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CHEMICAL CHARACTERIZATION OF VOLCANIC GLASS FROM CENTRAL MEXICO AND ITS APPLICATION TO ARCHEOLOGICAL STUDIES

A Thesis

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ABSTRACT

Fifteen obsidian sources and three archeological sites located in the Trans-Mexico Volcanic Belt were geographically located, described, and sampled. The samples were analyzed by x-ray spectrometry for the elements Mn, Rb, Zr, Ti, Fe, P, Ca, Sr, K, and Ba. The analytical data were subjected to a series of statistical analyses. The characterization of each source was made using the sample characteristics of mean, range, standard deviation, coefficient of variability and correlation coefficient values between the variables.

Generalized statistical distance values (D^2), f values between sites, discriminant equations and principal component analysis were used in the evaluation of the relative similarities or differences between sites. The low D^2 and F values indicated close relationship in the chemical composition between certain sites at the 99 percent confidence level. Comparison of D^2 values made possible the assignment of the three archeological sites to certain known sources, and discriminant function analysis gave an approximate idea of the relative importance of each variable in discriminating any pair of sites. The results of these analyses indicate that Rb, Mn, Ti, Zr and Sr are the most important discriminative elements. Factor analysis (R-mode) studied the variation in the inter-relationship between the variables in the pooled sample population. The variability was related to four factors that account for 85.2 percent of the variation within the obsidian population. Three of those factors are attributed to the concentration of the accessory minerals, apatite,

zircon, iron-oxides and ferromagnesian minerals and the fourth factor is attributed to the degree of acidity of the magma from which the obsidians originated. Obsidian source identification for archeological sites were made by assuming that the obsidian samples came from a unique and known source. The use of multivariate analysis provided the tools for a fast and accurate assignment of the archeological sites to known sources.

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INTRODUCTION

Obsidian is a volcanic glass similar in chemical composition to granite. It can be geographically characterized by its assemblage of trace elements. Obsidian has been used by ancient people in many parts of the world as a primary material for the manufacture of weapons, tools and different types of artifacts (Armitage, et al. 1971; Dixon, et al. 1968; Gordus and Wright, 1969).

The primary objective of this thesis was to locate and characterize fifteen central Mexican obsidian sources by their geological, petrographical and geochemical characteristics. The geochemical data from these sources provided the opportunity to apply different types of statistical methods to interpret the geochemical information. These methods permitted the identification of the sources of obsidian artifacts. The assignment of artifacts to unique source areas is extremely important in documenting and determining prehistoric trading links especially in Mesoamerica where obsidian was widely utilized over a region which was far more extensive than the area of source deposits.

Previous geological work has been oriented toward the determination of the geochemistry of a few scattered samples without a real characterization of the sources. Cobean et al, (1971) reported twenty obsidian sources in Central Mexico and Guatemala in which at least three samples, varying between 5 to 300 grams in weight, were collected. Even though some deposits were rather extensive and the number of samples collected from them was small, they described and characterized only eight of those source areas, admittedly sampling with time restrictions. The characterizations were made using the concentration ranges for Zr, Rb, Sr and Mn in parts per million. From a statistical and geological point of view no characterization can be made using range determinations, especially when they are based on very small sample populations which were collected without regard to the stratigraphic relationship within the sites. Jack _et al_. (1972) studied three of the same source areas mentioned by Cobean _et al_. (1971) and found different ranges for Sr, Zr, and Rb. Data from these studies have been used in attempts to determine the source for those archeological sites and thus delineate the trade routes that were operative in prehistoric times. This study will rectify many of the short-comings of the previous studies by providing accurate geographical, geological and statistical characterization of fifteen obsidian source areas in Mesoamerica.

The data derived from this study will thus provide archeological investigators with a statistically and geologically valid data bank to which future artifacts may be compared to determine their source localities.

GEOLOGICAL SETTING

The obsidian deposits are located along the Trans-Mexico Volcanic belt that covers the central part of the Mexican highlands. The volcanic belt is situated along the 19° parallel and is about 25 kilometers wide. It consists of an elongate zone of andesite strato-volcanoes, scoria cones, lava domes and obsidian domes. There are very few active volcanoes, considering the length of the volcanic belt; but there are numerous prehistoric cinder cones that make up several clusters, each of which strikes transverse to the main volcanic axis.

The Mexican Volcanic belt is considered by Mooser (1961) as an old zone of crustal weakness which has been reopened since Tertiary times. The main fault and graben of the entire volcanic belt have an east-west trend and can be interpreted as being either a continental extention of the Clairon Fracture Zone, a transform fault intersecting the Mid-Pacific Rise or as faulted slices recurving from a southern continuation of the San Andreas Fault (Mooser and Maldonado, 1961). Both the San Andreas-Chapala Line and the Clairon Fracture Zone are active at the present. Thermal springs, recent lavas, and youthful cones are scattered over their entire extensions. The oldest volcanic activity within the belt occurred along North-South fractures that may reveal the width of a pre-existing zone of weakness. In southeastern Mexico the volcanic belt does not connect with the Guatemalan volcanic belt, but it does extend eastward and passes into a line of Tertiary folds, that extends to Belice. The

Mexican Volcanic Belt is tectonically related to the Acapulco Trench (Fig. 1), on which subduction has been occurring at a relatively low angle, producing andesitic magmas which rise under the Mexican Volcanic Belt 200 to 300 kilometers from the coastline. A fact that supports this connection is that the bulk composition of the magma from the Mexican volcanic belt is also andesitic (Mooser, 1973). Foshag and Gonzalez (1956) list the most recent activity of the Mexican volcanoes as follows: Orizaba (1687), Jorullo (1759), San Martin Tuxtla (1793), San Juan (1859), Ceborruco (1870-75), Colina (1913), Popocatepetl (1920-24) and Paricutin (1943-1957). Of these, V. Colina, V. Popocatepetl and Pico de Orizaba are in a fumarolic quiescent stage and the rest are considered dormant.

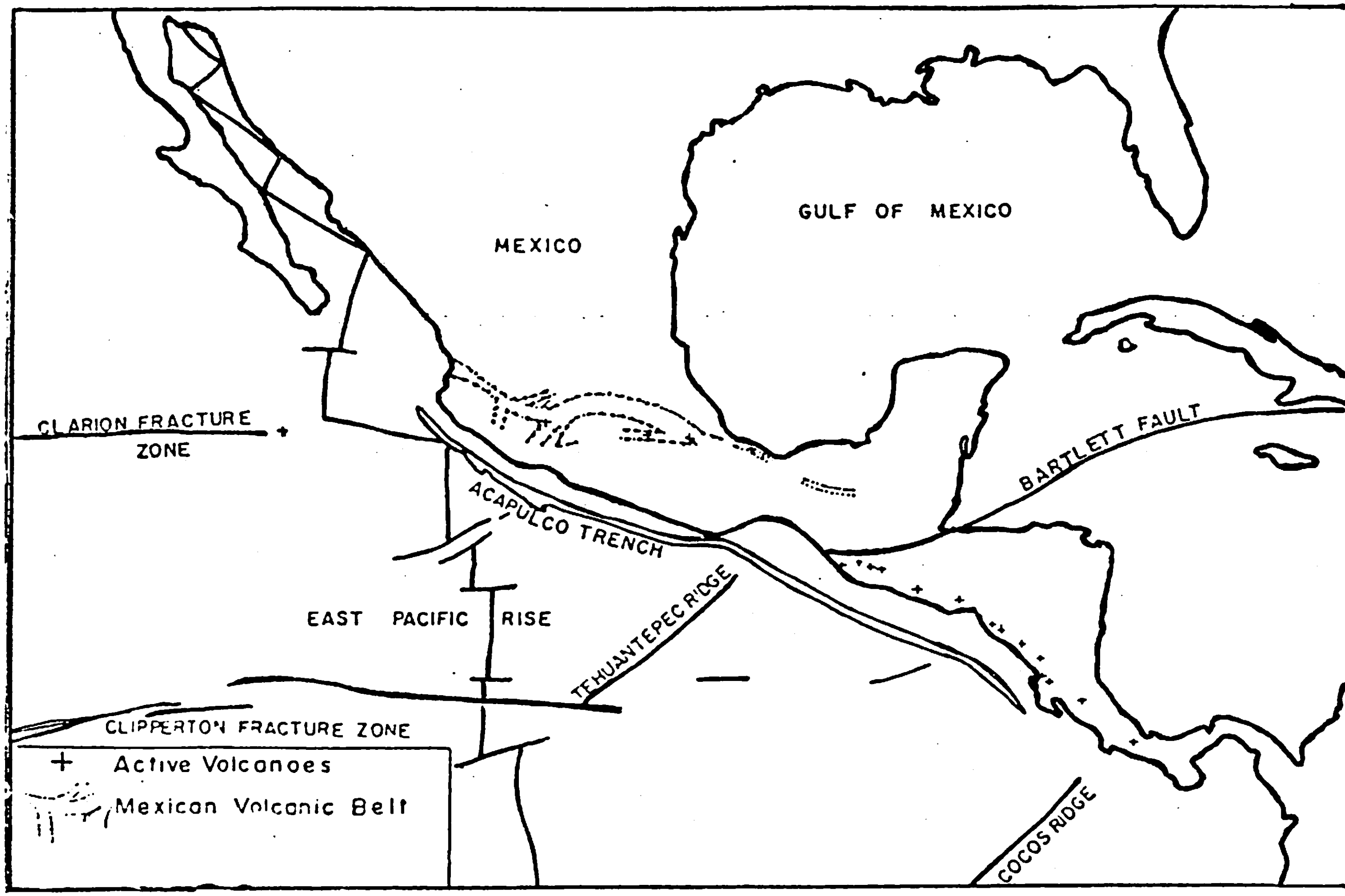

Figure 1. Tectonic relationship between the Mexican volcanic belt and the Acapulco trench. (Adapted from Mooser, 1973).

DESCRIPTION OF OBSIDIAN DEPOSITS

Fifteen obsidian deposits (Fig. 2), mentioned by Cobean et al in 1971 (names in parenthesis), were sampled and twenty to twenty-five samples were taken from each site. The weights of the sample sizes vary between one and three pounds. Obsidian color determinations were made using the GSA Rock-Color Chard (Geological Society of America, 1970).

Clamalapa (Guadalupe Victoria), Site No. 1

This deposit of obsidian is located 2 kilometers northwest of the small town of Clamalapa, located in the NW part of the state of Puebla (Fig. 3).

The deposit is exposed at the top of the hill, on which the small stream, Rio dos Aguas, originates. This stream flows down the east flank of the hill cutting two deep ravines in which the obsidian is exposed. The obsidian deposit is interbedded between thick beds of volcanic ash (Fig. 4). There are large cobble-and boulder sized fragments of obsidian that are commonly dark gray (N3), massive and sparsely spherulitic in texture. Some samples from this deposit show grayish brown (5 YR 3/2) and dark gray (N3) bands. Obsidian appears to be of average working quality.

Eroded fragments from the deposit have been transported by the river and later deposited downstream in terrace deposits and in the river bed in the upper part of the Guadalupe Victoria valley.

Ten samples were collected from each outcrop. Before sampling,

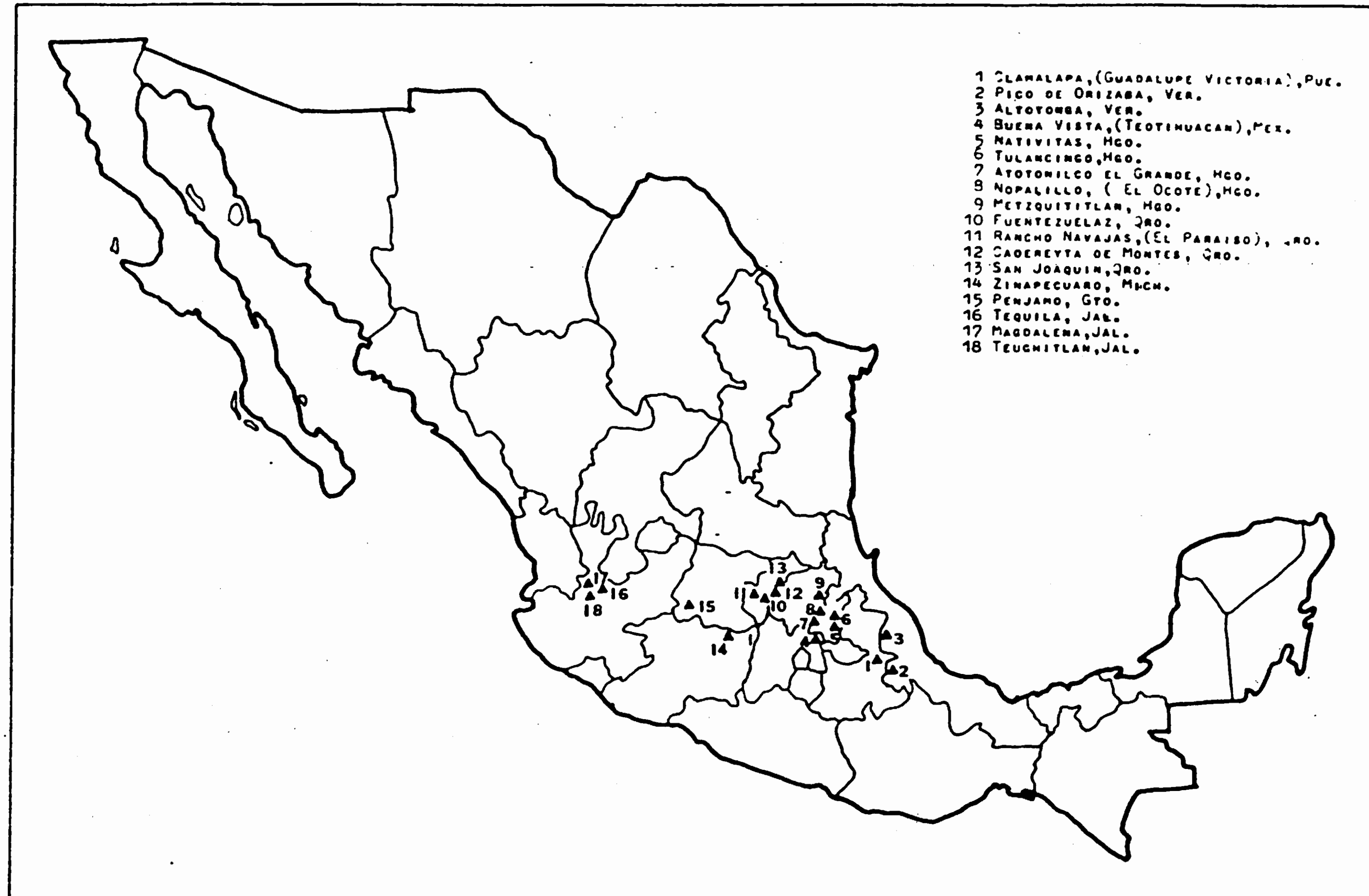

Figure 2. General location map of the obsidian sites in central Mexico.

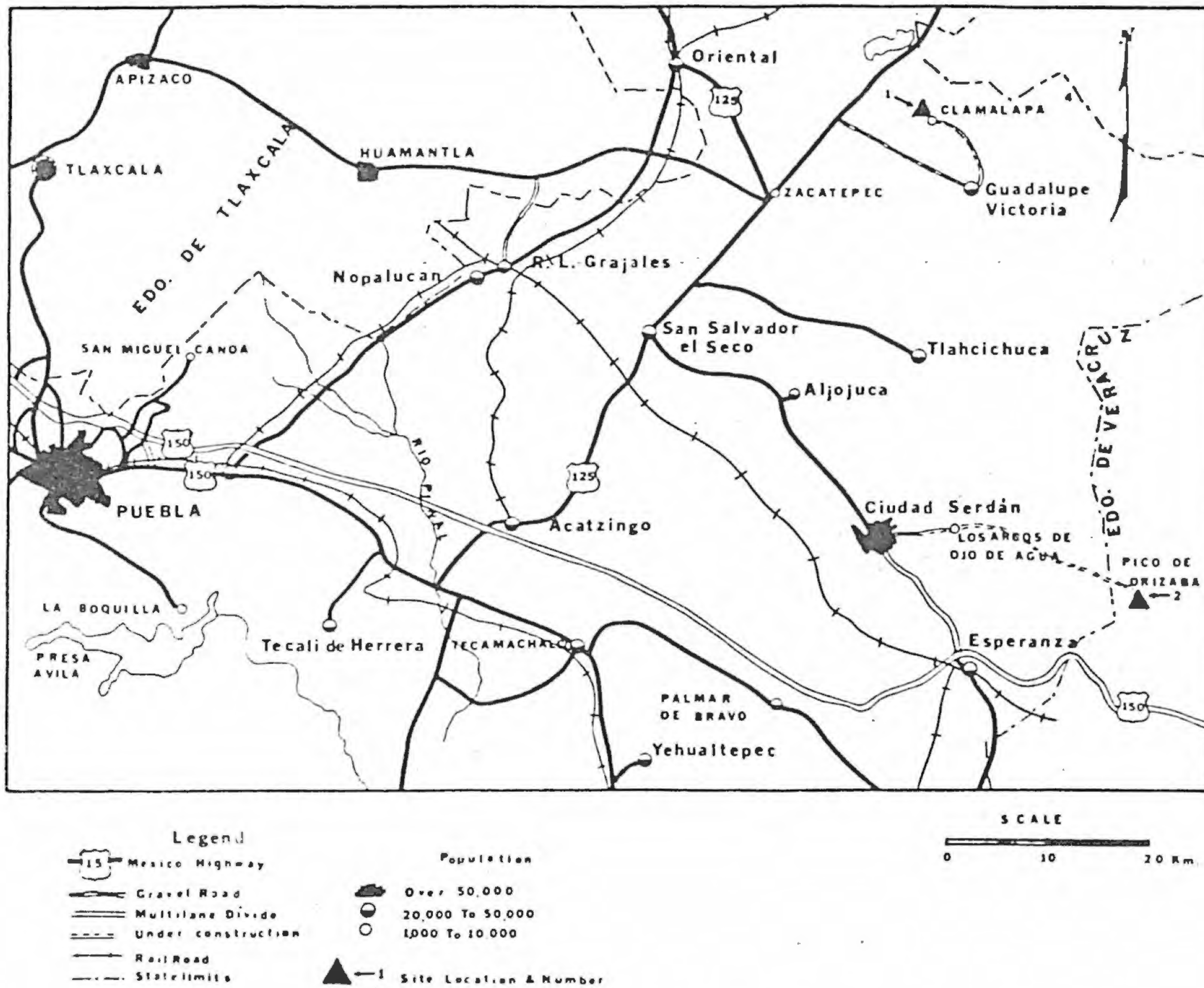

Figure 3. Location map. Sites No. 1, Clamalapa and No. 2, Pico de Orizaba.

Figure 4. Obsidian interbedded between thick beds of volcanic ash, (Clamalapa).

the vertical homogeneity was determined, looking especially for color changes and textural variations. Samples were taken from the bottom to the top of the outcrop at almost equal intervals. Samples from the northernmost ravine were labelled 1-A-1 to 1-A-10; samples from the southernmost ravine were labelled 1-B-1 to 1-B-10.

Pico de Orizaba, Site No. 2

The obsidian deposit is located 25 kilometers southeast of Los Arcos de Ojo de Agua (Fig. 3), in a mountain called "La Montaña de Arena", two kilometers south of the southeast flank of the Orizaba Peak (Fig. 5-6).

Obsidian crops out between two thick deposits of volcanic ash. It is banded with transparent and dark gray (N3) bands and appears to be of good working quality. The vertical homogeneity of the outcrop was not determined because its north flank is very steep and access is difficult. The outcrop is only exposed in this northern flank, where particles of obsidian can be seen blanketing the site. Twenty random samples were taken from the bottom of the outcrop and labelled 2-1 to 2-20.

Altotonga, Site No. 3

One and a half kilometers north of Altotonga in the state of Veracruz, on Highway 131 (Fig. 7), there is a bridge which crosses a ravine called "El Zanjon" by the local people. Three kilometers upstream from the bridge on the west side of the ravine, large cobble-sized pieces of grayish black (N2) and medium dark gray (N4) obsidian are associated with volcanic ash and rhyolitic tuff. Only a few

Figure 5. La Montaña de Arena (Pico de Orizaba).

Figure 6. Southeast flank of the Orizaba peak.

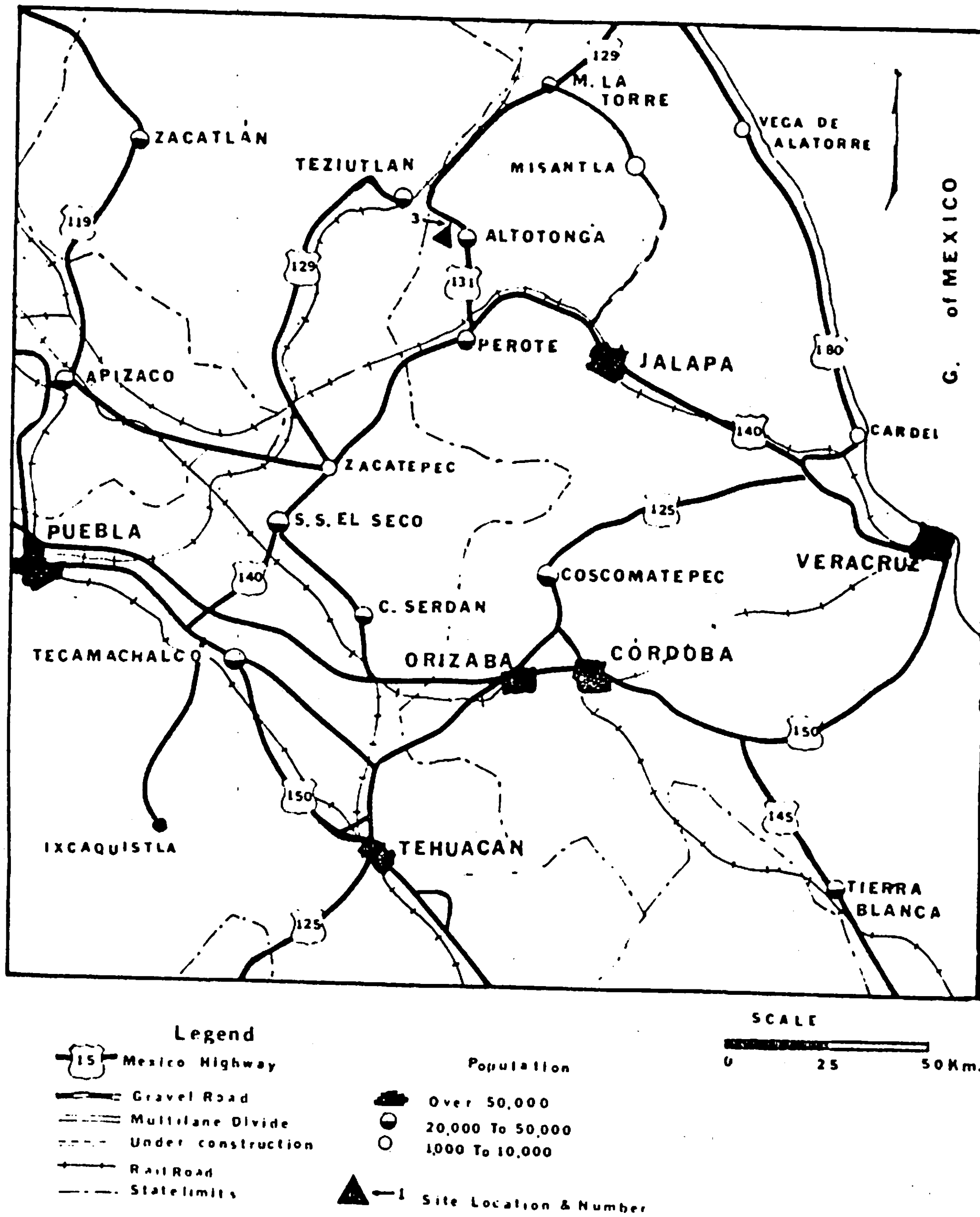

Figure 7. Location map, site No. 3 Altotonga.

exposures were found but significant amounts of the material have been eroded and transported downstream. Twenty samples of obsidian which appear to be of good working quality were collected in a random manner and labelled 3-1 to 3-20.

Buena Vista, (Teotihuacan), Site No. 4

Two large, parallel rhyolitic obsidian flows crop out one and a half kilometers northeast of the town of Buena Vista, which is located fifteen kilometers east of Otumba in the State of Mexico (Fig. 8). Obsidians from this source have medium dark (N4) to dark gray (N3) bands, and appear to be of good working quality. Ten samples were collected from the east flow and ten from the west flow. All the samples were taken from obsidian found in place (Fig. 9). Sampling was from the bottom to the top at approximately equal intervals. Samples were labelled 4AE-1 to 4AE-10 and 4AW-1 to 4AW-10.

Nativitas, Site No. 5

A large flow of interbedded volcanic ash and rhyolitic obsidian was found 500 meters east of the cemetery in the small town of Nativitas, which is located southeast of Tulancingo in the State of Pachuca (Fig. 10). Obsidian crops out in abundant scattered exposures, as large cobble and boulder-sized fragments in a hard rhyolitic matrix. Large amounts of obsidian are also found in the soil layer and are exposed in tilled fields. The obsidian is banded dark gray (n3) to black (N1) and is also sparsely spherulitic in texture. Twenty samples were collected from a traverse west to east across the flow and labelled 5-1 to 5-20.

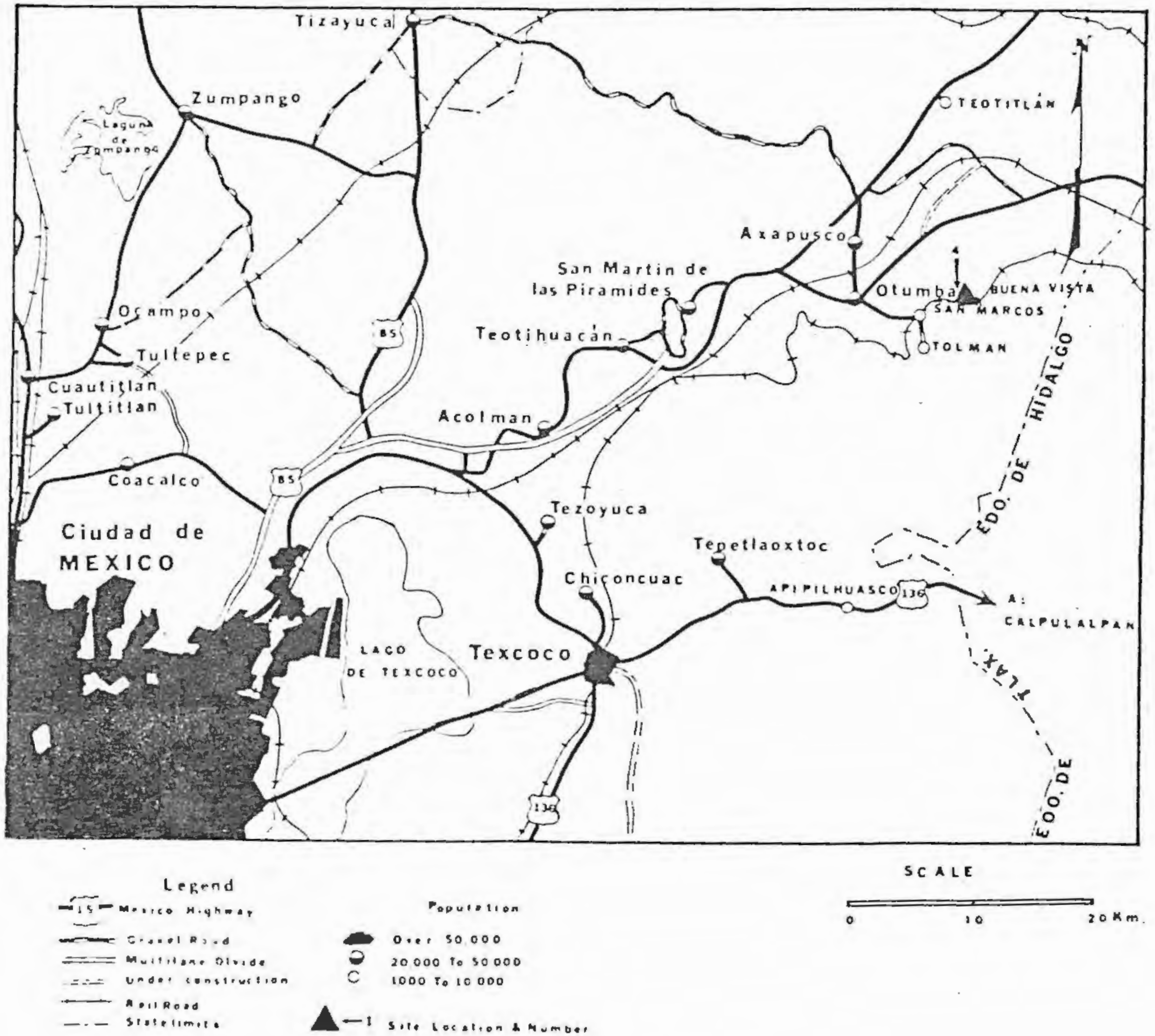

Figure 8. Location map. Site No. 4 Buena Vista.

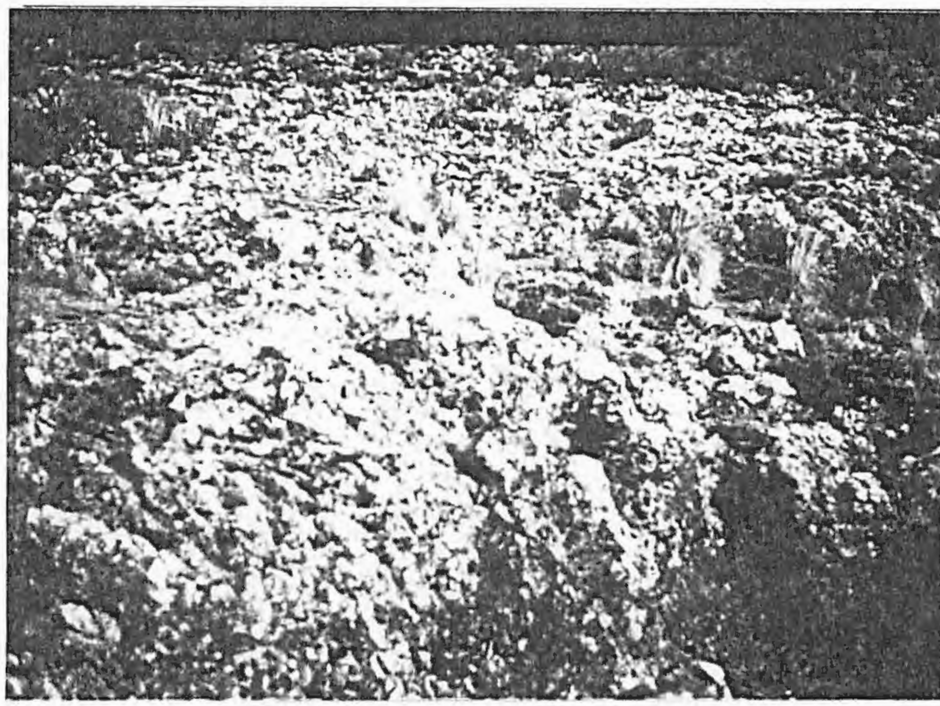

Figure 9. Lower portion of the outcrop site No. 4, Buena Vista.

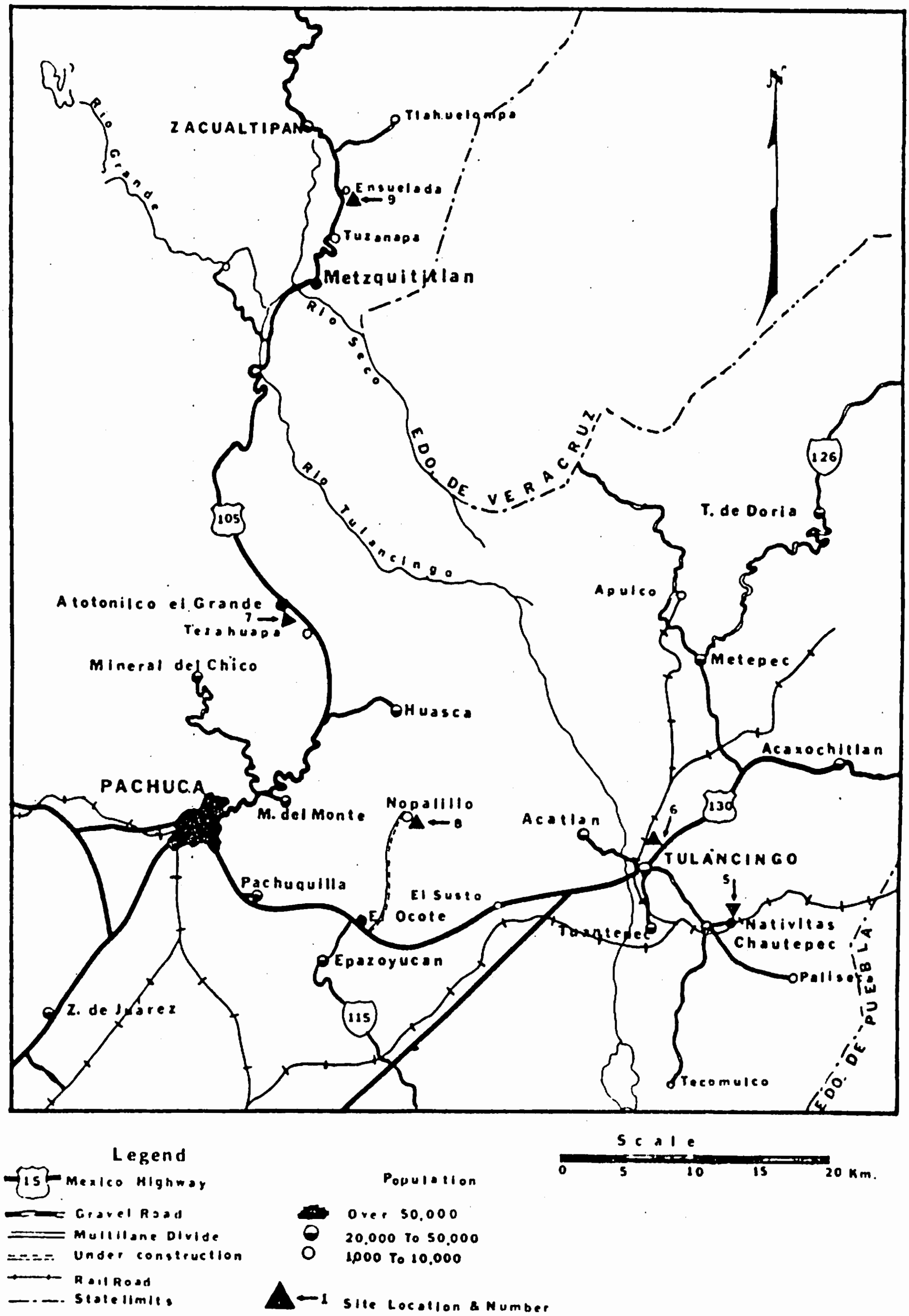

Figure 10. Location map sites, No. 5, Nativitas; No. 6, Tulancingo; No. 7, Atotonilco; No. 8, Nopalillo; and No. 9; Metzquititlan.

Tulancingo, Site No. 6

One kilometer northeast of Tulancingo in the state of Pachuca (Fig. 10), Highway 130 cuts a pyroclastic flow composed of interbedded yellow volcanic ash and smooth black (N1) obsidian. Exposures crop out along the north side of the highway (Fig. 11), and in a small stream which runs parallel to the south side of the highway.

The thickness of the obsidian beds is variable and ranges between two to fifty cms. (Fig. 12). The obsidian is black (N1) in color and appears to be of good working quality. Twenty samples were collected in a traverse made from the lower part of the stream bed to 150 meters north of the road cut. The samples were labelled 6-1 to 6-20.

Site No. 7 is described in the section on Archeological Sites.

Nopalillo, (El Ocote) Site No. 8

A vast accumulation of light olive-green (5 Y 5/2) obsidian disseminated throughout widespread dark-yellow volcanic ash in located in the vicinity of the small town of Nopalillo in the state of Pachuca. This town is located 10 kilometers north of the intersection of a dirt road and Highway 130, 19 kilometers east of Pachuca (Fig. 10). The obsidian in this deposit has a probable pyroclastic origin. The bottle green color of this obsidian is unique to this deposit and is not present in other obsidian deposits studied. Twenty samples were collected in an area of about three square klms. around the town. Samples were labelled 8-1 to 8-20.

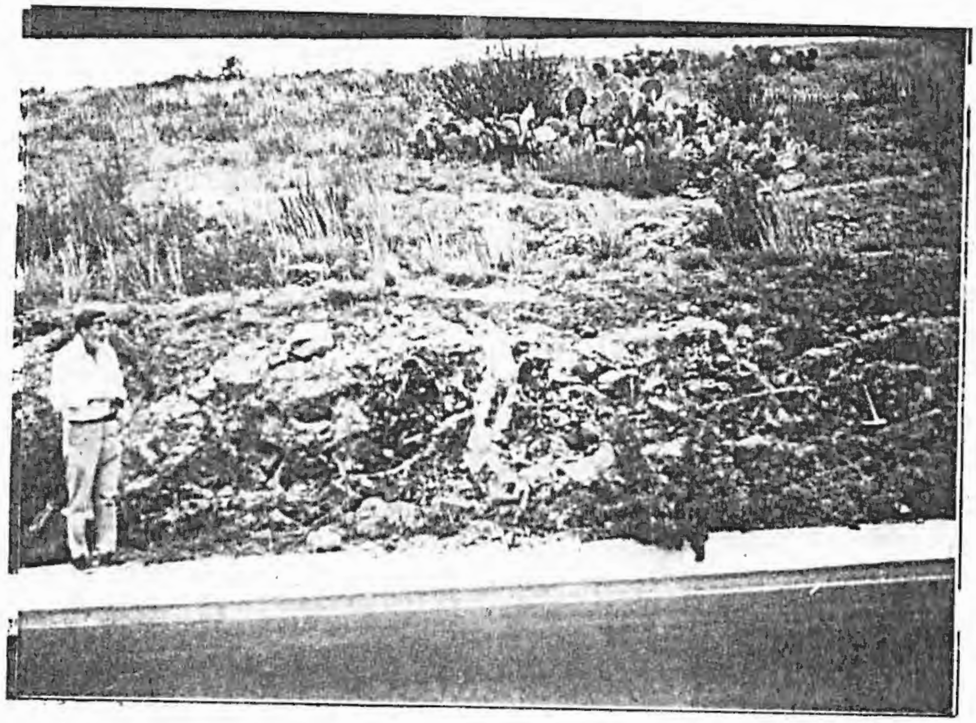

Figure 11. North exposure of the outcrop, site No. 6, Tulancingo

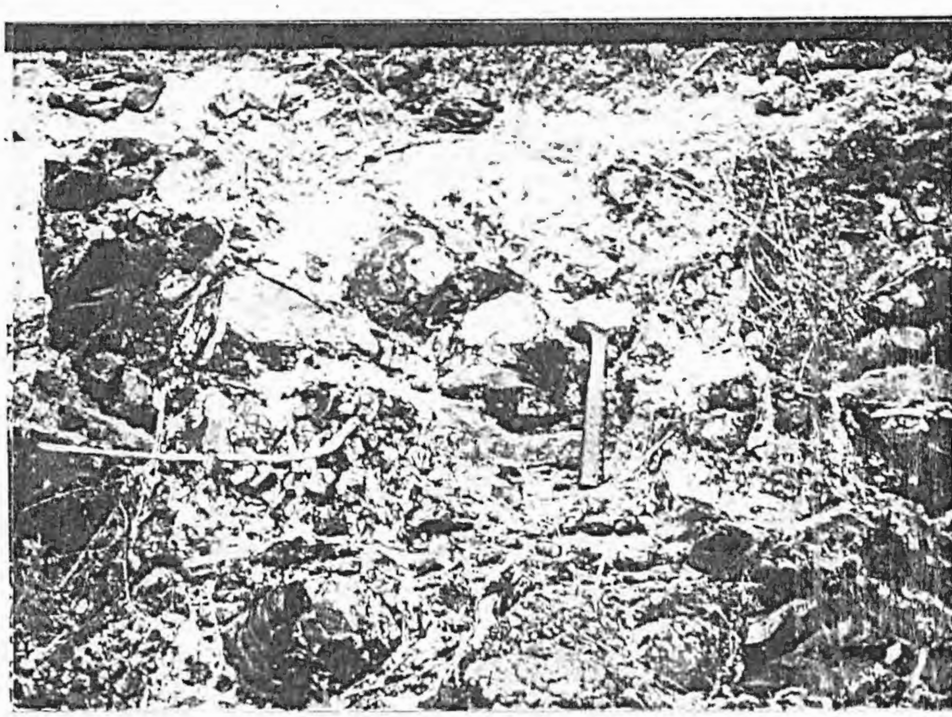

Figure 12. Interbedded yellow volcanic ash and black obsidian, site No. 6, Tulancingo.

Figure 13. General view of the outcrop, site No. 9, Metzquititlan

Figure 14. Obsidian boulders and cobble sized fragments, site No. 9, Metzquititlan.

Metzquititlan, Site No. 9

This deposit is located on the east side of Highway 105, twelve and a half kilometers north of Metzquititlan in a place called "Ensuelada", in the state of Pachuca (Fig. 10). A large flow of smooth black (N1) obsidian in a soft rhyolitic ash matrix is exposed and extends over an area of about 1500 square meters, (Fig. 13). Obsidian occurs as big boulder- and cobble-size pieces that appear to be of good working quality (Fig. 14). The flow has been excavated the the local people and the excavation covers a very large area in which twenty samples were randomly collected and labelled 9-1 to 9-20.

Fuentezuelas, Site No. 10

Sixteen kilometers south of Ezequiel del Monte in the state of Queretaro, along Highway 120, is a dirt road going northwest to Fuentezuelas. Three kilometers southwest of Fuentezuelas is a large rhyolitic obsidian flow (Fig. 15). The obsidian from this flow shows different textures and the mode of occurrence changes within the flow. Obsidian from the lower portion is smooth in texture and occurs as cobble- and boulder-size fragments in an ash matrix. The middle part is sparsely spherulitic and occurs as boulder-size fragments in a hard rhyolitic matrix (Fig. 16). Obsidian from the upper part of the flow is mainly spherulitic and appears to be of poor working quality. The working quality of the obsidian increases towards the bottom of the flow. This flow has been excavated and is now a big cave in which some artifacts were found. Obsidian is mainly dark gray (N3) to black (N1) in color. Twenty samples were

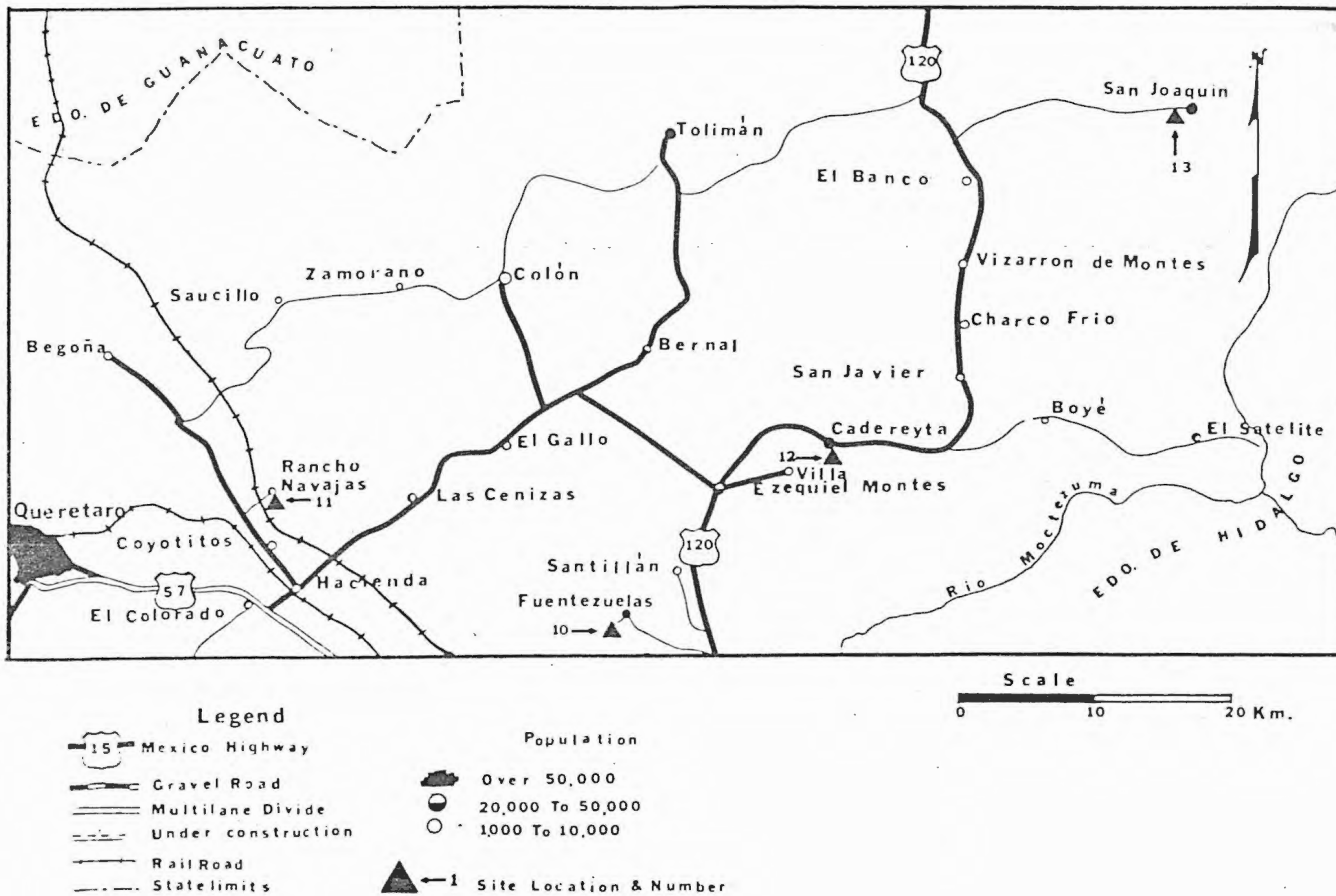

Figure 15. Location map. Sites No. 10, Fuentezuelas, No. 11, Rancho Navajas, No. 12, Cadereyta de Montes and No. 13, San Joaquin.

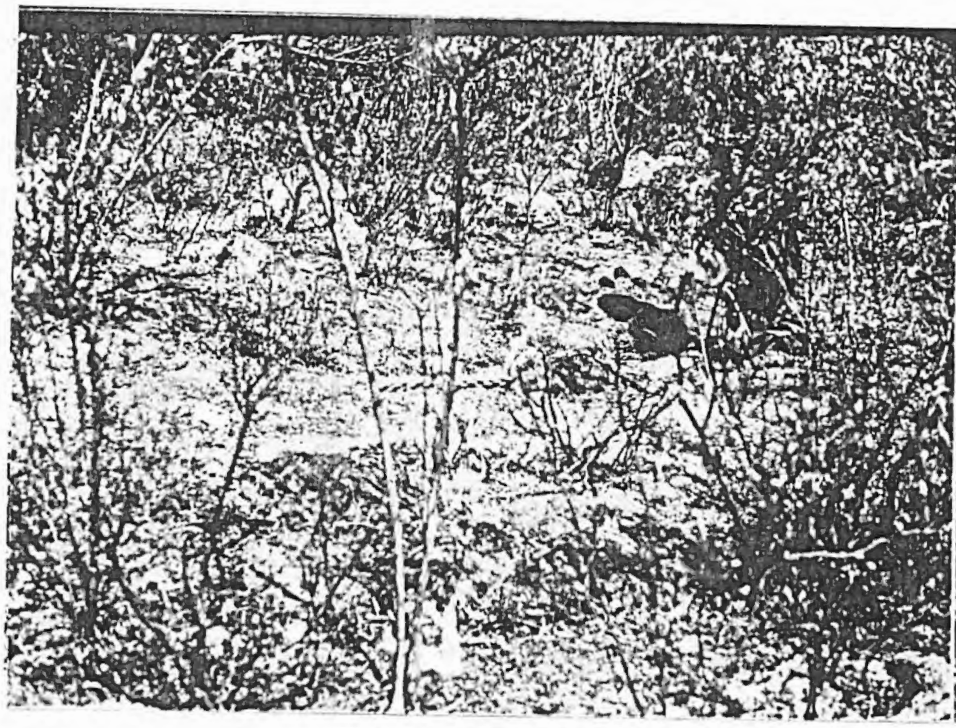

Figure 16. Obsidian cobble and boulder size pieces in a hard rhyolitic matrix, site No. 10, Fuentezuelas.

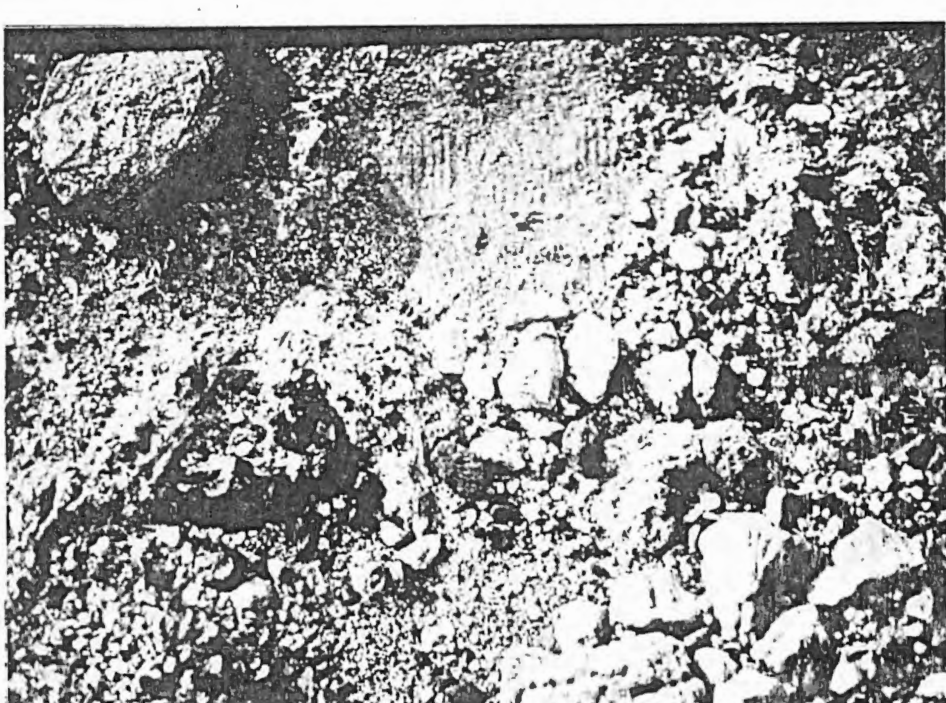

Figure 17. Obsidian cobble size pieces in a hard rhyolitic matrix. Site No. 11, Rancho Navajas.

collected in an east-west traverse. The samples were labelled 10A to 10A-8, 10B-1 to 10B-5, 10C-1 to 10C-5, and 10D-1.

Rancho Navajas, (El Paraiso), Site No. 11

The obsidian flow is found at Rancho Navajas located seven kilometers northwest of the town of Hacienda in the state of Queretaro (Fig. 15). Obsidian interbedded with perlite and volcanic ash is exposed in the north flank of the flow. The thickness of the obsidian beds is variable and ranges between 10 cms and 80 cms. Obsidian also occurs as cobble-size pieces in a hard rhyolitic matrix (Fig. 17). The obsidian is grayish black (N2) to black (N1) in color and appears to be of good working quality. The obsidian is called "pedernal" by the local people which means chert. Twenty-one samples were collected in a north-wouth traverse and labelled 11-1 to 11-21.

Sites Nos. 12 and 13 are described in the section for archeological sites.

Ucareo, (Zinapecuaro), Site No. 14

Six kilometers northeast of Zinapecuaro on Highway 120, is a dirt road that goes to Ucareo in the state of Michoacan. Ten kilometers east from this intersection a large flow of volcanic ash and obsidian can be seen to the east side of the road (Fig. 18-19). Obsidian occurs in layers of variable thickness and appears to be of good working quality (Fig. 20). The flow has been excavated by the local people and the material used in road construction. Twenty-five samples of black (N1) obsidian were collected from the bottom to the top of the flow and labelled 14-1 to 14-25.

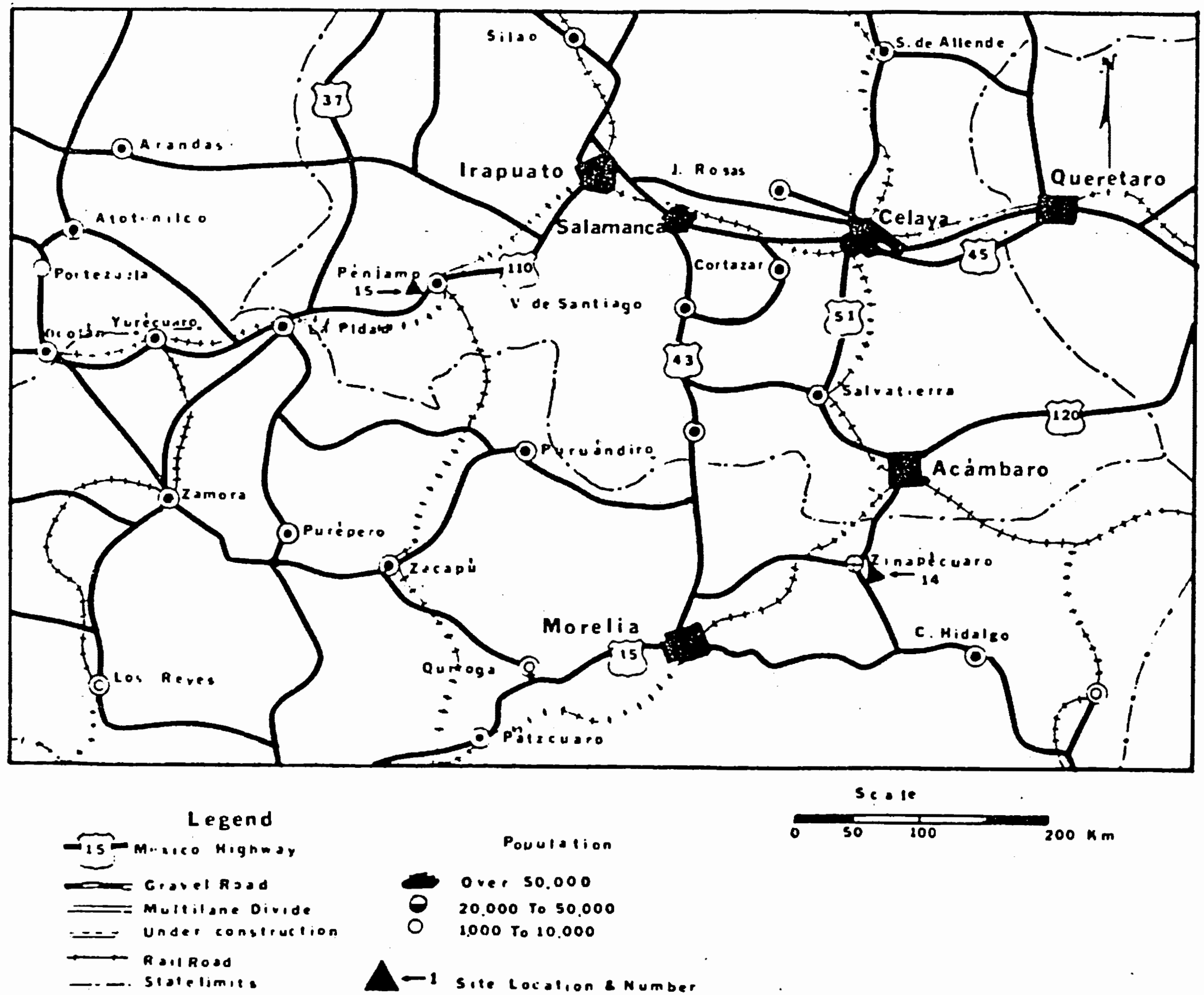

Figure 18. Location map. Sites No. 14, Zinapecuaro and No. 15, Penjamo.

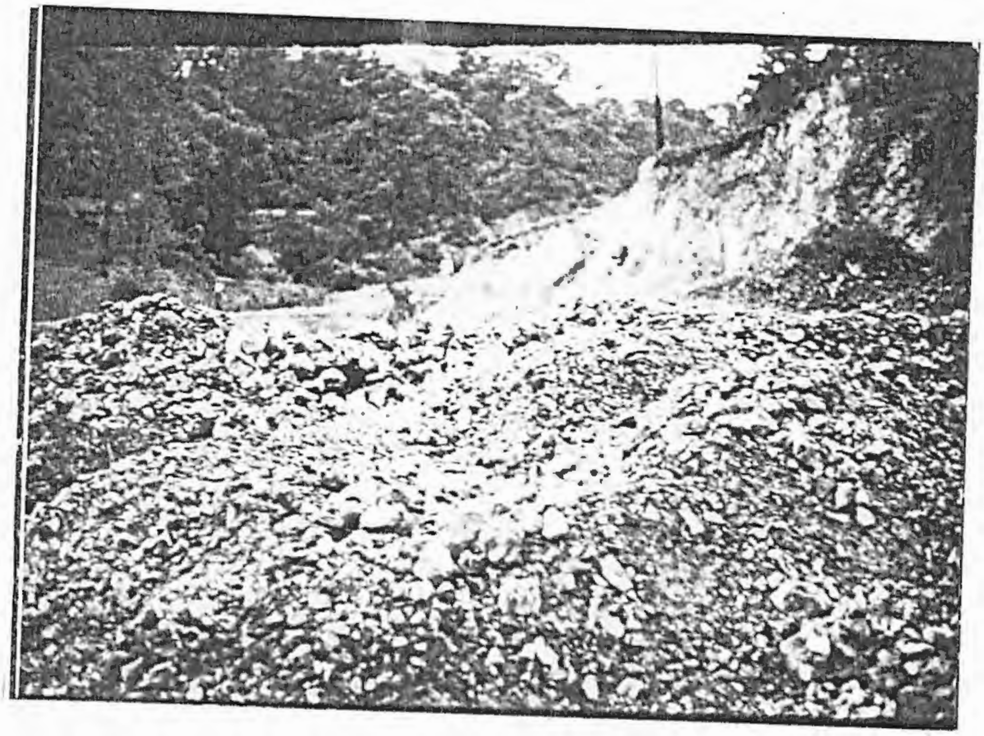

Figure 19. General view of site No. 14, Zinapecuaro.

Figure 20. Obsidian layers of variable thickness,
site No. 14, Zinapecuaro.

Penjamo, Site No. 15

This obsidian deposit is located on the west side of Highway 110, one and a half kilometers south of Penjamo in the state of Guanajuato (Fig. 18). The flow has been excavated revealing a large circular exposure (Fig. 21). This exposure shows cobble-size pieces of obsidian in a hard rhyolitic matrix and also in associated obsidian and perlite interlayers. The thickness of the layers is on the order of 5 to 150 cms. (Fig. 22).

The uniformity of the flow changes towards the northernmost part of the exposure where pebble and cobble-size pieces of obsidian occur in a perlitic matrix that has been altered to a yellowish clay. Thick layers of spherulitic perlite were also found in this area. Obsidian is black (N1) and appears to be of good working quality. Twenty samples were collected along the circular exposure and labelled 15-1 to 15-20.

Tequila, Site No. 16

The obsidian deposit crops out in the lower portion of a large ash flow located south of Tequila in the state of Jalisco (Fig. 23). The flow runs parallel to Highway 15 and shows structural and textural variations from bottom to top. The flow description was made in a place located 1.6 kilometers northeast of Tequila along Highway 15 to Magdalena (Fig. 24).

In this area, the lower portion of the flow is composed of dark gray (N3) to black (N1) sparsely spherulitic obsidian in an easily eroded yellowish brown ashy matrix which is also exposed in tilled fields (Fig. 25).

Figure 21. Obsidian outcrop, site No. 15, Penjamo.

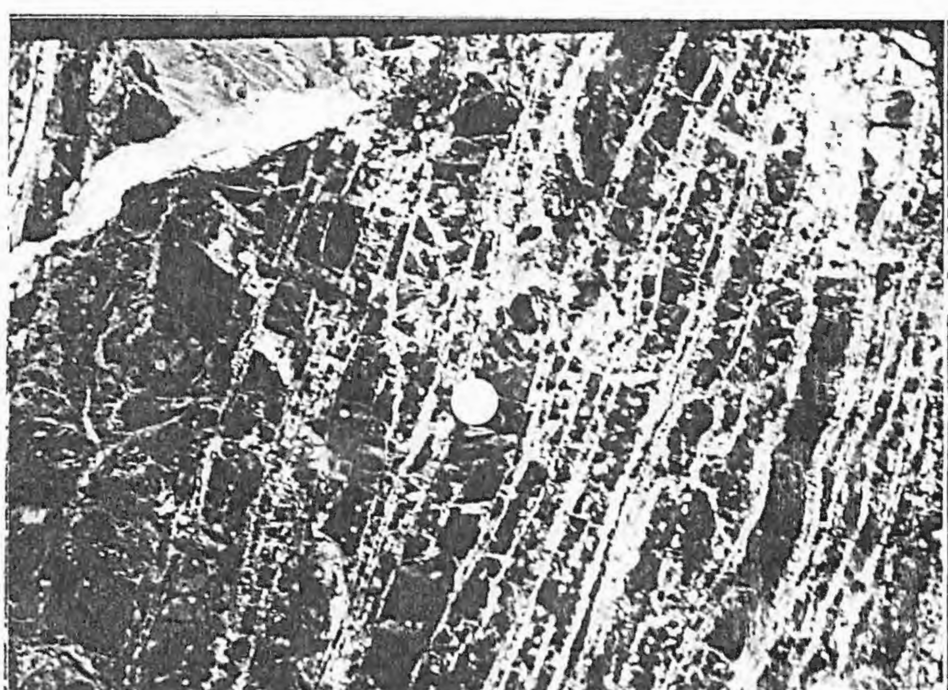

Figure 22. Obsidian perlite interlayers, site No. 15, Penjamo.

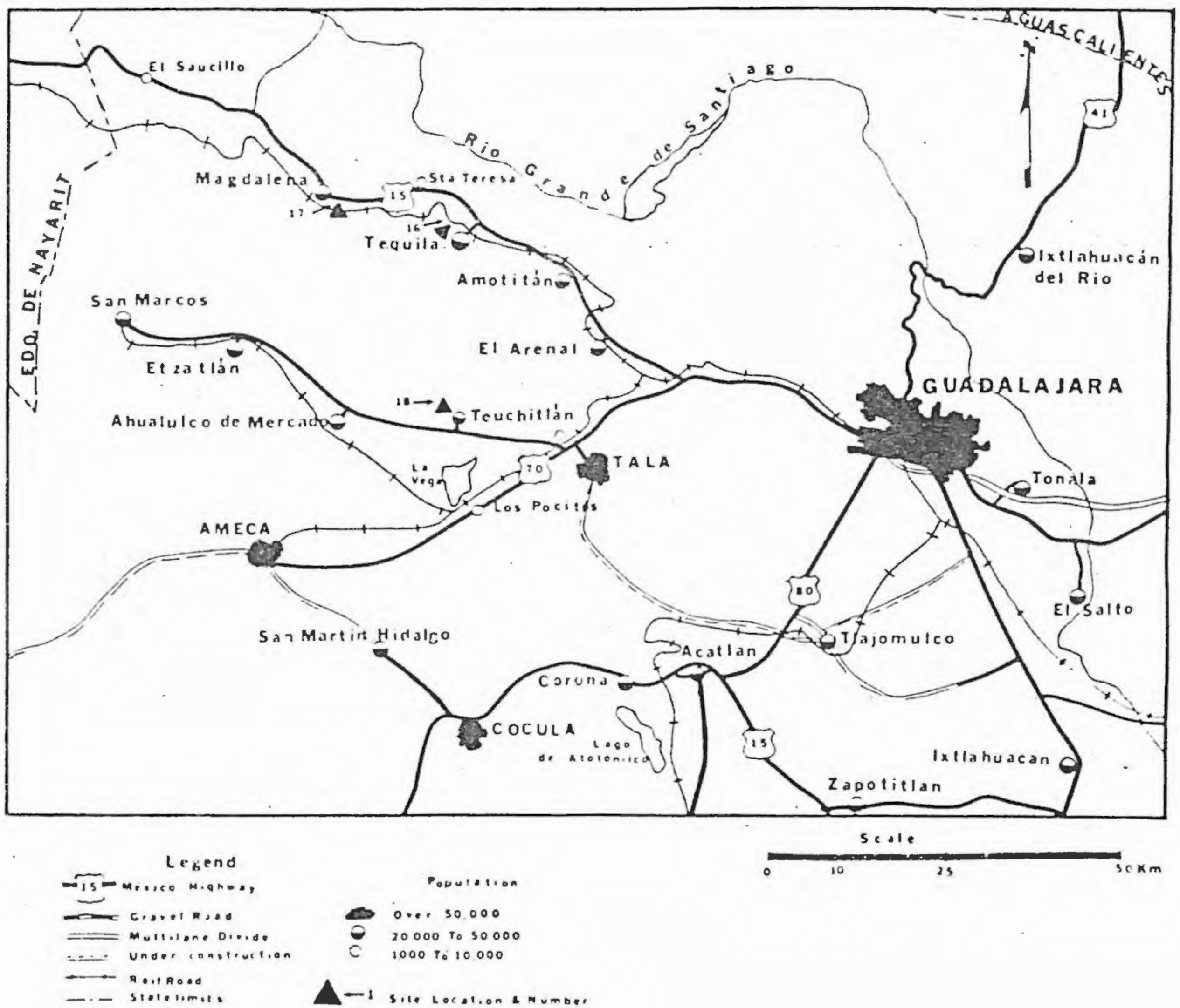

Figure 23. Location map. Sites No. 16; Tequila, No. 17 Magdalena; and No. 18 Teuchitlan.

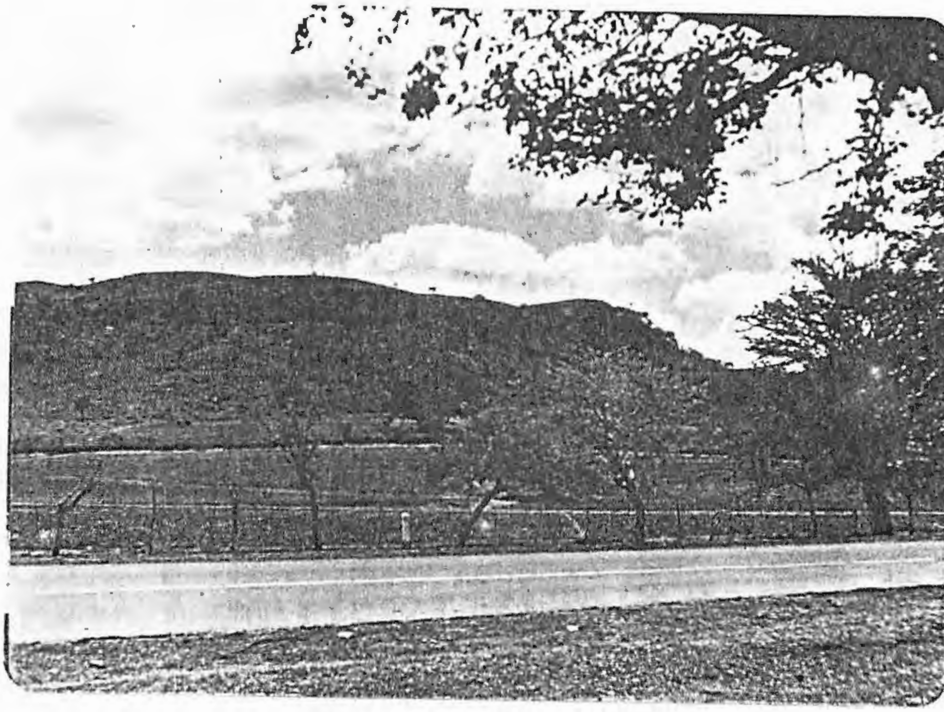

Figure 24. Obsidian flow, site No. 16, Tequila.

Figure 25. Obsidian in an easily eroded yellowish brown ashy matrix, site No. 16, Tequila.

Overlying the lower portion is a bed of volcanic ash and pebble-size obsidian pieces in a sparsely perlitic matrix. The thickness of the individual layers is on the order of 5 cm and the thickness of the whole section is about 20 meters. The upper portion of the flow is rhyolitic in texture and shows scattered divitrified rhyolitic fragments. Twenty samples were collected in different areas of the flow and labelled 16-1 to 16-20. The obsidian appears to be of average working quality and is called "istete" by the local people.

Magdalena, Site No. 17

The obsidian deposit is located along Highway 15 where it cuts a large ash flow 3 kilometers east of Magdalena in the state of Jalisco (Fig. 23). The flow consists of beds 1 to 3 meters thick composed of dark gray (N3) to black (N1), sparsely spherulitic obsidian sandwiched between layers of dark yellowish orange ash Fig. 26-27. The obsidian appears to be of good working quality. Twenty samples were collected along the flow at intervals of about 0.5 kilometers and labelled 17-1 to 17-20.

Teuchitlan, Site No. 18

The obsidian deposit is located two kilometers northwest of Teuchitlan in the state of Jalisco in a Hill called "El Monte de Porcelana" by the local people (Fig. 23). The flow is oriented north-south and presents two different sections. The lower section of the flow is composed of dark gray (N3) cobble-size pieces in a hard rhyolitic matrix. In the upper section big cobble- and boulder-size fragments of dark gray (N3) to black (N1) sparsely spherulitic obsidian in a soft ashy matrix can be seen (Fig. 28-29). The obsidian appears to be of good working quality and is called "porcelena" by the local people. Twenty samples were collected in an east-west traverse across the flow and labelled 18-1 to 18-20.

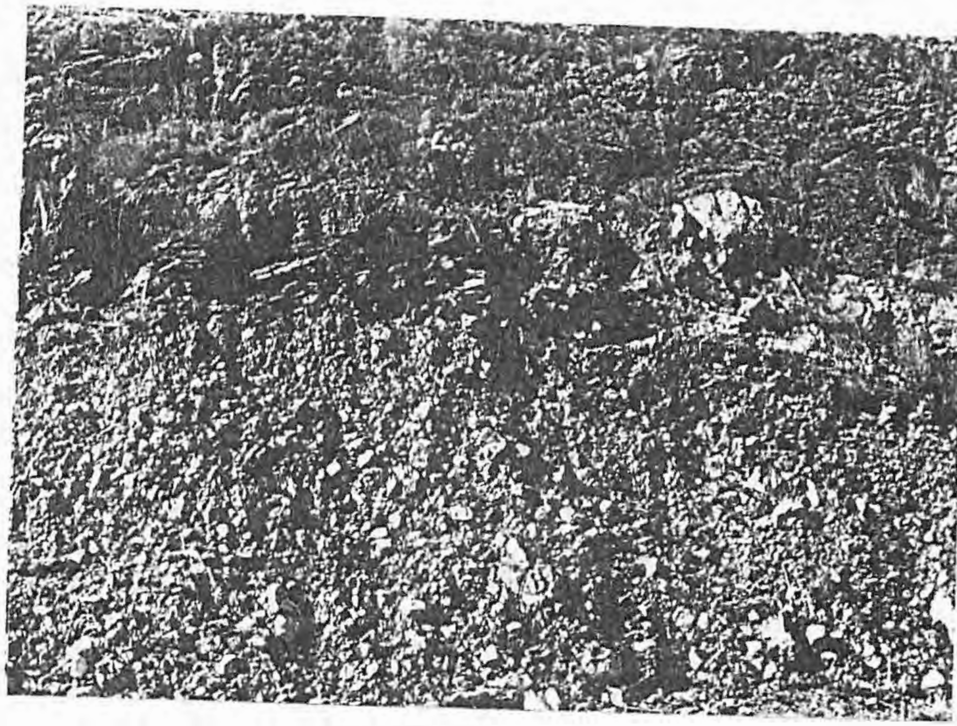

Figure 26. Obsidian sandwiched between layers of dark yellowish orange ash.

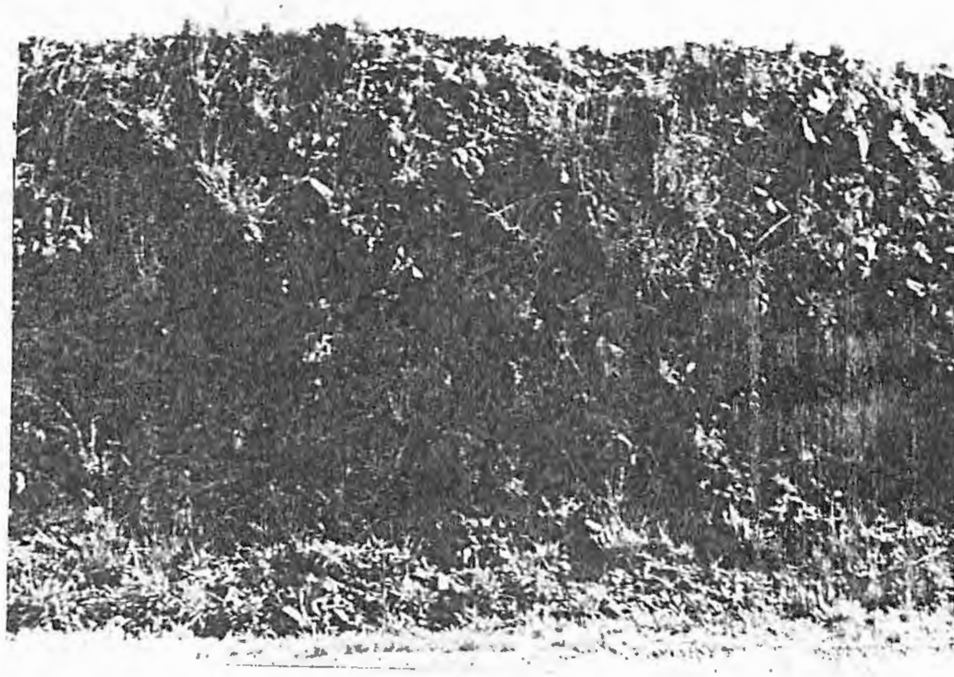

Figure 27. Thick layers of dark grey to black obsidian, site No. 17, Magdalena.

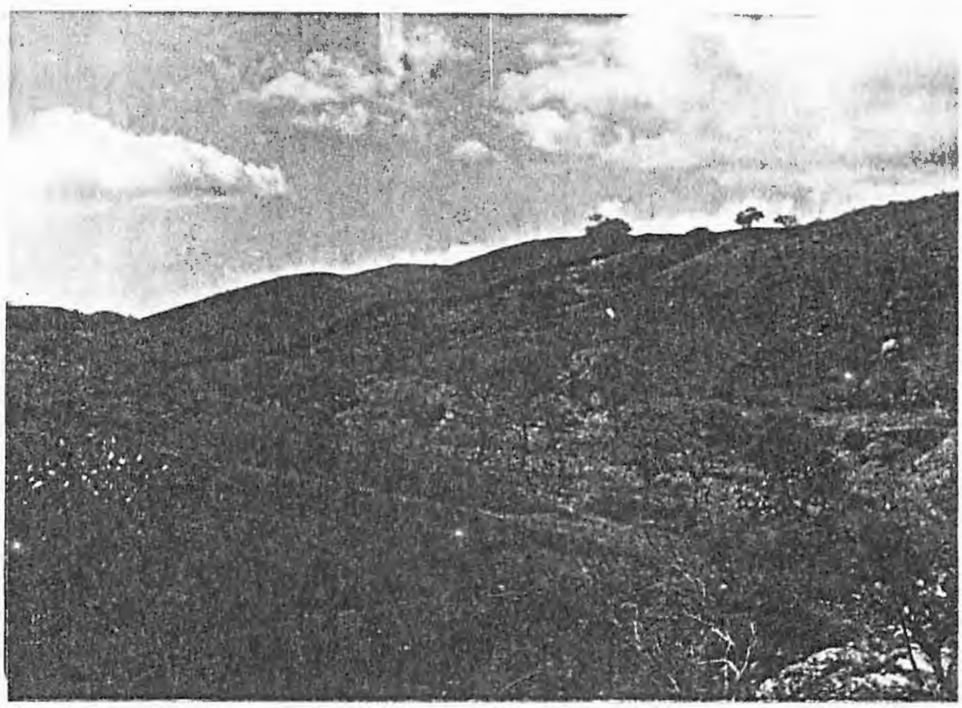

Figure 28. Obsidian flow site No. 18,Teuchitlan.

Figure 29. Cobble and boulder size fragments in a soft ashy matrix, site No. 18,Teuchitlan.

ANALYTICAL TECHNIQUES

X-ray spectrographic determinations of P, K, Ca, Ti, Mn, Fe, Rb, Sr, Zr and Ba were performed on rock powders representing three hundred and twenty-seven obsidian samples from eighteen different source areas.

Sample Preparation

The obsidian samples were crushed in a Braun chipmunk (jaw-type) crusher and then ground to-325 mush in a Pitchford Selective Particle Size Grinder. Grinding time for all the samples was approximately ten minutes. About one gram of the powdered sample was mounted between two sheets of Spectrofilm 0.00015" Mylar in a Somar Spectro-cup for light and heavy elemental determinations. U.S. Geological Survey standard granite G-2 was mounted in the same way as the samples.

X-Ray Spectrographic Analyses

The quantitative analysis of all the elements was done in a Norelco Universal Vaccuum Spectrograph equipped with either a Norelco High Intensity Tungsten or Chromium X-ray tube. The analyzing crystals were lithium fluoride with a 2"d" spacing of 4.028°A and EDDT with a 2"d" spacing of 8.808°A. Either a P-10 gas flow-proportional counter or a scintillation counter was used. Samples were run in either vacuum or air. Instrumental conditions for each of the elements are listed in Table 1.

After appropriate instrumental conditions were chosen, five measurements were made of the number of counts accumulated over a

TABLE 1. INSTRUMENTAL CONDITIONS FOR ANALYSES OF MEXICAN OBSIDIANS BY X-RAY SPECTROGRAPHY

Element	Target Tube	Crystal	KV-MA	Base Volts PHA	Window Volts PHA	Counter and Atmosphere	Counting Time	Peak	Back-ground
P	Cr	EDDT	45-40	0.6	2.0	Prop*-Vac*	10 sec.	60.1	58
K	Cr	EDDT	45-40	0.6	1.5	Prop-Vac	10 sec.	21.1	19.5
Ca	W	LiF	45-40	0.9	2.0	Prop-Vac	10 sec.	113.01	114.56
Ti	W	LiF	45-40	1.10	0.6	Prop-Vac	10 sec.	86.07	85.5
Mn	W	LiF	50-45	1.2	2.20	Prop-Vac	10 sec.	62.91	64.5
Fe	W	LiF	40-20	1.2	1.10	Prop-Vac	10 sec.	57.49	55
Rb	W	LiF	55-50	0.9	1.8	Scint*-Air	10 sec.	26.58	25.9
Sr	W	LiF	55-50	1.0	0.8	Scint-Air	10 sec.	25.09	24.3
Zr	W	LiF	52-50	0.7	2.0	Scint-Air	10 sec.	22.50	21.5
Ba	Cr	LiF	45-40	1.0	2.0	Prop-Vac	10 sec.	73.25	72.5

*Prop - Flow-proportional
*Scint - Scintillation
*Vac - Vacuum

specified time, generally 10 seconds, at both the peak and background 2θ settings for the element. The background intensity was subtracted from the peak intensity to yield the net peak intensity. These net peak intensities given in counts per second (cps), were then converted to concentrations (c) given in parts per million, using the granite standard, G-2 (Flanagan, 1973), and the conversion formula:

$$\frac{I\ \text{unknown}}{I\ \text{standard}} \times C\ \text{standard} = C\ \text{unknown}$$

<u>Analytical Precision</u>

The precision of the results is limited by errors made in sample preparation and in the determination of the counting rate. Counting errors are produced by variable exitation at the cathode and by variations in the detection of the emitted radiation. Sample preparation errors are also produced when the thickness of the mounted powdered sample is not uniform and varies from sample to sample.

Table 2 gives the analytical precision for each of the 10 elements analyzed. The analytical precision was determined by mounting the same sample ten times, running individual analyses for each one of these replicates, and then calculating the relative standard deviation for each element. Relative accuracy was determined by analyzing samples of the standard granites GH and GA (Roubault, <u>et</u> <u>al</u>., 1966).

TABLE 2.
ANALYTICAL PRECISION AND ACCURACY

	MEAN	PERCENT VARIABILITY	ACCURACY GA Accepted*	GA Found	GH Accepted*	GH Found
Rb	224.5	±6.35%	175	165	390	424
Sr	0	±0.00%	305	315.4	10	0
Zr	831	±3.06%	140	127.9	160	145

* Roubault, *et al*. 1966

GEOCHEMISTRY

Statistical Analysis

The use of statistical analysis and quantitative methods in geochemistry gives an explicit and useful way to handle a large amount of data. The elemental data collected from each of the different sites (Appendix A) were studied using several types of statistical techniques, including univariate measures of central tendency and dispersion such as means, ranges, standard deviations and coefficients of variability. The intensity of the relationship between the variables within the sites was also tested using correlation coefficients. Interpretations were made within and between the various sites.

Several types of multivariate techniques were used to characterize relationship between variables and between sites.

D^2 analysis (Mahalanobis, 1930; Anderson, 1958, p. 56) measures the degree of similarity between the mean vectors of two sites based upon the simultaneous considerations of all variables. The D^2 value feeds into the multivariate testing of differences in mean vectors. The distributions of D^2 is related to the "F" distribution with p and $[N_1+N_2-p-1]$ degrees of freedom, where p is equal to the number of variables and N_1 and N_2 represent the number of samples in each pair of sites.

Discriminant function analysis (Anderson 1958; pp. 133-150) makes possible the assignment of unknown sites to one of the known sites. The discriminant function analysis also gives good information for the selection of elements which best discriminate between sites.

R-mode factor analysis was useful in the manipulation, grouping of variables, and determination of factors that were needed to account for the compositional variation observed in the system.

Statistical Analysis Within The Sites

The elemental concentration of 10 variables: Mn, Rb, Zr, K, Ti, Fe, Ca, P, Sr and Ba was determined in twenty to twenty-five samples from each site. Tables 3, 4, 5 and 6 show the means, ranges, standard deviations and coefficients of variability for each element in the different sources and the archeological sites. Tables 7 to 21 show the correlation coefficient matrices of the ten variables for each of the sites. The significance of the correlation coefficients was determined at the 99 percent confidence level and n-2 degrees of freedom, where n represents the number of samples in each site. From the study of the aforementioned tables characterizations and interpretations can be made for each site.

1. Site No. 1 Clamalapa: Obsidian from this site can be characterized by: relatively high concentrations of Ba (859-453 ppm) and Sr (75-25 ppm); relatively low concentrations of K (28780-20440 ppm) and Rb (78-40 ppm); and high variability in Zr, P and Sr contents. Positive correlations are seen between Ca and P and Ca and Fe at the 99 percent confidence level and 18 degrees of freedom.

2. Site No. 2 Pico de Orizaba: Obsidian from this site can be characterized by: relatively high concentration of Mn (843-568 ppm); low concentration of Fe (4450-3397 ppm) and Zr (31-12 ppm);

TABLE 3. MEAN VALUES IN PARTS PER MILLION FOR SITES

Element / Site	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba
1	611.1	63.1	33.7	26747.8	630.7	4976.8	4351.7	112.1	47.8	668.8
2	672.7	82.1	24.9	33097.2	520.9	4018.5	3507.7	107.4	22.0	478.5
3	342.4	133.2	84.6	33808.1	716.9	10752.2	3989.7	108.5	5.4	0.0
4	443.6	87.10	84.1	30091.3	998.8	10260.1	7896.6	295.4	99.6	554.5
5	545.2	84.6	411.0	30905.7	1242.0	32058.6	5377.2	140.4	20.5	642.0
6	453.2	99.1	466.7	33861.4	1180.6	22609.3	4174.4	60.9	8.9	513.7
8	1358.2	144.6	647.8	32690.6	1261.7	20237.0	1611.3	1.4	0.0	0.0
9	210.1	241.6	133.4	42089.2	1273.6	12510.5	5119.8	108.9	22.9	0.0
10	283.2	137.9	477.4	32430.0	721.1	16426.4	2277.9	3.75	0.0	0.0
11	292.1	204.0	750.2	32942.3	869.4	24423.9	1970.3	0.0	0.0	0.0
14	221.4	144.8	50.4	32682.2	433.8	8812.4	3956.7	86.8	2.12	0.0
15	399.2	121.1	357.4	31534.9	700.3	17055.1	2374.9	10.8	1.55	0.0
16	431.9	71.4	137.4	35063.4	1054.2	12063.6	4435.6	133.5	21.2	558.3
17	502.5	127.1	188.0	38300.6	897.7	13397.7	3696.2	101.4	7.2	0.0
18	367.8	149.9	410.9	30528.8	640.6	17058.5	2209.7	5.9	0.0	60.2
7	1253.3	181.8	719.7	30966.8	1305.5	22048.5	1599.6	0.0	0.0	0.0
12	285.7	175.1	665.8	32560.5	801.5	21444.4	3066.7	47.2	2.2	0.0
13	317.0	213.3	960.3	33010.3	918.0	24470.6	2133	0.0	0.0	0.0

TABLE 4. RANGES OF THE ELEMENTS IN PARTS PER MILLION FOR SITES

Element Site	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba
1	727-519	78-40	63-12	28780-20444	679-487	5817-3925	6293-3961	211-82	75-25	859-453
2	843-568	120-56	31-12	41174-26502	600-424	4450-3397	5313-2899	576-51	38-13	792-228
3	669-285	183-81	118-60	38023-27792	965-470	14655-6837	4749-3271	185-80	15-0	0-0
4	548-374	145-54	108-45	35758-22265	1106-874	11412-9208	9249-7097	344-233	144-61	828-325
5	626-479	108-46	502-328	34889-20641	1370-1157	25907-19443	5729-4977	175-112	30-13	892-498
6	501-401	133-74	620-371	39493-27082	1245-1087	26215-18903	5400-3793	81-40	19-0	822-294
8	1638-985	189-89	757-452	36513-28325	2122-786	25101-16706	1996-1438	28-0	0-0	0-0
9	241-189	292-186	169-110	55336-34471	1372-1172	14094-11183	5526-4898	168-63	54-0	0-0
10	317-234	188-92	632-350	38973-27628	807-563	18652-12837	2676-1838	28-0	0-0	0-0
11	315-266	249-155	1092-491	38030-27896	936-806	29080-18931	2809-1733	0-0	0-0	0-0
14	301-182	251-94	91-28	37917-24185	516-241	10226-7645	4440-3241	113-56	12-0	0-0
15	467-337	182-32	542-178	35497-29027	781-624	18651-14310	8234-1659	183-0	26-0	0-0
16	679-322	135-45	334-76	39565-31031	1341-918	19986-9334	5303-1865	174-36	39-0	979-0
17	585-440	168-94	235-127	45251-33211	1066-709	22794-10453	4824-2691	168-0	26-0	0-0
18	493-312	186-87	505-247	37649-20707	689-586	20419-14351	2446-1812	36-0	0-0	351-0
7	1361-1175	220-112	825-579	36254-27689	1434-1210	23906-20489	1780-1490	0-0	0-0	0-0
12	367-221	229-129	985-354	38932-21403	915-701	28805-14625	7429-1958	291-0	15-0	0-0
13	324-307	228-189	1023-8585	26480-29915	975-834	27727-21242	2172-2064	0-0	0-0	0-0

TABLE 5. STANDARD DEVIATIONS FOR SITES

Element / Site	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba
1	56.0	9.9	10.1	2156.4	42.1	422.1	487.6	27.1	12.0	122.8
2	93.0	16.0	5.12	3954.3	36.8	302.4	646.0	113.4	7.1	158.0
3	80.0	27.1	16.0	3785.0	137.2	1918.3	401.7	26.2	4.2	0.0
4	45.2	22.7	16.3	3022.6	66.1	524.4	439.0	28.5	15.6	134.7
5	44.7	16.9	50.3	3261.1	53.5	1574.6	205.9	15.9	3.8	112.0
6	28.8	13/2	58.3	3135.4	42.8	2078.1	346.7	11.9	3.8	125.1
8	117.8	22.6	78.5	1712.2	243.8	2490.8	158.2	6.2	0.0	0.0
9	13.8	30.7	18.3	5475.3	58.4	842.8	223.2	27.7	9.86	0.0
10	23.4	23.1	86.4	2825.2	55.3	1712.3	200.7	6.46	0.0	0.0
11	12.1	26.1	164.4	3404.4	35.4	3014.4	225.9	0.0	0.0	0.0
14	26.51	34.1	13.6	3935.1	53.7	720.0	272.7	12.7	3.7	0.0
15	35.9	45.0	118.0	1707.2	37.3	1231.5	1395.3	40.7	5.8	0.0
16	86.3	22.7	54.3	2704.2	104.1	2128.4	769.5	29.7	11.2	381.5
17	40.0	19.0	30.0	2944.8	123.8	2724.2	511.9	38.8	9.2	0.0
18	43.7	21.5	60.2	5543.1	33.1	1548.3	172.4	11.4	0.0	112.1
7	74.9	34.2	73.5	2905.0	82.5	1066.5	94.8	0.00	0.00	0.00
12	38.11	31.7	236.8	5863.2	64.2	3971.9	1867.1	93.3	5.0	0.0
13	8.8	21.2	89.3	3298.4	74.2	3242.5	59.9	0.00	0.00	0.00

TABLE 6. COEFFICIENTS OF VARIABILITY FOR SITES

Element / Site	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba
1	9.17	15.79	30.15	8.06	6.68	8.48	11.20	24.24	25.16	18.36
2	13.83	19.54	20.59	11.94	7.07	7.52	18.41	105.6	32.21	33.02
3	23.37	16.6	18.91	11.19	19.14	17.84	10.06	24.16	77.96	0.00
4	10.22	26.17	19.4	10.0	6.62	5.11	5.55	9.64	15.7	24.3
5	8.2	19.9	12.2	10.5	4.3	6.8	3.8	11.3	18.9	17.45
6	6.36	13.3	12.4	9.2	3.6	9.1	8.3	19.6	43.7	24.3
8	8.6	15.6	12.1	5.2	19.3	12.3	9.8	447.2	0.00	0.00
9	6.5	12.7	13.7	13.0	4.5	6.7	4.3	25.5	43.0	0.00
10	8.2	16.7	18.1	8.7	7.6	10.4	8.8	172.3	0.0	0.00
11	4.1	12.7	21.9	10.3	4.0	12.3	11.4	0.0	0.0	0.0
14	11.9	23.6	27.1	12.0	12.3	8.1	6.8	14.6	176.1	0.0
15	9.0	37.1	33.0	5.4	5.3	7.2	58.7	375.5	375.8	0.0
16	19.9	31.8	39.5	7.7	9.8	17.6	17.3	22.2	52.7	68.3
17	7.9	14.9	15.9	7.6	13.7	20.3	13.8	38.2	127.2	0.0
18	11.8	14.3	14.6	18.1	5.1	9.0	7.8	192.3	0.00	186.1
7	5.9	18.8	10.2	9.3	6.3	4.8	5.9	0.0	0.0	0.0
12	13.3	18.1	35.5	18.0	8.0	18.5	60.8	197.6	227.5	0.00
13	2.8	9.9	9.3	9.9	8.0	13.2	2.8	0.0	0.0	0.0

and high variability in P, Sr and Ba content.

Positive correlation is seen between Ca and P at the 99 percent confidence level and 18 degrees of freedom.

3. Site No. 3 Altotonga: Obsidian from this site can be characterized by: relatively low concentrations of Zr (118-60 ppm) and Sr (15-0 ppm); no detectable Ba; and high variability in Mn, P and Sr content. Positive correlations are seen between Ti and Fe, and Ca and Sr at the 99 percent confidence level and 18 degrees of freedom.

4. Site No. 4 Buena Vista: Obsidian from this site can be characterized by: relatively high concentrations of Ca (9249-7097 ppm), P (344-233 ppm), and Sr (144-61 ppm); and high variability in Rb, Ba and Zr content. No correlations are seen between the elements at the 99 percent confidence level and 18 degrees of freedom. Correlations between P and Fe, Sr and Rb, and Sr and Zr were significant at the 95 percent confidence level and 18 degrees of freedom.

5. Site No. 5 Nativitas: Obsidian from this site can be characterized by: relatively high concentrations of Ti (1370-1157 ppm), Fe (25907-19443 ppm), Ca (5729-4927 ppm) and Ba (892-498 ppm); and high variability in Rb, Sr and Ba content. No correlations are seen between the elements at the 99 percent confidence level and 18 degrees of freedom. Correlations between P and Rb, Ca and Ti, and Sr and Ti were significant at the 95 percent confidence level and 18 degrees of freedom.

6. Site No. 6 Tulancingo: Obsidian from this site can be

characterized by: relatively high concentrations of Fe (26215-18903 ppm), Ba (822-294 ppm) and Zr (620-371 ppm); and high variability in P, Sr, and Ba content. No correlation is seen between the variables at the 99 percent confidence level and 18 degrees of freedom. The correlations between Ca and Ba and Ba and Fe were significant at the 95 percent confidence level and 18 degrees of freedom.

7. Site No. 8 Nopalillo: Obsidian from this site can be characterized by: relatively high concentrations of Mn (1638-985 ppm), Zr (757-452 ppm) and Ti (2122-786 ppm); low concentrations of Ca (1996-438 ppm) and P (28-0 ppm); no detectable Sr and Ba; and high variability in P, Ti and Rb content. Positive correlations are seen between Rb and Zr and Ti and P. Negative correlations are seen between Mn and Ti, Mn and P, Rb and P, and Zr and P at the 99 percent confidence level and 18 degrees of freedom.

8. Site No. 9 Metzquititlan: Obsidian from this site can be characterized by: relatively high concentrations of Rb (292-186 ppm), K (55336-34471 ppm), Ti (1372-1172 ppm) and Ca (5526-4698 ppm); low concentration of Mn (241-189 ppm); no detectable Ba; and high variability in P and Sr content. Positive correlation is seen between K and P at the 99 percent confidence level and 18 degrees of freedom. Positive correlation of Sr with Rb were significant at the 95 percent confidence level and 18 degrees of freedom.

9. Site No. 10 Fuentezuelas: Obsidian from this site can be characterized by: relatively low concentration of P (28-0 ppm); no detectable Sr and Ba; and high variability in P, Zr and Rb content. Positive correlation is seen between Rb and Zr at the 99 percent

Positive correlation is seen between Rb and Zr at the 99 percent confidence level and 18 degrees of freedom. Significant correlations between Mn and Zr, Rb and K, and Fe and Ca at the 95 percent confidence level and 18 degrees of freedom.

10. Site No. 11 Rancho Navajas: Obsidian from this site can be characterized by: relatively high concentrations of Rb (249-155 ppm), Zr (1092-491 ppm) and Fe (29080-18931 ppm); low concentration of Ca (2809-1733 ppm); no detectable P, Sr and Ba; and high variability in Zr and Rb content. No correlations were seen between the variables at the 99 percent confidence level and 19 degrees of freedom. Significant correlations between Zr and Ti, Zr and Ca, and K and Ti at the 99 percent confidence level and 19 degrees of freedom.

11. Site No. 14 Zinapecuaro: Obsidian from this site can be characterized by: relatively low concentrations of Mn (301-182 ppm), Zr (91-28 ppm), Ti (516-241 ppm) and Sr (12-0 ppm); no detectable Ba; and high variability in Sr, Rb and Zr content. Positive correlations between Rb and Mn and negative between Ti and Rb at the 99 percent confidence level and 23 degrees of freedom.

12. Site No. 15 Penjamo: Obsidian from this site can be characterized by: relatively low concentrations of Sr (27-0 ppm) and P (183-0 ppm); no detectable Ba; and high variability in Rb, Ca, P, Zr and Sr content. Strong positive correlations are seen between Rb and Zr, Ca and P, and Ca and Sr at the 99 percent confidence level and 18 degrees of freedom.

13. Site No. 16 Tequila: Obsidian from this site can be

characterized by: relatively high concentrations of K (39565-31031 ppm), Ca (5303-1865 ppm), Ba (979-0 ppm) and P (74-36 ppm); low concentrations of Rb (135-45 ppm); and high variability in Zr, Rb, Sr and Ba content. Positive correlations are seen between Mn and Rb, Mn and Zr, Mn and Fe, Rb and Zr, Zr and Fe, Sr and Ca, and P and Sr. Negative correlation between Mn and Ca, Mn and P, Mn and Sr, Rb and Ba, Zr and Ca, Zr and P, Ca and P, Ca and Sr, and Ca and Ba at the 99 percent confidence level and 18 degrees of freedom.

14. Site No. 17 Magdalena: Obsidian from this site can be characterized by: relatively high concentrations of K (45251-3321 ppm) and Mn (585-440 ppm); low concentrations of Sr (26-0 ppm); no detectable Ba; and high variability in Sr, P and Fe content. Positive correlations are seen between Zr and Ti, Zr and Sr, Fe and Ca, Fe and Sr, Ca and P and Ca and Sr. Negative correlations between Rb and Ca, and Rb and Sr at the 99 percent confidence level and 18 degrees of freedom.

15. Site No. 18 Teuchitlan: Obsidian from this site can be characterized by: relatively low concentrations of P (36-0 ppm) and Ba (351-0 ppm); no detectable Sr; and high variability in P and Ba content. Strong Positive correlations are seen between Mn and Ba and K and Ca at the 99 percent confidence level and 18 degrees of freedom.

Even though a large amount of data was considered, the preceding characterizations are sufficiently accurate to differentiate between some of the sites. However, some overlaps in the concentrations of the elements are apparent and make the actual characterization and

TABLE 7. CORRELATION MATRIX SITE No. 1

VAR.										
Mn	1.000									
Rb	-0.150	1.000								
Zr	0.145	-0.186	1.000							
K	-0.237	-0.213	-0.009	1.000						
Ti	0.066	0.134	0.078	0.159	1.000					
Fe	-0.008	0.043	0.074	0.144	0.233	1.000				
Ca	0.123	0.121	-0.046	0.198	0.285	0.576	1.000			
P	0.152	0.144	-0.156	0.158	-0.026	0.453	0.786	1.000		
Sr	0.197	-0.029	0.107	0.092	0.032	0.086	0.207	0.290	1.000	
Ba	-0.113	-0.434	0.336	0.232	-0.210	0.316	0.202	0.062	-0.071	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

TABLE 8. CORRELATION MATRIX SITE No. 2

VAR.										
Mn	1.000									
Rb	0.279	1.000								
Zr	-0.225	0.115	1.000							
K	-0.276	0.032	0.130	1.000						
Ti	0.145	0.008	0.261	-0.006	1.000					
Fe	0.007	0.133	0.149	0.197	0.278	1.000				
Ca	-0.275	-0.031	0.238	0.029	0.245	0.462	1.000			
P	-0.276	-0.266	-0.134	-0.023	0.082	0.136	-0.092	1.000		
Sr	-0.028	0.200	0.286	0.101	0.270	0.420	0.860	-0.210	1.000	
Ba	0.171	0.043	-0.405	-0.115	0.096	0.196	0.023	0.261	-0.042	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

TABLE 9. CORRELATION MATRIX SITE No. 3

VAR.

Mn	1.000									
Rb	0.489	1.000								
Zr	-0.373	-0.085	1.000							
K	0.095	0.279	0.223	1.000						
Ti	-0.359	-0.478	0.350	-0.134	1.000					
Fe	-0.519	-0.538	0.233	-0.181	0.747	1.000				
Ce	-0.387	-0.311	0.214	-0.110	0.728	0.664	1.000			
P	-0.039	0.028	-0.406	0.280	-0.077	-0.178	0.110	1.000		
Sr	-0.303	-0.311	0.412	-0.203	0.720	0.720	0.730	-0.229	1.000	
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

TABLE 10.CORRELATION MATRIX SITE No. 4

VAR.	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba
Mn	1.000									
Rb	-0.124	1.000								
Zr	-0.174	0.398	1.000							
K	0.167	-0.141	-0.185	1.000						
Ti	0.126	0.057	-0.194	0.200	1.000					
Fe	0.231	-0.048	0.063	0.229	-0.176	1.000				
Ca	0.187	-0.274	-0.437	0.112	0.296	0.261	1.000			
P	-0.075	0.021	-0.119	-0.128	0.081	0.497	0.320	1.000		
Sr	-0.399	0.558	0.481	0.276	0.196	0.019	-0.091	0.173	1.000	
Ba	-0.279	-0.132	-0.385	-0.123	-0.287	-0.049	0.067	0.209	-0.211	1.000

TABLE 11.CORRELATION MATRIX SITE No. 5

VAR.										
Mn	1.000									
Rb	-.0106	1.000								
Zr	0.367	0.343	1.000							
K	-0.048	0.072	-0.203	1.000						
Ti	0.066	0.217	0.351	-0.425	1.000					
Fe	0.394	-0.085	0.208	0.032	0.089	1.000				
Ca	-0.110	0.313	-0.146	-0.311	0.496	0.178	1.000			
P	-0.028	0.472	0.248	-0.350	0.385	-0.086	0.269	1.000		
Sr	0.206	0.312	0.390	0.126	0.496	0.163	0.322	0.247	1.000	
Ba	0.203	0.218	0.144	0.147	0.088	0.285	-0.029	-0.166	0.185	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

TABLE 12. CORRELATION MATRIX SITE No. 6

VAR.										
Mn	1.000									
Rb	0.244	1.000								
Zr	-0.111	0.172	1.000							
K	-0.169	0.033	0.094	1.000						
Ti	0.005	-0.274	-0.293	0.138	1.000					
Fe	0.188	0.066	-0.056	0.432	0.023	1.000				
Ca	-0.371	-0.467	0.371	0.336	0.227	-0.018	1.000			
P	0.014	-0.154	0.167	-0.152	0.336	-0.199	0.412	1.000		
Sr	-0.208	0.082	-0.207	0.230	-0.132	0.396	0.129	-0.126	1.000	
Ba	-0.157	-0.118	0.416	0.186	0.036	0.522	0.543	0.143	0.342	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

TABLE 13. CORRELATION MATRIX SITE No. 8

VAR.	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr.	Ba
Mn	1.000									
Rb	0.274	1.000								
Zr	0.404	0.680	1.000							
K	-0.001	-0.327	-0.411	1.000						
Ti	-0.706	-0.374	-0.333	0.239	1.000					
Fe	0.422	0.039	0.329	0.091	-0.256	1.000				
Ca	-0.141	-0.512	-0.320	0.172	0.398	0.154	1.000			
P	-0.745	-0.577	-0.586	0.263	0.830	-0.333	0.529	1.000		
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

TABLE 14.CORRELATION MATRIX SITE No. 9

VAR.										
Mn	1.000									
Rb	0.260	1.000								
Zr	0.275	0.497	1.000							
K	-0.147	0.004	0.084	1.000						
Ti	0.225	0.037	0.195	0.301	1.000					
Fe	-0.102	0.311	0.141	0.355	0.231	1.000				
Ca	0.045	-0.112	0.300	0.173	0.406	0.115	1.000			
P	-0.080	-0.137	-0.102	0.770	0.344	0.257	0.158	1.000		
Sr	-0.269	-0.467	0.048	-0.068	0.320	0.133	0.523	0.114	1.000	
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

TABLE 15.CORRELATION MATRIX SITE No. 10

VAR.	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba
Mn	1.000									
Rb	0.074	1.000								
Zr	0.527	0.655	1.000							
K	0.091	0.453	0.524	1.000						
Ti	-0.397	0.373	-0.036	0.313	1.000					
Fe	-0.135	-0.061	0.195	0.255	0.208	1.000				
Ca	0.105	0.051	0.248	-0.257	-0.077	0.452	1.000			
P	-0.214	0.159	-0.044	-0.032	0.325	0.203	0.320	1.000		
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

TABLE 16. CORRELATION MATRIX SITE No. 11

VAR.	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba
Mn	1.000									
Rb	-0.272	1.000								
Zr	0.309	0.163	1.000							
K	-0.202	0.426	-0.360	1.000						
Ti	-0.200	0.224	-0.471	0.480	1.000					
Fe	-0.201	0.150	0.112	0.236	-0.012	1.000				
Ca	-0.289	-0.173	-0.463	0.216	0.399	0.096	1.000			
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000		
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

TABLE 17. CORRELATION MATRIX SITE No. 14

VAR.										
Mn	1.000									
Rb	0.680	1.000								
Zr	-0.199	-0.161	1.000							
K	-0.528	-0.401	0.033	1.000						
Ti	-0.522	-0.684	0.388	0.461	1.000					
Fe	-0.172	-0.153	0.012	-0.028	-0.064	1.000				
Ca	0.055	0.095	-0.051	-0.103	0.030	-0.306	1.000			
P	0.380	0.366	0.165	-0.316	0.105	-0.002	0.257	1.000		
Sr	-0.006	-0.116	0.028	0.199	0.224	0.092	-0.386	-0.116	1.000	
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

TABLE 18. CORRELATION MATRIX SITE No. 15

VAR.										
Mn	1.000									
Rb	0.429	1.000								
Zr	0.212	0.847	1.000							
K	-0.206	-0.30	-0.197	1.000						
Ti	0.093	-0.390	-0.157	0.011	1.000					
Fe	0.333	0.351	0.356	-0.222	0.318	1.000				
Ca	-0.323	-0.486	-0.266	0.569	0.194	-0.445	1.000			
P	-0.303	-0.518	-0.343	0.578	0.137	-0.518	0.989	1.000		
Sr	-0.358	-0.525	-0.355	0.559	0.114	-0.503	0.984	0.987	1.000	
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

TABLE 19. CORRELATION MATRIX SITE No. 16

VAR.										
Mn	1.000									
Rb	0.602	1.000								
Zr	0.609	0.601	1.000							
K	0.147	0.355	-0.192	1.000						
Ti	0.209	0.182	-0.038	0.293	1.000					
Fe	0.737	0.548	0.821	-0.066	-0.173	1.000				
Ca	-0.821	-0.416	-0.668	0.039	0.107	-0.716	1.000			
P	-0.672	-0.190	-0.576	0.046	0.167	-0.668	0.692	1.00		
Sr	-0.713	-0.429	-0.284	-0.450	-0.066	-0.494	0.660	0.611	1.000	
Ba	-0.770	-0.679	-0.437	-0.471	-0.343	-0.531	0.604	0.452	0.772	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

TABLE 20. CORRELATION MATRIX SITE No. 17

VAR.										
Mn	1.000									
Rb	-0.183	1.000								
Zr	-0.000	-0.059	1.000							
K	-0.221	0.381	-0.127	1.000						
Ti	0.114	-0.261	0.715	-0.052	1.000					
Fe	0.182	0.283	0.354	0.033	0.279	1.000				
Ca	0.146	-0.664	0.343	-0.149	0.657	-0.356	1.000			
P	-0.216	-0.402	0.019	0.091	0.273	-0.396	0.591	1.000		
Sr	0.180	-0.603	0.567	-0.303	0.786	-0.113	0.866	0.465	1.000	
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

TABLE 21. CORRELATION MATRIX SITE No. 18

VAR.										
Mn	1.000									
Rb	0.029	1.000								
Zr	0.142	0.557	1.000							
K	0.027	-0.036	0.283	1.000						
Ti	0.052	0.242	0.184	0.212	1.000					
Fe	0.278	0.334	0.257	0.115	0.190	1.000				
Ca	-0.011	0.136	0.114	0.595	-0.074	-0.012	1.000			
P	0.229	-0.403	-0.040	0.110	-0.023	-0.174	-0.203	1.000		
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	
Ba	0.652	0.003	-0.142	0.050	0.059	0.260	-0.127	0.394	0.000	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

and differentiation between the sites difficult. Therefore the use of multivariate techniques are necessary to maximize the optimum separation between sites.

Statistical Analysis Between Sites

Two computer programs were available for performing all the operations listed for the analysis between the sites. The first program, developed by the University of Missouri Geology Department (Wolleben, et al, 1968), provides values for the test of variance-covariance homogeneity, generalized distances, on F value or a test of equality of multivariate means, and discriminant equations. The University of Pittsburgh has developed the spss-10 version 5.02.2 program that performs principal component analysis (R-mode). Both programs are written in Fortran IV.

The evaluation of the relative similarities or differences between sites should take into account the differences between the values of the measured variables, the total amount of variation in each variable within the sites, and the fact that the variables may or may not be independent of each other. D^2 is a measure of similarity between populations, that was introduced by P. C. Mahalanobis in 1930. This measure is not strongly dependent on the sample size, but it does take into account the intercorrelation between the variables; its square root is analogous to a straight line distance between two points in space which makes a graphical representation of the similarities between the sites convenient when a large number of variables are involved, the methods of computation of D^2 makes it easy to select only those variables which contribute most to the statistical distance between the sites. Mahalanobis' statistical D^2 is defined by the quadratic:

$$D^2 = ([x]_i - [x]_j)^T \, [s]^{-1}([x]_i - [x]_j)$$

where $[x]_i$ and $[x]_j$ are the respective sample mean vectors and $[s]^{-1}$ the pooled inverse covariance matrix of all samples.

Table 22 shows the D^2 matrix comparing the sites. Sites with high D^2 value suggest that the difference in chemical composition is great. The low D^2 values between sites 10 and 15, 10 and 18, and 15 and 18 indicates a similarity in the chemical composition between the three sites. Therefore the significance of these similarities must be tested.

The D^2 value feeds very well into the multivariate testing of differences in mean vectors. The distribution of D^2 has been worked out and it is related to the "F" distribution in the following manner:

$$F = \frac{(N_1N_2)\ (N_1 + N_2 - P\text{-}1)}{P(N_1 + N_2)\ (N_1 + N_2 - 2)}\ D^2$$

with p and $[N_1 + N_2 - p\text{-}1]$ degrees of freedom.

Table 23 shows the F values used in testing the differences in mean vectors between the sites. High F values indicate significant differences between the sites. The F value of 4.00 for the comparison of sites 10 and 18 indicates that there is not a significant difference between the mean vector of those sites at the 99 percent confidence level. Sites 15 and 18 show a F value of 2.25 which also indicates no significant differences between the mean vectors of those sites

TABLE 22. D^2 MATRIX BETWEEN THE SITES

Site	1	2	3	4	5	6	8	9	10	11	14	15	16	17	18
1	0	16.02	108.93	112.51	185.26	200.50	394.07	227.17	209.02	350.22	163.89	156.33	63.07	93.87	173.50
2		0	94.15	178.31	214.59	215.35	371.42	229.83	197.24	347.37	144.86	144.32	69.69	76.93	161.50
3			0	187.57	168.23	135.56	521.46	75.91	59.46	154.12	20.79	39.06	57.88	21.34	44.17
4				0	203.63	259.33	562.10	207.51	315.18	408.13	254.84	267.50	144.70	175.75	285.48
5					0	16.18	269.77	197.84	155.72	154.67	277.92	122.81	63.18	99.88	137.22
6						0	39.47	168.99	88.79	86.05	226.19	72.29	58.61	79.37	81.05
8							0	591.19	516.67	329.28	719.58	438.50	341.46	345.72	475.19
9								0	146.02	193.84	122.60	138.51	112.63	83.00	138.17
10									0	36.44	79.44	9.34	104.09	65.76	5.46
11										0	191.09	58.72	183.46	139.77	46.97
14											0	70.54	131.94	80.15	66.71
15												0	71.88	36.21	2.97
16													0	27.23	86.72
17														0	49.05
18															0

at the 99 percent confidence level. Obsidian from these three sites are very closely related in chemical composition and only differ in geographic location.

The application of discriminant function analysis made possible the assignment of the three archeological sites to certain known sources. The presupposes that the obsidian for those archeological sites actually do come from one of the known sources. This part of the analysis will be discussed later in the interpretation made for the archeological sites.

The linear discriminant function between two sites may be defined as:

$$Y = (\overline{X}_1 - \overline{X}_2)\ S^{-1}\ X$$

where X_1 and X_2 are the mean vectors for the respective samples, S^{-1} is the reciprocal of the pooled sample dispersion matrix, and X is a vector of variables (ten dimendional).

The coefficients of the discriminant functions are defined as:

$$a = S^{-1}\ (\overline{X}_1 - \overline{X}_2)$$

where a is the vector of coefficients. If the variance of variables are almost equal, the discriminator coefficients give an approximate idea of the relative importance of each variable to the discriminatory power of the function (Blackith and Reyment, 1971).

In the results of this analysis, the loadings of the discriminant function coefficients for each one of the elements between the sites indicates that there are five elements that account for about 95 percent of the discrimination. Those elements are: Mn, Rb, Zr, Ti and Sr. Tables 24 to 28 show the discriminant function coefficient

TABLE 23. F VALUES USED IN TESTING THE SIGNIFICANCE OF THE MEAN VECTORS BETWEEN THE SITES

Site	1	2	3	4	5	6	8	9	10	11	14	15	16	17	18
1	0	12.3	84.5	77.6	121.7	127.7	264.3	171.4	141.5	232.1	146.3	106.9	45.1	69.2	118.3
2		0	72.3	125.7	142.8	138.9	245.4	173.2	132.8	229.7	128.8	97.8	50.4	55.6	109.2
3			0	133.9	114.9	85.7	369.9	56.1	32.3	86.4	17.8	21.3	44.2	14.8	24.1
4				0	130.5	159.7	384.3	149.1	202.5	258.8	212.8	173.1	95.7	120.6	185.6
5					0	10.5	205.1	142.1	114.8	115.5	222.4	89.3	40.2	69.9	101.0
6						0	235.6	115.1	66.6	66.6	171.6	52.4	34.5	51.7	60.1
8							0	432.1	388.9	417.4	591.1	325.5	244.4	247.2	355.6
9								0	99.0	123.2	103.7	97.1	85.2	62.4	96.4
10									0	22.6	49.7	6.67	7.43	43.8	4.00
11										0	123.6	36.3	123.3	88.1	28.5
14											0	48.3	114.4	66.6	43.1
15												0	52.6	24.0	2.25
16													0	21.8	63.4
17														0	33.4
18															0

TABLE 24. DISCRIMINANT FUNCTION COEFFICIENT MATRIX FOR Mn

Site	1	2	3	4	5	6	8	9	10	11	14	15	16	17	18
1	0	-0.92	13.19	3.75	2.97	7.69	-23.49	15.47	17.84	19.11	79.02	13.44	5.88	6.81	15.16
2		0	14.11	4.68	3.90	8.62	-22.56	16.40	18.76	20.04	20.02	14.37	6.80	7.74	16.09
3			0	-9.43	-10.21	-5.49	-36.68	2.28	4.65	5.92	5.90	0.25	-7.31	-6.37	1.97
4				0	-0.77	3.93	-27.25	11.71	14.08	15.35	15.33	9.69	2.12	3.05	11.41
5					0	4.71	-26.47	12.49	14.86	16.13	16.11	10.47	2.90	3.83	12.19
6						0	-31.18	7.71	10.14	11.41	11.39	5.75	-1.81	0.88	7.47
8							0	38.96	41.35	42.60	42.58	36.94	29.37	30.30	38.66
9								0	2.36	3.64	3.61	-2.02	-9.59	-8.65	-0.30
10									0	1.27	12.52	-4.39	-11.96	-11.02	-2.67
11										0	-0.02	-5.66	-13.23	-12.30	-3.94
14											0	-5.64	-13.21	-12.27	-3.92
15												0	-7.56	-6.63	1.72
16													0	0.93	9.28
17														0	8.35
18															0

TABLE 25. DISCRIMINATE FUNCTION COEFFICIENTS MATRIX FOR Rb

Site	1	2	3	4	5	6	8	9	10	11	14	15	16	17	18
1	0	-0.84	-12.9	-12.2	0.37	1.13	8.5	-38.3	-1.37	-8.38	-15.97	-0.30	-1.51	-7.69	-4.91
2		0	-12.0	-11.4	1.22	1.98	9.35	-37.4	-0.53	-7.53	-15.12	0.541	-0.66	-6.84	-4.06
3			0	0.67	13.39	14.07	21.4	-25.39	11.55	4.55	-3.03	12.83	11.42	5.24	8.02
4				0	0.76	13.39	20.76	-26.07	10.88	3.87	-3.71	11.95	10.74	4.56	7.34
5					0	0.76	8.13	-38.70	-1.75	-8.75	-16.34	-0.68	-1.88	-8.07	-5.29
6						0	7.36	-39.47	-2.51	-9.52	-17.10	-1.44	-2.64	-8.83	-6.05
8							0	-46.8	-9.88	-16.88	-24.47	-8.81	-10.01	-16.20	-13.42
9								0	36.95	29.95	22.36	38.02	36.82	30.63	33.41
10									0	-7.00	-14.59	1.07	-0.132	-6.31	-3.53
11										0	-7.58	8.07	6.87	0.68	3.46
14											0	15.66	14.46	8.27	11.05
15												0	-1.20	-7.39	-4.61
16													0	-6.18	-3.40
17														0	2.78
18															0

TABLE 26. DISCRIMINANT FUNCTION COEFFICIENTS MATRIX FOR Zr

Site	1	2	3	4	5	6	8	9	10	11	14	15	16	17	18
1	0	0.37	0.43	0.004	-6.87	-8.36	-10.73	1.85	-8.99	-13.16	1.12	-5.89	-2.10	-1.83	-6.58
2		0	0.06	-0.36	-7.24	-8.73	-11.10	1.48	-9.36	-13.53	0.75	-6.26	-2.47	-2.20	-6.95
3			0	-0.43	-7.30	-8.79	-11.17	1.41	-9.43	-13.59	0.68	-6.33	-2.53	-2.27	-7.02
4				0	-6.81	-8.36	-10.74	1.84	-9.00	-13.16	1.11	-5.90	-2.10	-1.84	-6.59
5					0	-1.49	-3.86	8.72	-2.12	-6.29	7.99	0.97	4.77	5.03	0.28
6						0	-2.37	10.21	-0.63	-4.80	9.48	2.46	6.26	6.52	1.77
8							0	12.58	1.74	-2.42	11.85	4.83	8.63	8.89	4.14
9								0	-10.84	-15.01	-0.73	-7.75	-3.95	-3.69	-8.44
10									0	-4.16	10.11	3.10	6.89	7.15	2.40
11										0	14.28	7.26	11.06	11.32	6.57
14												-7.02	-3.22	-2.96	-7.71
15												0	3.79	4.059	-0.69
16													0	0.26	-4.48
17														0	-4.75
18															0

TABLE 27. DISCRIMINANT FUNCTION COEFFICIENTS MATRIX FOR Ti

Site	1	2	3	4	5	6	8	9	10	11	14	15	16	17	18
1	0	0.68	0.97	-1.21	-6.81	-5.89	-12.62	-5.42	0.99	-0.18	5.29	0.80	-4.47	-2.19	1.47
2		0	0.29	-1.89	-7.49	-6.57	-13.30	-6.10	0.31	-1.46	4.61	0.12	-5.15	-2.87	0.79
3			0	-2.18	-9.79	-6.86	-13.60	-6.40	0.02	-1.75	4.31	-0.17	-5.45	-3.16	0.50
4				0	-5.60	-4.67	-11.41	-21.21	2.20	0.43	6.50	2.01	-3.26	-0.99	2.69
5					0	0.92	-5.81	1.38	7.81	6.03	12.10	7.62	2.34	4.62	8.29
6						0	-6.73	0.46	6.88	5.11	11.18	6.69	1.41	3.70	7.37
8							0	7.20	13.62	11.84	17.91	13.43	8.15	10.43	14.10
9								0	6.42	4.64	10.71	6.23	0.95	3.23	6.90
10									0	-1.77	4.29	-0.19	-5.47	-3.18	0.48
11										0	6.07	1.58	-3.69	-1.40	2.26
14											0	-4.48	-9.76	-7.48	-3.81
15												0	-5.27	-2.99	0.67
16													0	2.28	5.95
17														0	3.66
18															0

TABLE 28. DISCRIMINANT FUNCTION COEFFICIENTS MATRIX FOR Sr

Site	1	2	3	4	5	6	8	9	10	11	14	15	16	17	18
1	0	28.97	51.30	-65.91	52.54	66.74	64.09	34.68	62.69	67.43	50.98	58.04	45.76	51.21	60.80
2		0	22.33	-94.88	23.57	37.77	35.12	5.70	33.72	38.46	22.01	29.07	16.79	22.24	31.89
3			0	-117.22	1.23	15.43	12.78	-16.62	11.38	16.12	-0.32	6.73	-5.53	-0.09	9.56
4				0	118.4	132.6	130.0	100.59	128.61	133.35	116.89	123.95	111.68	117.12	126.78
5					0	14.20	11.55	-17.86	10.15	14.89	-1.56	5.50	-6.77	-1.32	8.32
6						0	-2.65	-32.06	-4.05	0.68	-15.76	-8.70	-20.98	-15.53	-5.88
8							0	-29.41	-1.39	3.34	-13.10	-6.04	-18.32	12.87	-3.22
9								0	28.01	32.75	16.30	23.36	11.08	16.53	26.18
10									0	4.74	-11.71	-4.65	-16.92	-11.48	-1.82
11										0	-16.45	-9.39	-21.66	16.22	-6.56
14											0	7.06	-5.21	0.23	9.88
15												0	-12.27	-6.83	2.82
16													0	5.44	15.09
17														0	9.65
18															0

matrices for the above mentioned elements. The interpretation from these tables is condensed in the following list, which indicates the site pairs that can be differentiated using each of the discriminative elements.

Discriminative Differentiate Site Pairing Element

Rb 1-3; 1-4; 1-9; 1-4; 2-3; 2-4; 2-9; 2-14; 3-5; 3-6; 3-8; 3-9; 3-10; 3-11; 3-15; 3-16; 4-5; 4-6; 4-8; 4-9; 4-10; 4-15; 4-10; 5-9; 5-14; 6-9; 6-14; 8-9; 8-11; 8-14; 8-16; 8-17; 8-18; 9-10; 9-11; 9-14; 9-15; 9-16; 9-17; 9-18; 10-14; 14-15; 14-16; 14-18.

Mn 1-3; 1-8; 1-9; 1-10; 1-11; 1-14; 1-15; 1-18; 2-3; 2-8; 2-9; 2-10; 2-11; 2-14; 2-15; 2-18; 3-5; 3-8; 4-8; 4-9; 4-10; 4-11; 4-14; 4-18; 5-8; 5-9; 5-10; 5-11; 5-14; 5-15; 5-18; 6-8; 6-10; 6-11; 6-14; 8-9; 8-10; 8-11; 8-14; 8-15; 8-16; 8-17; 8-18; 10-16; 10-14; 10-17; 11-16; 11-17; 14-16; 14-17.

Ti 1-8; 2-8; 3-8; 4-8; 5-14; 5-18; 6-14; 8-10; 8-11; 8-14; 8-15; 8-17; 9-14; 4-16.

Zr 1-8; 1-11; 2-8; 2-11; 2-10; 3-8; 3-10; 3-11; 4-8; 4-10; 4-11; 6-8; 6-14; 8-9; 8-14; 8-10; 9-11; 10-14; 10-9; 11-14; 11-16; 11-17.

Sr 1-2; 1-3; 1-4; 1-5; 1-6; 1-8; 1-10; 1-11; 1-14; 1-15; 1-16; 1-17; 1-18; 2-3; 2-4; 2-5; 2-6; 2-8; 2-10; 2-11; 2-14; 2-15; 2-16; 2-17; 2-18; 3-4; 3-6; 3-8; 3-9; 3-10; 3-11; 4-5; 4-6; 4-8; 4-9; 4-10; 4-11; 4-14; 4-15; 4-16; 4-17; 4-18; 5-6; 5-8; 5-9; 5-10; 5-11; 6-9; 6-14; 6-16; 6-17; 8-9; 8-14; 8-16; 8-17; 9-10; 9-11; 9-14; 9-15; 9-16; 9-17; 9-18; 10-14; 10-16; 10-17; 11-14; 11-16; 11-17; 15-16; 16-18.

TABLE 29. POOLED MEANS, STANDARD DEVIATION AND COEFFICIENTS OF VARIABILITY

	MEANS	STANDARD DEVIATIONS	COEFFICIENTS OF VARIABILITY
Mn	482.9	294.9	61.0
Rb	130.3	53.8	41.2
Zr	310.3	259.9	83.7
K	33040.3	4799.7	14.5
Ti	877.9	288.0	32.8
Fe	14941.7	6496.9	43.4
Ca	3702.1	1667.0	45.0
P	80.8	83.5	103.3
Sr	15.9	25.8	162.2
Ba	212.6	300.1	141.15

Pooled Data

Table 29 shows the means, standard deviations, and coefficients of variability for each of the variables, when the analytical data of the 327 obsidian samples, representing the 18 sites, was pooled. The study of this table shows a relatively high variability based on the coefficient of variability in P, Sr, Ba, Zr and Mn, and a very uniform distribution, i.e. low variability, in K contents. The significance of these relatively high and low variabilities can not be understood without knowledge of the factors that control the distribution of variables within the obsidian population. The correlation coefficients provide a better understanding of these variables when they are compared. The pooled correlation coefficient matrix (Table 30) indicates that K, Mn and Ti are partially independent variables because the correlation coefficient of each of these variables with all other variables is uniformly low.

The significance of each correlation coefficient was tested at the 99.9 percent confidence level. This probably indicates that the distribution of these elements in the obsidian population is independent from the interactive effects of the other variables, and is due to fixed factors. The correlation coefficient matrix also shows a relatively strong correlation between the following pairs of variables: Zr and Fe; and Ca, P and Sr. The reason for the strong correlation between Zr and Fe is not easily understood. Ca, P, and Sr may be due, in part, to variations in the content of apatite in the specimens.

R-mode factor analysis (Imbrie and Van Andel, 1964) was performed on the pooled data. This type of analysis concerns itself with the

TABLE 30. POOLED CORRELATION COEFFICIENTS MATRIX

VAR.	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba
Mn	1.00	-0.160	0.271	-0.164	0.354	0.131	-0.264	-0.147	-0.020	0.085
Rb		1.00	0.424	0.342	0.128	0.337	-0.342	-0.390	-0.383	-0.664
Zr			1.00	0.065	0.355	0.861	-0.573	-0.588	-0.445	-0.313
K				1.00	0.356	0.039	0.037	0.001	-0.169	-0.262
Ti					1.00	0.517	0.190	0.103	0.122	0.134
Fe						1.00	-0.368	-0.450	-0.406	-0.219
Ca							1.00	0.875	0.793	0.553
P								1.00	0.771	0.528
Sr									1.00	0.590
Ba										1.00

study of the variation in the inter-relationships between the variables in the pooled sample population. The cause of the variability can often times be related to one, two or more principal or causal factors in this type of analysis. Identification of the factors is sometimes possible, and the contribution of each factor to the total variability can be estimated. Table 31 is the list of the eigenvalues obtained from the correlation coefficient matrix. These eigenvalues tell how much of the variation can be accounted for by each factor. This table indicates that 85.2 percent of the variation within the obsidian population is due to four factors: Factor I accounts for 42.0 percent, Factor II for 19 percent, Factor III for 15.5 percent, and Factor IV for 8.6 percent of the variation.

Table 32 shows the varimax rotated factor matrix; the columns in this matrix are the eigenvecotrs. Each eigenvector is associated with a given eigenvalue, and the loadings of the eigenvectors tell how much each variable is influencing the positioning of the eigenvector. As can be seen examining down the columns of the varimax rotated matrix, loading on Ca, P and Sr are extremely high on Factor I and very low in the other factors. This would lead to the interpretation that the new variable, Factor I, is in some way an apatite mineral indicator. Apatite is a P-Ca rich mineral whose concentration in obsidian varies from site to site. Strontium is geochemically related to calcium, as they share a good atomic relationship and the same chemical characteristics. Similary, Factor II shows high loadings on Zr and Fe. This factor could reflect the interaction between magma contamination and magma sources. Magma could be contaminated by

TABLE 31. EIGENVALUES OF CORRELATION MATRIX

FACTOR	EIGENVALUE	PERCENT OF VARIANCE EXPLAINED	CUMULATIVE PERCENT
I	4.202	42.0	42.0
II	1.895	19.0	61.0
III	1.554	15.5	76.5
IV	0.864	8.6	85.2
V	0.618	6.2	91.4
VI	0.287	2.9	94.2
VII	0.240	2.4	96.6
VIII	0.179	1.8	98.4
IX	0.935	0.9	99.4
X	0.062	0.6	100.0

TABLE 32. VARIMAX ROTATED FACTOR MATRIX

VAR.	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6	FACTOR 7	FACTOR 8	FACTOR 9	FACTOR 10
Mn	-0.112	0.083	0.967	-0.087	-0.088	0.163	0.035	0.010	-0.005	0.006
Rb	-0.201	0.203	-0.109	0.182	0.890	0.061	-0.275	-0.021	-0.001	0.005
Zr	-0.355	0.853	0.160	-0.075	0.206	0.102	-0.072	0.031	-0.029	0.230
K	-0.010	-0.035	-0.085	0.972	0.142	0.128	-0.094	-0.024	0.001	-0.003
Ti	0.183	0.352	0.230	0.182	0.059	0.864	0.071	0.011	0.005	0.001
Fe	-0.227	0.909	-0.002	0.014	0.080	0.273	-0.051	-0.080	0.019	-0.171
Ca	0.882	-0.222	-0.191	0.037	-0.120	0.158	0.187	-0.005	0.241	-0.029
P	0.914	-0.260	-0.046	0.025	-0.146	0.040	0.135	-0.099	-0.203	0.008
Sr	0.800	-0.192	0.046	-0.126	-0.097	0.045	0.219	0.494	0.007	0.009
Ba	0.383	-0.084	0.050	-0.140	-0.352	0.079	0.830	0.053	0.003	-0.002

sediments rich in some heavy minerals such as zircon and iron oxides, whose concentrations changed from locality to locality. The variation in magma sources is explained basically by the variation in the concentrations of Zr and Fe within each source.

The loading of Mn is extremely high in Factor III and very low in the other factors, therefore this factor can be in some way a ferromagnesian minerals indicator. Potasium has an extremely high value in Factor IV which can be considered as some index of acidity in the magmas from which obsidian originate.

In general four factors control the chemical composition, variation and characterization of the obsidian from Central Mexico, three of those factors are interpreted as being related to the concentration of certain accessory minerals in obsidians and one is believed to be related to the degree of acidity of the magma.

ARCHEOLOGICAL SITES

Archeological sites are described here as those sites in which obsidian was not found in place and only flakes and small fragments of probable archeological origin were collected.

Site Location

Atotonilco el Grande, Site No. 7

Atotonilco el Grande is a small town located 25 kilometers north of Pachuca on Highway 105 (Fig. 10). Obsidian flakes and artifacts were collected in a small ravine located two kilometers east of the town in a place called "Campo de Tiro". Approximately forty fragments and flakes of light olive green (5 Y 5/2) obsidian range from 50 to 200 grams in weight were collected. Eight of these fragments were selected in a random way for further analysis and labelled 7-1 to 7-8.

Cadereyta de Montes, Site No. 12

Ten fragments of black (N1) obsidian were collected in a cave, 500 meters west of a place called "La Mina de Piedra" (stone mine). This mine is located 1.7 kilometers northeast of Cadereyta de Montes in the state of Queretaro (Fig. 15). The fragments were labelled 12-1 to 12-10.

San Joaquin, Site No. 13

A sample bag full of fragments and flakes of black (N1) obsidian was collected in a place called "Santa Maria de Gracia", five kilometers south of San Joaquin in the state of Queretaro (Fig. 15). Three of these flakes were selected in a random way and labelled 13-1 13-3.

Statistical Analysis

Statistical analyses were performed in the same manner as in the preceding source localities. Tables 3, 4, 5 and 6 show the means, ranges, standard deviations and coefficients of variability. Tables 33 to 35 show the correlation coefficient matrices for each of the archeological sites. After the analysis of the aforementioned tables, the following obsidian characterizations can be made for each of the archeological sites.

1. Site No. 7 Atotonilco el Grande

Obsidian flakes and fragments from this site are characterized by: relatively high concentrations of Mn (1361-1175 ppm); Rb (220-112 ppm) and Ti (1434-1210 ppm); low concentration of Ca (1780-1990 ppm); no detectable Sr, Ba and P; and high variability in Rb content. Positive correlation between Zr and Mn, and Ca and Fe at the 95 percent confidence level and six degrees of freedom.

2. Site No. 12 Cadereyta de Montes

Obsidian artifacts and fragments from this site can be characterized by: relatively high concentrations of Rb (229-129 ppm), Zr (985-354 ppm) and Fe (28805-14625 ppm); low concentration of Sr (15-0 ppm); no detectable Ba; and high variability in Sr, P and Ca content. Positive correlations between P and Sr, K and Ti, and Zr and Ti; and negative correlations between Ti and Sr, Ti and P, K and Sr, and P and K at the 99 percent confidence level and eight degrees of freedom.

3. Site No. 13 San Joaquin

Obsidian fragments and artifacts from this site can be characterized by: relatively high concentrations of Rb (228-189 ppm), Zr (1023-858 ppm)

TABLE 33. CORRELATION MATRIX SITE No. 7

VAR.										
Mn	1.000									
Rb	0.358	1.000								
Zr	0.806	0.615	1.000							
K	-0.228	0.0971	-0.212	1.000						
Ti	0.332	0.609	0.260	0.102	1.000					
Fe	0.513	0.364	0.221	0.550	0.422	1.000				
Ca	0.368	0.342	0.110	0.540	0.238	0.752	1.000			
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000		
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

TABLE 34. CORRELATION MATRIX SITE No. 12

VAR.										
Mn	1.000									
Rb	0.312	1.000								
Zr	0.310	0.531	1.000							
K	0.016	0.178	0.676	1.000						
Ti	0.020	0.083	0.774	0.890	1.000					
Fe	0.414	0.442	0.024	-0.453	-0.529	1.000				
Ca	0.276	0.014	0.064	0.168	0.334	-0.576	1.000			
P	0.149	0.074	-0.623	-0.874	-0.968	0.706	-0.370	1.000		
Sr	0.152	0.076	-0.621	-0.873	-0.967	0.708	-0.370	1.000	1.000	
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

TABLE 35. CORRELATION MATRIX SITE No. 13

VAR.										
Mn	1.000									
Rb	0.994	1.000								
Zr	0.995	0.999	1.000							
K	-0.128	-0.019	-0.030	1.000						
Ti	0.908	0.948	0.945	0.297	1.000					
Fe	0.954	0.916	0.920	-0.419	0.742	1.000				
Ca	-0.735	-0.657	-0.665	0.766	-0.385	-0.904	1.000			
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000		
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
	Mn	Rb	Zr	K	Ti	Fe	Ca	P	Sr	Ba

and Fe (36488-29975 ppm); no detectable P, Sr and Ba; and high variability in Fe content. Positive correlation between Rb and Mn, Mn and Zr, and Zr and Rb at the 99 percent confidence level and three degrees of freedom.

Two assumptions were made before attempting to interpret the data. They were: 1) obsidian samples from each one of the archeological sites come from an unique source; and 2) the source must be one of the known sites. The comparison of the aforementioned characterizations with those made for the known sites indicates that obsidian from archeological site 7, Atotonilco, could come from site 8, Nopalillo, as they have the same chemical and petrographic characteristics. Obsidian from archeological sites 12 and 13 show close relationship with site 10, Fuentezuelas, and 11, Rancho Navajas, but no further assignment can be made using this type of analysis.

The use of multivariate analysis provided the answer for assignment with a high degree of accuracy. Tables 36 and 37 show the D^2 and F values obtained when the mean vector of the archeological sites were compared and tested against those of the known sources. Study of these tables indicate the following similarities between archeological sites and known sources: D^2 of 9.18 between sites 7 and 8; D^2 of 6.2 between sites 12 and 11; D^2 of 9.2 between sites 13 and 11; and D^2 of 17.08 between sites no. 12 and no 13. The significance of these differences was tested at the 99 percent confidence level using the corresponding F values. The results of the test indicate that there is no significant differences in the mean vectors between the above mentioned sites. Therefore obsidian from archeological site 7 is more

TABLE 36.
D^2 VALUES FOR THE ARCHEOLOGICAL SITES COMPARED WITH SOURCE SITES

	7	12	13
1	324.2	248.5	331.1
2	305.5	246.0	329.8
3	419.8	78.0	154.7
4	455.7	277.3	362.4
5	210.92	136.0	163.4
6	242.5	79.8	100.2
8	9.18	527.1	521.5
9	475.9	141.2	199.8
10	429.1	15.70	49.7
11	428.7	6.2	9.2
14	597.4	98.7	187.7
15	358.4	30.2	75.7
16	273.5	130.4	188.5
17	272.5	86.8	146.6
18	390.3	27.8	64.3
7	0	432.9	419.6
12	-	0	17.08
13	-	-	0

TABLE 37.
F VALUES FOR THE ARCHEOLOGICAL
SITES COMPARED WITH SOURCE SITES

	7	12	13
1	121.1	112.4	49.3
2	114.1	111.3	49.1
3	156.8	35.3	23.0
4	170.2	125.4	54.0
5	78.8	61.5	24.3
6	90.6	36.1	14.9
8	3.43	238.4	77.7
9	177.8	63.9	29.7
10	160.3	7.1	7.4
11	165.5	2.9	1.4
14	256.9	51.3	32.8
15	133.9	13.7	11.2
16	102.2	58.9	28.1
17	101.8	39.2	21.8
18	145.8	10.3	9.59
7	0	84.1	0.0
12	-	0	0.71
13	-	-	0

closely related to site 8 than any other site, and obsidian from archeological sites 12 and 13 are more closely related to site 11. This suggests that obsidian from sites 12 and 13 were collected from the same known source.

Archeological site 7 is located about 25 kilometers northwest of site 8 and the obsidians have the same light olive green color and smooth texture that occur at the known source. Source site 11 is located about 50 kilometers southwest of site 13. Obsidian from these sites present the same black color, smooth texture and good working quality. Source site 10 is geographically closer than site 11 to the archeological sites 12 and 13, but obsidian from this site is sparsely spherulitic in texture and of average working quality. This explains why obsidian from site 11 was selected as source for sites 12 and 13.

Some important aspects were carefully studied after the assignments of archeological sites were made. Those aspects are:

1. The distance of the archeological sites from each obsidian source;
2. The obsidian quality and accessibility of the sources;
3. Interpretation of the duration of exploitation of each source site.

Obsidian source identification for archeological sites will become easy if all the known sources were characterized and completely studied. The use of multivariate analyses will provide the tools for handling a large amount of data and for a fast, and accurate assignment.

SUMMARY

This work has provided an accurate method of characterizing obsidian from fifteen major Central Mexico sources that may be of archeological significance.

Three archeological sites were also studied, characterized, and assigned to known sources. The application of statistical methods has yielded definitive characterization of those source sites. Obsidian from one of the major sources was found in two archeological sites and obsidian from another source was found in the third site. This indicates that obsidian trade routes in pre-historic Mexico may be determined using geochemical "fingerprints".

The use of discriminant function analysis indicates that the concentrations of Mn, Rb, Ti, Zr, and Sr are the best discriminative elements. R-mode factor analysis indicates that the cause of variability within the obsidian population is related to four main factors that can control the chemical composition and variation of the obsidians from Central Mexico. Further detailed geological and petrographic studies are recommended within each source site, if a better understanding of obsidian variability within the area is necessary. More intensive investigations of natural source obsidian may be needed for future and accurate archeological work, characterizations must be made using a large number of analyses in trace and major elements. The use of multivariate techniques is necessary in handling the large amounts of data needed for the determination of the archeological site to geologic source relationships and the determination of trade routes.

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APPENDIX. ELEMENTAL DATA FOR SITES

SITE NO. 1: GUADALUPE VICTORIA

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
619	61	39	27647	674	4812	4425	82	46	816
618	40	28	28379	626	5425	4350	112	39	779
585	55	47	27308	656	5063	4323	107	43	803
643	55	35	26049	638	5316	4364	104	45	859
627	51	45	28105	635	5370	4420	108	44	746
587	63	36	24521	669	5091	4048	110	67	453
584	55	32	26288	487	4671	4153	107	48	810
519	65	38	25673	644	4759	4320	109	38	823
554	68	32	28325	654	4978	4180	84	40	599
727	66	30	20444	610	4467	3961	95	46	517
698	66	37	28244	679	4981	4355	89	48	537
673	68	31	28077	666	5817	6293	211	69	724
663	71	32	22810	630	5048	4254	108	42	636
564	70	26	27899	659	5082	4342	109	32	554
530	78	25	25172	614	5042	4659	128	25	538
538	66	31	26998	617	5177	4230	97	75	679
629	74	28	28198	585	5421	4029	143	49	699
643	46	28	28668	611	3925	3986	121	54	562
638	70	63	27372	614	4661	4139	109	55	676
582	75	12	28780	647	4431	4203	108	51	567

SITE NO. 2: PICO DE ORIZABA

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
569	69	29	32361	521	4164	5055	135	36	408
598	56	31	29487	567	4450	4112	102	25	391
843	87	25	29260	562	3864	3564	84	25	575
832	92	27	33822	600	4196	3421	106	27	578
807	99	26	26942	512	4089	3619	72	25	377
701	120	30	31918	530	4383	3786	102	30	423
680	85	23	26502	539	3728	3061	62	14	749
772	60	29	38684	524	3835	2899	72	18	358
600	88	29	37461	545	3767	3163	77	13	228
578	85	28	41174	499	4157	3334	75	25	436
603	85	27	33597	522	3689	3229	51	26	302
640	83	30	32840	477	4385	3395	85	17	334
622	60	19	31325	535	3717	3389	68	18	293
568	95	29	32363	464	3397	3163	83	18	436
672	74	18	32903	526	4254	3111	155	15	792
599	82	22	37248	535	4284	5313	72	38	634
682	93	25	37960	498	4272	3477	55	21	689
770	98	12	34750	497	4125	3020	63	19	448
570	65	21	32983	521	4059	3041	576	14	623
749	66	18	28365	424	3556	3003	53	17	496

SITE NO. 3: ALTATONGA

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
314	118	93	37701	777	12316	3980	93	11	0
351	140	73	37701	864	12270	4591	150	7	0
309	157	77	36370	650	12928	4173	112	6	0
321	81	93	29370	947	14655	3972	80	10	0
335	118	76	29582	867	12932	4581	135	11	0
323	121	81	28230	624	10241	3786	85	2	0
325	127	87	36627	672	11377	4229	119	2	0
298	142	102	36651	699	12144	3754	87	5	0
342	142	114	36307	710	10028	4105	106	7	0
355	129	118	35538	875	10123	4330	100	8	0
363	135	63	35166	617	8470	3446	126	0	0
355	147	73	37534	592	7943	3596	185	0	0
298	155	106	38023	617	8749	3610	86	4	0
334	132	81	34265	965	11614	4145	98	7	0
285	143	82	30368	617	9997	3741	89	0	0
291	112	66	27792	654	10241	4104	121	4	0
310	147	90	28108	858	12099	4749	86	15	0
331	137	82	29808	605	9819	3507	113	5	0
669	183	60	33870	470	6837	3271	86	0	0
340	98	75	37151	639	10261	4124	113	4	0

SITE NO. 4: TEOTIHUACAN, BUENA VISTA

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
461	61	45	32816	1072	9839	8324	291	94	593
466	60	48	30322	1011	9995	7818	287	61	648
465	81	54	28892	1023	10710	9249	343	95	723
446	60	87	30934	965	10005	8176	265	96	408
548	57	92	31199	1019	11013	8119	315	89	376
492	54	93	30356	1029	10106	8033	278	90	581
530	145	91	28371	962	10337	7767	270	96	582
415	102	94	30681	964	10366	7880	268	117	415
407	103	108	27481	980	9208	7728	279	115	504
374	78	89	31702	971	10442	8141	290	110	654
451	83	82	31116	959	9659	7408	297	88	743
438	86	86	28084	908	9780	7097	281	96	469
383	81	91	24379	893	10408	7642	317	98	828
420	78	88	30380	874	11412	7595	318	94	652
438	97	100	31373	1064	10956	8181	323	106	401
393	104	87	22265	1081	9719	7917	327	96	495
468	109	93	30198	1072	10664	7542	308	111	325
403	113	86	35758	1067	10353	7750	344	144	634
415	92	86	31556	1106	9738	7554	233	104	582
439	96	81	33964	957	10293	8011	275	102	478

SITE NO. 5: NATIVITAS

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
503	92	379	30133	1196	19443	5171	152	13	526
528	76	404	28269	1220	22500	5409	140	20	584
498	61	333	30578	1202	23248	5286	137	17	596
546	64	357	28677	1298	20584	5608	136	21	564
626	67	403	31549	1207	23875	5400	119	20	559
599	58	368	31633	1254	25907	5319	112	17	892
503	102	386	32620	1247	24409	5624	149	21	760
510	96	460	34327	1250	20998	5377	123	26	748
479	90	413	34427	1208	23931	5254	123	14	542
521	90	360	34535	1242	22999	5401	154	23	675
517	89	328	32449	1263	23225	5729	152	23	602
542	89	379	34869	1202	20901	5021	136	21	622
618	98	502	31266	1245	23136	5086	163	21	854
612	87	438	31499	1228	23575	5395	144	18	498
585	108	495	33352	1299	25151	5576	161	30	595
570	92	444	29036	1339	23653	5311	131	25	715
534	86	479	20641	1370	23345	5603	175	21	543
547	46	437	31640	1165	24061	4977	131	21	535
494	95	444	28826	1249	22350	5486	132	20	698
573	104	391	27768	1157	23882	5509	138	19	733

SITE NO. 6: TULANCINGO

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
452	106	455	37048	1123	26018	4224	53	11	702
458	106	552	39493	1195	26215	4006	62	8	553
472	97	377	36415	1199	25128	4190	55	10	487
445	92	371	35631	1210	26082	4208	55	19	633
466	102	480	34893	1236	24755	4038	56	11	644
501	96	516	33888	1133	21936	4054	44	6	528
477	103	488	32489	1199	23038	4251	74	10	521
414	74	417	35137	1212	21782	4299	40	7	429
429	99	495	27082	1137	21411	3935	66	12	574
430	110	518	35244	1087	20468	4057	42	11	361
488	87	444	28473	1179	21992	3830	75	0	445
483	87	434	29077	1193	21905	4122	57	8	518
491	108	455	33318	1150	23088	3921	62	7	294
483	133	504	32264	1213	21557	4126	60	7	546
445	116	456	33341	1115	21406	3793	60	12	477
401	108	459	32526	1182	22638	3951	53	6	483
435	91	413	31669	1225	18903	4197	72	8	337
442	96	444	37411	1245	19589	4224	71	4	405
408	80	620	35641	1180	22384	5400	80	8	822
450	90	437	36189	1199	21892	4662	81	13	516

SITE NO. 8: EL OCOTE, NOPALILLO

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
1638	147	635	32953	1078	19723	1837	0	0	0
1410	125	663	31476	1105	16766	1528	0	0	0
1492	135	710	34151	1213	25101	1709	0	0	0
1441	135	631	32288	1176	22229	1561	0	0	0
1327	141	605	32379	1250	23780	1674	0	0	0
1379	127	716	31388	1213	24164	1996	0	0	0
1325	148	704	33043	1379	18347	1499	0	0	0
1380	161	661	32961	1249	19460	1463	0	0	0
1368	129	546	33120	1181	21680	1568	0	0	0
1337	122	510	32778	1229	18080	1564	0	0	0
1290	168	752	28325	1133	19392	1458	0	0	0
1316	156	723	32869	1243	20445	1563	0	0	0
1358	189	697	34585	1271	21134	1576	0	0	0
1320	173	663	31986	1383	17150	1671	0	0	0
1340	176	757	30201	1460	20517	1438	0	0	0
1318	145	624	31817	1240	17948	1608	0	0	0
1335	156	600	32564	786	19182	1512	0	0	0
1379	132	628	36513	1264	19731	1508	0	0	0
985	89	452	34604	2122	16706	1967	28	0	0
1427	139	679	33812	1259	23205	1526	0	0	0

SITE NO. 9: METZQUITITLAN

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
191	253	126	49828	1238	12700	5003	150	18	0
218	223	114	49405	1294	13237	5019	168	18	0
205	265	169	55336	1372	13459	5450	161	27	0
209	195	119	47095	1281	11503	5178	150	24	0
223	247	125	48273	1231	12117	5108	117	20	0
241	262	147	35268	1172	11929	5096	85	11	0
210	213	143	41775	1240	12411	5157	63	25	0
192	186	125	38652	1243	12804	5302	117	54	0
196	221	147	42235	1242	12043	5024	89	20	0
214	273	162	41420	1353	12164	5526	96	32	0
223	284	167	38828	1277	13457	5205	104	25	0
194	240	110	34476	1221	11345	4720	89	21	0
210	282	136	42240	1217	12301	4698	91	0	0
202	252	137	34471	1215	11183	5238	86	21	0
220	207	120	40051	1352	11427	5044	99	26	0
189	223	111	41357	1223	13945	5212	97	24	0
205	292	133	42814	1285	14094	4841	97	21	0
217	257	111	40365	1343	12850	5455	101	21	0
230	250	143	37545	1360	12898	4936	108	27	0
214	208	124	40350	1313	12344	5185	110	23	0

SITE NO. 10: FUENTEZUELAS

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
296	120	392	31933	736	16138	2225	3	0	0
234	113	350	32111	734	15000	2254	0	0	0
251	124	392	30976	771	18467	2438	28	0	0
236	144	476	33520	789	18048	2210	1	0	0
274	130	415	32155	751	18529	2320	2	0	0
272	118	431	29985	689	17891	2556	6	0	0
295	126	441	30103	728	18652	2509	1	0	0
287	144	430	27628	676	12637	2166	1	0	0
277	136	525	30109	699	16532	2073	0	0	0
291	160	456	27712	724	13407	2405	8	0	0
302	124	501	33965	677	17136	2251	0	0	0
317	167	632	35338	750	15098	2325	9	0	0
306	132	564	32229	563	16590	2435	0	0	0
316	120	577	30669	698	17684	2676	0	0	0
291	176	622	38973	780	16847	2318	6	0	0
303	92	377	33095	648	14583	1838	0	0	0
274	157	492	35344	707	15938	2072	0	0	0
263	144	379	31795	755	14769	2174	3	0	0
295	144	494	34733	807	16281	1977	0	0	0
285	188	603	36228	740	18102	2334	7	0	0

SITE NO. 11: EL PARAISO, RANCHO NAVAJAS

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
292	169	702	30991	867	20416	2148	0	0	0
303	170	704	31222	846	19840	1824	0	0	0
308	218	1044	32362	867	21677	2025	0	0	0
293	155	786	31312	828	24664	1879	0	0	0
300	202	906	29186	806	27881	1991	0	0	0
296	242	1092	26920	882	24033	1751	0	0	0
302	158	845	29901	829	23766	1866	0	0	0
287	193	944	27896	808	27283	1733	0	0	0
295	186	786	28264	900	27211	1937	0	0	0
285	220	702	32742	842	20735	1974	0	0	0
304	212	716	37890	890	22662	2082	0	0	0
294	213	560	28770	868	18931	1965	0	0	0
277	229	756	36546	872	28299	1949	0	0	0
278	249	942	38030	857	27386	1755	0	0	0
266	191	491	34818	920	27277	2809	0	0	0
302	212	559	37443	674	29080	1977	0	0	0
281	206	637	35880	936	24054	2078	0	0	0
315	191	683	34879	908	26331	2012	0	0	0
290	231	704	34799	852	25225	2028	0	0	0
292	220	681	36776	909	22956	1806	0	0	0
275	218	515	33162	895	23195	1788	0	0	0

SITE NO. 14: ZINAPECUARO, UCAREO

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
245	157	47	27548	485	8370	3998	104	8	0
218	149	91	27182	456	8333	4440	102	0	0
222	141	46	30838	465	8445	4256	88	4	0
210	148	61	33863	469	8848	3953	102	0	0
235	159	65	33920	435	9353	3241	93	10	0
233	94	44	34889	502	8415	4132	83	5	0
209	129	47	35053	444	9929	4011	97	0	0
223	154	60	33531	516	8858	3908	94	0	0
190	158	48	36706	459	9229	4052	76	7	0
183	158	55	37917	438	8665	4239	96	0	0
245	152	76	34941	429	8514	3759	83	0	0
217	152	36	35060	397	7645	4088	86	0	0
222	132	36	37748	469	8463	4061	81	0	0
202	143	40	34405	440	8652	3560	90	7	0
216	131	42	34035	409	7917	3750	71	0	0
182	123	48	37202	440	9620	3847	56	0	0
218	111	55	37280	432	9295	3741	65	12	0
205	132	52	32022	415	9277	4151	81	0	0
233	134	51	31636	443	7855	4242	64	0	0
223	144	62	33735	459	8545	3760	98	0	0
207	104	39	32133	430	8410	4208	88	0	0
206	112	46	26815	419	9857	3505	79	0	0
210	121	50	26321	420	10226	3848	84	0	0
301	231	26	28091	335	9654	4203	113	0	0
280	251	35	24185	241	7735	3966	78	0	0

SITE NO. 15: PENJAMO

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
353	32	204	35497	715	14390	8234	183	26	0
337	37	176	32500	715	17075	2330	8	4	0
362	64	401	31909	781	17769	2610	12	0	0
467	92	189	33437	714	15990	1956	14	0	0
424	155	433	30395	732	17691	2201	0	1	0
418	89	223	30969	709	17251	1992	0	0	0
387	97	256	31918	706	16713	1990	0	0	0
398	95	245	29027	703	15668	1659	0	0	0
379	98	205	29681	708	17930	1961	0	0	0
390	151	385	29139	658	16801	1881	0	0	0
445	144	418	31140	669	16709	2092	0	0	0
449	182	468	32716	662	18612	1872	0	0	0
374	171	464	32932	702	17301	2139	0	0	0
365	150	432	34256	653	16510	2103	0	0	0
399	152	424	32342	700	18608	2006	0	0	0
445	173	542	29806	766	17835	2378	0	0	0
364	160	470	30357	624	14310	1796	0	0	0
415	160	505	30478	703	18651	2204	0	0	0
428	103	322	31503	719	17816	2042	0	0	0
386	118	389	30696	665	17472	2053	0	0	0

SITE NO. 16: TEQUILA

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
373	47	95	32026	989	11877	4689	145	23	844
399	67	159	31031	1074	11822	4673	159	39	857
332	67	171	35351	1043	11422	4481	150	36	959
367	54	106	35435	967	11846	4561	142	21	979
322	45	136	35567	978	11313	5180	147	27	666
398	82	149	31403	1048	10808	4852	174	36	954
357	66	133	32210	1039	10466	5179	118	32	829
416	71	123	37912	1107	10701	4688	140	30	836
447	135	173	39006	1109	12606	4643	171	15	0
517	84	144	35585	1154	13576	4325	138	17	419
508	65	128	34169	1236	10925	3174	138	11	0
525	81	157	38991	1341	12795	4607	104	13	0
679	108	334	31960	918	19986	1865	36	0	0
353	55	136	33162	988	12583	4935	135	30	601
477	96	108	39565	927	13205	3858	114	7	38
527	85	143	36732	1066	11980	4176	119	12	135
397	45	87	33038	966	9334	4517	108	20	899
392	65	108	37663	1086	10759	4687	135	4	598
443	50	76	36660	966	11043	4320	149	23	708
409	60	83	33803	1083	12226	5303	149	29	843

SITE NO. 17:MAGDALENA

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
544	139	127	38521	813	13208	3639	81	0	0
560	118	135	37152	773	10560	3484	86	0	0
470	143	151	39544	805	12848	3289	168	0	0
501	126	159	33850	781	14777	3172	64	1	0
474	103	186	37877	774	14403	3401	85	4	0
456	131	186	36063	794	15411	3265	92	0	0
494	132	172	36164	709	10453	3482	78	0	0
556	122	184	40066	750	11468	3507	85	0	0
496	120	229	33211	1066	11226	4333	122	24	0
496	113	195	39335	1029	13080	3918	157	13	0
490	113	196	39825	976	14457	3721	100	4	0
511	94	197	38702	1063	15938	4442	141	24	0
488	124	173	38424	932	11137	3907	58	12	0
585	104	215	38645	1056	13092	4824	152	26	0
490	118	226	35765	1049	13428	4509	128	13	0
569	166	235	38352	992	22794	2691	0	0	0
496	120	225	34979	994	12057	3837	87	17	0
440	160	196	45251	961	13991	3535	107	1	0
459	143	177	43606	627	12132	3497	84	0	0
476	150	197	40681	810	11495	3471	133	6	0

SITE NO. 18: TEUCHITLAN

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
386	161	393	35998	639	17791	2216	0	0	349
386	133	447	37648	638	18355	2446	0	0	0
372	172	407	29168	674	16664	2239	0	0	0
493	133	410	29348	608	16057	2308	11	0	229
445	155	393	27278	683	18877	1997	36	0	351
407	155	401	29109	620	18914	2053	0	0	70
353	150	378	24311	596	20419	2258	0	0	57
312	165	428	27737	586	17145	2049	7	0	0
316	87	319	37649	623	14455	2221	29	0	53
375	143	499	31775	617	15604	2187	29	0	0
357	163	504	36302	659	18050	2337	0	0	0
381	147	467	31670	652	17735	2008	0	0	0
385	161	399	37497	680	18010	2436	0	0	48
327	154	429	36195	675	17609	2266	7	0	13
330	169	418	33699	686	16924	2446	0	0	0
357	166	400	34268	603	15547	2441	0	0	0
347	186	505	24020	634	15547	2223	0	0	26
347	131	387	22854	648	16873	2069	0	0	9
351	144	388	23344	689	16243	1812	0	0	0
330	123	247	20707	602	14351	2182	0	0	0

SITE NO. 7: ATOTONILCO (ARCHEOLOGICAL SITE)

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
1180	215	675	30508	1361	21841	1574	0	0	0
1175	112	579	30583	1227	21249	1598	0	0	0
1226	171	703	28305	1248	21507	1490	0	0	0
1361	200	825	27689	1245	21977	1663	0	0	0
1238	192	766	29456	1361	20489	1495	0	0	0
1343	168	767	30719	1358	23046	1561	0	0	0
1312	220	734	34221	1434	23906	1780	0	0	0
1192	177	709	36254	1210	22373	1636	0	0	0

SITE NO. 12: CADEREYTA DE MONTES (ARCHEOLOGICAL SITE)

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
367	202	835	36508	915	23119	5534	120	7	0
308	139	493	37509	753	19116	2181	8	0	0
221	170	354	31412	735	17499	2511	7	0	0
276	160	368	23777	701	14625	7429	291	15	0
302	182	927	30494	817	28805	2042	0	0	0
299	229	985	35107	881	25535	2511	0	0	0
284	205	892	35843	813	21867	1958	0	0	0
274	149	468	34620	779	21887	2481	37	0	0
269	129	664	21403	814	21020	2027	9	0	0
257	186	672	38932	807	20971	1993	0	0	0

SITE NO. 13: SAN JOAQUIN (ARCHEOLOGICAL SITE)

MN	RB	ZR	K	TI	FE	CA	P	SR	BA
307	189	858	32636	834	21242	2172	0	0	0
320	223	1000	36480	975	24443	2163	0	0	0
324	228	1023	29915	945	27727	2064	0	0	0