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The Graduate School

Department of Anthropology

Obsidian Studies and the Archaeology of the Valley of Guatemala

A Thesis in

Anthropology

by

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Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

November 1977

ABSTRACT

Pursuing the proposition that the social organization of the Valley of Guatemala was causally related to patterns of production and consumption of obsidian tools, three sets of hypotheses are examined in the present study. Two of these have to do with the territorial scope and nature of relationships of the Precolumbian chiefdoms of Kaminaljuyu, Amatitlan, and Chimaltenango. The third concerns obsidian redistributional patterns within the nuclear center of Kaminaljuyu.

Results of this study strongly support extant hypotheses on the spatial delimitation of the three chiefdoms but require an expansion of the criteria to characterize the interaction between them on a diachronic basis. There seem to be sufficient insights now regarding diverse instances of conflict apparently related to control over obsidian quarries and agricultural land.

Redistribution of obsidian in Kaminaljuyu during the Late Terminal Formative (1-200 A.D.) proves to be archaeologically detectable and testable following the rules of statistical inference. Besides, it is noted that redistribution phenomena cannot be considered a simple, homogeneous process throughout the studied society as a whole. Instead, the data examined suggest an uneven occurrence of redistribution, negatively related to sociopolitical ranking, among social subunits.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

Three research problems are studied in this thesis. The first has to do with patterns of obsidian distribution among archaeological sites in the Valley of Guatemala. Data on these patterns are observed in connection with the territorial parameters of the proposed three polities that shared the region in Precolumbian times (Michels 1976b, 1977b).

The second one deals with the nature of the relationships between these polities. The port-of-trade hypothesis elaborated by Brown (1975, 1977) covers the relationship between Kaminaljuyu and Amatitlan during the Middle Classic phase. No research yet undertaken, however, has been successful in defining the nature of these relations at other times.

Finally, the third problem concerns the internal structure of the Kaminaljuyu chiefdom itself. Since redistribution is regarded as the most pervasive characteristic of the economic configuration of chiefdoms (Service 1962), an attempt is made to measure the magnitude of redistribution that may have existed at Kaminaljuyu during the Late Terminal Formative.

The first two problems have been examined before by other investigators. Their research has produced a number of generalizing statements that constitute sets of hypotheses bearing upon the socio-political organization of the Valley of Guatemala. The third problem involves the general theory of chiefdoms.

The present study constitutes an explicit attempt to test some hypotheses associated with these three problem areas using novel data exclusively elicited from obsidian artifacts. Implicitly, this work is an exploration of the potential of obsidian source studies for archaeological research.

It has been proposed that three chiefdoms coexisted as distinctive political entities in the region centered in the Valley of Guatemala from Late Formative to Late Classic times (Michels 1976b). These chiefdoms were named Kaminaljuyu, Amatitlan, and Chimaltenango after the localities in which their respective nuclear centers were located. The territorial extent of these chiefdoms was also determined and actual boundaries within the Valley of Guatemala were drawn (Michels 1977b).

These boundaries are thought to have remained practically unchanged throughout the long span of 1500 years during which the three proposed polities interacted (ibid.). This seems a remarkable pattern of unperturbed coexistence that would have found its ultimate crystalization during the Middle Classic when mutual economic interests led to the institutionalization of a highland port of trade (Brown 1975, 1977) similar in many respects to the model that was first suggested by ethnographic and archaeological data from Dahomey (Arnold 1957) and Mesoamerica (Chapman 1957), and then formally elaborated by Polanyi (1963).

Such a model relies heavily on the concept of long-distance trade as an administered institution mainly reserved for luxury items and their raw materials. It is supposedly carried out by an elaborate professional organization, like the Pochteca of the Aztec empire, and is largely dependent on the establishment of locational foci where the exchange transactions take place. Brown's thesis is that the valley of Guatemala was one of these enclaves in Mesoamerica during the Middle Classic.

The data examined by Brown strongly support such interpretation. However, given that his study mainly focused upon the Middle Classic the results of his research could not be applied to other times. Consequently, an attempt to find clues regarding the interaction between the three Guatemalan chiefdoms in a diachronic perspective seemed justified.

This is done here by looking for significant departures from the prevalent patterns of obsidian types distribution in the region studied. These departures are interpreted in reference to sociopolitical and economic relationships between the three proposed polities, an endeavor that was significantly assisted by an expanded chronological control attained by means of source-specific obsidian hydration dates.

Pursuing the proposition that Kaminaljuyu was a Polynesian-type chiefdom, first proposed by Sanders (1969), Michels established that the spatial configuration of the site's architectonic remains closely resembles a conical clan-type chiefdom.

Michels pursued the hypothesis further by examination of settlement pattern data and an evaluation of the artifact assemblages recovered through excavation (Michels 1976a, 1977a, 1977b).

These data have suggested a well-defined sociopolitical organization that found physical expression in the layout of the site.

Five ranked subchiefdoms, supposedly controlled by lineages were distinguished, each divided into two moieties. Two of these lineages, El Incienso and Santa Rosita, were component units of a distinctly larger intermediate segment of the society which Michels calls the Northeast District. The other three lineages--Caterina Pinula, San Carlos, and Mixco--composed the Southwest District.

Michels' reconstruction seemed sufficiently explicit as to appeal to the kind of test that was to be implemented. Thus, each of the ward subunits were sampled for obsidian artifacts that had been dated in the Late Terminal Formative. This was done following the spatial divisions proposed by Michels.

A single phase in the culture-historical sequence of the site was selected not only to increase sample size, thus permitting an analysis based on statistical inference, but also in order to perform an intense synchronic study. The Late Terminal Formative was preferred because in this period Kaminaljuyu could be considered still free of any major external influence that might have affected its pristine development.

Background information and more detailed discussions on each of these problems will be inserted as an introduction to the relevant chapters in this work. Also, some of the analytical parameters will be included in these. This is done in order to keep each research problem as self-contained as possible.

A by-product of this research is the estimation of a hydration rate for the obsidians that originate in the general area between Chimaltenango and Aldea Choatalum, department of Chimaltenango, that are given the generic name of Chimaltenango. The treatment of this particular subject is part of the chapter on methodology. Another by-product, having to do with the generation of a hierarchical taxonomy of obsidian types from sources in the central highlands of Guatemala, constitutes a separate chapter.

As stated before, the data on which this work is based come exclusively from obsidian material. Besides the obsidian artifact samples obtained from archaeological contexts, a control sample of obsidian source specimens obtained from a number of source localities throughout the region has been included. Both the natural and artifactual samples were intendedly increased in size as much as possible but this was limited by the actual availability of time and material resources. The samples, nevertheless, include material from no less than 80 sites. More than 50 of these are archaeological and all of them are spread over an area of about 4600 km^2.

Dated obsidians indicate that at least 11 consecutive culture-historical phases are represented, from the late Archaic to Modern times, spanning over more than 4000 years of human occupation.

Obsidian artifacts have already proved to be a powerful means by which to detect major features of the social and economic subsystems of ancient societies. Patterns of distribution of obsidian types among defined social subunits have been observed to covary with the level of sociocultural integration of the society as a whole (Winter and Pires-Ferreira 1976) and with social rank affiliation of these subunits (Johnson 1976b). These works have suggested the elaboration of an objective measure of these social phenomena rendering social structure much more visible to archaeologists.

The results of this study can be classified into two major categories. The first comprises those results that simply test the validity of extant hypotheses. The second, results that provide new insights as to suggest the modification of some hypotheses, or propose new ones.

Hypothesis testing necessarily leads to the generation of new hypotheses. Thus, the results of this study are seen to suggest a modification of diverse concepts prevalent in the theory of redistribution and of the composition of chiefdoms. This is not intended to challenge those hypotheses. Instead, the primary concern is to attain an expansion of our knowledge of the past so that the archaeology of the Valley of Guatemala may be included as a sound and crucial case study that helps to reach the common goal of achieving explanation of cultural phenomena.

II. METHODOLOGY

Introduction

No thorough treatment of the general method used in this work is attempted in this chapter. The present research is not primarily methodological in purpose although this particular application may be found to constitute a contribution of some sort. Instead, reasonably accepted techniques to record, gather, and analyze the corpus of data that are needed have been used, without justifying them as methods themselves.

All that can be said as an apology for the techniques used here is that they are, in a sense, still within the same basic category of tools of measurement together with scaled microscopes, calipers, and metric tapes. The measurements, however, thanks to the level of sophistication of these techniques, are highly accurate. Yet, they still have an expected margin of error. However, these measurements have reached a level of comparativity which would be almost unattainable using other available techniques. In this sense, these methods, or analytical tools, are novel and considering the results obtained they surely expand the possibilities of archaeological research whenever trace elemental studies are called for.

A description of the techniques used in this study may be organized within two major spheres of analysis: contextual and specific.

Contextual analysis, on one hand, is represented by a carefully controlled sampling observation and a more explicit gathering of material by means of excavation and surface collections. Also, extensive chronological controls were achieved by means of obsidian hydration date determinations. In both instances, this study has profitted extensively on the field and laboratory work of members of the Kaminaljuyu Project. Obsidian artifacts recovered from test trenches performed at the site of Kaminaljuyu during the field work seasons between 1968 and 1970 constitute the sample to look upon the internal structure of the Kaminaljuyu chiefdom. These were all dated specimens processed in The Pennsylvania State University Obsidian Dating Laboratory.

All other aspects of this work required short-term field work to sample both obsidian source localities and rural archaeological sites in the central highlands of Guatemala. The geochemical characterization of these specimens and their dating were part of the present project. This included an estimation of a hydration rate for the Chimaltenango obsidian, thus expanding chronological control to about 96 per cent of all the obsidian material utilized in the region studied.

Specific analysis, on the other hand, was more directly concerned with the particular nature of the research problems examined. These called for a reliable means of classification of obsidian types. Interest was beyond the simple correlation of artifacts with given obsidian sources. It was, thus, necessary to discriminate among different flows within a major geologic source. Given this need, the focus was strictly on the geochemical characterization of the obsidians included in the samples, by means of neutron activation analysis.

It was performed using the facilities of The Pennsylvania State University Breazeale Nuclear Reactor.

The data obtained proved highly adequate for a multivariate statistical classification, thus yielding objective criteria for a taxonomy of obsidian types at four inclusive levels of similarity. Such outcome called for a modification of the obsidian source concept in archaeology, with connotations of indisputable utility for geology as well.

Field Work and Sampling

This section mainly describes the acquisition of the obsidian material that constitutes the geologic source samples and the archaeological obsidian specimens. Geologic source samples will be called "source specimens" and archaeological material will be referred to as "artifact specimens."

In order to have an objective basis for the comparison of the artifact specimens found in archaeological sites, it was first necessary to attempt a determination of the geochemical characteristics of the material that was thought to have been used by Precolumbian populations. Thus, a first major concern was to sample all the natural obsidian sources that could be located within a geographical perimeter that was reasonably accessible to the inhabitants of the valley of Guatemala. Also, the intention to test the validity of hypotheses on the sociopolitical configuration of the valley called for a sampling of many rural archaeological sites in the territory thought to have been controlled by each of the three proposed polities.

A short field survey was thus undertaken during the summer months of 1976 to sample obsidian source localities and archaeological sites in the region delineated in the map shown in Figure 1. The survey did not include excavation operations. The sites sampled and recorded were located on the basis of their surface visibility. The survey yielded 79 sampled localities. Forty-seven of these produced source specimens (Table 1) and 52 yielded artifact specimens" (Table 2). A number of sites had both source and artifact specimens. These are locations where quarry or reduction operations took place leaving behind evidence of human utilization.

The sample of source specimens amounts to 179 specimens. Of these, 32 were also selected to represent source systems in the collateral analysis to determine contents of sodium and manganese in the obsidians studied. The artifacts from valley sites total 262. To these, a third sample of 166 dated specimens from the site of Kaminaljuyu is added. This third sample (Table 3) represents the Late Terminal Formative (0-200 A.D.). The tables listing the number of specimens included in each sample also provide entry numbers for sites. Names and locational data agrees with the standard nomenclature for the Kaminaljuyu Project (Sanders and Michels 1969: 7-11). Zones and Areas are numbered. Sectors are not considered. Since the area originally considered by the Kaminaljuyu Project had to be expanded to include most obsidian sources in the region, the new Zones were given numbers that would not conflict with the original system. This expansion is shown in Figure 1. It will be used for all purposes of horizontal provenience control in this work hereinforth.

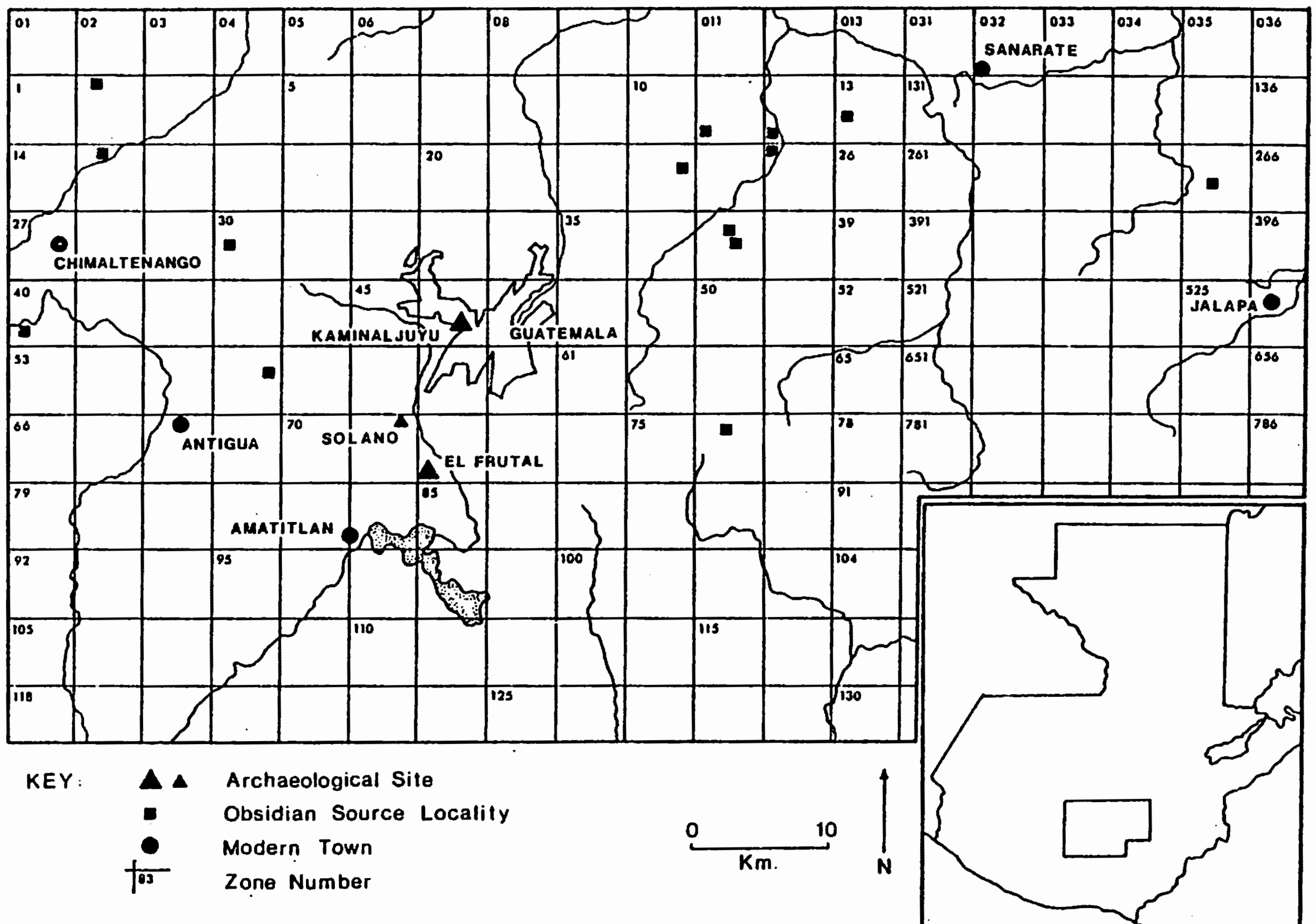


Figure 1. The Central Highlands of Guatemala.

Table 1. Provenience of Obsidian Source Specimens

Locality	Z-A-S[a]	Name	n (2)[b]
00	25-00	Chayal Chipping St.	5
01	12-40	Cerro Chayal	20
02	23-24	El Fiscal	6 (1)
03	24-14-398	Matuloj	5 (1)
04	13-02	San Antonio La Paz	5 (1)
3	12-40	Km 24	2
4	13-21	San Antonio (N)	2
5	13-31	San Antonio (S)	1
6	13-31	Barranco del Viejo	2
7	13-32	El Remudadero	2 (1)
8	13-32	El Chorro	2
9	13-31	Las Vacas	2
10	12-31	Agua Caliente	1
11	12-40	Km 25	1 (1)
12	24-13	Azacualpilla	3 (1)
13	24-40	Km 19	5 (1)
14	24-40	Ruta 6	3 (1)
15	24-41	Rio Canas	3 (1)
16	34-12	La Joya	5 (1)
17	34-12	Las Vacas (Palencia)	5 (1)
18	37-23	Palencia	5 (1)
20	23-14	Mogollon	3
21	23-04	Piedra Gorda	2
22	11-40	La Periquera	5 (1)
23	11-31	San Jose del Golfo	3 (1)
25	11-12	El Pinal	4 (1)
29	30-04	Cruz de Apan	3 (1)
32	41-40	Finca Panal	1
43	40-24	Los Aposentos	1
44	40-13	Santa Monica	1
45	40-31	San Andres Itzapa	3 (1)
46	15.02	Pixcaya	4
47	15-02	Quemaya	5 (1)
48	28-30	Departamental 1	1
50	15-41	El Rosario	1
52	2.01	San Martin J.	4 (1)
54	56-24	Finca Matilandia	8 (1)
55	84-41	Amatitlan	1
56	98-21	El Cerrito	2 (1)
59	99-12	Tapacun	4 (1)
68	75-24	Hacienda Nueva	2 (1)
69	76-02	Agua Tibia	2 (1)
70	50-00	Los Mixcos	6 (1)
73	37-12	El Pedrero 1	8 (2)
74	37-12	El Pedrero 2	5 (1)

Table 1. Continued

Locality	Z-A-S[a]	Name	n ( )[b]
75	265-22	La Joyita	5 (1)
76	265-22	Los Mezcales	5 (1)
99	999-99	Las Animas	5 (2)

[a]The Zone-Area-Sector grid system for the Valley of Guatemala is described in Sanders and Michels (1969).

[b]Collateral subsample used for Na,Mn analysis.

Table 2. Provenience of Obsidian Artifacts from Valley Sites

Site Number	Zone-Area	Name	n
4	13-21	San Antonio la Paz	1
10	12-31	Agua Caliente	7
10a	12-31	Cementerio	5
14	24-40	Ruta 6	2
15	24-41	Rio Canas	2
19	23-44	El Chato	3
20	23-14	Mogollon	2
21	23-04	Piedra Gorda	3
23	11-31	San Jose del Golfo	2
24	11-01	Las Curenas	3
25	11-12	El Pinal	1
26	5-34	Lo de Ruiz	1
27	6-12	Los Queche	1
28	30-04	La Finquita	1
29	30-04	Cruz de Apan	3
30	17-43	Los Pajoc	4
31	30-21	Xenacoj	2
34	67-24	San Lorenzo el Cubo	7
35	67-13	San Antonio Aguas Calientes	2
36	67-02	Santa Catarina Barahona	5
37	82-20	Santa Maria de Jesus	7
38	44-41	San Lucas Sacatepequez	10
39	57-33	La Embaulada	8
41	66-44	San Sebastian	13
42	54-00	Parramos	4
43	40-24	Los Aposentos	16
44	40-13	Santa Monica	1
45	40-31	San Andres Itzapa	1
49	28-20	Departamental 1	4
51	2-21	Chojoma	4
52	2-01	San Martin Jilotepeque	5
53	57-20	San Jose Buena Vista	5
54	56-24	Matilandia	2
55	84-41	Amatitlan	8
56	98-21	El Cerrito	6
57	71-44	Villa Nueva	8
58	86-41	San Jose El Tablon	7
59	99-12	Tapacun	8
60	99-22	Las Victorias	7
61	111-23	Santa Elena Barillas	7
62	112-04	Santa Rosita	6
63	113-20	La Concha	5
64	73-10	Boca del Monte	6
65	60-33	Santa Catarina Pinula	5
66	60-34	El Pilar	8

Table 2. Continued

Site Number	Zone-Area	Name	n
67	75-13	San Jose Pinula	6
68	75-24	Hacienda Nueva	1
69	76-02	Agua Tibia	10
70	50-00	Los Mixcos	9
	69-24	Magdalena	3
	70-10	Magdalena	2
	72-40	El Frutal	13

Table 3. Obsidian Artifacts from Kaminaljuyu, by Lineages, Late Terminal Formative (0-200 A.D.)

Lineage/Ward	Moiety	Test-Pits Sampled	Number of Specimens	Total
El Incienso	A	14	16	
	B	26	44	60
Santa Rosita	A	10	17	
	B	10	13	30
Santa Catarina Pinula	A	5	6	
	B	–	–	6
San Carlos	A	5	12	
	B	1	1	13
Mixco	A	19	30	
	B	14	27	
Total		104		166

Note: Dates and provenience of individual specimens in Appendix 1.

Chronological Control

Table 4 lists the El Chayal obsidian specimens from valley sites that have been dated by measuring their hydration rim thickness. The hydration rate used for these determinations is equal to 7.03 μ^2/1000 years. Table 5, on the other hand, lists the Chimaltenango obsidian artifacts from valley sites that were dated by using a hydration rate equal to 6.16 μ^2/1000 years. The particularities of estimating a hydration rate constant for the Chimaltenango obsidians are described below.

Given the fact that this is a source-specific hydration rate, only attainable after the obsidian artifacts had been geochemically identified, it is considered necessary to use data on the geologic origins of obsidian artifacts which will be discussed later.

Obsidian hydration dating is proving to be a very effective technique in age determinations of archaeological assemblages in the Valley of Guatemala. Based on the experimentally demonstrated process of hydration defined by the so-called Friedman's rate equation (Friedman and Smith 1960; Friedman and Long 1976), it has been possible to establish a hydration rate for El Chayal obsidian (Michels 1973). The reliability of this hydration rate was tested by calibrating hydration rim measurements in obsidian artifacts with contextually associated radiocarbon dates covering a time span of about 1300 years.

The chemical composition of the obsidians in the site of Kaminaljuyu, from which the samples were taken, was found to be highly homogeneous and corresponding to the El Chayal source system in 95 per cent of the cases (Hurtado de Mendoza 1973b). This figure reflects very well the pattern that is prevalent in practically all

Table 4. El Chayal Obsidian Hydration Dates: Provenience Data (hydration rate constant = 7.03 μ^2/1000 years)

Site Number	Zone-Area	Specimen Number	Micron Value	Date
4	13-21	4 -11	1.86	1485 A.D.
10	12-31	10 -12	1.44	1682 A.D.
		10 -13	5.06	1665 A.D.
		10 -14	1.83	1501 A.D.
		10 -15	3.00	694 A.D.
10a	12-31	10a-11	4.56	987 B.C.
		10a-12	5.06	1665 B.C.
		10a-13	6.40	3853 B.C.
		10a-14	5.13	1767 B.C.
		10a-15	5.20	1874 B.C.
37	82-20	37 -11	2.69	948 A.D.
		37 -12	2.38	1174 A.D.
		37 -13	3.25	477 A.D.
38	44-41	38 -22	2.28	1237 A.D.
41	66-44	41 -13	2.64	986 A.D.
		41 -15	2.54	1059 A.D.
		41 -16	2.32	1211 A.D.
		41 -17	1.91	1456 A.D.
		41 -18	3.17	549 A.D.
		41 -19	2.76	893 A.D.
		41 -20	3.00	694 A.D.
43	40-24	43 -11	2.49	1092 A.D.
55	84-41	55 -11	5.43	2223 B.C.
		55 -11	5.09	1708 B.C.
		55 -12	4.10	418 B.C.
		55 -13	3.65	80 A.D.
		55 -14	2.85	822 A.D.
		55 -15	2.17	1307 A.D.
		55 -16	3.18	539 A.D.
		55 -17	2.98	714 A.D.
		55 -18	3.76	34 B.C.
56	98-21	56 -12	2.94	750 A.D.
		56 -13	0.75	1897 A.D.
		56 -13	0.95	1854 A.D.
		56 -15	1.36	1712 A.D.
		56 -16	1.04	1823 A.D.
		56 -16	0.91	1860 A.D.
67	71-44	57 -11	4.28	627 B.C.
		57 -12	3.87	157 B.C.
		57 -13	3.27	459 A.D.
		57 -14	3.86	144 B.C.
		57 -15	2.98	713 A.D.
		57 -16	3.44	291 A.D.

Table 4. Continued

Site Number	Zone-Area	Specimen Number	Micron Value	Date
		57 -17	3.02	675 A.D.
		57 -18	3.12	589 A.D.
58	86-41	58 -11	3.62	110 A.D.
		58 -12	2.07	1369 A.D.
		58 -13	3.44	294 A.D.
		58 -14	3.48	256 A.D.
		58 -14	3.81	89 B.C.
59	99-12	59 -11	2.95	742 A.D.
		59 -13	2.59	1019 A.D.
		59 -16	2.43	1135 A.D.
		59 -17	2.60	1016 A.D.
		59 -21	3.65	80 A.D.
		59 -23	0.79	1888 A.D.
		59 -24	0.00	
60	99-22	60 -15	3.10	608 A.D.
		60 -16	1.87	1479 A.D.
		60 -25	2.25	1255 A.D.
		60 -26	1.01	1833 A.D.
		60 -27	2.12	1340 A.D.
61	111-23	61 -28	3.34	389 A.D.
		61 -30	4.09	405 B.C.
		61 -31	0.00	
62	112-04	62 -11	2.87	780 A.D.
		62 -12	0.68	1911 A.D.
		62 -14	2.06	1374 A.D.
63	113-20	63 -09	2.47	1109 A.D.
		63 -10	1.81	1509 A.D.
		63 -11	0.70	1907 A.D.
		63 -12	3.49	247 A.D.
		63 -13	0.85	1873 A.D.
		63 -15	3.63	107 A.D.
		63 -32	2.45	1124 A.D.
		63 -33	3.12	593 A.D.
		63 -35	2.09	1353 A.D.
64	73-10	64 -10	0.00	
		64 -14	0.00	
		64 -15	3.04	660 A.D.
		64 -15	3.38	355 A.D.
		64 -16	2.68	953 A.D.
		64 -16	3.50	236 A.D.
65	60-33	65 -12	0.00	
		65 -13	3.83	108 B.C.
		65 -14	3.41	323 A.D.

Table 4. Continued

Site Number	Zone-Area	Specimen Number	Micron Value	Date
66	60-34	66 -11	1.97	1425 A.D.
		66 -12	3.19	529 A.D.
		66 -13	1.21	1769 A.D.
		66 -14	3.02	675 A.D.
		66 -15	3.08	628 A.D.
		66 -16	3.08	628 A.D.
		66 -17	3.83	110 B.C.
		66 -18	4.20	532 B.C.
67	75-13	67 -11	2.10	1349 A.D.
		67 -12	2.67	961 A.D.
		67 -13	5.66	2588 B.C.
		67 -14	2.69	944 A.D.
		67 -15	2.86	813 A.D.
		67 -16	2.74	910 A.D.
69	76-02	69 -11	2.45	1121 A.D.
		69 -12	2.94	750 A.D.
		69 -17	2.21	1282 A.D.
77	133-34	77 -14	4.41	793 B.C.

Table 5. Chimaltenango Obsidian Hydration Dates: Provenience Data (hydration rate constant = 6.16 μ^2/1000 years)

Site Number	Zone-Area	Specimen Number	Micron Value	Date
28	30-04	28-11	1.90	1391 A.D.
34	67-24	34-12	2.28	1133 A.D.
		34-13	0.00	
		34-14	0.00	
		34-11	3.09	427 A.D.
		34-15	3.68	221 B.C.
		34-16	4.21	900 B.C.
		34-17	3.72	269 B.C.
36	67-02 a	36-11	2.98	535 A.D.
	67-02 c	36-14	3.70	245 B.C.
		36-15	3.04	477 A.D.
		36-15	2.87	640 A.D.
37	82-20 b	37-14	4.41	1180 B.C.
38	44-41 a	38-11	1.31	1698 A.D.
		38-11	1.00	1815 A.D.
	44-41 c	38-21	1.75	1480 A.D.
		38-23	0.00	
		38-24	2.42	1026 A.D.
39	57-33 a	39-16	3.53	46 B.C.
		39-16	4.15	819 B.C.
		39-15	3.60	127 B.C.
41	66-44 b	41-17	3.10	417 A.D.
43	40-24 a	43-13	1.97	1347 A.D.
		43-13	2.28	1133 A.D.
		43-15	1.87	1409 A.D.
		43-15	2.18	1205 A.D.
		43-16	2.20	1191 A.D.
	40-24 b	43-16	2.79	722 A.D.
		43-17	2.53	938 A.D.
		43-20	3.44	56 A.D.
51	2-21	51-11	0.00	
		51-12	2.96	555 A.D.
		51-13	0.00	
		51-14	3.54	57 B.C.
		51-14	3.61	139 B.C.
53	57-20	53-11	2.86	649 A.D.
		53-12	2.55	921 A.D.
		53-13	1.37	1672 A.D.
		53-14	2.37	1065 A.D.
54	56-24	54-12	1.48	1621 A.D.
		54-12	2.71	785 A.D.

rural sites within the territories thought to have been under the control of the Kaminaljuyu and Amatitlan chiefdoms (Table 6).

However, sites within the realm of a third chiefdom, which is being called Chimaltenango (Michels 1976b), show that only 18 per cent of their obsidians are from El Chayal. The larger proportion of these are from the system of quarries located in the general area between the town of Chimaltenango and Choatalum (see Chapter III). This source system has been given the more general name of Chimaltenango in an attempt to overcome the confusion arising from the variety of names being used in the specialized literature.

All source determinations for obsidians are based on neutron activation analysis whose results are described in Chapter III. From the data in Table 6 it is apparent that a very high proportion of the obsidians from sites in the valley and surrounding area correspond to either the El Chayal or the Chimaltenango source systems. In order to provide further chronological controls for archaeological assemblages in the region, a hydration rate for Chimaltenango obsidian was determined.

An accepted method to determine an obsidian hydration rate for dating purposes is to correlate hydration rim measurements with an independent chronometric scale (Johnson 1969). Here, such an independent scale is based on a number of El Chayal obsidian dates which were found in association with Chimaltenango obsidian artifacts. Both the El Chayal dates and the Chimaltenango obsidian hydration rims were measured and processed at the Obsidian Hydration Dating Laboratory at The Pennsylvania State University.

Table 6. Distribution of Obsidian Types among Chiefdoms in the Valley of Guatemala

Chiefdom	Source Systems: El Chayal	Chimal-tenango	Amatitlan	Other
Kaminaljuyu (15)[a]	49	-	-	2
Chimaltenango (21)	29	71	3	2
Amatitlan (18)	99	2	2	3
Totals	177	73	5	7

[a]Number of sites sampled, in parentheses; all in rural areas except for Solano and El Frutal in Amatitlan chiefdom territory.

Acceptable contextual associations between both El Chayal and Chimaltenango obsidians were found at only four sites. Three of these are in the Chimaltenango chiefdom territory. The fourth is in the southwestern part of the Kaminaljuyu chiefdom, close to the border with Chimaltenango (Table 7).

All four sites yielded El Chayal obsidian dates and presumably contemporaneous artifacts made of Chimaltenango obsidian. Hydration measurements obtained from these were utilized as reference points for an analysis by the least squares method.

Since the hydration process is exponential in the sense that it is ever decreasing, the regression line is curvilinear and defined by the exponential prediction equation of the form:

$$y = a \cdot x^b$$

Table 7. El Chayal Obsidian Dates and Chimaltenango Obsidian Hydration Measurements

Provenience						
Site Number	Zone-Area	Years B.P. (P=1977)	Log x	No. of Specimens	Mean Microns	Log y
38	44-41	740	2.869	2	2.085	0.319
43	40-24	885	2.947	3	2.220	0.346
41	66-44	1428	3.155	1	3.100	0.491
39	57-33	1715				
		2292[a]	3.302	2	3.565	0.552

[a]Mean date of activity = 2003 B.P.

where y is the hydration thickness in microns; x is the time in years; a is the y-intercept coefficient; and b is the slope coefficient.

To convert this relation into linear a logarithmic power function is used. It is defined by the linear regression equation:

$$\log y = \log a + b(\log x)$$

When this is solved we get: $\log a = -1.313$; $b = 0.567$; and $r = 0.99$ (Pearson's product moment correlation coefficient). A graphic representation of these is given in Figure 2.

Notice that the value of b is not 0.5 as in the hydration equation proposed by Friedman and Smith (1960). In all likelihood, this outcome is an artifact of the data. These, mounting to only four pairs of values, may not be sufficient. Nevertheless, if the value of log y is estimated, given x = 1000 years, we obtain 0.388. The antilogarithm of this value corresponds to y = 2.44 μ, which when squared provides an estimated hydration rate of 5.95 μ^2/1000 years.

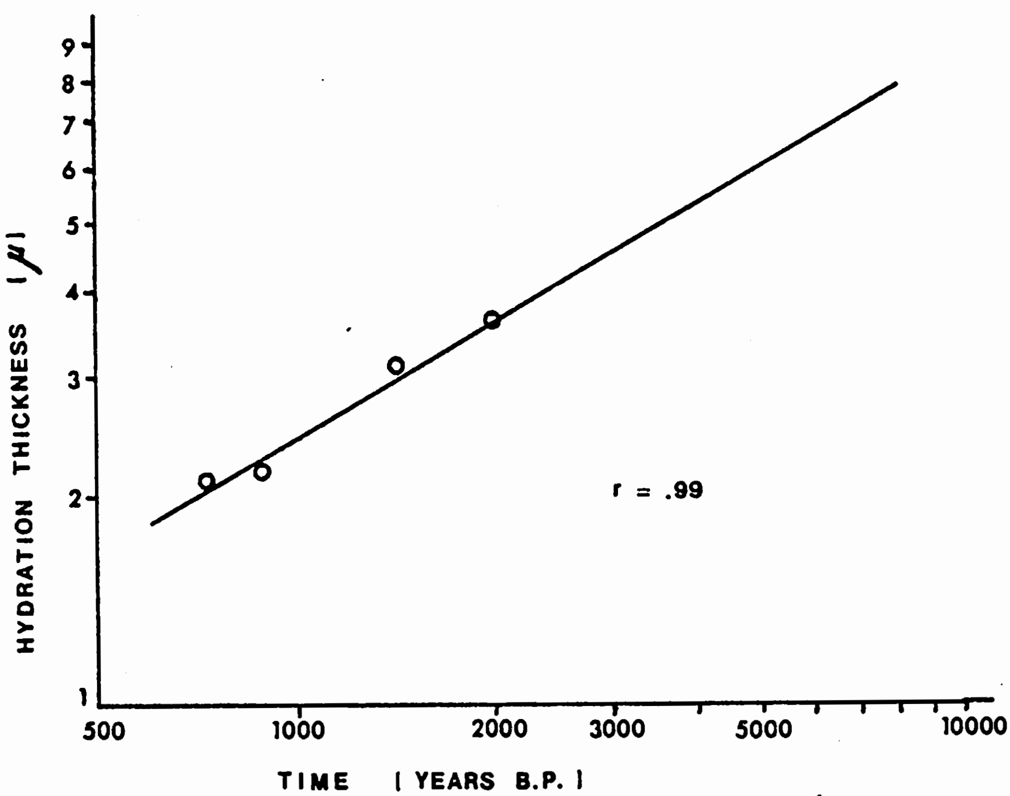


Figure 2. Least-Squares Regression Line for El Chayal Obsidian Hydration Dates (x-axis) and Chimaltenango Obsidian Hydration Rim Measurements (y-axis). Data points represent four sites on the western side of the Valley of Guatemala; r is the product moment correlation coefficient.

LeRoy Johnson (1969) also obtained a slope coefficient ($b = 0.512$) slightly inconsistent with Friedman's equation in his calculation of the hydration rate for obsidians in the Klamath basin. He preferred to substitute Friedman's experimentally determined $b = 0.5$ for the one that he found using the same method applied here. Such procedure led also to the substitution of the value for log a, since it is dependent upon the value of b.

If a similar substitution is made here, the new value for log a is -1.104, and the new estimated log y = 0.396. The hydration rate for the Chimaltenango obsidian then, would seem to be 6.20 μ^2/1000 years. This is obtained, as above, using the linear regression equation to solve for y, given log x = 3.0, and then calculating its corresponding square.

But this rate of hydration also can be determined by using the exponential prediction equation:

$$y = 0.785(1000)^{.5}$$

and solving for k in Friedman's equation:

$$H^2 = kt$$

where $2.482 = y = H$; $k = a^2$; $t = x$; and .5 (exponent of t) = b; or

$$k^{.5} = 2.482/1000^{.5}$$

which yields $k = 0.00616$. Therefore, the estimated hydration rate for the Chimaltenango obsidian, otherwise known as Aldea Chatalun, San Martin Jilotepeque, and Pixcaya, is 6.16 μ^2 per 1000 years.

The occupational time span at sites within the Chimaltenango chiefdom territory, as suggested by 14 El Chayal obsidian dates in five of these sites, has been used to test the applicability of this hydration rate in an archaeological context.

These dates span from 521 B.P. to 2292 B.P. with an average date of activity around 1140 B.P. There are, on the other hand, 36 Chimaltenango obsidian hydration measurements for 11 sites in the same territory. After excluding three of these measurements due to their extremely disparate clustering in the distribution, it was possible to obtain a range of values between 1.00 μ and 3.72 μ, with a mean micron value of 2.63.

If this mean is considered to be relatively contemporaneous with the observed average age determined by the El Chayal obsidian dates, a rate can be estimated as follows:

$$\text{Hydration Rate} = 2.63^2\ (1000)/1140$$

which yields 6.05 μ^2/1000 years.

This value does not differ substantially from the previously found 5.95 μ^2, or the determined 6.16 μ^2. The applicability of the latter, then, is possible within certain limits. Namely, since the range of the El Chayal obsidian dates used in the least squares analysis does not exceed 1300 years, any extrapolation of the rate beyond this range would need further substantiation. The use of either one of these hydration rates does not affect significantly the age determinations within that range, but it certainly does affect it for artifacts with a hydration rim thickness that suggests dates earlier than 1000 B.P. The difference observed in such cases exceeds 100 years.

Nevertheless, the success obtained in estimating a hydration rate for Chimaltenango obsidians represents a significant step toward the ultimate goal of a generalized use of obsidians for dating archaeological assemblages in Guatemala. Source-specific hydration rates, to be applied within relatively homogeneous climatic regions, are obviously needed. This is especially true for sites which clearly contain obsidians of diverse geologic origin. Once a chronometric scale is established for an obsidian type, it should be possible to estimate the hydration constant for all other types, provided they are found in clear contextual association.

Geochemical Characterization of Obsidians

The adoption of neutron activation techniques by archaeologists is relatively new. The late fifties witnessed their application to pottery after realizing the feasibility of identifying the clay sources used in ceramic vessels (Sayre and Dodson 1957; Sayre et al. 1958; Emeleus 1958, 1960). These procedures were cautiously used by some other investigators much more recently (Bennyhoff and Heizer 1965; Perlman and Asaro 1969; Al Kital et al. 1969; Harbottle 1970; Sayre and Chan 1971). Parallel efforts were directed toward other kinds of archaeological remains such as ancient coins (Ravetz 1963; Gordus 1971), copper artifacts (Friedman et al. 1966; Fields et al. 1971), and color pigments from the Precolumbian murals in Cholula and Teotihuacan (Ortega and Lee 1970). The main emphasis, however, has been put on the identification of obsidian artifacts recovered from archaeological sites with respect to their geologic source. These studies have permitted to look upon patterns of trade and their implications in terms of sociopolitical processes.

The pioneering works were performed on obsidian from New Zealand (Green 1962, 1964; Green et al. 1967), followed by similar efforts for the Near East and the Mediterranean region (Cann and Renfrew 1964; Renfrew et al. 1965; Dixon et al. 1968), the Midwest of the United States (Griffin and Gordus 1967; Griffin et al. 1969), Central America (Heizer et al. 1965; Cobean et al. 1971; Hammond 1972), and Northwestern Alaska (Patton and Miller 1970).

The increasing interest in this analytical tool produced a need for organizing and perfecting the methodology required for archaeological studies. A number of reports describing the technique (Sayre 1965; Johnson and Stross 1965; Wahl and Kramer 1967) have been published. Several methods to perform comparisons between different geologic sources on the basis of as few elements in the chemical composition of the raw material as possible have been proposed (Gordus et al. 1967; Gordus, Wright, and Griffin 1968).

In 1971 the Department of Anthropology of The Pennsylvania State University initiated a series of investigations based upon the use of the neutron activation technique. Both ancient (Kirsch 1972b; Deutsch 1972) and modern pottery from Guatemala and Peru were analyzed (Arnold 1971, 1972; Rice and Kirsch 1972). Obsidian from Guatemala (Rice 1972; Hurtado de Mendoza 1972) and the Mexican central plateau were also looked upon (Pires-Ferreira 1972; Westlake 1972).

This author's work began in the summer of 1972 with the processing of a sample of 50 obsidian artifacts recovered from Kaminaljuyu. The project's goal was a determination of the extent to which raw material homogeneity occurred at this site. This goal was achieved after analyzing the obsidians on the basis of their sodium and manganese contents. Ninety-eight per cent of the sample proved to correspond to the El Chayal geologic source (Hurtado de Mendoza 1972).

These results encouraged an expansion of the project in order to apply the anticipated outcomes to the validation of a number of hypotheses concerning unsolved problems in the interpretation of certain patterns in prehistoric Guatemala. These were: (1) the need of supportive evidence for an obsidian hydration rate estimated for the area; (2) the clarification of the effects of alien political control on the local exploitation and distribution of obsidian; and (3) the determination of some criteria to ascertain obsidian qualities in terms of geologic source, preference for the elaboration of given artifacts, and the association between chemical composition and visual appearance (Hurtado de Mendoza 1973b).

The first stage of this project had suggested that while most of the obsidian utilized at Kaminaljuyu came from the same geologic source, this proposed source--El Chayal--was not formed by a single volcanic extrusion, nor by only the three flows that have been already located--El Fiscal, Chayal, and San Antonio La Paz--but many others distributed over a still unspecified area. If obsidian was mined from all of these flows, it seemed evident that the variability in composition, as characterized by Na and Mn neutron activation analysis, was minimal. However, the possibility of ascertaining some characteristics in the chemical composition that could discriminate between them in the future was not discarded.

Another positive outcome of the first stage of this work was a test of the usefulness of the Na and Mn approach. Its utility in the identification of obsidians was not totally accepted. Gordus and his associates had perfected an automated method of Ma and Mn neutron activation analysis on the basis of over 1,900 obsidian specimens. These results proved that "the range in composition of these two elements for a geologic source is not more than 1.35" (Gordus et al. 1967: 93). The preliminary examination of El Chayal obsidians gave a range of 0.60 for Na and a range of 1.19 for Mn, suggesting Gordus' findings were reproducible. Moreover, after comparing data for 60 natural obsidian sources, the same authors observed that the manganese content showed "a between flow minimum-maximum mean value variation of 0.015-0.25 per cent" and that the "within flow minimum-maximum value range is only about 30 to 40 percent" thus making manganese an ideal element for characterization purposes (Griffin, Gordus, and Wright 1969).

Other positive aspects of this technique are: (1) the short irradiation time at relatively low power levels (1 minute at 1 MW) required; (2) the short half-lives of the ions produced, thus permitting counting to begin after only about two hours decay time; and (3) the short counting time necessary for the analysis (100 seconds).

The second stage of this work, initiated in the fall of 1972, and carried over into the first half of 1973, comprised the analysis of 84 additional artifacts from Kaminaljuyu. These were associated with radiocarbon dates. The project was designed to test alternative hypotheses related to the research problems specified for the first stage.

Once again, the sodium and manganese approach was selected. Results made apparent that up to 95 per cent of the 131 specimens analyzed were classified as of El Chayal origin. The remaining 5 per cent did not fit statistically into the main class, and were consequently considered of different origin.

Considering the span of time represented by this sample, from the Middle Formative to the Late Classic, three conclusions were reached. First, there was evidence now that a high level of continuity, covering at least 1300 years, had occurred in the pattern of obsidian acquisition at Kaminaljuyu. Second, the hydration rate estimated for El Chayal obsidian could now be reliably used for dating obsidians within the valley. Third, that the acquisition of non-local obsidian was extremely limited, suggesting that Kaminaljuyu, whatever its political status in the area relative to Teotihuacan influences, did not include a taxation system that compromised obsidian from surrounding regions (Hurtado de Mendoza 1973b: 49-50).

Regardless of how profitable the Na and Mn approach proved to be, results were limited to a very general level of discrimination, thus not permitting its application to the kind of research problems dealt with in this thesis.

Now it was shown that most of the obsidian used in Kaminaljuyu came from a single geologic source, and the presence of a multiple flow situation was sensed. Preliminary probings on the possibility of discriminating among these by looking at certain trace elements seemed feasible, and it became obvious that such level of analysis was crucial and indispensable in any attempt to look into patterns of obsidian utilization at the local level.

Within-source heterogeneity and interflow characterization were concepts only tenuously dealt with in the literature. Probably a major reason was that obsidian characterization studies were for the most part directed toward the elucidation of problems related to long-distance trade in prehistoric times, but some other important factors had their roots in a number of basic assumptions concerning the structure of obsidian sources. This is noticeable in the indiscriminate use of terms like source, extrusion, and flow (e.g., Stevenson, Stross, and Heizer 1971: 17; Kowalski and Schatzki 1972: 2176). Very few reports indicate perception, on the part of the investigators, of certain features that contradict the commonly held belief that obsidian sources are highly homogeneous and discretely localized volcanic flows (Bowman, Asaro, and Perlman 1973a, 1973b).

A transect sample of 33 specimens from the relatively small flow in Borax Lake, California, showed significant variability in composition as to suggest magmatic mixing of the obsidian with an underlying dacite prior to eruption (Bowman, Asaro, and Perlman 1973b: 318). However, this variability was clearly patterned and had differentially effected the diverse minor and trace elemental constituents tested for. While iron showed a standard deviation equivalent to 32.5 per cent of the mean value, lutetium only had 1.8 per cent dispersal. In other words, obsidian sources and obsidian flows were evidently homogeneous only in terms of certain constituent elements. Consequently, proper interflow, i.e., within source, discrimination seemed to depend upon an extremely careful selection of the elemental constituents.

Close examination of the results obtained by Bowman and associates called the attention of this author to certain trace elements. Th, Sm, U, Cs, La, Lu, and probably Pa, seemed good candidates due to their low variability even under the possibility of magmatic mixing. Moderate variability of other trace elements, like Rb, were also taken into consideration.

Neutron activation analysis was selected as the technique to perform the geochemical characterization of the Guatemalan obsidians due to its relatively higher sensitivity. Wavelength dispersive methods like X-ray fluorescence have become much more popular among specialists, however, but a number of objections raised concerning this latter technique could not be ignored. Problems with the reproducibility of the alignment of the apparatus, noise introduction at low angles of scattering, and sample preparation, proved to be unavoidable sources of error (Stross et al. 1971: 210), especially when dealing with numerous samples.

Further, the particular elements that are observable by means of this technique are not suitable, as a set of variables, for a classification based on multivariate techniques aiming to within-source discriminations (Johnson 1976a). Finally, the comparability of the data obtained by X-ray fluorescence may not be attainable. The manganese concentrations in Mesoamerican obsidians (Cobean et al. 1971), determined by X-ray emission spectroscopy, were observed to be significantly higher than those obtained by other laboratories using different techniques (Hurtado de Mendoza 1973b: 15). However, only recently (Stross et al. 1976: 257), admission of calibration differences has been made after realizing the much higher reliance of neutron activation determinations performed at the Lawrence Berkeley Laboratory. X-ray fluorescence data for Fe, Ba, Rb, and K proved to be inflated, and factors of reduction as high as 10 per cent were reported necessary to normalize the data reported in the past.

Recently, a proton particle-induced X-ray emission technique (proton PIXE) has been also used (Nielson et al. 1976). Again, discrepancies with expected values were obtained for most constituent elements tested for. This inconsistency is still more evident given the fact that the experiment included USGS rock standards. Values higher than expected were in the order of up to 40 per cent, while those lower than expected reached figures of 7 to 13 per cent (ibid.).

These discrepancies are partly blamed on the differential sensitivity of the elements to large target-thickness corrections that were necessary when dealing with rock standard samples, but the possibility of these same factors affecting the processing of obsidian samples cannot be discarded. Besides, it is likely that the excessive physical and chemical manipulation of the samples required by this technique may increase the probabilities of weight changes, thus introducing the observed errors in results. The most unfortunate outcome is that the introduced errors are not patterned, thus precluding the possibility of treating them as sufficiently consistent as to simply permit the use of a correction factor. While values result inflated in the case of some elements, they are lowered in the case of others.

The percentage error is variable from element to element (Nielson et al. 1976, Table 1).

In general, the fundamental limitations of both the X-ray fluorescence and the proton PIXE technique lie in the fact that these are primarily surface analyses rather than the analysis of the whole volume of a sample. Surfaces tend to be less uniform in the concentration of elemental constituents thus yielding data whose accuracy is not as good as that obtainable by means of neutron activation analysis.

Data Acquisition

All of the above factors considered together should make the selection of a neutron activation analytical approach sufficiently justified. Besides, this particular project included the performance of a multivariate statistical classification of obsidian types. This technique required data on a selected set of trace elemental constituents in the obsidians with special emphasis on rubidium. Conversations with geologists had suggested this element as of key classificatory power. Thus, an ad hoc strategy was designed with the help of Dr. William A. Jester, associate professor of Nuclear Engineering and director of the Radionuclear Applications Laboratory of the Breazeale Nuclear Reactor of The Pennsylvania State University.

The long irradiation approach described below resembles in part the analytical parameters used by De Bruin and associates for their study of European flints (De Bruin et al. 1972).

The classificatory approach based on multivariate techniques has also been explored in the past. Four different computer-aided methods were tested on obsidian trace elemental data before (Kowalski et al. 1972). This work emphasized the organization of subjective judgment by using an explicitly stated set of rules to perform the classification, i.e., the application of mathematical algorithms. The results of this study, based on X-ray fluorescence data, were successful only at the source level, thus not adding any newer information than simple Na and Mn analysis. Nevertheless, they made explicit the fact that multivariate techniques of classification were feasible.

The process of neutron activation analysis will not be detailed here. Good explications are available elsewhere (Deutsch 1972; Wahl and Kramer 1967). However, the particular strategy used to perform this study will be outlined.

Small wedges were cut from each obsidian specimen with a water-cooled diamond blade saw. Their size was kept wihtin the limits imposed by the inner diameter of the quartz tubing into which they were placed for irradiation. Their weights were determined to the one hundredth of a milligram using a Metler H54A balance. The average weight for 60 of these specimens was found to be 45.98 mg with a standard deviation of 17.33 mg.

The specimens were individually heat sealed in quartz capsules with an inner diameter of 5 mm and a length of about 7 cm. Twenty-four of these capsules can be irradiated simultaneously by using the "merry-go-round" device inserted against the front face of the core of The Pennsylvania State University's Breazeale Nuclear Reactor. Since two of these capsules were reserved for standards (with 4.96 micrograms of rubidium each), to be used for the determination of the content of rubidium in the obsidian specimens, initially only 22 obsidian specimens could be irradiated at any time. However, this apparent limitation was overcome by placing two specimens in each capsule. The capsules were numbered consecutively with the help of a diamond engraver. Each pair of obsidian specimens were identified afterwards by visually assessed characteristics on size and shape that were also recorded. This procedure permitted to increase up to 46 the number of specimens that could be run simultaneously, thus minimizing reactor time use.

The samples were submitted for irradiation at a flux of 2×10^{13} neutrons per cm^2/second, for a total of 20 non-consecutive hours at a power level of 1 MW followed by a 13-day decay intended to avoid interference from the activity of the macroscopic constituent elements in the obsidian, thus permitting an efficient detection of the activities due to the trace elements we were testing for (Table 8). Counting was performed with a Ge(Li) detector coupled to a 1024 channel Nuclear Data 2200 pulse height analyzer. Samples were transferred into 2-dram polyvials and these were placed at a distance of 0.5 cm from the detector in this step. Counting time was 1000 seconds for each specimen. The Chayal standard included with each batch was counted as the first and again as the last specimen of its corresponding batch in order to help determine decay particularities that might show interbatch variability.

Gamma-ray activity data thus attained was resolved in the form of some 50 photopeaks attributable to at least 30 different radionuclides within the energy spectrum segment from 0 to 2,000 keV. These data were transferred from the memory of the counter to punched paper tape for

Table 8. Characteristics and Identification of Selected Photopeaks in the Gamma-ray Spectrum

Element	Product	Half-life in Days 1	Half-life in Days 2	Energy keV	% Abundance	Peak Intensity[a]
^{140}Ce	^{141}Ce	27.7	32.5	145.4	48.0	100
^{176}Lu	^{177}Lu	7.4	6.75	208.4	6.1	100
^{130}Ba	^{131}Ba	12.7	12.0	216.0	19.0	100[d]
^{232}Th	^{233}Pa	24.5	27.0	311.9	44.0	100
^{174}Hf	^{175}Hf	93.9	70.0	344.0	85.0	100[e]
^{130}Ba	^{131}Ba	13.9	12.0	496.3	48.0	28
^{133}Cs	^{134}Cs		2.05[b]	604.7	98.0	100
^{45}Sc	^{46}Sc	83.6	84.0	889.2	100.0	100
^{85}Rb	^{86}Rb	18.7	18.66	1076.6	8.8	100
^{45}Sc	^{46}Sc	93.4	84.0	1120.5	100.0	100[f]
^{58}Fe	^{59}Fe	42.8	45.0	1291.6	44.0	80
^{23}Na	^{24}Na		14.96[c]	1368.4	100.0	90
^{55}Mn	^{56}Mn		2.57[c]	846.9	99.0	100

1 = measured; 2 = literature.

[a]After Adams and Dams (1969).

[b]Years.

[c]Hours.

[d]Strong interference from ^{160}Tb.

[e]Minor interference from ^{152}Eu.

[f]Minor interference from ^{182}Ta.

subsequent copy into magnetic tape and then qualitative and quantitative computer analysis.

Only 11 photopeaks representing nine radionuclides were selected for multivariate analysis. There are two peaks for ^{131}Ba and ^{46}Sc, respectively. Besides these, two other peaks corresponding to ^{24}Na and ^{56}Mn were examined in tests for sodium and manganese. The principal criterion for selection was that these were resolved within acceptable levels of statistical uncertainty (less than 10 per cent standard deviation).

The major features of the experimental design were different for the Na and Mn analysis. All 32 specimens together with four standards containing 1.5344 mg of sodium, and 0.02425 mg of manganese, were sealed in small polyethylene envelopes that were then fitted and heat sealed in a polyethylene tube which was submitted for irradiation at a flux of 1×10^{13} neutrons per cm^2/second for only 2 minutes, and at a power level of 1 MW. Only 2 hours of cooling time were allowed before counting. Each specimen was placed at a distance of 5 cm from the detector, for 100 seconds.

Counting statistics demonstrate that the peak determinations for these two radionuclides are highly reliable. Standard errors do not seem to exceed 2 per cent of the means calculated regardless of the relatively small size of specimens. Increments in size decrease the statistical uncertainty as would be expected. Since the counting process, in both instances, is done at different although consecutive moments in time, the data had to be corrected in order to account for differences in decay time. Also, interbatch variability due to slight yet unavoidable changes in the experimental conditions was corrected by referring all values to a set of Chayal standards that were included with every batch of obsidian specimens. Data for rubidium, sodium, and manganese have been reduced to weights in milligrams per milligram of obsidian. All other data are given as detected disintegrations in 1 minute for a milligram of obsidian.

Data Resolution

In the case of the 11 elements selected for analysis, the reaction taking place was of the neutron-gamma type, also called thermal-neutronic reaction, by which atoms first acquire an extra neutron and immediately emit one or more prompt gamma rays. The resultant products preserve their original number of protons, i.e., their atomic number, thus retaining their chemical identity.

Many of these daughter nuclides are unstable. They emit radiation as they undergo spontaneous decay. The gamma emanations from this process are characterized with the help of the radiation detecting equipment described in the previous section of this work.

Decay may take several forms. The most common type involves the emission of beta particles. Also called beta decay, it consists of a process of transformation of the excess neutron in the nucleus into a proton, a beta particle, and an antineutrino. The proton is retained in the nucleus thus changing the chemical identity of the resulting species. In many instances this process is not direct. The transition to the ground (stable) state of the daughter element is not a single step process. Instead, there is an intermediate, extremely excited state whose subsequent decay to the ground state is accompanied by the emission of one or more gamma ray photons.

In contrast with the non-monoenergetic nature of beta particles emission, gamma rays have energies that are characteristic of the radionuclides which produce them. This particularity permits the eventual identification of the daughter nuclide and thus its parent element.

Detection, then, is concerned with the determination of the energy levels of the emitted photons, and with the determination of the amount of radiation which is attributable to each of the photons emitted from the material that was irradiated. In other words, qualitative and quantitative analyses.

The particular solid-state detector used here is an ORTEC gamma ray coaxial lithium drifted germanium, Ge(Li), detector with a diameter of 33.8 mm, a length of 46.6 mm, and a total active volume of 36.0 cc. Its measured total resolution is equal to 2.0 keV FWHM using 1.33 MeV photons at 3 microseconds amplifier time constant with ORTEC amplifier system with a noise width of 1.2 keV. It has a 25 cm photopeak efficiency of 4.4 per cent relative to that of a 3" x 3" NaI(Tl) detector, measured at 1.33 MeV.

When the photons emitted from a sample are absorbed or scattered within the intrinsic region of the detector, which is a crystal ionization device, a p-i-n structure, they produce high-energy electrons which lose their energy by creating electron-hole pairs. These pairs are proportional to the amount of radiation absorbed by the detector, and they are collected in the form of electrical pulses that are first amplified and then sent to the pulse height analyzer.

The pulse height analyzer classifies the pulses as to their energy levels and counts them within 1024 channels each along a continuum from 0 to 2,000 keV. These data then are stored in the computer memory of the analyzer from which it can be outputed in the form of a pulse-height spectrum or gamma-ray spectrum.

Given the relatively numerous specimens analyzed, and the number of different photopeaks in the spectra that were examined, it was preferable to rely on a computer-aided method of data resolution. Thus, the data for each obsidian specimen were first punched onto paper tape and then transferred onto magnetic tape, using The Pennsylvania State University computer library available program PCOPY.

A gamma-ray spectrum has two major components, the Compton continuum and a number of peaks, each corresponding to a given radionuclide. In order to first identify the activity peaks in the spectrum, and then also to determine their area after deducing the contribution from the Compton effect, a special computer program is used. ENERGY (Schmotzer 1974) uses as input the table of counts per channel stored in the magnetic tape. Then it locates photopeaks and determines their exact channel addresses. Given that the segment of the energy spectrum relevant to this analysis is relatively small, a linear correspondence between channel addresses and energy levels is assumed. Thus, a conversion factor is determined on the basis of the energy level of two or more photopeaks, and it is used to calculate the gamma-ray energies of all other peaks in the spectrum.

Based on this information, an optional routine can be called to perform an initial identification screening of possible radionuclides. Half-life information can also be obtained for nuclide identification by counting irradiated samples repeatedly over a relatively long elapsed time.

ENERGY also performs an integration of each peak and calculates a peak area in counts per minute (CPM) after deducting the area that corresponds to the Compton continuum. Finally, the peak area is corrected for sample size. The output then includes an optional table with the raw data, a table of peak characteristics, and a table of peak energies, peak areas in CPM per unit of weight, and the statistical error implicit in the calculation of the peak area.

To better illustrate this process of data resolution it will be described using actual data. If a radioactive source of ^{22}Na is placed at a certain distance from the detector, it produces photopeaks at 511.0 and 1274.5 keV. It may be observed, however, that the analyzer addresses them to channels 262 and 652, respectively.

When these pairs of values are plotted in a X-Y graph, a precise curve can be determined and the slope and Y-intercept coefficients can be calculated. The conversion of any channel number (X-axis) into its equivalent energy level (Y-axis) may then be estimated by simply applying the equation that defines the linear relationship:

$$y = bx + a$$

where y is the estimated gamma ray energy of a given photopeak; x, its channel address; b is the slope coefficient ("gain" in ENERGY); and a is the Y-intercept coefficient ("zero-intercept" in ENERGY).

For the two pairs of values given above, a = -1.92 and b = 1.958. Thus, if a photopeak is found at channel 433.5 its equivalent in the energy spectrum will be 846.87 keV, suggesting the peak is due to the activity of ^{56}Mn whose experimentally determined energy level is known to be 846.9 keV (Adams and Dams 1969).

Besides this qualitative analysis, which is replicated for all other peaks in the spectrum, a quantitative determination is performed by ENERGY. The manganese in an obsidian sample of, say, 30 mg produces a peak at 846.9 keV which is spread over several channels due to the statistical variation inherent in its production. These counts are added up, including the values in two other channels at each side of the peak itself. These provide the average contribution per channel of the Compton continuum allowing then to deduct it from the total observed peak area to assess a net area.

Thus, it may be the case that the manganese peak appears between channels 432 to 435, with count values of 179, 1205, 1227, and 167. The two channels before and the two channels after these yield values of 88, 97, 133, and 123, respectively, establishing the continuum on which the peak sits, being about 110.0 counts per minute per channel. When this value is multiplied times 8 (the number of channels taken into account), the resulting 880 counts is an estimate of the Compton continuum contribution to the peak area. When deducted from the total counts for all eight channels, this gives a net peak area of 2337 counts. This is a measure of the detected activity due to manganese during a given unit of time. In this case, counting was performed, say in 100 seconds (i.e., 1.667 minutes). Then the obsidian sample is said to yield:

$$2337 / 1.667 \times 30 = 46.73 \text{ CPM/mg}$$

Although not all the radiation emitted from the sample has been detected, mainly due to counting geometry, this measure is directly proportional to the actual amount of the parent element in the sample. If the experimental conditions are not changed between samples, this measure has comparative power. If standards are counted under the same geometry conditions, having known amounts of this element, a conversion can be performed to assess the actual concentration of the element in a sample of known weight.

The values output by ENERGY, however, need to be corrected to account for differences in decay time. As explained before, this is done because the obsidian specimens were processed in batches of 20-40 each. While irradiation was performed at the same time for all specimens in any single batch, that was not the case with the counting process. Only one specimen at a time can be analyzed in this step, thus making it necessary to account for the difference in decay time between specimens.

Radioactive decay is an exponential process. Its rate varies with time and is different for each radionuclide. It is conventionally expressed as the half-life of an isotope. Half-life may be defined as the period of time that takes the activity to decrease by one-half, and it is mathematically expressed by the equation:

$$T_{1/2} = 0.693t / \ln (A_o/A_t)$$

where $T_{1/2}$ is the half-life; t is the time elapsed; A_o is the initial activity; A_t is the activity detected after the elapsed time; and 0.693 is the natural logarithm of 2.

Therefore, the decay correction equation is represented by the expression:

$$A_o = A_t \, e^{t\lambda}$$

where $\lambda = 0.693 / T_{1/2}$; e = 2.7183 (the base of the natural logarithm); and A_o and A_t are the initial and elapsed time activities, respectively.

Thus, if the ENERGY outputed value of 46.73 CPM/mg corresponds to the nth specimen in a batch that was submitted for counting 6 hours and 30 minutes after the first specimen in the same batch, one can then correct for this time difference because we know that the half-life of ^{56}Mn is equal to 2.58 hours. The application of the formula for decay correction provides a value for A_o equal to 268.0 CPM/mg.

Data Normalization

Decay time corrections are relatively easy to be performed for specimens within a batch as described above. Interbatch variability, however, is much less controllable. There are many factors that can affect the process of irradiation. Availability of reactor time is perhaps the most important. The 20-hour term irradiation cannot be completed in a continuous fashion due to reactor time scheduling. Instead, usually it is performed in three or more non-consecutive times spread over a number of days. Also, the elapsed time between the end of irradiation and counting, and probable differences in the neutron flux itself, may be included among these factors.

The effects of these variations are reflected in the activity observed at the time the samples are released to the experimenter for subsequent analysis. Table 9 lists data concerning times of different procedural steps, by batch, illustrating the amount of interbatch variability in the experimental conditions.

As would be expected, these differences do inflict an ineludible amount of variability to the acquired data. In order to render the values comparable, four small samples totalling 32 specimens (Table 10) from Locality 01 of the El Chayal obsidian source have been used, as a set of in-house standards (Batch LHX in Table 9) to which all values for specimens in other batches were referred to.

To determine individual correction factors for the 11 radionuclides selected for analysis each batch of specimens included at least one obsidian specimen cut from any of the four El Chayal obsidian samples used as standards. After irradiation, these were counted twice, as the first and last specimen in a batch. Further, whenever the process of counting could not be performed within the acceptable limits of 100 hours due to limitations in the scheduling of the analyzer, then the batch was split in two sub-batches each having the El Chayal specimen used as reference, counted again as the first and last specimen in the sub-batch.

Besides providing the basis for the calculation of factors to correct for interbatch variability, this procedure also served the purpose of detecting any possible unexpected outcome within a given batch. The corrective factors were based on the ratios between the

Table 9. Neutron Activation Analysis Schedule

Batch Name	Irradiation Data: Run Date	Irradiation Data: Time (h)	Cooling (days)	Counting (hours)	Activity at Release: MGR	Activity at Release: Obsidian	d (cm)	n
JEV01	18-20 Feb 76	23.68	14	73.27	480	150	8.0	22
JEV02	25-27 Feb 76	24.00	17	32.65	340	120	7.0	22
JEV03	4-12 Mar 76	24.83	6	27.65	750	140	0.5	20
LHX	9-12 Mar 76	24.00	13	96.40	410	580	10.0	32
MAW01	29 Mar- 2 Apr 76	30.90	10	102.10	680	45	0.5	25
MAW02	12-15 Apr 76	28.90	11	102.35	880	120	2.1	25
DAF01	5- 9 Apr 76	27.50	10	75.62	800	610	2.1	22
DAF02	19-23 Apr 76	31.70	10	30.28	750	366	2.1	22
MAY10	27-29 Apr 76	27.13	12	66.72	1130	107	2.1	22
OCT19	19-22 Oct 76	20.00	14	100.22	815	6	10.0	36
OCT25	28-29 Oct 76	20.00	13	26.80	565	< 1	5.0	36
NOV01	3- 5 Nov 76	20.00	13	92.05	734	9	5.0	36
NOV07	10-11 Nov 76	18.34	12	188.92	1076	6	5.0	36
NOV18	18-19 Nov 76	20.50	19	46.53	1130	< 2	0.0	36
NOV28	1- 3 Dec 76	20.00	14	87.98	1087	61	10.0	37
DEC07	8- 9 Dec 76	20.00	14	245.93	1358	6	5.0	46
DEC14	14-15 Dec 76	20.00	22	285.09	880	6	5.0	46
JAN07[a]	7 Jan 77	0.03	0.1	3.51	n.a.	400	20.0	32
JAN12	12-13 Jan 77	20.00	15	63.62	1174	5	10.0	46
JAN19	19-20 Jan 77	20.00	15	170.85	869	12	10.0	44
JAN26	26-27 Jan 77	20.00	16	143.51	1358	49	10.0	44
FEB03	3- 4 Feb 77	20.00	14	75.67	1359	12	10.0	47
FEB09	9-11 Feb 77	20.00	14	174.70	1223	12	10.0	33

[a]Short time irradiation to test for Na and Mn only.

Table 10. Chayal Obsidian Standards (CPM values)

	X-1 (n=10)		X-2 (n=10)		X-3 (n=6)		X-4 (n=6)		All 32	
Isotopes	Mean	s.d.[a]	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
^{141}Ce	25.44	4.8	26.56	2.2	26.36	3.2	26.26	2.8	26.12	3.6
^{177}Lu	4.96	6.2	5.12	2.2	5.11	5.2	5.23	5.8	5.09	4.8
^{131}Ba-^{160}Tb	5.39	4.3	5.31	3.0	5.31	2.3	5.57	7.7	5.38	4.4
^{233}Pa	23.50	3.1	23.04	2.7	22.95	2.9	22.77	4.6	23.11	3.2
^{175}Hf-^{151}Eu	6.04	1.5	6.04	2.3	6.00	1.3	5.88	1.8	6.00	1.91
^{131}Ba	4.55	3.5	5.83	2.8	5.86	7.7	5.13	6.2	5.27	12.14
^{134}Cs	6.57	2.9	6.52	3.2	6.49	0.8	6.41	4.2	6.51	2.86
^{46}Sc-^{182}Ta	13.95	4.1	13.51	2.4	13.85	2.6	13.77	7.8	13.76	4.13
^{86}Rb	2.41	5.8	2.43	4.6	2.62	5.3	2.45	6.7	2.46	5.85
^{46}Sc	11.30	2.1	11.29	0.6	11.36	0.5	10.92	3.1	11.23	2.12
^{59}Fe	2.82	5.3	2.75	3.9	2.79	3.7	2.55	2.2	2.74	5.31

[a]Standard deviations as percentages of the mean.

obtained data for the control specimens, and their equivalents in the set of standards in batch LHX.

Since each radionuclide had to be treated separately due to their different rates of decay, and given the relatively large number of specimens involved in the correction process, a simple computer program was prepared. The listing of program FACTOR is available in Appendix 2 at the end of this thesis.

Classification of Obsidian Types

Cluster-analytic techniques are utilized for the basic problem of deriving a classification scheme to group a given sample of objects, each of which is measured on each of a number of variables. In a statistical sense, it is an analysis of multivariate data. An algorithm that minimizes variance (error sum of squares) was chosen. The CLUSTAN 1C package of Fortran IV computer programs prepared at the University of St. Andrews, Scotland, and University College, London (Wishart 1975), was used. The package is organized following the usual procedure for cluster-analyzing data. First, a program called FILE reads the data from cards or card images in magnetic disk and stores them for immediate reference and processing. FILE counts with a number of optional statistics intended to help in the interpretation of the results. Means and standard deviations for each variable are computable as well as a principal component analysis. Non-standardized scores were used in the present study. Standard scores tended to mask subtle differences thus leading to excessive misclassifications.

The second step is performed by CORREL which computes the similarity matrix, a triangular array of $n(n-1)/2$ coefficients each constituting a measure of the similarity between two individual specimens. CORREL offers some 40 possible coefficients of similarity or distance. The "Squared Euclidean Distance" coefficient (Sokal 1961) was chosen since this is the one that best fits the Ward's error sum of squares method of fusion which was used in this work. Individual cases are theoretically represented by points plotted in an 11-dimensional Euclidean space, whose coordinates are the values of the 11 variables selected for analysis. The squared Euclidean distance between any two of these points is the coefficient used. Thus, for specimens 1 and 2 their squared Euclidean distance may be represented by:

$$d^2_{1,2} = \sum_{i=11}^{11} (\chi_{i1} = \chi_{i2})^2$$

where χ_{i1} is the measurement obtained for specimen 1 on variable i; χ_{i2} is the measurement obtained for specimen 2 on the same variable; and Σ is the sum of the 11 squared differences between these two specimens.

Given that Ward's algorithm is a hierarchical technique for the formation of groups, a variable parametric transformation of the similarity coefficients is performed by program HIERAR after each fusion of clusters. Each individual in the sample being analyzed is considered to be a "cluster." Were n = 3, then these clusters would be identified as p, q, and r. When p and q are fused, then the distance between the new cluster p + q and the other cluster, r, can be represented by the following equation.

$$d_{r,p+q} = ap(d_{r,p}) + aq(d_{r,q}) + b(d_{p,q}) + g(abd[d_{r,p} - d_{r,q}])$$

where: $ap = (nr + np) / (nr + np + nq)$

$aq = (nr + nq) / (nr + np + nq)$

$b = -nr / (nr + np + nq)$

$g = 0.0$

The single criterion for fusion is an objective function, the error sum of squares, which reflects loss of information resulting from the grouping of clusters. The minimization of these values as to approach the ideal of 0.0 (i.e., no loss of information) is attained by means of an iterative procedure which evaluates each of the possible unions of clusters and preserving the union that has an objective function value equal to or better than any other. The same procedure is repeated until the number of clusters is reduced to a specified number.

RESULT, the last of the programs used, produces a printout with the results of the cluster analysis. It includes a classification array as generated by HIERAR, the sets of data stored and processed by FILE, and a number of optional cluster diagnostic statistics intended to help in the interpretation of the clusters obtained. These are, thus, groups of entities linked as minimum-variance spherical clusters at coefficient values that are twice the increase in the error sum caused by fusion.

Ward's algorithm (Ward 1963) is considered to be one of the most efficient (Wishart 1975: 38). Its adoption by archaeologists, however, is still extremely limited regardless of its unquestionable utility in problems of classification. Numerical taxonomy in general was not regarded an efficient means to cope with large (n > 30) sample problems even in very recent times (Renfrew and Sterud 1969: 265). The first version of CLUSTAN (Wishart 1970) which included Ward's technique was reported as a novelty to the field much more recently (Johnson 1972) and its first applications were reported only by 1973 and 1974 (Redman 1973; Matson and True 1974). Its use, however, is becoming more generalized as time passes (Brown 1975; Hatch 1976; Rice 1976; Aldenderfer 1977), although usually with a sense of distrust about the soundness of its results, an attitude which tends to ask for the use of diverse techniques using the same data hoping that "an underlying structural similarity would be observed in the solutions" (Hatch 1976: 156). Such strategy is by all means highly recommended whenever the experimental conditions do not allow for a control sample. That is, whenever one does not count with examples of the real world that would suggest a primordial or "natural" pattern of recognition. However, the design of this study, based on obsidian raw material and artifacts, contemplates the inclusion of a sample of source specimens which is expected to reflect conditions in the real world that should render a classification measurable in terms of goodness of fit, resemblance, or isomorphism to a true model.

In fact, this particular approach, as will be seen in Chapter III, permitted the elaboration of an objective measure of the degree of accuracy of Ward's algorithm at diverse levels of discrimination of different obsidian types, in reference to their geologic origin. This has obviated the use of other algorithms that would be intended to look for certain levels of agreement in results which in turn would have suggested that any regularity observed would be structurally valid, but yet without much certainty.

III. OBSIDIAN SOURCES IN GUATEMALA

Introduction

Two basic assumptions underlie the source identification of obsidians being currently conducted. First, that each source locality "represents a single lava flow, which in turn might be presumed to be well mixed in a volcanic eruption" (Stross et al. 1971: 210); and second, that "the possible sources of volcanic glass are . . . relatively few and discrete . . . ." (Bowman et al. 1973a: 123). It follows that a certain degree of homogeneity in the chemical composition of a single-source obsidian is expected, thus rendering practical any correlation between some archaeological material and its parent geologic source.

Regardless of how important it is that these assumptions are tested correct, no comprehensive attempts have been made to determine either the geographic and physiographic characteristics, or the actual range of variability in the chemical composition of many obsidian sources.

The problem is not trivial. Important lines of archaeological research are involved, perhaps the most traditional one being the reconstruction of prehistoric trade routes. More recently sourcing studies are being applied to the validation of obsidian hydration rates used for chronological dating (e.g., Michels 1973), and to test hypotheses on the structure of Precolumbian regional sociocultural systems (Winter and Pires-Ferreira 1976; Johnson 1976b; Hurtado de Mendoza 1977).

Such versatility of uses calls for a closer look at the basic structure of obsidian sources which may be better thought of as complex regional systems that excape conceptualization in terms of single, discrete localities mutually exclusive and discriminable. Localities like Aldea Choatalum (Cobean et al. 1971), San Martin Jilotepeque (Johnson 1976b), and Pixcaya (Stross et al. 1971) have been reported as separate sources each with a different name. One of the purposes of this study is to demonstrate that these, and other localities, should be regarded instead as different extrusions all corresponding to the same source. This obsidian source may be thought of as a geological composite with a territorial scope that can be determined with the help of techniques of analysis like geochemical characterizations.

Another commonly found belief is that the well-known El Chayal obsidian source is limited to the quarries and chipping station "on a small hill 25 kilometers northeast of Guatemala city" (Cobean et al. 1971: 670). This study provides data that should help overcome such a misconception in favor of a more accurate determination of the actual geographic extent of El Chayal, and other source systems in what geologists call the physiographic Volcanic Province of Guatemala.

One of the main purposes of this study has been to test whether it is possible to reliably determine the exact geological origins of obsidian tools. Thus, there was a special interest in examining the fit between procedural results and samples whose origin had been specified objectively in the field.

Procedure

Diverse obsidian sources were sampled in an attempt to illustrate the variability of the material between extrusion localities. Degrees of homogeneity were determined objectively by means of a multivariate classificatory technique. This procedure produced a hierarchical discrimination of obsidian types that were found to highly correspond to the geographical distribution of the localities studied. Results thus obtained allowed to draw reliable territorial boundaries between source systems in the region.

The data obtained by means of neutron activation are, as previously described, gamma-ray spectra measured by a high resolution Ge(Li) detector containing discrete peaks whose location in the spectra provides the identification of the radionuclides produced in the irradiated obsidian and whose peak areas are proportional to the concentration of the parent element in the sample. These data were rendered comparable by referring all values to an in-house set of standards whose statistical range of variability was empirically determined (see Table 10). The standards are specimens collected from Cerro Chayal (Route CA1, km 25). Provided that the analytical parameters described below are replicated within certain limits, these data can be reproduced by others. Chayal standards are available on request for interlaboratory calibration.

Results were also checked against prepared standards containing known amounts of rubidium. Thus, it was possible to calculate the absolute content of this element in each specimen, traduceable either into parts per million or percentages. In addition, selected specimens from major source systems were tested for their contents of sodium and manganese in an attempt to correlate our results with determinations of geochemical identifications that have been previously considered sufficient criteria to reduce to a minimum the number of possible sources as quarry sites for a given artifact (Gordus et al. 1967). More ambitious applications based on these elements have been reported, however (Pires-Ferreira 1975).

Sampling

As a result of extensive survey in the central highlands of Guatemala, a total of 79 localities were sampled for obsidian specimens. Forty-seven of these localities yielded source specimens, that is, rock samples not showing signs of intentional modification by human hands. In addition, some specimens were collected at a number of localities between the town of Agua Blanca and the Ixtepeque volcano, in Jutiapa. Only five specimens from the village of Las Animas have been included for analysis at this stage.

Not all localities in our list (see Table 1) are lava flows. In some cases obsidian source specimens were found in areas where such flows were not conspicuous. The physical presence of obsidian rocks in these instances appeared to have resulted from what we may call "drift" processes. This general term is intended to cover two main kinds of transport agents: natural and cultural. The former includes downslope erosion and related alluvial transport. The latter refers to either prehistoric human transport of raw material that ultimately was left unmodified and modern movements of material mainly due to road construction and road maintenance operations. Some examples illustrating these processes will be given below as part of the evaluation of results obtained.

In at least one case, namely the "Cruz de Apan" source system, the source itself has been inferred from such "drifted" obsidian specimens which upon analysis were found definitively distinct from other obsidians in the region. Local informants had said that the main deposit is located in the headwaters of the Agua Caliente creek, south of Cerro Nacoj, near the town of Santo Domingo Xenacoj, but the place was not found.

The relative invisibility of this and perhaps other sources cannot be definitively explained at this point, but a number of possibilities can be forwarded. It is generally known that the larger proportion of any volcanic output is constituted by ejecta other than lavas (Poldervaart 1971: 13). These products, especially pyroclastics and lahars of Tertiary origin, form thick layers over most of the mountainous surface in the surveyed region. The so-called valleys are covered by heavy fills of Quaternary pumice and other kinds of Quaternary alluvia.

Considering the overwhelming magnitude of these deposits, almost continually incremented by the activity of the volcanoes, it should not come as a surprise that the better known obsidian flows are located in physiographically abrupt areas whose erosion has helped expose the lavas, as in the case of Pixcaya and most of the El Chayal extrusions.

More recently, roadcuts and other modern features have also uncovered other flows, as in the case of some of the localities in the vicinity of Palencia, but perhaps the most dramatic example of modern activities that helped locate obsidian flows is the case of the Amatitlan source. This system could perhaps have remained undiscovered, except for its "drifted" obsidian, were it not for relatively recent water-seeking operations in Finca Matilandia, some 8 km northeast of Antigua. A tunnel was drilled in Cerro La Libertad which yielded not water but a very bright obsidian of remarkably fine quality.

The extent of this obsidian's distribution in Precolumbian times had been hinted only slightly until now. It has been referred to as "San Bartolome Milpas Altas" (Cobean et al. 1971; Stross et al. 1976), after the village of this name located some 3 km north of Finca Matilandia.

With the exception of Ixtepeque, no attempts were made to sample other sources in Guatemala that are known to be located out of the region studied (see Figure 1). My interest was mainly focused in obsidian sources that were readily available to Precolumbian societies in the Valley of Guatemala and surrounding area. Correlations between source data and archaeological obsidians in this region will be the subject of Chapters IV and V.

As listed in Table 1, the samples from each source locality were of variable size. Of the 179 specimens, 32 were also selected as representing source systems in the collateral analysis to determine contents of sodium and manganese in the obsidians studied.

Data Analysis

Gamma-ray peaks selected for analysis were identified as to correspond to particular radionuclides by determining the location at which they appear in the energy spectrum. Besides, their rate of decay was also checked. The latter was achieved by analysis of selected specimens at diverse points in time over a total span of 215 days.

The relationship between the natural logarithm of the activity of a radionuclide and time is linear, thus a line of best fit for the plotted values of these two variables permitted to estimate the half-lives associated to the decay of the selected radionuclides.

When this procedure was implemented it became apparent that the photopeak observed at 216.0 keV in the spectrum was attributable to the composite activities of ^{131}Ba and ^{160}Tb in almost equivalent proportions. Two other peaks corresponding to ^{175}Hf at 344 keV and ^{46}Sc at 1120.5 keV were also observed to be effected by minor interferences from ^{152}Eu and ^{182}Ta, respectively.

This outcome did not seem to affect the anaylsis in any significant way. Unquestionably, care in keeping the analytical parameters, especially the decay time, within narrow limits played an important role. However, it is important to take this into consideration whenever attempts are made to convert gamma-ray activity data into mass values.

Once the data were standardized with respect to the Chayal standards (Table 10), the resultant matrix of 179 observations on

11 variables was subjected to the classificatory multivariate technique based on Ward's "error sum of squares" clustering algorithm (Ward 1963). This procedure was selected because it fits efficiently the nature of the data. Ward's technique forms a hierarchy of mutually exclusive subsets suggested by the data themselves, these groups being conformed by "members that are maximally similar with respect to specified characteristics . . . ." (Ward 1963: 236).

Results obtained by means of this treatment are graphically depicted as a dendrogram in Figure 3. It can be observed that distance coefficients range from 0 to over 1350. It may be necessary here to remind the reader that these coefficients have no absolute significance outside the context of this specific set of data. Individual observations linked at distance coefficients equal or less than 2.8 have been fused as single labelled blocks. Table 11 provides an analysis of the source localities that were included in each of these 19 basic groups, which will be called "locality complex" henceforth. Values given correspond to the calculated means for all specimens in each locality complex.

Since the induced activities due to the observed isotopes in our samples are proportional to the amount of the parental elements in the specimens, these statistics may be regarded as accurate measurements of the actual variability in composition between locality complexes.

Assuming that obsidian specimens gathered within the same locality and/or from the same quarry are highly likely to have a similar geochemical composition and thus belong to the same locality

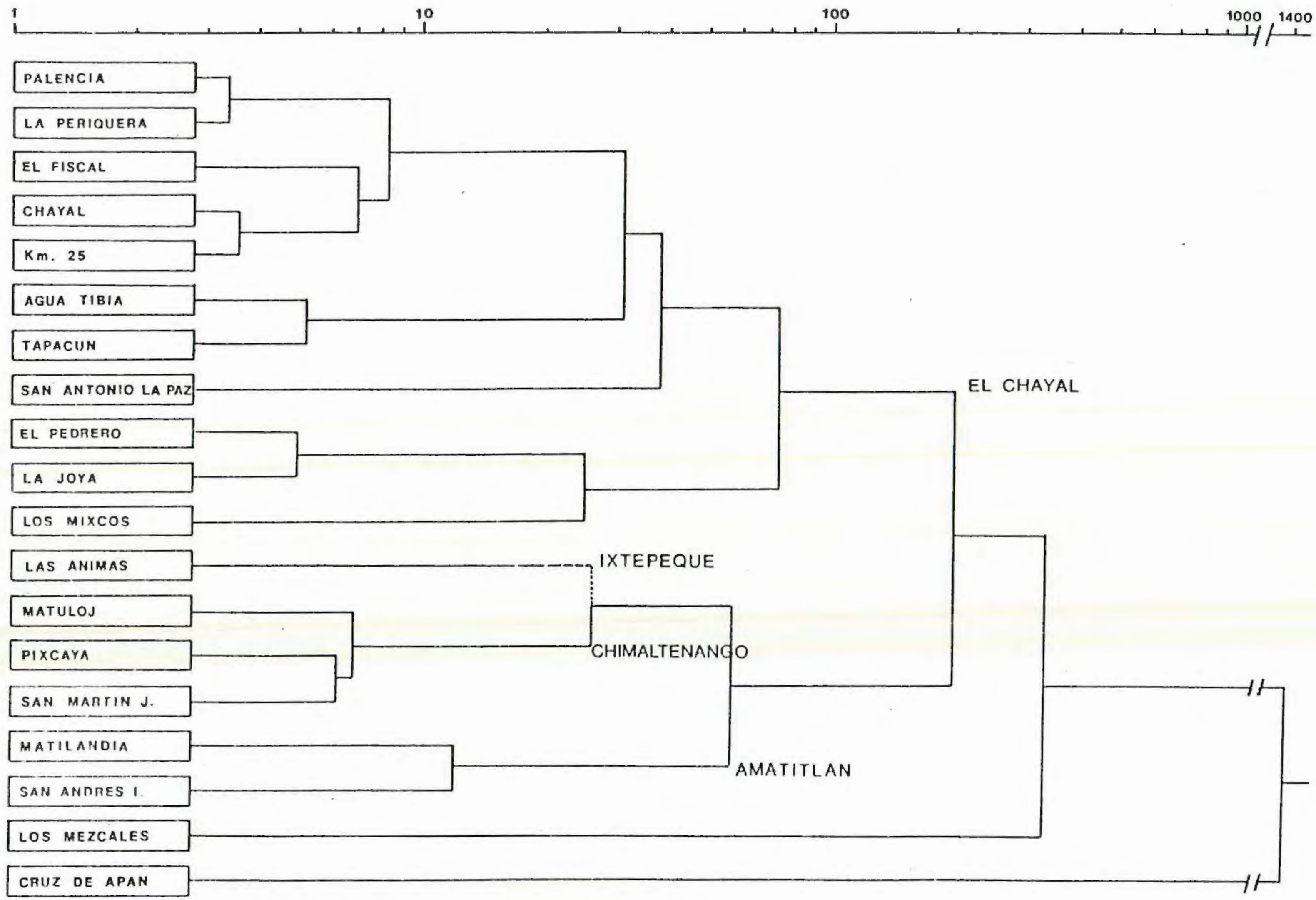


Figure 3. Hierarchical Classification of 179 Obsidian Source Specimens.

Table 11. Gamma-ray Activity Data (CPM) by Source Locality Complexes (after cluster solution in Figure 3, mean values)

Cluster	^{141}Ce	^{177}Lu	^{131}Ba ^{160}Tb	^{233}Pa	^{175}Hf	^{131}Ba	^{134}Cs	^{46}Sc	^{86}Rb	^{46}Sc	^{59}Fe	Misclassified[a]
1	26.37	4.77	4.79	23.94	5.84	4.75	6.65	14.60	2.27	11.71	2.94	(1)
2	26.74	5.38	6.19	23.25	6.09	5.20	6.47	15.08	2.55	11.58	2.96	1
3	24.35	5.88	5.86	23.46	5.95	4.21	6.41	13.75	2.44	11.35	2.65	
4	26.03	5.16	5.52	23.04	6.01	5.11	6.49	13.87	2.47	11.19	2.72	(8)
5	25.91	5.05	5.35	22.87	5.99	5.39	6.48	13.61	2.44	11.18	2.70	
6	28.73	5.88	6.35	24.44	6.23	5.68	6.92	15.14	2.58	11.74	2.59	(1)
7	29.71	5.81	6.14	25.52	6.14	6.40	7.03	14.53	2.67	12.05	2.79	(1)
8	24.28	5.21	5.11	24.08	5.82	5.35	5.62	11.24	2.48	9.56	2.45	
9	24.35	5.15	5.01	23.26	5.89	5.42	6.29	14.53	2.77	12.03	3.23	5 (1)
10	22.34	5.16	4.89	21.62	5.78	4.87	6.21	14.51	2.52	11.65	3.30	(2)
11	23.45	4.18	5.23	24.87	5.77	5.27	5.52	16.18	2.61	13.28	3.47	(1)
12	25.39	5.27	6.79	16.21	5.83	4.70	2.36	15.78	1.67	12.55	4.01	
13	27.65	4.08	6.64	19.71	5.38	4.77	2.97	14.03	1.85	11.37	2.69	
14	27.54	4.28	7.58	21.27	5.56	6.33	3.10	15.22	1.98	12.05	2.78	(3)
15	26.13	4.96	6.90	21.30	5.91	6.38	3.60	16.22	1.98	12.88	3.42	
16	24.24	5.70	7.79	22.89	5.87	7.65	3.24	17.51	2.12	13.36	3.56	
17	27.74	6.29	8.52	23.77	5.40	6.36	3.57	19.21	1.89	13.67	4.02	
18	29.78	4.16	4.36	26.33	6.38	4.50	6.98	23.08	2.94	18.75	3.82	
19	25.28	8.05	10.85	16.41	7.79	5.74	2.32	55.01	1.84	41.06	9.57	

[a]Numbers in parentheses correspond to the source locality level, while others represent misclassifications at the locality complex level.

cluster, we have then an index of the accuracy of the clustering algorithm. Cases of probable mismatch are listed in Table 11. About 13.9 per cent of the sample was not allocated to its expected source locality. Thus, Ward's algorithm correctly classified observations on at least 86.1 per cent of the cases.

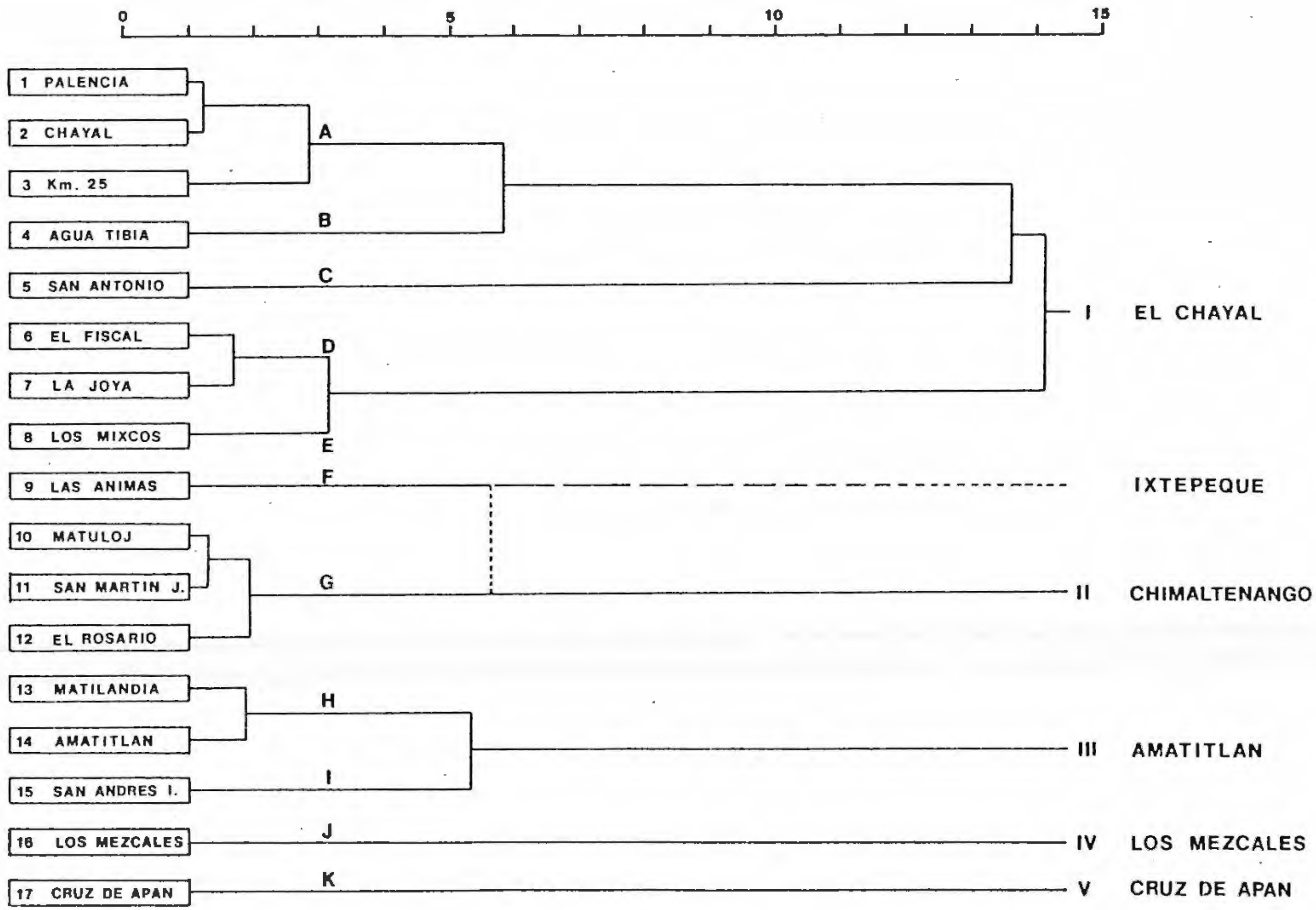
Most of the misclassifications occurred between highly similar source localities. Only six specimens (3.35 per cent of our sample) could actually be considered relatively serious cases of misclassification in the sense that they were allocated to some locality complex that is dissimilar beyond a distance coefficient equal or larger than 10.0 (Figure 3). Of these, five correspond to locality complex 9 which has a very high variability due mainly to its observed complexity. The El Pedrero 1 locality, near Palencia, a member of this complex, may have undergone more than one volcanic event involving production of obsidian. Recent mining of material from here has exposed at least two uneven layers of visually different obsidians. It was noticed that the upper stratum is formed by a limy rock containing nodules of a lustrous and red-banded obsidian, while the lower stratum has a bright gray obsidian embedded in an ash matrix.

The hierarchical clustering illustrated in Figure 3 also shows a conspicuous lack of linkages between coefficients 12.3 and 24.5 which may be interpreted as a reflection of a set of clusters having a certain degree of operational significance. These were labelled after major source localities and are considered intermediate entities that can be further aggregated into the six major source systems that are represented by the data.

At distance coefficients beyond 40.0, this clustering technique appears to somehow lose its discriminatory power, probably due to overlaps in measurements, and perhaps it should be considered to only reflect trends at this level. For instance, the El Chayal groups are linked at a point in the scale which is higher than that at which two source systems, Chimaltenango and Amatitlan, are fused which is inconsistent with the geology of the region. Such anomaly must be carefully considered as an indication of the limitations of the classificatory algorithm used here, but it may also reflect characteristics of the data that render analysis difficult.

In an attempt to clarify these results, the same technique was applied again using as data the locality mean values listed in Table 11 rather than individual measurements. Such procedure was expected to decrease the spread in measurements that had evidently caused overlap problems observed in our previous solution. Representativeness of the individual entities, however, was not assumed to be affected significantly. Figure 4 shows the results of this modification. Only the leftmost part of the dendrogram is depicted in detail for it is the more descriptive. Linkages beyond a coefficient of 9.0 are shown with less detail. Although most of the major features already observed in the former cluster solution are replicated in this second analysis, an improvement is readily observed. This time, the component groups of El Chayal source system are linked at a distance coefficient equal to 13.6 while the first intersource fusion takes place at 17.8.

As before, the Ixtepeque source system, represented by only five specimens from Las Animas, department of Jutiapa, shows relative



Key: I-V = Source System   A-K = Source Subsystem   1-17 = Locality Complex

Figure 4. Hierarchical Classification of Obsidian Source Localities.

affinity with the Chimaltenango source system. This outcome is accounted for by limited sample size for this source. When other samples from localities within the Ixtepeque source were included for an ulterior analysis, linkage between these two entities occurred at a much higher level of dissimilarity. Furthermore, it took place in an indirect way (i.e., each source system was grouped with different entities before being mutually linked).

The most significant changes observed in this second analysis took place within the El Chayal source system. Localities were reassorted resulting in a modified structuring of both its locality complexes and the "operational groups" (A-E in Figure 4), which we would like to call source "subsystems" henceforth. Since this solution was observed to show much more consistence with the geographical distribution of the source localities considered, it was preferred to the former to document further interpretations.

The map in Figure 5 is intended to show the regional scope of the five major source systems available to the central plateau in the Guatemalan highlands. Figure 6, on the other hand, provides a detailed description of El Chayal source system with indications of the diverse levels of association between source localities as suggested by the variable degrees of similarity in their obsidian.

The results of our determination of sodium and manganese contents in selected obsidians from most of the locality complexes as defined by the multivariate classificatory technique are presented in Figure 7. Raw data used to prepare the scatter diagram are listed

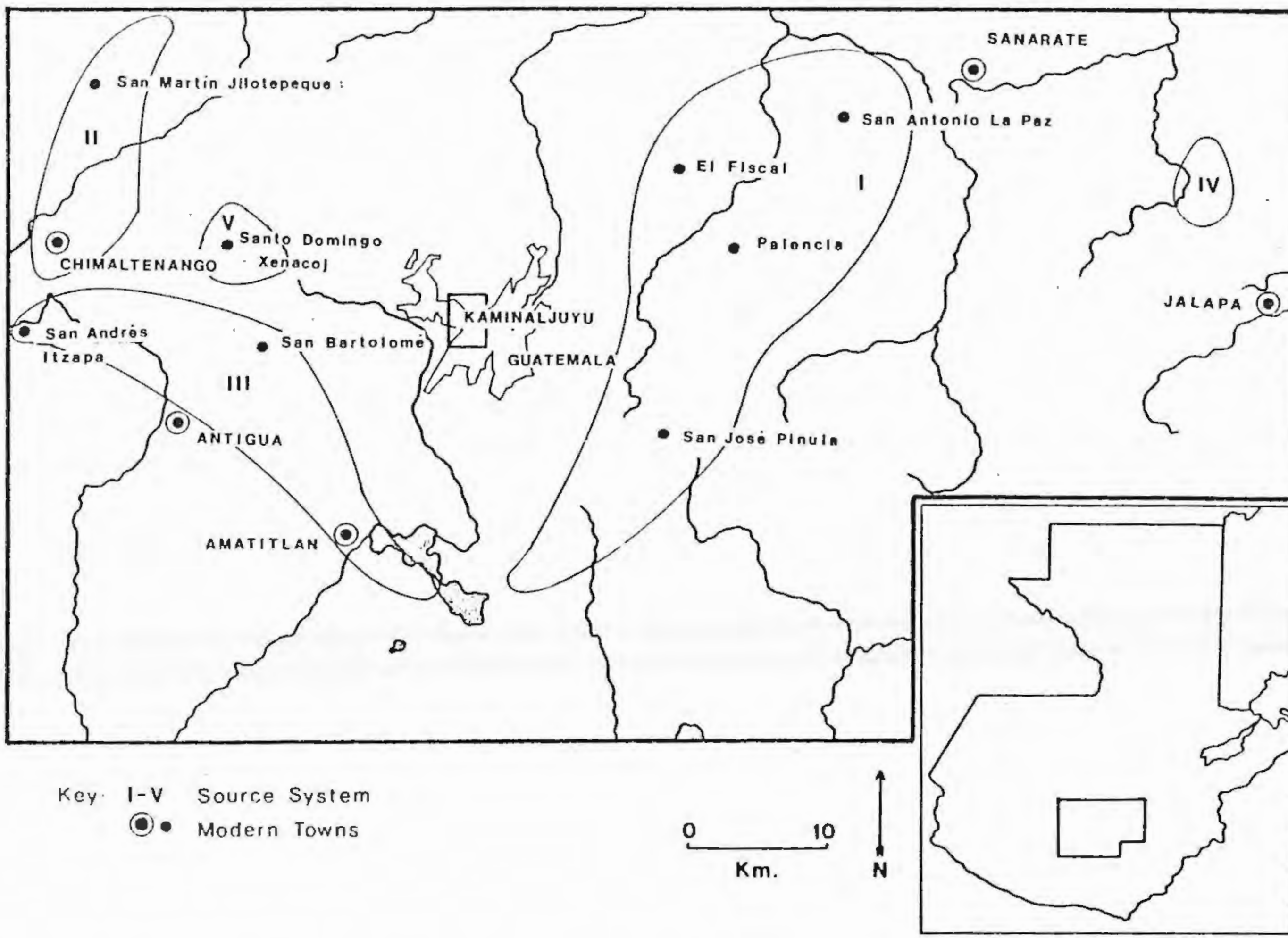


Figure 5. Regional Scope of the Five Major Source Systems in the Central Highlands of Guatemala.

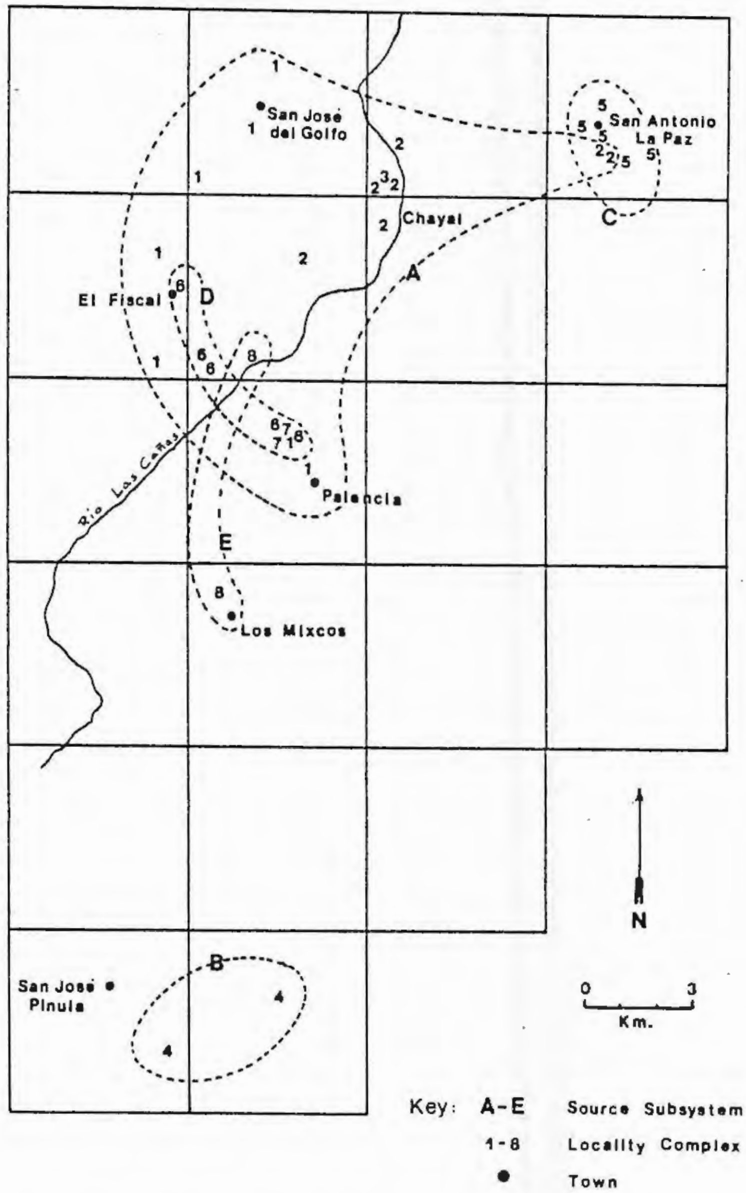


Figure 6. Regional Structure of El Chayal Source System.

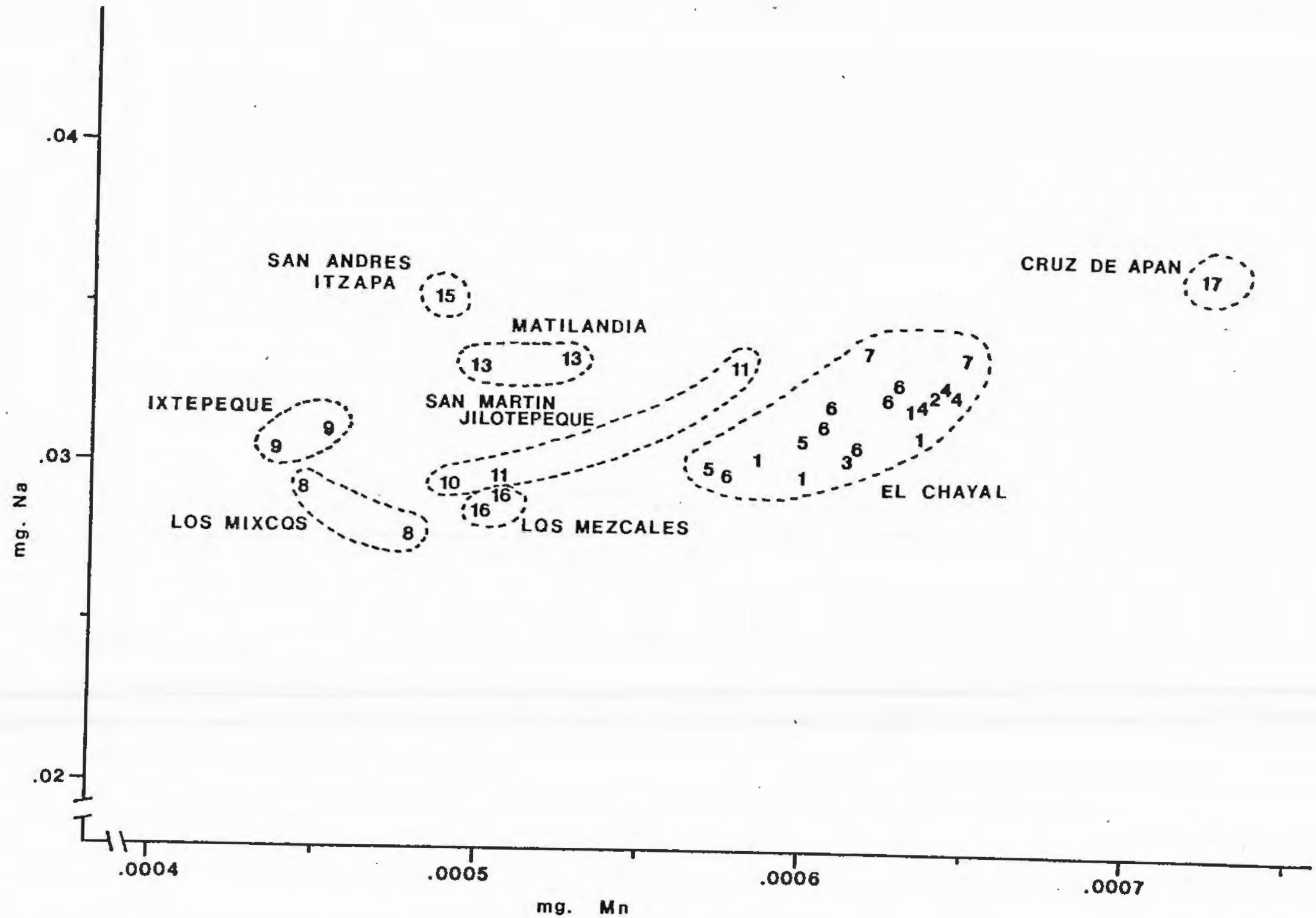


Figure 7. Scatter-diagram of Obsidian Source Specimens based on Sodium and Manganese.

in Table 12. In addition to the values for sodium and manganese, this table includes measurements on the amounts of rubidium in specimens.

The scatter diagram shows that most of the locality complexes within El Chayal source system cannot be distinguished when this two-dimensional analysis is performed. Only the Los Mixcos obsidian is observed to occupy a widely separate location in the graph, rendering this cluster discriminable. This outcome is quite consistent with previous analyses performed on obsidian artifacts from the Kaminaljuyu site (Hurtado de Mendoza 1973a). However, in light of these results it may be necessary to correct previous interpretations. It seems that some of the specimens that were considered to correspond to the Ixtepeque source in that report may have originated in Los Mixcos instead. The location of the Ixtepeque cluster in the sodium and manganese plot has evidently contributed to such confusion.

A somehow similar problem arises when a discrimination is attempted between the Chimaltenango and Los Mezcales source systems. The leftmost area of the Chimaltenango cluster may be undistinguished from the plotted points corresponding to Los Mezcales. Both the Cruz de Apan and the Amatitlan sources, on the other hand, seem to be reliably distinct from the others, thus illustrating the point that an analytical scheme based on the two elements specified may still be useful within certain limitations.

Table 12. Content of Na, Mn, and Rb in Obsidians from Guatemala, by Locality Complexes (values for s, as percentage of the mean)

Locality Complex			Sodium		Manganese		Mean		Rubidium	
No.	Name	n	mg	s	mg	s	Na/Mn	n	PPM	s
1	Palencia	4	.030740	3.17	.000613	4.02	50.19	22	119.05	7.06
2	Chayal	1	.032080		.000640		50.12	30	123.16	5.55
3	Km 25	1	.030328		.000613		49.47	1	125.35	
4	Agua Tibia	3	.032209	0.10	.000641	0.80	50.25	8	131.68	3.91
5	San Antonio	2	.030384	3.30	.000579	2.32	52.43	12	124.30	4.67
6	El Fiscal-A	2	.030971	5.39	.000601	5.77	51.58	11	123.57	5.43
	El Fiscal-B	4	.031576	2.65	.000614	1.65	51.43	13	143.94	5.29
7	La Joya	2	.033635	0.50	.000634	3.30	53.08	10	126.40	3.04
8	Los Mixcos-A	1	.027737		.000479		57.91	6	133.37	3.82
	Los Mixcos-B	1	.029182		.000446		65.43	3	114.15	5.66
9	Los Animas	2	.030716	1.60	.000445	2.50	69.03	5	83.53	10.15
10	Matuloj	1	.029290		.000492		59.53	5	92.86	2.24
11	San Martin J	2	.031352	7.97	.000543	9.75	57.73	13	99.16	6.94
12	El Rosario							2	99.52	6.06
13	Matilandia	2	.033197	0.49	.000514	3.57	64.62	11	107.34	6.79
14	Amatitlan							1	92.25	
15	San Andres I	1	.035213		.000489		72.01	5	94.76	3.17
16	Los Mezcales	2	.028823	1.04	.000501	1.26	57.47	10	147.41	5.10
17	Cruz de Apan-A	1	.036069		.000724		49.82	1	106.79	
	Cruz de Apan-B							2	84.98	5.42

Discussion

A relatively thorough description of the structure of a number of obsidian source systems available to Precolumbian populations in the central highlands of Guatemala has been achieved after treatment of these geologic entities as complex, regional systems composed by a series of source localities that can be hierarchically classified on the basis of their geochemical characteristics.

Generally accepted assumptions on which sourcing studies are based seem to require modification in the light of empirical evidence presented in the study. Obsidian sources should not be considered single lava flows discretely distributed on the landscape. Evidently, obsidian deposits of extremely similar material may occur at points spread over large areas, sometimes comprising hundreds of square kilometers. Such regional scope may also be considerably incremented by obsidian "drift" processes. Indeed, float obsidian specimens can be found at considerable distance from their parental matrix due to erosion and human transport. Although the latter may be considered of little relevance for archaeological application, the former should be taken into account especially when discrimination between component flows in a source system are pursued to increase the analytical power of sourcing studies.

An alternative to such analytical power is here supplied. It is proposed that the source concept in archaeology should be modified to be defined as a hierarchical ordering of taxa organized in four objectively determinable levels of discrimination. The geological correlates of these taxa in time and space escape the scope of this investigation.

The lower level of discrimination may correspond to the traditional obsidian source concept, and this we call the "source system" level. Its usefulness may be related to problems of source-specific obsidian hydration rates applicable to dating purposes. Also, it should continue being of relative value in attempts to reconstruct routes of trade and patterns of economic interaction between regions during prehistoric times. These have been labelled I-V in Figure 4 and correspond to El Chayal, Chimaltenango, Amatitlan, Los Mezcales, and Cruz de Apan, respectively.

A second level of discrimination corresponds to the determined obsidian "source subsystems." These are labelled A-K in Figure 4 and could be referred to by the name of some particular locality and its corresponding letter (e.g., Chayal A, Agua Tibia B, El Fiscal D, etc.). This level of discrimination is of crucial importance for studies on the structural characteristics of diverse sociopolitical entities within regions like the Valley of Guatemala that had immediate availability of obsidians from different deposits of a single source system. Certainly it should also help refine analyses concerning obsidian trade over long distances.

The third level here proposed corresponds to the "locality complex," an entity that comprises one or more source "localities" as defined above, and which pertains to our highest level of discrimination. There are 17 locality complexes determined by our analysis and 47 source localities as listed in Table 1.

As the level of discrimination increases with each of these operational categories the analytical power also increases, but the level of realiability has been observed to decrease as shown objectively with the application of Ward's classificatory technique. If reliability is measured in terms of proportions of individual cases in the sample that were correctly classified, then the reliability index for the locality complex level is equal to .97 while it is equal to .86 for the source locality level.

Although this study comprises only a limited number of obsidian source systems in Mesoamerica, it illustrates effectively the possibility of attaining practical and accurate levels of identification of obsidian types. The possibilities opened by such refinement in source identification should be obvious.

IV. OBSIDIAN EXPLOITATION AND SOCIAL STRUCTURE IN THE VALLEY OF GUATEMALA

Introduction

Recent archaeological research in the Valley of Guatemala is directed toward eventual elucidation of processes of change in Precolumbian times. Emphasis has been placed on social organization as suggested by diverse lines of evidence.

Work based on the ceramics from the site of Kaminaljuyu (Wetherington 1970) recovered during an extensive program of excavations between 1968 and 1970 (Sanders and Michels 1969; Michels and Sanders 1973), quantitative analyses of the inventory of artifacts from test trenches, and observations on the history of settlements have permitted the elaboration of a processual model for the evolution of sociocultural entities in the valley (Michels 1976a).

Kaminaljuyu has been regarded as having reached the level of an incipient state by the Middle Classic and early Late Classic phases (Sanders and Webster 1976). However, Michels (1977a) takes issue with this interpretation. Sufficient insights have been obtained to conclude that by Late Formative and Classic times the site had attained the characteristics of a level of sociocultural integration equivalent to what Service has called a "chiefdom" (Service 1962). According to Michels (1976a, 1977a), Kaminaljuyu was only one of three major chiefdoms that coexisted in the Valley of Guatemala.

The territorial scope of these three proposed chiefdoms had been tentatively delineated as follows: (1) the Amatitlan chiefdom occupied the southern part of the valley and the uplands to the southeast (Brown 1977); (2) the Chimaltenango chiefdom was located in the western slopes of the valley and adjacent uplands in Sacatepequez and Chimaltenango; and (3) the Kaminaljuyu chiefdom comprised "the northern half of the valley and the topographically rugged drainage system to the northeast"(Michels 1976b).

More recently, explicit boundaries between the three chiefdoms were proposed by Michels (1977b). These boundaries (Figure 8) are based on a locational analysis of settlements performed by means of a Thiessen polygon method built upon central place zones observed in the field.

This chapter discusses the results of a study intended to test a set of hypotheses based on the observations outlined above. It was felt that the three proposed chiefdoms in the Valley of Guatemala could be spatially discerned further by examination of the magnitude of exclusiveness in their access to the obsidian sources in the region. Exclusiveness in access to obsidian is here assumed to be a crucial indicator of the degree of economic, and therefore, political, and social independence among competitive sociopolitical units.

Competition over resources is a recognized trait among chiefdoms. Service (1962: 152) defines it as associated with cycles of expansion by incorporation and subsequent disintegration. These cycles, in turn, are presumed to be "a common cause of the origin and spread of many chiefdoms."

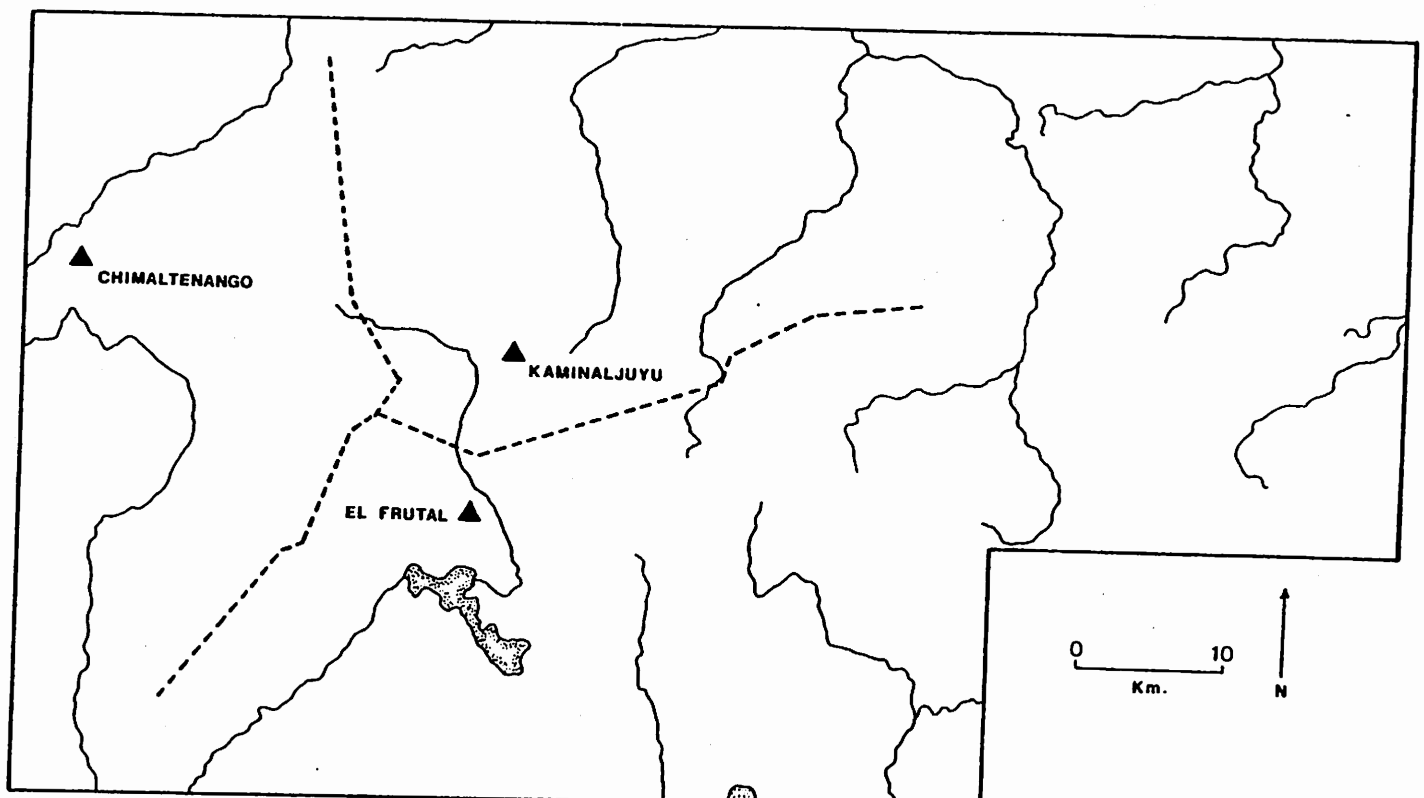


Figure 8. The Boundaries between the Three Chiefdoms in the Valley of Guatemala, as proposed by J. W. Michels.

Such processes were occurring among chiefdoms in the Valley of Guatemala. The results of this study indicate that two major sources of competition could have been obsidian and agricultural land. These two natural resources became bones of contention for different but related reasons. As the population in the Valley of Guatemala increased (Michels 1977b), pressure over agricultural land was expectably incremented also. All three chiefdoms were involved in this type of competition at one moment or another.

Obsidian became a source of conflict in an indirect way. The extent of trade activities based on this resource has been extensively illustrated elsewhere (e.g., Cobean et al. 1971; Hammond 1972; Graham et al. 1972; Stross et al. 1976). The increasing success of this export may be presumed linked to an increasing reliance on certain non-local products. Thus, control over obsidian quarries became crucial to secure supply of these imports.

Both forms of competition have been detected in times preceding and following the establishment of a "port of trade" during the Middle Classic (Brown 1977), thus suggesting that this regional institution constituted a relatively short-lived interlude during which some form of stability in the valley may have resulted from its contact with Teotihuacan.

In a competitive situation such as the one presumed to have existed in the Valley of Guatemala, it is possible that forceful means of control were exercised over obsidian quarries in order to prevent mining by others. This is especially likely for the populations being studied, since it has been demonstrated that obsidian blade production was an important factor in the economy of the Kaminaljuyu chiefdom (Michels 1976b) and, therefore, had a direct effect on the sociopolitical fabric of each culture-historical phase.

If we assume active competition over obsidian resources among the three chiefdoms we would expect a high degree of exclusiveness in obsidian acquisition by diverse, distinguishable political units. If such exclusiveness can be empirically demonstrated, then we have a means by which to identify the territorial extent of each political unit. Thus, analysis was based on the assumption that differential distribution of obsidian types, as opposed to a non-discriminant distribution, would reveal the locational parameters of sociopolitical units. Also, perceivable changes through time in the patterns of distribution of obsidians among sites in the region are here treated as a direct consequence of time-linked shifts in the overall sociopolitical configuration of the valley.

Procedure

To test the hypothesis that three independent sociopolitical units coexisted in the Valley of Guatemala, 54 archaeological sites were sampled for obsidian artifacts (Table 2). Source identification was positive for all but five of 262 analyzed specimens, thus slightly reducing the sample size. About 53 per cent of the sample consisted of cores, fragments, and non-utilized flakes, all of which were loosely classified as debitage. Finished artifacts and utilized flakes constitute the remaining 47 per cent of the sample. All material used was collected off the surface of archaeological sites. Some measure of chronological control was possible for most of the sites since they yielded El Chayal obsidian and could thus be hydration dated. One hundred obsidian dates were secured for 22 sites. About half of these dates were obtained from debitage material. Debitage is considered to be a by-product of tool production activities, while artifacts reflect actual utilization. Also, 28 obsidian hydration measurements were obtained for specimens identified as Chimaltenango obsidians and dates were calculated for these (see Chapter II).

Data Analysis

Five source systems are represented in the sample studied. About 68 per cent of the specimens were classified as El Chayal obsidian, while 28 per cent were identified as Chimaltenango obsidians. Only 2 per cent corresponds to the Amatitlan source system. Los Mezcales and Ixtepeque have only one specimen each, or about 1 per cent of the total sample (Table 13). Although all six El Chayal subsystems are represented, two do not occur in significant proportions. Classification at the locality complex level was achieved for both El Chayal and Chimaltenango obsidians. The former is especially important, as will be seen below.

The map of the region studied (Figure 9) has been divided into a 5 km by 5 km grid pattern consistent with the horizontal provenience control system developed for the Kaminaljuyu Project (Sanders and Michels 1969). These zones have been classified according to the

Table 13. Distribution of Obsidian Types among Chiefdoms

Source Subsystem:	A			B	C	D		E	F	G			H	J	?	
Locality Complex:	1	2	3	4	5	6	7	8	9	10	11	12	13	16		Total
Chimaltenango	5	5	6	3	2	7	1	–	–	13	56	2	3	–	2	105
Kaminaljuyu	1	23	1	4	13	4	2	1	1	–	–	–	–	1	–	51
Amatitlan	25	11	–	26	4	30	2	1	–	–	2	–	2	–	3	106
Total	31	39	7	33	19	41	5	2	1	13	58	2	5	1	5	262

Totals by Source Systems:

El Chayal (A-E)	177	(67.9%)
Chimaltenango (G)	73	(27.8%)
Amatitlan (H)	5	(1.9%)
Ixtepeque (F)	1	(0.3%)
Los Mezcales (J)	1	(0.3%)
Undetermined	5	(1.9%)

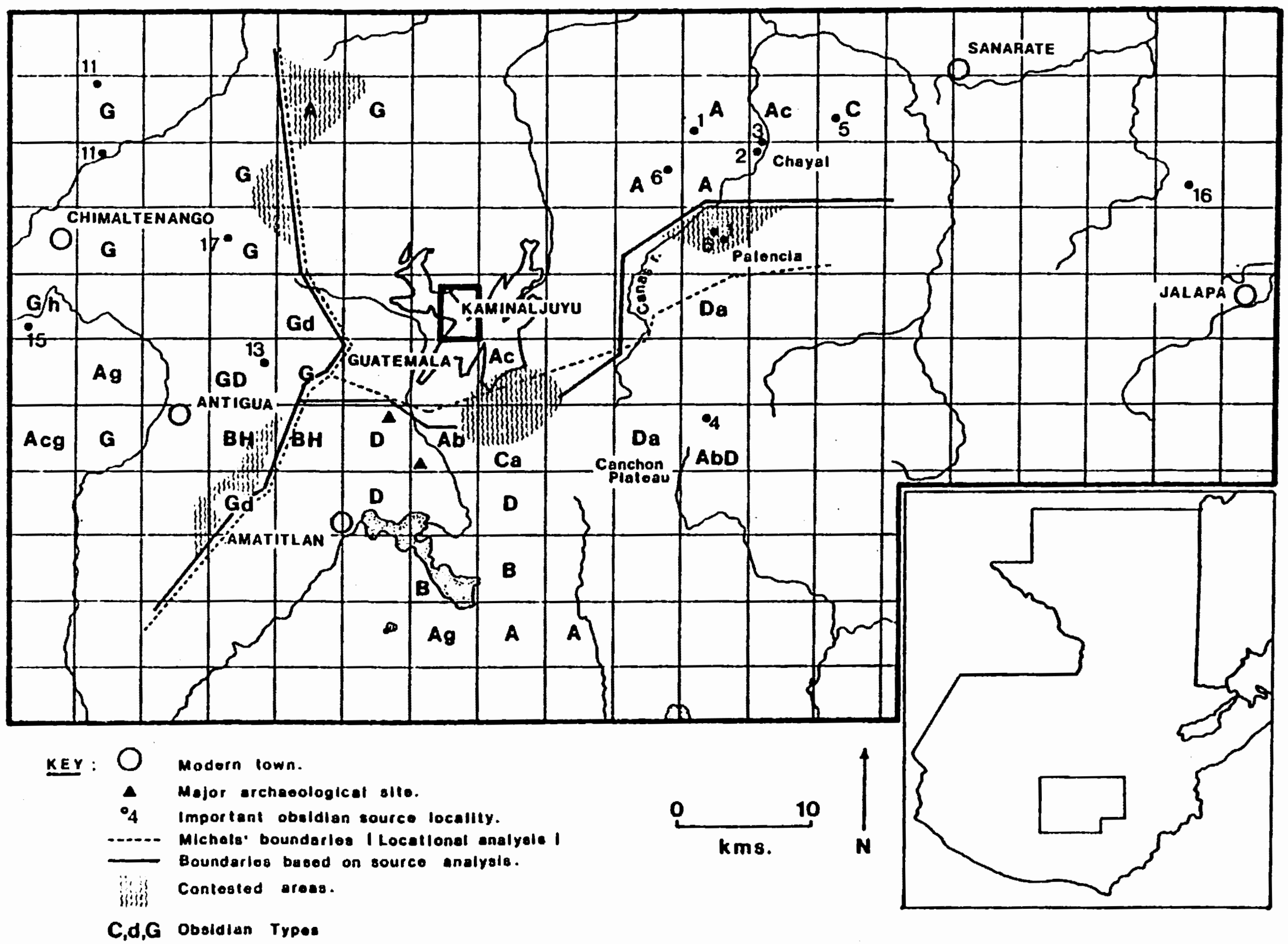


Figure 9. Spatial Distribution of Obsidian Types among Zones in the Valley of Guatemala (non-quarry sites).

prevalent obsidian types found within them. The types correspond to obsidian source subsystems labelled A to H.

A rapid scanning of the map shows a clear pattern in the spatial distribution of obsidians. Most Chimaltenango (G) obsidians are found in the northwest and west portions of the Valley of Guatemala. Agua Tibia (B), and especially El Fiscal (D) obsidians predominate in the southern end of the valley and in the southeast. They are also found scattered in the southwestern and, significantly, eastern sectors of the region, not far from the obsidian deposits located in the vicinity of Palencia. Some Amatitlan (H) obsidians can be observed associated with Agua Tibia (B) specimens near Antigua.

This distribution (Figure 9) generally supports the boundaries proposed by Michels (1977b), although some modifications of the boundaries between Amatitlan and Kaminaljuyu are clearly called for. The Amatitlan chiefdom should be extended into the Palencia area, all the way north to the right bank of the Las Canas River. The implications of this observation in terms of patterns of acquisition of obsidian by these two chiefdoms are clear. Both Amatitlan and Kaminaljuyu had direct access to the El Chayal quarries (Figure 10). Amatitlan had a line of supply running south from Palencia to the Canchon Plateau, located at the headwaters of the Las Canas River, then west into the Valley of Guatemala. Kaminaljuyu was supplied directly from the Chayal quarries located on the left bank of the Las Canas River and farther northeast. Apparently, the river could have formed a natural boundary between the two.

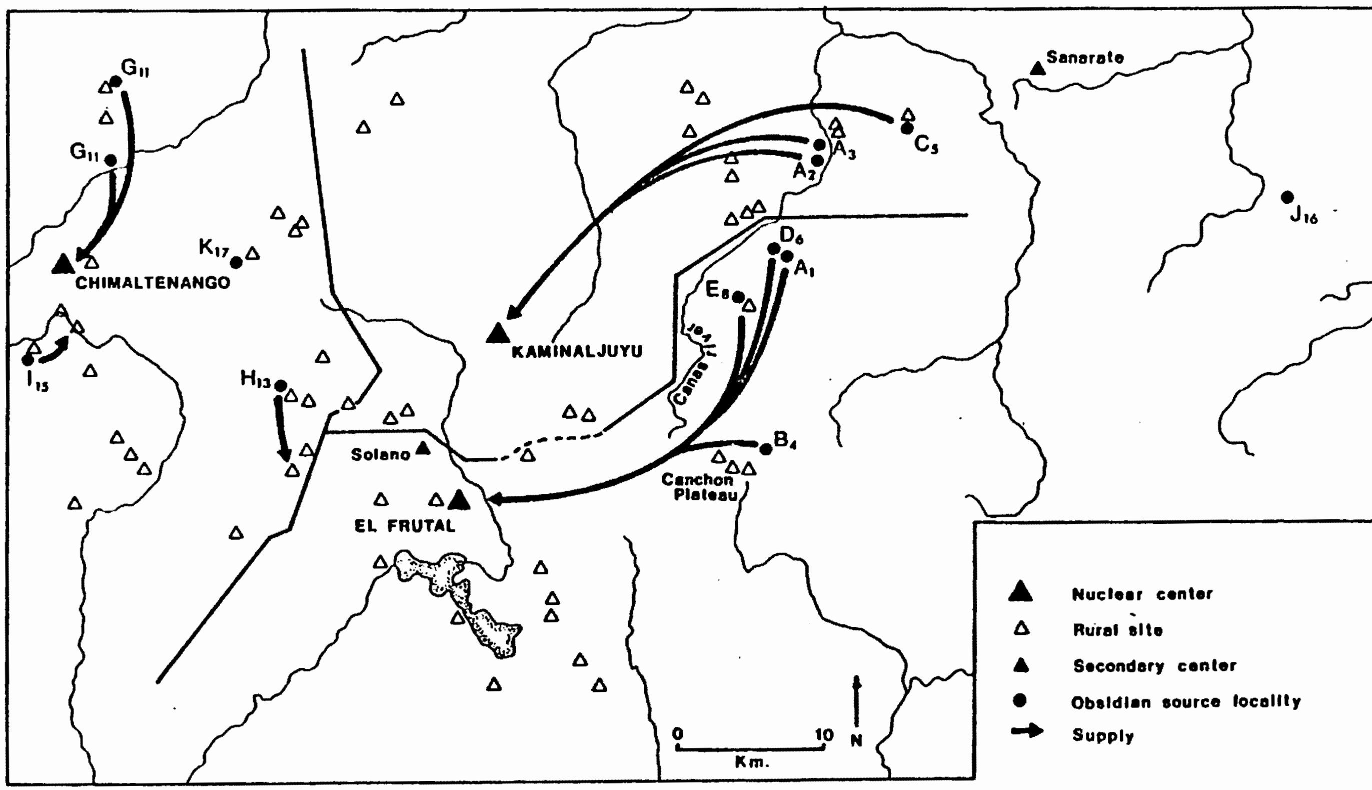


Figure 10. Major Obsidian Supply Lines of the Three Chiefdoms in the Valley of Guatemala.

A less well-defined distributional pattern characterizes the Chayal (A) obsidian subsystem. Although most of it seems limited to the valley floor and the area northeast of the valley, it also occurs in both the western and southern parts of the valley which are in the areas thought to be under the control not of Kaminaljuyu but the other two chiefdoms. However, it is significant that in the "core" area of Chayal (A) obsidian distribution (Table 13) no other types are abundant except for obsidian classifiable as San Antonio La Paz (C).

These results reveal a generally well-delimited pattern of distribution which would seem to correspond with the proposed territorial divisions in the region. The picture is further strengthened when we examine more specific taxonomic units such as the locality complexes. We find that 92 per cent of the Chayal (A) obsidian in the area attributable to the Kaminaljuyu chiefdom is actually classifiable as Chayal (A-2). Conversely, in the area assigned to the Amatitlan chiefdom, delinated by types D, B, and H, 69 per cent of the Chayal (A) obsidian is of Palencia (A-1) origin, while only 31 per cent corresponds to Chayal (A-2) obsidian (see Table 13). This explains the apparently anomalous distribution mentioned earlier.

Differential frequencies of Chayal (A) obsidian for the Chimaltenango chiefdom do not seem as drastic as those for Kaminaljuyu and Amatitlan, but when chronological control for this material is introduced into the analysis it is readily noticeable that El Chayal obsidian in this area is limited to Classic and Post Classic times.

Figure 11 presents distributional curves of four different El Chayal obsidians as represented in the subsample of 100

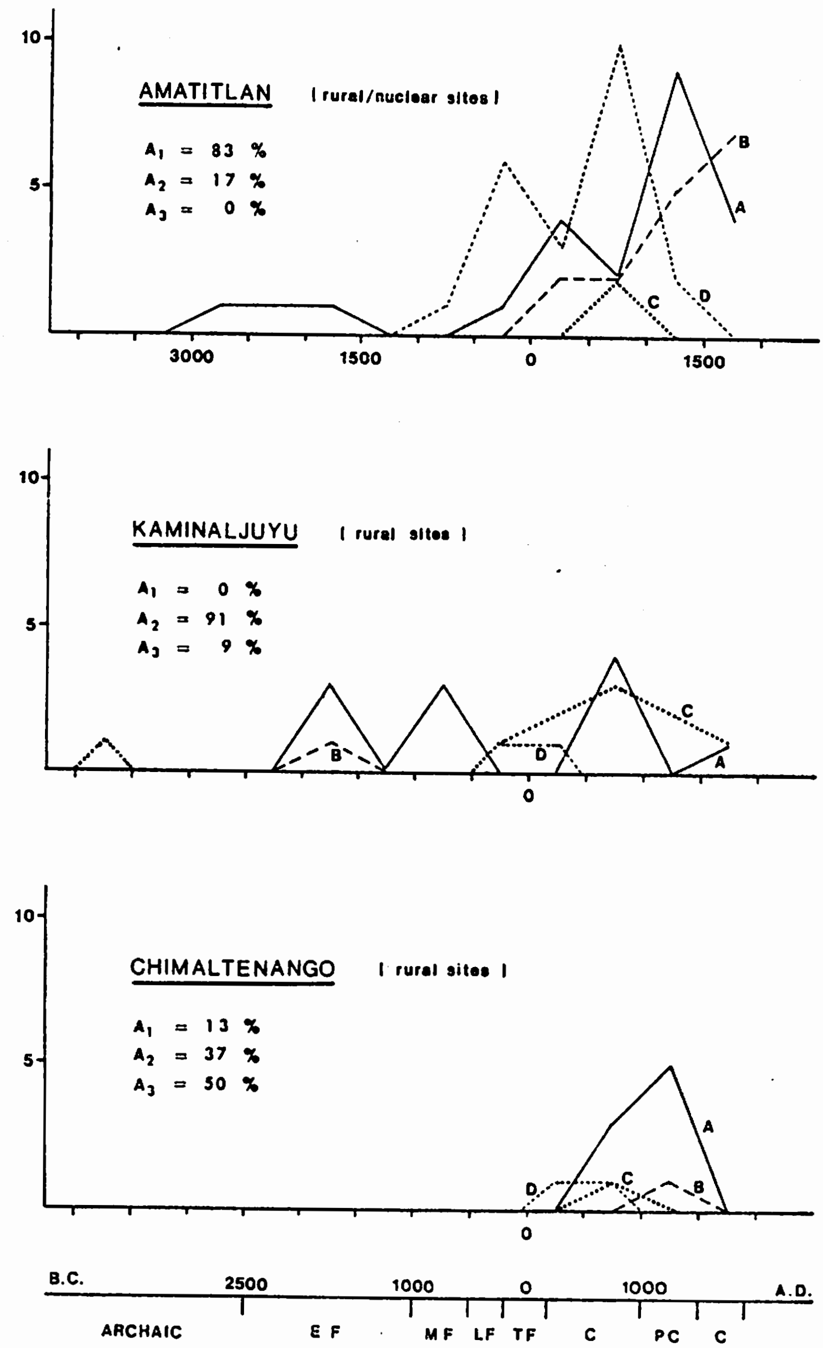


Figure 11. Distribution of Dated Obsidians among the Three Chiefdoms in the Valley of Guatemala. Culture-historical phases are given in the time scale at the bottom. EF = Early Formative; MF = Middle Formative; LF = Late Formative; TF = Terminal Formative; C = Classic, PC = Post Classic; C = Colonial.

dated specimens. Of these, 63 are from the Amatitlan chiefdom, 25 correspond to Kaminaljuyu, and 11 correspond to Chimaltenango.

It is interesting to note that these data suggest differential patterns of obsidian acquisition that are clearly time sensitive. The Amatitlan chiefdom shows a long tradition of Chayal (A) obsidian utilization, going back to the end of the Archaic period. Kaminaljuyu seems to be a "newcomer" in this respect, for only in Early Formative times does it begin to acquire this particular obsidian type. The much more recent introduction of Chayal obsidians into the Chimaltenango chiefdom area may perhaps be linked to the disproportionate growth of Kaminaljuyu during Classic times, thus facilitating economic interaction between these two political units.

It should again be emphasized that Chayal (A) obsidians are indeed differentially distributed among chiefdoms. Percentage figures based on dated specimens only (Figure 11), by chiefdoms, do not seem to differ substantially from those calculated on the basis of the entire sample analyzed (Table 1).

Also noticeable in Figure 11 is the historical variation in acquisition of obsidian types at Kaminaljuyu. Besides Chayal (A), only San Antonio La Paz (C) obsidians were utilized by this chiefdom in significant amounts. Acquisition of the latter seemingly began by the end of the Middle Formative, reaching a peak by Classic times, only to drop again later. This observation suggests an increment of demand that forced the inhabitants of Kaminaljuyu to expand exploitation of obsidian to deposits located not only farther in absolute distance, but also across the Las Canas River which runs along a deep depression, thus constituting a natural barrier that presumably interfered with transportation. On the other hand, the short-lived outburst of Agua Tibia (B) obsidian in the Early Formative may represent an ultimately unsuccessful attempt to obtain obsidian from an area that was under the control of the Amatitlan chiefdom.

A different situation is revealed by the El Fiscal (D) obsidian. Low frequencies of this type of obsidian in Kaminaljuyu chiefdom sites, after the Late Terminal Formative phase, may simply be due to inadequate site survey in that part of the valley. However, if the pattern is real, the most plausible explanation would be that it is the result of a shift in the location of workshops controlled by Kaminaljuyu. Due to increasing demand for obsidian blades in other regions it may have become necessary to decrease labor input by confining obsidian-blade production to areas in the immediate vicinity of the quarries.

Distributional patterns in the Amatitlan area seem to have a processual relationship with those observed at Kaminaljuyu. El Fiscal (D) obsidian was still controlled by the Amatitlan chiefdom during the Middle Classic. Subsequently, it was replaced by Agua Tibia (B) obsidian which had been exploited only moderately until this phase. A concomitant appearance of El Fiscal (D) obsidian occurs at Kaminaljuyu, and a possible attempt on the part of the Amatitlan chiefdom to obtain San Antonio La Paz (C) obsidian did not succeed. This circumstance, associated with the interruption in the acquisition of El Fiscal (D) obsidian, clearly produced a much more intensive exploitation of the Palencia (A-1) deposits.

These shifts in obsidian utilization may be interpreted as corresponding with minor changes in the economic and sociopolitical configuration of the region under study. Kaminaljuyu had developed a major commitment to long-distance trade involving obsidian and other commodities by Early Classic times (Michels 1977a). Its increasing economic power could have played a role in expropriating the El Fiscal obsidian deposits north of Palencia. The obsidian deposits of Palencia were also lost by Amatitlan during Late Post Classic times at the hands of the kingdom of Beleh, or Chinautla, forcing Amatitlan to exploit the Agua Tibia deposits located deeper within its own territory.

The shaded areas in the map of the region (Figure 8) mark the spots at which time-linked changes in the distribution of different types of obsidian have occurred, thus rendering the boundaries somehow "flexible." Changes in the Palencia area are associated with those described above. Evidently by Late Classic times the number of sites on the left bank of the Las Canas River had increased substantially. All these sites were utilizing Chayal (A-2) obsidian exclusively. However, this type of obsidian is also observed for the first time in sites located on the right bank of the river. These are mixed with the El Fiscal (D) obsidians. This mixture of types is also observed across the border, in Kaminaljuyu territory, during the Early Post Classic. Such a mixture did not include Palencia (A-1) obsidians. Therefore, it can be concluded that Kaminaljuyu expropriated the El Fiscal quarries north of Palencia, but not Palencia itself, during the Late Classic.

Kaminaljuyu confronted the Amatitlan chiefdom at a second place in the valley floor. Alternate occurrence of obsidian types whose quarries were exclusively exploited by the two chiefdoms suggest a constant friction in this area. Dated obsidians from sites in this area indicate that such friction did begin during the Late Formative and lasted until the Middle Classic, when Kaminaljuyu seemed to have consolidated its presence, shifting the frontier farther south.

The Amatitlan chiefdom responded to these two losses by expanding west into Chimaltenango territory. Dates available for this process suggest a two-stage expansion. The first took place in Middle Classic times, the second during the Late Classic.

Finally, the boundaries between the Chimaltenango and Kaminaljuyu chiefdoms were also subject to fluctuations in the northwestern part of the valley. A long-term but decisive advance of Chimaltenango settlements into the valley floor ended in Early Classic times when Kaminaljuyu responded by advancing west. This particular advance seemingly did not include the northernmost area, which remained Chimaltenango's until the Late Classic when Kaminaljuyu reestablished itself there.

Although the Palencia friction area was clearly related to competition over obsidian resources, this was not the case at the other spots in the valley. Instead, it is here proposed that these were areas at which competition over agricultural land took place.

Discussion

Neutron activation analysis of obsidian sources and compared obsidian artifacts supports the prevailing hypothesis that there were three independent sociopolitical units in the Valley of Guatemala and its surrounding area during Precolumbian times.

Differential patterns of obsidian acquisition show a relatively high degree of segregation and are here regarded as strong evidence that these sociopolitical entities were not only independent but also competing for resources. Such competition reached a critical stage by Classic times.

Seemingly, competition over obsidian resources was a function of the increasing role played by the populations of the Valley of Guatemala in the extensive trade of obsidian blades over almost all of the Mesoamerican area.

Other contested areas detected by this study, not involving obsidian quarries, are interpreted as corresponding to competition over agricultural land.

V. OBSIDIAN REDISTRIBUTION IN KAMINALJUYU

Introduction

Chiefdoms are said to be "redistributional societies with a permanent central agency of coordination" (Service 1962: 144) but the universality of this statement is being increasingly questioned with the continuous expansion in the analysis of ethnographic information. African chiefdoms, for example, are known to be much less emphatic on redistributive patterns than the Polynesian chiefdoms. In fact, it is now apparent that Service's characterization of chiefdoms was based on a particular kind of chiefdom (Sanders and Webster 1976) and the argument seems to have reached the point at which the total removal of the redistribution criterion as an indicator of chiefdoms has been suggested (Peebles and Kus 1977).

Generalizations in the synchronic (ethnographic present) typology of chiefdoms have their commensurates also when the problem is treated in diachronic perspective. This should be expectable since any society is subject to change and thus generates variability. It follows, then, that no single model intended to describe chiefdoms can possibly cover all the possible instances that the archaeologist is bound to confront.

If a single general model is utilized, perhaps due to lack of a more adequate model, then certain degrees of departure from the norm of defined characteristics can safely be expected when data from archaeological contexts are analyzed. Extensive elaborations on these matters are now available (Hatch 1976; Peebles and Kus 1977). Both studies propose alternative models to the general model generally in use (Sahlins 1958, 1972; Service 1962; Fried 1967).

The hypothesis tested in this chapter is based on the general theory on chiefdoms as structured by these latter authors. However, interpretations of the results will also rely on some of the alternative concepts forwarded by others.

For the specific case of Kaminaljuyu, it has been repeatedly stated that this society was, for most of its history, a chiefdom of the Polynesian type (Sanders 1969; Bebrich 1969; Michels 1976a, 1976b, 1977a, 1977b). All the lines of evidence so far examined consistently support this statement and an evaluation of the archaeological data in relation to natural environmental parameters in the Valley of Guatemala, such as agricultural risk, heterogeneity, and productivity, further indicate the validity of this interpretation (Sanders and Webster 1976). "The overall conditions [Sanders and Webster state] would seem to be prime for a relatively rapid evolution of a chiefdom type of society . . . followed by little subsequent societal evolution (ibid.: 26).

If redistribution is a characteristic of Polynesian-type chiefdoms and Kaminaljuyu is thought to be a society organized as such, this issue seems amenable for research. A quantifiable index of redistribution would enable a test of the hypothesis following statistical rules, thus minimizing subjectivity and enhancing objectivity.

Before stating the nature and formal structure of such hypothesis, it is relevant to define clearly what redistribution means and how it is related to other aspects in the structure of ranked societies. If we follow Service's model and implement his scheme to this particular study, redistribution is the cornerstone of the power of the chief. Resource exploitation in chiefdoms, including mining, transport, and subsequent or associated tool making, is expected to comprise highly specialized activities at the local level that allow for the generation of surpluses in production. These are not readily consumed. Instead, they are delivered to the chief. The rationale behind this delivery of goods to a central agency is twofold. First, a need for the organization of increasing trade, and second, the very nature of some transformed goods that would render valuable any higher level of specialization and redistribution (Service 1962: 145-147).

It is felt here that both mechanisms may have been at work in Kaminaljuyu. A relatively unsystematic impression is that the skills required to produce prismatic obsidian blades were not common. This may be illustrated by results obtained in previous investigations. An examination of the obsidian industry in Kaminaljuyu (Michels 1976b) has yielded data that suggest restriction of the productive activity of obsidian blades to about one-fourth of the household units sampled. This is the average proportion for seven consecutive phases of occupation, and although a peak of 39 per cent was observed for the Early Terminal Formative, the tendency afterwards was of a slow but determined reduction in the proportion of the households engaged in this activity. This tendency is much more accute if we consider the fact that the site generally experienced an increase in population until the Middle Classic when a sharp decline took place (Michels 1977a). Also, parallel to these processes of relative concentration of the craft, obsidian production seemingly tended to be in the hands of the high-ranked strata of the society. In the average, about 70 per cent of the households involved in blade production were elite households.

If such tendency toward the monopolization of obsidian blade production is real, then it can be expected that in order for the commoners to obtain their share of this commodity a redistributive system could have been operating. This should be especially likely in the absence of a market system, for which no data exist.

Trade, on the other hand, is sufficiently illustrated by the information available on the geologic origin of obsidians found in numerous sites throughout the Maya area. Artifacts made of El Chayal obsidian are reported to have been traded uninterruptedly since 1500 B.C. at San Lorenzo Tenochtitlan in Veracruz (Cobean et al. 1971) and at Laguna Zope in the isthmus of Tehuantepec (Zeitlin 1976). The presence of these obsidians originating in quarries that were controlled by the populations living in the Valley of Guatemala has also been distinctively determined for Palenque in Chiapas (Johnson 1976b), and Seibal, Piedras Negras, Tikal, Altar de Sacrificios, and Lubaantun in the lowland Maya region (Hammond 1972; Graham et al. 1972).

The mechanics of obsidian trade in Formative times, involving El Chayal obsidian and others, have been discussed at the interregional level by diverse authors (Cobean et al. 1971; Hammond 1972; Pires-Ferreira 1975, 1976). The relevance of such exchange to instances of redistribution at particular communities has also been treated using data from village sites in Oaxaca (Pires-Ferreira and Flannery 1976; Winter and Pires-Ferreira 1976). Of special interest to the present study is the latter interpretation of archaeological data on trade using consonant models based on ethnographic examples. These illustrate how pooling and redistribution fulfill needs of the chief to reinforce his status and at the same time contribute to the enhancement of social integration.

Also relevant is the observation that, at least for the case of the site of San Jose Mogote for which carefully controlled data exist, pooling and redistribution appear associated to the first introduction of prismatic obsidian blades (Pires-Ferreira and Flannery 1976: 289), a relationship which can be considered neither accidental nor without significance. Obsidian by itself may not seem to justify its inclusion in a redistributive network if its relative abundance and easy accessibility in areas like the Guatemalan highlands are taken into account. It may not even seem so in the Maya lowlands where cherts were known to be abundant, easily workable, and much more durable in terms of wear. Instead, it is plausible that it was the modification of the obsidian by means of the particular skills presupposed in the production of prismatic blades that made this commodity a must in Precolumbian households in Mesoamerica.

The trend observed at Kaminaljuyu toward increasing monopolization not only of obsidian sources by a sector of the population, and even more important, of the production of prismatic obsidian blades, may be indicative of the increasing role of this commodity in the redistributive framework of the society.

In most cases, hypothesis testing in archaeology is limited to analysis of qualitative data. This is fundamentally how the hypothesis that Kaminaljuyu reached the chiefdom level of sociocultural integration was elaborated. The presence of elaborate burials with indications of sacrificial practices and craft offerings, the observation of a nucleated pattern of settlement with relatively considerable architectural remains, and the recovery of artifacts that unmistakingly required a non-negligible level of craft specialization are among the kinds of data from which such a test is accomplished. In no instance, with perhaps the sole exception of regional surveys, was a more expansive approach pursued.

When the general statement that Kaminaljuyu was a Polynesian-type chiefdom is forwarded, one is confronted with what has been aptly called "a scenario hypothesis" (Tattersall and Eldredge 1977). This is a complex hypothesis at a high level of generalization. It is equivalent to state that Kaminaljuyu, an archaeological entity, is isomorphic to the Polynesian societies described by Sahlins (1958). In order to prove such assertion correct, it would at least be necessary to structure a hypothesis in such an extensive way as Sahlins' monograph itself. Then, data would be required to match each and all specific traits included in the treaty.

Even when much more specific aspects of such societies (e.g., as in redistribution) are selected and isolated for test and eventual validation, one encounters the unavoidable need to treat the problem in relation with other aspects of at least the economic and the social subsystems. Further, a description of the nature of such relationship usually seems required.

Neither of these levels of analysis are easily amenable to quantitative treatment of the data. Following a deductive framework, a more basic level of hypothesis testing is deemed profitable in order to build generalizations at higher levels of complexity. Agreement, intersubjectivity, then would tend to predominate over dissension.

Rather than focusing on the hypothesis that Kaminaljuyu was a chiefdom, the intention here is to examine the issue of redistribution patterns. Further, an attempt will be made only to test the hypothesis that Kaminaljuyu had a redistributive obsidian network in operation during the Late Terminal Formative.

The relationship of redistribution to other aspects of chiefdom societies will be addressed only when specifically pertinent, since the higher levels of analysis stated above appear to be successively further removed from the data available. A simple research hypothesis, suitable to statistical treatment, is thus stated. Its concatenation to the more complex, relational hypotheses concerning the existence of generalized redistribution at Kaminaljuyu, which eventually would support the statement that this society was a chiefdom of the Polynesian type, will be left open for further substantiation by other lines of evidence for which these data are only a complement.

The present test is limited to a single phase in the culture-historical sequence of Kaminaljuyu to ensure a sufficiently large sample for reliable statistical analysis. As specified before, the

Late Terminal Formative (0-200 A.D.) was preferred because it was evidently a crucial moment in the evaluative path of this society. It was the last phase of relative independence for this polity, thus permitting a look upon its pristine condition. Dual organization within component lineages assumed physical expression in the settlement patterns of the site during this phase. Separate ceremonial complexes were built by each "moiety" (Michels 1976b), suggesting a significant change toward increasing complexity in the structure of the society. Concomitant to this spatial horizontal physical modification, related to an expansion of the population, the society at Kaminaljuyu may have also attained a much more complex configuration in terms of stratification. To the already existent rank I and rank II elite strata, complemented by a single level stratum of commoners, an intermediate rank III level of commoners emerges (Michels 1976b).

Examination of these events that characterized the Late Terminal Formative leads to the assumption that perhaps during this phase Kaminaljuyu assumed the features which led archaeologists to propose the isomorphism of this ancient society to chiefdoms of the Polynesian type.

Redistribution has been defined as an economic transaction which comprises two sequential "centralized movements: collection from members of a group, often under one hand, and redivision with this group"(Sahlins 1972: 188). Pooling, the first movement, implies redistribution, the second movement. The separation of these two is arbitrary so that one can distinguish redistribution, which is a "system of reciprocities," from two-way reciprocity--horizontal reciprocity or reciprocity proper. Two-way reciprocity creates bonds between equivalent parties, whereas redistribution implements centricity, cooperation within a group, within a society (Sahlins 1972).

Such being the case, it may be assumed that in the absence of social inequality the mode of acquisition of commodities by any subunit of a society would tend to be independent from the mode of acquisition of other equivalent subunits. In the case of obsidian, each subunit

multi-centered control of obsidian →

(e.g., a lineage) would have its independent system of quarrying, transporting, and tool preparation. Conversely, in a redistributive framework of socioeconomic organization, these activities would tend

centralized control of obsidian →

to be centralized as close to the hands of the chief as possible so that the commodity involved is assuredly accessible to the consumers, but only after it is pooled by the central agency.

lineages

In the first case, each social subunit would be characterized by a high consistence in the relative frequencies of obsidian types utilized, each with a marked preference for some particular type or types, resulting in considerable variation between such subunits. In

central control

the second case, the opposite pattern would be evident. That is, diverse types of obsidian would be evenly distributed among subunits in the society as a result of randomness created by the shuffling at the central agency of all types available.

Summarizing, in the presence of redistribution, all types of obsidian available to the society would have similar probabilities of being represented at any specific subunit. The frequencies that may be observed should reflect a random situation only constrained by the proportional availability of each type. Any departure from this pattern would have to be interpreted as indicative of aberrations not corresponding to the expected conceptualization of redistribution as it is defined by Sahlins, Service, and Fried. The particular analytical framework implemented here is similar to the strategy utilized to attempt an explanation of the differences that were observed in obsidian type frequencies at village sites in Oaxaca (Winter and Pires-Ferreira 1976). These were markedly different from Early to Middle Formative times, showing a tendency of reduction of obsidian types used in the later period accompanied by a much more even distribution of these types among households, thus suggesting pooling before consumption.

Even though a shift in the social organization of Oaxacan villages from an egalitarian to a ranked society was deducted from these data, no conclusive test was attained due to insufficient size of the sample studied. Nevertheless, the tentative model which resulted from this work suggested its utilization here.

In the present study, the null hypothesis that there was a system of redistribution of obsidian at Kaminaljuyu during the Late Terminal Formative is tested by means of Pearson's Chi-square model.

Whether redistribution actually existed in Kaminaljuyu during the Late Terminal Formative can be stated as a test of a hypothesis concerning specified cell probabilities within the general framework of a Chi-square test. If the observed frequencies of obsidian types in the site of Kaminaljuyu as a whole are assumed to represent good estimates of the real distribution of types during this period, then the claim may be made that in the Late Terminal Formative the population of Kaminaljuyu was acquiring 41.5 per cent Agua Tibia (B) obsidians, 28.7 per cent Chayal (A-2) obsidians, 18.3 per cent Km 25 (A-3) obsidians, 6.1 per cent Palencia (A-1) obsidians, and 5.5 per cent El Fiscal (D) obsidians.

The claim also states that the proportions of obsidian types observed to occur for the site as a whole reflect the actual availability of these diverse types. Therefore, if redistribution prevailed in the city, these proportions would be expected to be found throughout the city. Following the specifications of statistical inference, this would be the null hypothesis to be tested. The alternative hypothesis, then, would state that such was not the case. It would be necessary to find at least one instance of significant departure from the claimed proportions in order to reject the null hypothesis in favor of the alternative one which says that no redistribution of obsidian took place at Kaminaljuyu.

Unfortunately, such testing is not possible for each of the subunits that have been delineated for the site. Insufficient sample size in some subunits precludes statistical treatment throughout the site. Thus, only those suitable for the kind of test selected are included.

Table 14 presents the data utilized, showing their organization and the aggregation of certain frequencies in order to fulfill the requirement of the Chi-square test (i.e., a minimum of five counts in each cell).

Table 14. Observed and Expected Frequencies of Obsidian Types among Social Subunits at Kaminaljuyu

Subunit		A-1 D-6 B-4	A-1 D-6	A-1	A-2	A-3	B-4	D-6
1. El Incienso Moiety A:	O	5			4	7		
	E	8.49			4.59	2.93		
2. El Incienso Moiety B:	O		5		9	15	14	
	E		4.98		12.32	7.86	17.83	
3. El Incienso Lineage:	O		5		13	22	19	
	E		6.84		16.91	10.79	24.46	
4. Mixco Lineage:	O		5		13	7	31	
	E		6.49		16.05	10.24	23.22	
5. Northeast District:	O			6	27	22	28	6
	E			5.43	25.51	16.28	36.90	4.89
6. Southeast District:	O		7		20	8	40	
	E		8.69		21.50	13.72	31.10	

Analysis at the level of the smallest social subunit, that of moieties, is restricted to the El Incienso lineage. Lineages themselves are represented by El Incienso and Mixco only. These were traditionally the highest and lowest ranked in the Kaminaljuyu hierarchy of prestige. Finally, the two major sociopolitical divisions, the Norhteast District and the Southwest District proposed by Michels (1976b), are also analyzed.

Procedure

The sample of obsidian artifacts from the nuclear center of Kaminaljuyu were analytically treated in the same way as those from valley sites in the sustaining area. They were first identified as to their geologic source by means of neutron activation analysis. They were then subjected for classification according to types established for obsidian sources in Chapter III. Direct comparison to those was accomplished by means of a cluster analysis as to ensure proper identification.

Due to limitations in time and resources, the entire site is not evenly represented in the sample of 166 dated specimens included for analysis. These are listed in Appendix 1, detailing provenience, obsidian hydration dates, source identification, and their assignation to specific sociopolitical subunits at the site, as defined spatially by previous research (Michels 1976a, 1977a, 1977b). A summarized tabulation of the sample by lineages and moieties is provided in Table 3 (p. 16). It can be seen from this table that neither the

Santa Caterina Pinula nor the San Carlos lineages have large enough subsamples as to permit statistical treatment.

A total of 104 test-pits at the site have provided obsidian specimens. These are spread over the six 1 km by 1 km areas in Zone 46 where the most nucleated part of the site is located. The criterion for sampling was constrained by the actual availability of specimens for which a date has been determined.

As a collateral effort, 21 artifacts from hamlet sites located in Zone 58 were included for analysis. These were also dated in the Late Terminal Formative. After analysis two of these were identified as Ixtepeque (F-10) obsidian, thus invalidating the dates calculated for them because the hydration rate used was the one calculated for El Chayal obsidian only.

The specimens are classified into three more general levels of similarity. Specific analysis is here referred to only the two most relevant levels: source subsystems and locality complexes. These are denoted by letters and numbers, respectively, in accordance with the scheme illustrated in Figure 4 and the taxonomic chart provided in Appendix 3.

The summary provided in Table 15 constitutes the data basis upon which the hypothesis that redistribution of obsidian took place at Kaminaljuyu in Late Terminal Formative times is tested. A graphic analysis based on relative frequencies of obsidian types for each lineage is supplied in Figure 12.

After the data were tabulated, it became apparent that detailed, in-depth examination of redistribution at the sub-chiefdom level was

Table 15. Distribution of Obsidian Types in Kaminaljuyu by Lineages (Late Terminal Formative)

Lineage	A-1	A-2	A-3	B-4	D-6	Total
El Incienso	2	13	22	19	3	59
Santa Rosita	4	14	0	9	3	30
Caterina Pinula	0	4	0	2	0	6
San Carlos	1	3	1	7	1	13
Mixco	3	13	7	31	2	56
Total	10	47	30	68	9	164

possible only for the El Incienso and Mixco lineages, which have been ranked highest and lowest, respectively, in terms of the hierarchical scale of prestige elaborated for the site (Michels 1976a). However, since a spatial division of the site in two districts has also been defined (Michels 1976b) these were also examined statistically.

Data Analysis

Examination of Table 15 shows that only the El Chayal obsidian source system was represented in Kaminaljuyu during the Late Terminal Formative. These obsidians are classified as corresponding to five of the eight source locality complexes known to comprise this source.

Among the locality complexes that are not represented, the most conspicuous is San Antonio La Paz (C-5). This outcome further validates previous observations in the sense that Kaminaljuyu did not acquire this specific type in any substantial way before Classic times (see Chapter IV). The low proportions of Palencia (A-1) and El Fiscal

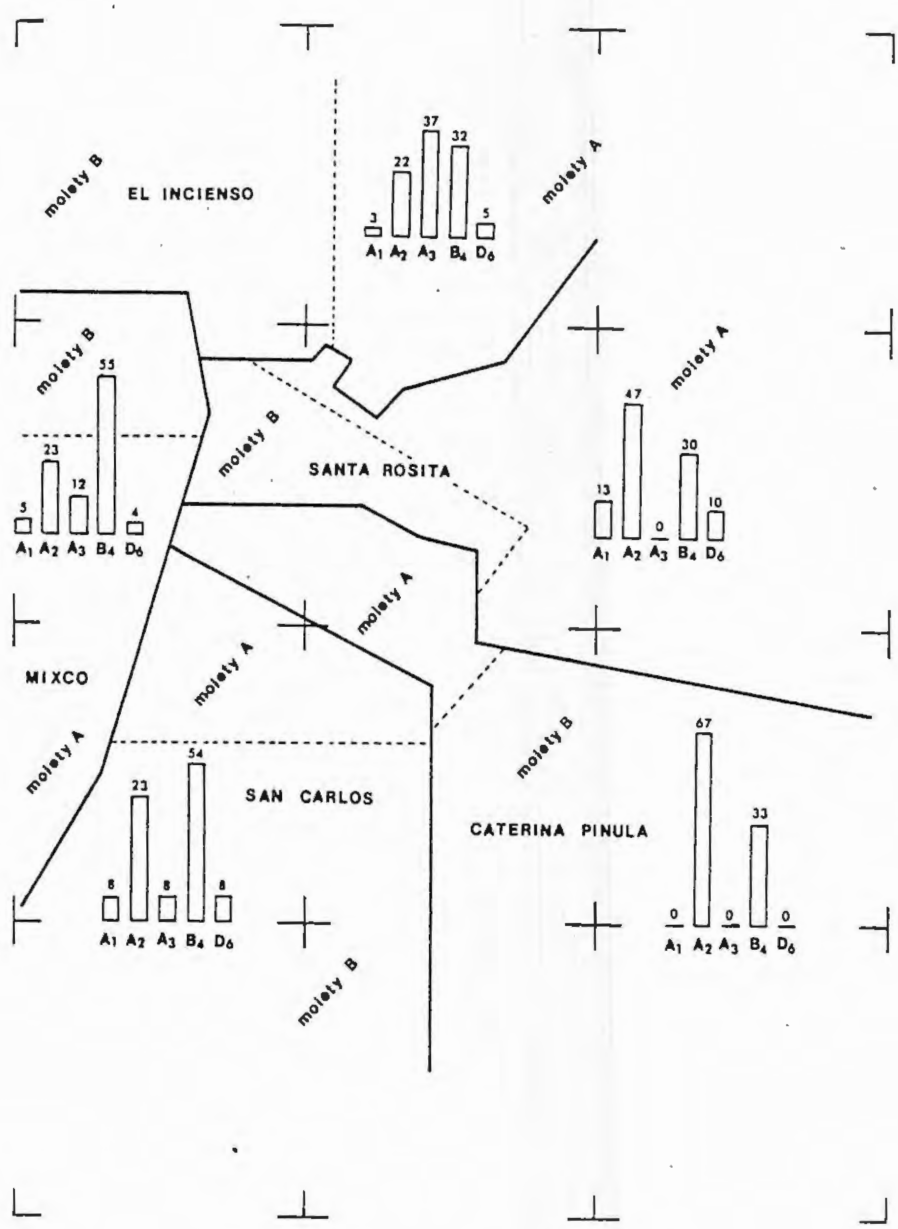


Figure 12. Relative Frequencies of Obsidian Types for Each Lineage-Ward in Kaminaljuyu.

(D) obsidians are also consistent with former conclusions in the sense that these types were not accessible to the Kaminaljuyu chiefdom throughout most of its history.

However, this also seemed to be the case with the Agua Tibia (B) obsidian. In this sample, nevertheless, Agua Tibia (B) obsidian represents 41 per cent of the obsidian in Kaminaljuyu. This type originates in the general area of San Jose Pinula, east and southeast of the Canchon Plateau, which presumably was under the control of a different polity--the Amatitlan chiefdom. This chiefdom itself did not seem to actually exploit this source in any significant way before the Terminal Formative period. Thus, the overwhelming proportion of this type of obsidian at the site of Kaminaljuyu during the Late Terminal Formative deserves special consideration.

The subject is even more significant if we examine some observed patterns in the distribution of the Agua Tibia (B) obsidian. This type is found almost exclusively in the nuclear area of Kaminaljuyu. Only four other specimens (i.e., 1.5 per cent of the sample for the valley) were found in village sites pertaining to this chiefdom (Table 13). Further, these were limited to the northeastern part of the territory controlled by Kaminaljuyu, and constitute scarcely 8 per cent of the subsample from Kaminaljuyu rural sites. None of these obsidians were found in the neighborhood of the southern border with Amatitlan. The complex of hamlet sites in Zone 58, immediately north of the borderline, for instance, has consistently yielded obsidian classifed as Km 25 (A-3) type, an expected outcome, as Zone 58 had previously been considered to be under the control of Kaminaljuyu on the basis of material representing other phases (see Chapter IV), since all obsidian specimens had been identified as originating from sources that were apparently controlled by Kaminaljuyu. The sample for the Late Terminal Formative represents 86 per cent of type Km 25 (A-3), 9 per cent from Ixtepeque, and only 5 per cent El Fiscal (D) type. Only the latter may be assumed to have been traded in from the Amatitlan chiefdom, thus indicating the definitive chiefdom affiliation of the cluster of settlements in Zone 58.

As previously described, within the urban center of Kaminaljuyu the distribution of the Agua Tibia (B) obsidian is not unpatterned. It consistently constitutes about one-third of all the obsidian at each lineage ward with the exception of San Carlos and Mixco, where the proportions exceed 50 per cent.

No definitive answer can be forwarded at this point with respect to these observations. However, some possibilities deserve to be considered. Obsidian production in Kaminaljuyu during the Late Terminal Formative has been described as restricted to only three of the five constituent lineages. Neither Santa Rosita nor Santa Caterina Pinula were involved in this industry (Michels 1976a), a pattern that is clearly at odds with the one prevalent in other phases. With variants, all lineages were involved in this craft through time. It is especially not negligible that the Santa Rosita lineage would be one of the lineages that were deprived of obsidian and had production interrupted at Kaminaljuyu in the Late Terminal Formative. A locational analysis performed on the basis of settlement clusters used as central places (Michels 1977b) suggested that the Santa Rosita lineage had control over the El Chayal quarries northeast of the valley. For some reason, this hold was probably lost by this lineage. The same reasons that were responsible for such an event may also account for the substantial predominance, by all means unusual, of the Agua Tibia (B) obsidian in Kaminaljuyu--obsidian presumably supplied by the Amatitlan chiefdom.

At this point two equally plausible explanations may be suggested, although no substantive evidence is yet available to validate either one. The first one states that no actual loss of the Chayal quarries did take place. Kaminaljuyu would have just reacted to increments in the demand of obsidian blades from long-distance trade partners by redeploying its obsidian production operations. In this scheme the Santa Rosita lineage would have delegated the production of obsidian blades to intermediate or low-ranked chiefs who were settled in the vicinity of the Chayal quarries. They would have been responsible for the export of the obsidian blades directly from the workshops.

This somehow modified scenario of decentralization has been originally proposed by Michels (1977b) as a tentative interpretation of the observed high ratio between blades and polyhedric cores found at the site of Kaminaljuyu, where obsidian blade production may have been limited to the demands of local consumption. Even though this interpretation was made in reference to times subsequent to the Middle Classic (ibid.: 16), there does not seem to be a reason why it could not be also operative for earlier times.

The alternative explanation implies the actual loss of the Chayal quarries by the Santa Rosita lineage during the Late Terminal Formative. Preliminary field observations associated with some still incomplete analysis, suggest that another autonomous political entity, different from the three chiefdoms that shared the Valley of Guatemala, may have developed in the general area of the modern town of Sanarate, some 15 km east of the Chayal chipping station site. This fourth polity may have taken advantage of its geographic position with respect to the strategic Motagua Valley to implement the expropriation of some Chayal quarries forcing Kaminaljuyu to contract supply of Agua Tibia (B) obsidian by the Amatitlan chiefdom.

The possibility of a loss of quarries in the Chayal area during the Late Terminal Formative by Kaminaljuyu seems also to be substantiated by the fact that the most distinctive type of obsidian traditionally used by the Kaminaljuyu polity throughout its history--Chayal (A-2)--dropped from 45.1 per cent in rural sites to the observed 28.7 per cent in the center. Conversely, Km 25 (A-3) obsidian, timidly used in the sustaining area, resulted comparatively important in the center, where it exceeded 18 per cent of the sample analyzed. The circumstance that the hamlets in Zone 58, the southwesternmost outpost of the Kaminaljuyu polity, had such predominance of Km 25 (A-3) obsidian in this phase cannot be discarded as resulting from chance.

It also seems significant that the San Carlos lineage and its neighboring Mixco lineage accounted for the higher proportion of Agua Tibia (B) obsidian in the site. These two lineages together were practically monopolizing the obsidian blade production with more than two-thirds of the households involved in this craft in Late Terminal Formative times (Michels 1976a). Their strategic location with respect to Amatitlan may have played an important role in securing a steady supply of obsidian for the population in Kaminaljuyu.

The likely event that these two lineages were independently acquiring obsidian from the neighboring chiefdom in the south has innumerable connotations for further questions regarding the nature of relations between these two polities. Also, internally, a well-established system of redistribution would seem crucial for the observed preservation and stability of the social integration of Kaminaljuyu. In the next chapter, some further elaboration on these matters is undertaken. Here, the discussion ought to be limited to the specific problems at hand.

A significance level of $< .05$ is commonly regarded in anthropology as sufficient to reject null hypothesis. That is, if there is less than one chance in 20 that the observed pattern of frequencies in obsidian types could be a result of randomness alone, this is sufficient criteria to suggest that there is sufficient deviance from the pattern of redistribution for the segment of the Kaminaljuyu society undergoing test. In other words, if the observed frequencies at a given spatial segment of the site prove to differ significantly from the frequencies claimed to represent the actual availability of obsidian types in Kaminaljuyu, then the suggestion would be that redistribution is not supported by the data at hand. Conversely, if the observed frequencies do not seem to differ from the expected ones beyond the limits of randomness, then the stated claim expressed in terms of equitable sharing of available obsidian types would find support in the data analyzed.

Examination of the Chi-square test results in Table 16 show that on the basis of the data analyzed, redistribution occurred at Kaminaljuyu in the Late Terminal Formative, however, following a distinctly uneven pattern. Plainly absent from the El Incienso lineage, it was yet prevalent in Mixco. Within El Incienso lineage, the situation seems to be less radical. Redistribution is not supported when the level of confidence is limited to 95 per cent, in terms of probabilities, but when the Chi-square critical value is shifted toward higher degrees of certainty then the null hypothesis is not rejected.

The data from the two districts, on the other hand, largely support the null hypothesis, thus suggesting that these two major segments of the Kaminaljuyu society had equitable access to the diverse types of obsidian that were available to the chiefdom in the Late Terminal Formative.

Observed Chi-square values may also be considered a fairly indicative measure of the extent of redistribution existing at Kaminaljuyu during the phase studied. The mathematical rationale implicit in the calculation of this statistic is represented by the function:

$$X^2 = \sum_{i=1}^{n} \frac{(O-E)^2}{E}$$

where O = observed frequencies; E = expected frequencies; and i=1, n. Thus, the more an observed distribution resembles the expected one, the smaller would be the value of Chi-square. It follows that the Chi-square values in Table 16 may be interpreted as reflecting relative differences in terms of redistribution. An ideal situation in which redistribution is perfect would yield Chi-square values approaching zero.

Table 16. Chi-square Calculations to Test Redistribution among Social Subunits in Kaminaljuyu

Subunits	Critical Values		Degrees of Freedom	Observed Chi-square	Decision	
	p=.05	p=.025			p<.05	p<.025
El Incienso Moiety A	5.99	7.38	2	7.16	*	
El Incienso Moiety B	7.82	9.35	3	8.20	*	
El Incienso Lineage	7.82	9.35	3	14.26	*	*
Mixco Lineage	7.82	9.35	3	4.56		
Northeast District	9.49	11.14	4	4.55		
Southwest District	7.82	9.35	3	5.36		

*Reject the null hypothesis.

Discussion

Obsidian artifacts classified on the basis of their geochemical composition which reflect their geologic origin have permitted to test the basic question of whether a pattern of economic redistribution existed in the proposed Kaminaljuyu chiefdom during the Late Terminal Formative.

Redistribution is assumedly a major indicator for the detection of chiefdoms of the Polynesian type, but the difficulties that are usually encountered by archaeologists when attempts are made to objectively determine it through investigation (associated to the increasing certainty that redistribution is by no means a universal characteristic of chiefdoms) has led to the comfortable decision to dispensate it from archaeological attention.

In this chapter, it has been demonstrated that the relative invisibility of redistribution in the archaeological context is not necessarily a deterrent for research. The ever increasing sophistication of methods for the acquisition of data and their analysis is breaking barriers that may have seemed insurmountable in the past.

Results obtained by this study show that during the Late Terminal Formative a pattern of redistribution of obsidian existed in Kaminaljuyu. This pattern seemingly assured the population of the site a relatively equitable access to this commodity. Departures from the general network of redistribution were also noticeable, especially in the case of the El Incienso lineage. Such aberration may be interpreted as indicative of a situation of privilege enjoyed by this lineage due to its relative position in the ranked hierarchy of prestige. El Incienso has been shown to be the paramount lineage in the pyramidal structure of the Kaminaljuyu society (Michels 1976a), an interpretation that finds support in these results.

Highly significant is the observation that during this phase the site of Kaminaljuyu was relatively deprived of the Chayal (A-2) obsidian. It is especially so because we know that this happened at the same time that the Santa Rosita lineage, which controlled the quarries from where this obsidian type originates, experienced a drastic cessation of its traditional production of obsidian blades during the Late Terminal Formative (Michels 1976b).

An unexpected observation, on the other hand, shows that the obsidian from Agua Tibia largely substituted the deficiency in supply of the Chayal (A-2) obsidian. The data at hand strongly support that the Agua Tibia (B) obsidian was introduced from the neighboring Amatitlan polity. It is also highly probable that the San Carlos, and perhaps also Mixco, lineages were responsible for this import.

While these observations open new questions as to the nature of the events involved, it is highly suggestive that such major change in the pattern of obsidian distribution in Kaminaljuyu did not disrupt in any fundamental way the internal structure of the society. Integration seems to have been strong enough as to ensure continuation in the equitable access to obsidian regardless who the main providers of this commodity were.

Finally, it is noted that these data are also suggestive of some processes that could have taken place in the region. Both the highly probable loss of the Chayal quarries by Kaminaljuyu and its concomitant acquisition of an alternative provision of obsidian by recourse to the Amatitlan polity need to be explored further. It may very well be the case that such events constitute the basis for the subsequent establishment of the port-of-trade institution which is known to have existed in Classic times.

VI. FUTURE RESEARCH OBJECTIVES

The present study of specific problems on the archaeology of the Valley of Guatemala has permitted an examination of a number of lines of archaeological research that are also relevant to more general issues--methodological and theoretical in nature. The results obtained, however, cannot be taken as definitive answers. It is implicit in the testing of hypotheses that new questions are generated. These, in turn, constitute problems amenable to future investigation.

In closing, then, it seems appropriate to make a statement specifying some of the new questions that may be suggested by the outcome of this study. It will be done so, first looking at methodological issues and then theoretical ones.

This study, in the sense that the data utilized were exclusively obtained from the analysis of obsidian material, has significant implications for the methodology of obsidian hydration dating and obsidian sourcing studies. The estimation of a hydration date for the Chimaltenango obsidian, attained as a direct consequence of this research, brings up the possibility of obtaining source-specific hydration rates for other obsidian kinds that were used in the region.

The procedure used here is simple. If different obsidian kinds are found contextually associated in archaeological sites and the hydration rate of at least one of them is known, then the hydration rate of the others can be estimated by means of a linear regression statistic.

Although the central highlands of Guatemala may be considered as a relatively homogeneous climatic zone, thus allowing relative control for the crucial temperature variable that is known to affect the hydration process, distantly traded obsidian may encounter significantly different ambient temperature environment. This calls for what could be referred to as a concatenated set of hydration rates for archaeological obsidians known to be derived from the same source.

Once the mean variation in temperature for one zone with respect to that of the Valley of Guatemala is known, it should be possible to correct for these differences. This is mathematically feasible. For example, the Mesoamerican area is known to vary in temperature as a direct function of altitude. Thus, it would be only necessary to use the temperature gradient determined for any zone other than the Valley of Guatemala in order to have a correction factor that would render hydration rates applicable to archaeological assemblages in a wider area.

With respect to obsidian sourcing studies, the simple approach, based on the concentration of sodium and manganese in obsidian, seems to be sufficient whenever identifications are performed with respect to obsidian hydration dating. The observed limitations of this approach may not be of such a magnitude as to justify its substitution by the multi-element strategy implemented in this work. However, the possibility of inclusion to the analysis of a third element besides sodium and manganese, in order to attain better discrimination of obsidian sources, should be taken into consideration.

The more traditional application of obsidian sourcing studies to prehistoric long-distance trade is likely to be enhanced by the results of this work. With very few exceptions trade studies in Mesoamerica, and other areas in the world, have been limited to the elucidation of patterns of interaction at the interregional level, usually relying on gross chronometric controls. For instance, the presence of El Chayal obsidian at sites in the southern Gulf coast tells us that this general region had interacted economically with the central highlands of Guatemala. No further information can be elicited from such observation.

Given that the data obtained in this study suggest a discriminant pattern of access to different quarries of the El Chayal source system by at least two independent sociopolitical entities in the Valley of Guatemala, the question arises as to whether only one or both of these two polities might have been engaged in such trade with the Gulf coast sites, or for that matter with any other region.

If the identification of obsidians originating from El Chayal is performed at those sites following the approach used here, then it should be possible to determine areas of influence and interaction for each of the polities involved. Beyond the descriptive power of such an approach, the possibilities for throwing light on changes through time in patterns of interaction would add invaluable evidence concerning the evolutionary processes by which the sociocultural entities in the area had evolved.

At the local level, when examining the economic and sociopolitical structure of a given society, the taxonomy of obsidian types using categories at the intrasource level opens new possibilities. For the first time it is feasible to look at patterns of obsidian distribution within small segments of a society permitting access to information on levels of economic relationships between these segments, from which conclusions can be made regarding their sociopolitical affiliation. Spatial proximity, as a criterion for such inferences, is thus further complemented.

These methodological observations also concern the topic of how obsidian sourcing studies contribute to theoretical issues on the sociopolitical structure of the Valley of Guatemala in Precolumbian times. The possibilities seem unlimited. In this sense, obsidian is proving to be an almost inexhaustible source of valuable data on a wide spectrum of research problems. Here, the discussion will be limited to those instances that appear to merit most immediate implementation.

It is now apparent that the boundaries between the three chiefdoms were not quite stable through time. Their relative fluidity, seemingly related to processes of interaction between the detected entities in the region, is a subject that certainly needs further examination. A more intensive sampling of obsidian artifacts from as many sites as possible in the region, together with an extensive program of chronometric controls, should provide substantive evidence concerning not only the history of settlements in the region but also the intrinsic nature of their interaction in a diachronic perspective. The insertion here of the concept of conflict and conflict theory cannot be ignored.

Another area of interest related to the sociopolitical structure of the valley appears to be suggested by the observation that the overall pattern of consumption of obsidian, in terms of source identification, at the center of Kaminaljuyu during the Late Terminal Formative does not resemble the prevalent distribution of obsidian types among sites in the sustaining area of this chiefdom. Such discrepancy cannot be fully explained with the data at hand, but the intensive approach of regional scope suggested above should yield more relevant information that would eventually lead to the generation of useful hypotheses.

Redistribution, understood as a distinctive economic feature of the chiefdom level of sociocultural integration, is now known to be a process which has archaeological visibility and is also amenable to mathematical treatment. So far, only obsidian has been susceptible to redistribution analysis. Yet, there is reason for optimism in our quest for other archaeologically analyzable commodities since many are equally susceptible to trade element analysis.

Results thus far are limited in their generalizing power given the circumstance that only one phase in the development of Kaminaljuyu has been examined. These results should gain much more significance when all phases in the occupational history of the site are studied in the same fashion. Only then will the relationship of redistribution phenomena to overall processes of sociocultural evolution be discernible.

Since the method of obsidian hydration dating yields chronometric determinations with relatively small standard errors, it is here suggested that any future program of research aimed at the problem of redistribution in a diachronic perspective should be based on samples representing very small spans of time. The gains in analytical power of such a strategy should largely compensate for the extra demands imposed by the increased number of samples that would have to be included for study.

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APPENDIX 1

DATED OBSIDIAN ARTIFACTS FROM KAMINALJUYU,

LATE TERMINAL FORMATIVE

Z-A-S	ODL No.	Date (A.D.)	Obsidian Source	Ward-Lineage	Moiety
46-12-143	8086	177	A-3	El Incienso	B
148	8088	22	A-3	El Incienso	B
185	8104	177	B-4	El Incienso	B
187	8070	11	A-1	El Incienso	B
189	7136	64	A-3	El Incienso	B
215	8115	32	A-3	El Incienso	B
228	4726	105	A-3	El Incienso	B
228	4712	177	A-2	El Incienso	B
229	5219	197	A-3	El Incienso	B
229	5217	85	A-2	El Incienso	B
229	5226	53	A-3	El Incienso	B
248	4715	136	A-2	El Incienso	B
248	6546	85	B-4	El Incienso	B
248	4731	85	A-1	El Incienso	B
248	6551	116	B-4	El Incienso	B
248	6552	1	A-2	El Incienso	B
248	6554	74	B-4	El Incienso	B
249	4706	177	A-3	El Incienso	B
256	8132	64	A-2	El Incienso	B
314	5298	187	D-6	El Incienso	B
315	5311	74	A-3	El Incienso	B
336	5309	85	A-3	El Incienso	B
337	8198	197	A-2	El Incienso	B
357	5284	95	D-6	El Incienso	B
358	8200	1	A-3	El Incienso	B
359	8202	156	B-4	El Incienso	B
374	5264	43	A-3	El Incienso	B
396	5244	116	A-3	El Incienso	B
399	8210	116	A-3	El Incienso	B
46-13-165	7428	156	A-3	El Incienso	A
223	8214	11	A-3	El Incienso	A
223	8215	105	A-3	El Incienso	A
263	8218	136	A-3	El Incienso	A
284	8223	105	A-3	El Incienso	A
284	8224	197	A-3	El Incienso	A
347	6882	95	B-4	El Incienso	A
383	6895	197	B-4	El Incienso	A
385	6905	197	B-4	El Incienso	A
385	6910	136	B-4	El Incienso	A
388	6922	146	B-4	El Incienso	A
46-22-007	8544	105	A-3	Mixco	B
011	8546	32	A-1	Mixco	B
015	5228	156	B-4	El Incienso	B
015	5233	74	Undet.	El Incienso	B
015	5241	74	A-2	El Incienso	B
015	5235	64	B-4	El Incienso	B

Z-A-S	ODL No.	Date (A.D.)	Obsidian Source	Ward-Lineage	Moiety
015	5236	53	B-4	El Incienso	B
015	5234	64	B-4	El Incienso	B
015	5239	22	B-4	El Incienso	B
46-22-016	5205	11	B-4	El Incienso	B
016	5209	177	B-4	El Incienso	B
016	5208	177	B-4	El Incienso	B
016	5206	74	B-4	El Incienso	B
035	5279	126	A-2	El Incienso	B
035	5281	126	A-3	El Incienso	B
051	5272	187	B-4	Mixco	B
058	5289	177	D-6	El Incienso	B
058	5292	43	A-2	El Incienso	B
079	6566	32	A-2	Santa Rosita	A
079	6565	22	B-4	Santa Rosita	A
079	6567	22	A-1	Santa Rosita	A
079	6568	146	A-1	Santa Rosita	A
079	5242	74	D-6	Santa Rosita	A
079	5243	32	D-6	Santa Rosita	A
090	6572	105	A-3	Mixco	B
091	4700	64	A-2	Mixco	B
091	6540	85	A-2	Mixco	B
093	4664	53	A-2	Mixco	B
093	4663	43	B-4	Mixco	B
096	7753	1	A-2	Santa Rosita	B
098	7755	197	A-2	Santa Rosita	B
110	4674	126	B-4	Mixco	B
110	4677	105	B-4	Mixco	B
110	4686	53	B-4	Mixco	B
110	6537	136	B-4	Mixco	B
110	6538	74	B-4	Mixco	B
110	6539	84	Undet.	Mixco	B
110	4673	22	A-2	Mixco	B
110	4678	32	B-4	Mixco	B
110	4741	136	D-6	Mixco	B
111	4644	197	B-4	Mixco	B
112	4750	85	B-4	Mixco	B
112	6559	105	B-4	Mixco	B
112	4749	32	B-4	Mixco	B
116	7763	95	D-6	Santa Rosita	B
127	7766	53	B-4	Mixco	B
129	7769	95	A-3	Mixco	B
135	7773	167	A-2	Santa Rosita	B
147	7783	126	B-4	Mixco	B
151	7698	167	D-6	Mixco	B
158	7702	53	A-2	Santa Rosita	B
173	7792	64	A-2	Mixco	B

Z-A-S	ODL No.	Date (A.D.)	Obsidian Source	Ward-Lineage	Moiety
173	7793	197	A-2	Mixco	B
175	7799	105	A-2	Santa Rosita	B
179	7707	105	A-2	Santa Rosita	B
186	7710	197	A-2	Mixco	A
187	7711	167	A-3	Mixco	A
187	7712	146	A-2	Mixco	A
189	7714	146	A-2	Mixco	A
190	7717	74	A-2	Mixco	A
192	7720	85	B-4	Mixco	A
194	7721	126	A-1	Mixco	A
194	7723	64	A-2	Mixco	A
46-22-219	6397	197	B-4	Santa Rosita	B
221	7801	43	A-3	Mixco	A
229	7639	116	B-4	Mixco	A
229	7354	1	B-4	Mixco	A
229	8190	116	B-4	Mixco	A
229	8194	156	B-4	Mixco	A
229	7579	167	B-4	Mixco	A
229	7577	136	B-4	Mixco	A
229	7586	167	B-4	Mixco	A
229	7361	85	B-4	Mixco	A
233	7809	1	A-3	Mixco	A
246	7813	85	B-4	Mixco	A
246	7815	85	B-4	Mixco	A
251	7643	156	B-4	Mixco	A
270	7645	95	A-1	Mixco	A
293	8663	126	B-4	Caterina Pinula	A
296	8665	116	A-2	Caterina Pinula	A
306	8671	1	B-4	Mixco	A
308	7435	85	A-2	Mixco	A
308	7466	11	B-4	Mixco	A
318	8672	85	B-4	Caterina Pinula	A
345	8684	197	B-4	Mixco	A
384	8706	64	B-4	Mixco	A
388	8707	53	B-4	Mixco	A
390	8712	95	A-2	Mixco	A
392	7949	156	A-2	San Carlos	A
392	7950	22	B-4	San Carlos	A
392	7951	126	B-4	San Carlos	A
393	8718	53	A-3	San Carlos	A
46-23-004	5569	177	A-2	El Incienso	A
061	8371	187	A-1	Santa Rosita	A
068	7443	136	A-2	El Incienso	A
070	8384	43	A-2	El Incienso	A
072	6429	177	A-2	Santa Rosita	A
082	8451	85	A-1	Santa Rosita	A

Z-A-S	ODL No.	Date (A.D.)	Obsidian Source	Ward-Lineage	Moiety
086	5901	32	A-2	El Incienso	A
103	7210	149	A-3	El Incienso	A
111	6115	105	A-2	Santa Rosita	A
128	6136	116	A-2	Santa Rosita	A
147	6161	105	A-2	Santa Rosita	A
165	6189	95	B-4	Santa Rosita	A
165	6191	167	B-4	Santa Rosita	A
166	6192	136	B-4	Santa Rosita	A
166	6197	53	A-2	Santa Rosita	A
168	6341	74	A-2	Santa Rosita	A
184	6362	53	B-4	Santa Rosita	B
185	6368	95	B-4	Santa Rosita	B
185	6367	32	A-2	Santa Rosita	B
185	6370	64	B-4	Santa Rosita	B
185	6376	156	B-4	Santa Rosita	B
222	6410	187	A-2	Caterina Pinula	A
241	6413	177	A-2	Caterina Pinula	A
241	6414	53	A-2	Caterina Pinula	A
46-32-074	6435	146	A-2	San Carlos	A
094	6420	126	B-4	San Carlos	A
094	8178	105	B-4	San Carlos	A
094	8179	167	A-1	San Carlos	A
094	8181	197	B-4	San Carlos	A
094	8731	53	D-6	San Carlos	A
113	6451	197	B-4	San Carlos	A
113	6453	1	B-4	San Carlos	A
204	8747	217	A-3	Mixco	A
46-33-162	8306	95	A-2	San Carlos	B

Z-A-S	ODL No.	Date (A.D.)	Obsidian Source
SUPPLEMENT: Hamlet Sites in Zone 58			
58-02-344	10676	108	A-3
03-229	10559	77	A-3
03-320	10635	179	A-3
10-220	10501	179	A-3
11-314	10616	18[a]	A-3
11-314	10617	239	F-10
13-035	10504	87	A-3
13-035	10505	179	A-3
14-132	10646	179	A-3
14-132	10647	18[a]	A-3
23-079	10669	14	A-3
23-165	10672	14	A-3
23-209	10568	199	A-3
23-209	10569	169	A-3
23-325	10650	328	A-3
24-156	10621	209	A-3
31-053	10541	552	F-10
40-079	10613	179	D-6
40-083	10555	118	A-3
43-153	10666	108	A-3
43-354	10684	A-3	

[a]Date B.C.

APPENDIX 2

COMPUTER PROGRAM FACTOR

```
C   FACTOR:  A program to perform a column by column transformation
C            of values in a NNx11 data matrix using a different conver-
C            sion factor for each column.  The term "column" is here
C            used in the statistical sense of "variables."  Each column
C            is an array of measurements on a variable for up to NN
C            cases (rows).
C
C   VARIABLES:  FACT = Conversion factors.  First card of data deck.
C                      Format (11F6.0).
C               NN   = Number of cases (raws in data matrix).  Second
C                      card of data deck.  Format (I2).
C               OLD  = Raw data matrix.  Third to NNth cards in data
C                      deck.  Format (11F6.0).
C               SNEW = Corrected data marrix.
C
C   INPUT:   Either cards or card images in BAT files.  First card must
C            be the FACT card, followed by NN and OLD.  If NN larger
C            than 99, a change in the dimension of SNEW and OLD, and
C            the Format of NN are imperative.
C
C   OUTPUT:  SNEW is listed in format (1X,11F6.2) with no titles.
C
C
//  EXEC FWCG
//SYSIN DD*
      INTEGER NN
      DIMENSION FACT(1,11), SNEW(99,11), OLD (99,11)
 100  FORMAT (11F6.0)
 110  FORMAT (I2)
 200  FORMAT (1X,11F6.2)
      DO 5 M=1
      READ 100,(FACT(1,N),N=1,11)
      READ 110, NN
   5  CONTINUE
      DO 15 I=1,NN
      READ 100,(OLD(I,J),J=1,11)
  15  CONTINUE
      DO 25 J=1,11
      DO 35 II=1,NN
      SNEW(II,J)=OLD(II,J)*FACT(1,J)
  35  CONTINUE
  25  CONTINUE
      DO 45 K=1,NN
      PRINT 200,(SNEW(K,L),L=1,11)
  45  CONTINUE
      STOP
      END
//DATA.INPUT DD *
C
C ---------Include data deck---------
C
/*
```

APPENDIX 3

TAXONOMIC CHART OF OBSIDIAN SOURCES IN GUATEMALA

Source System	Subsystem	Locality Complex	Locality
I. El Chayal	A. Chayal	1. Palencia	Palencia El Pinal Mogollon Piedra Gorda Pedrero 1 La Periquera San Jose del Golfo
		2. Chayal	Cerro Chayal Chayal Chpp. St. Km 24 Azacualpilla
		3. Km 25	Km 25
	B. Agua Tibia	4. Agua Tibia	Hacienda Nueva Agua Tibia Tapacun
	C. S. Antonio La Paz	5. San Antonio La Paz	San Antonio La Paz El Remudadero El Chorro San Antonio (N) San Antonio (S)
	D. El Fiscal	6. El Fiscal	El Fiscal Pedrero 2 Km 19 Ruta 6 Pedrero 1 (L.S.) Pedrero 1 (U.S.)
		7. La Joya	La Joya Las Vacas (Palencia)
	E. Los Mixcos	8. Los Mixcos	Los Mixcos Rio Canas

Source System	Subsystem	Locality Complex	Locality
Ixtepeque	F. Las Animas	9. Las Animas	Las Animas
II. Chimaltenango	G. Chimaltenango	10. Matuloj	Matuloj
		11. San Martin Jilotepeque	San Martin Jilotepeque Quemaya Pixcaya
		12. El Rosario	El Rosario Departamental 1
III. Amatitlan	H. Amatitlan	13. Matilandia	Finca Matilandia El Cerrito Finca Panal
		14. Amatitlan	Amatitlan
	I. San Andres Itzapa	15. San Andres Itzapa	San Andres Itzapa Los Aposentos Santa Monica
IV. Los Mezcales	J. Los Mezcales	16. Los Mexcales	Los Mexcales La Joyita
V. Cruz de Apan	K. Cruz de Apan	17. Cruz de Apan	Cruz de Apan