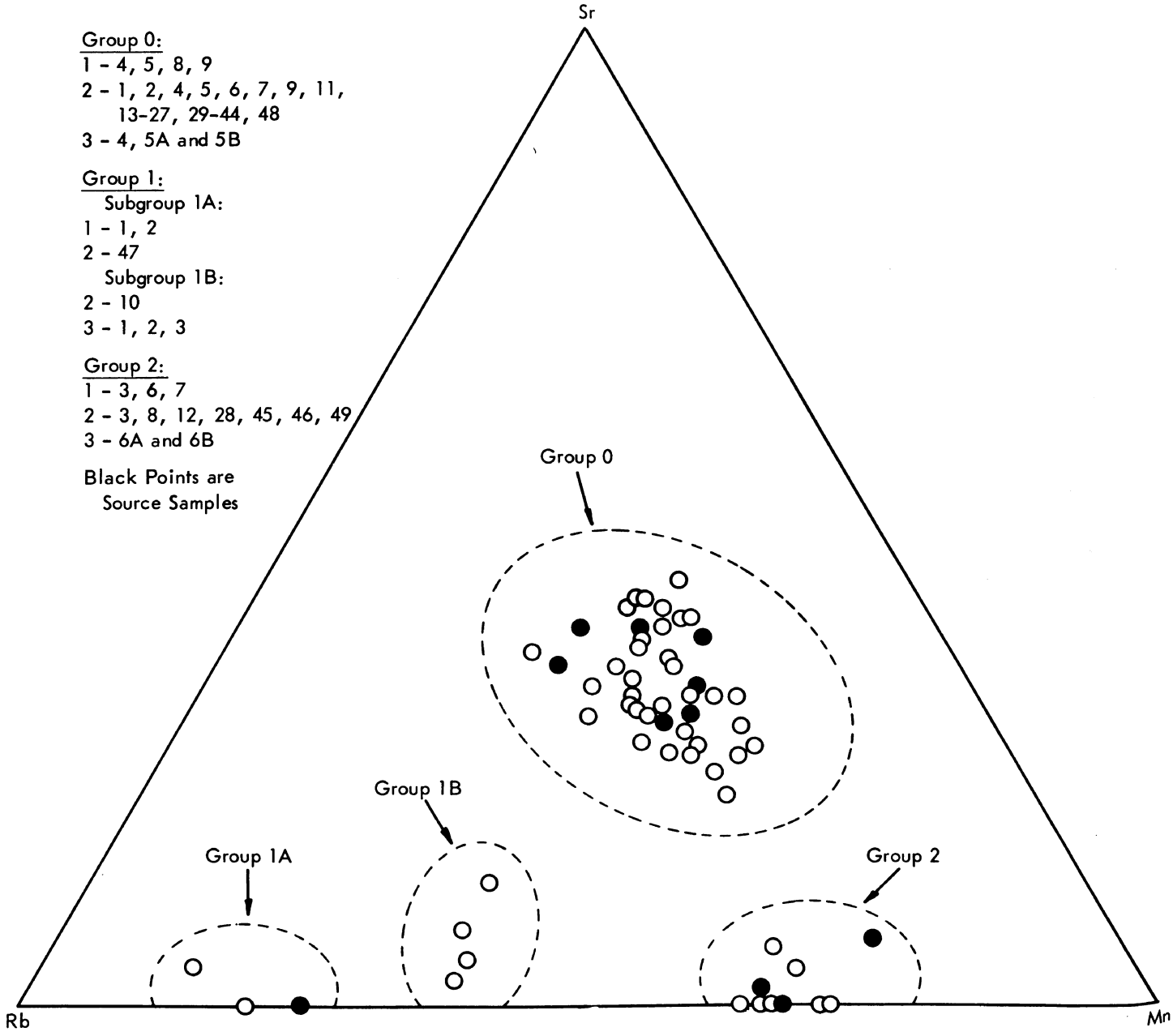

Figure 3. NORMALIZED RATIOS OF Mn-Sr-Rb

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