THE CHIPPED STONE INDUSTRY OF CIHUATAN AND SANTA MARÍA, EL SALVADOR, AND SOURCES OF OBSIDIAN FROM CIHUATAN

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The chipped stone industry of Cihuatan and Santa María, Postclassic sites of north-central El Salvador, is discussed briefly in terms of behavioral/technological typology. The industry was based almost exclusively on obsidian and emphasized specialized production of prismatic blades. Source determinations by X-ray fluorescence and neutron activation analysis of 20 obsidian specimens from Cihuatan indicate that at least three highland Guatemalan sources supplied obsidian to the site. Twelve specimens are attributed to the Ixtepeque source, seven to El Chayal, and one to San Martín Jilotepeque. The multiple-source procurement pattern is interpreted as a hedge against the fragility of Postclassic sociopolitical alliances and shifting exchange networks.

One of the most important advances in Mesoamerican lithic studies of recent years has been the development of behavioral and technological typologies based on linear reduction models of manufacturing trajectories (Clark 1979, 1981a; Clark and Lee 1979; Moholy-Nagy et al. 1984; Sheets 1972, 1975a, 1978a). These typologies focus on the behavior involved in the manufacture, use, and recycling of lithic artifacts, thus attempting to model the real technological structure of lithic industries. Behavioral/technological typologies are now available for about 20 sites in the Maya area and the southeastern periphery of Mesoamerica (Fowler 1985).

Another significant advance has been the development of techniques for accurate, high-precision chemical characterization of obsidian as a means of source determination (Stross et al. 1968; Stross, 1976). The results of precise geochemical analyses to determine the sources of archaeological obsidian in Mesoamerica have led to better understanding of the nature and degree of long-distance exchange in the area. Three factors make obsidian an excellent indicator of long-distance exchange contacts: (1) good-quality, workable obsidian occurs in a relatively limited number of geological deposits; (2) obsidian artifacts deposited in archaeological contexts are virtually imperishable; and (3) it is possible to determine, within limits of statistical certainty, the geological sources of obsidian artifacts through precise geochemical characterization. It is a fair assumption that obsidian exchange is an indicator of the exchange of other items that left no trace in the archaeological record. At the very least, the "buyers" had to offer something to the "sellers" in exchange for the obsidian. Whether or not perishable goods moved in appreciable quantities along the same routes of exchange as obsidian (see Drennan 1984), the reconstruction of Precolumbian obsidian exchange in Mesoamerica sheds light on prehistoric interregional contacts and exchange networks in general and provides a foundation for hypotheses concerning ancient sociopolitical ties that operated over long distances.

When behavioral/technological typologies and obsidian source determination are used conjunctively, the analyst learns more about the cultural context within which a given lithic industry developed and functioned (Moholy-Nagy et al. 1984). The resulting reconstruction is more detailed and is a more fruitful source of hypotheses than either of the approaches used alone.

The chipped stone industry of the ancient settlements of Cihuatan (Bruhns 1980; Fowler 1981; Kelley 1985) and Santa María (Fowler 1981), in the Paraíso (or Cerrón Grande) Basin of north-

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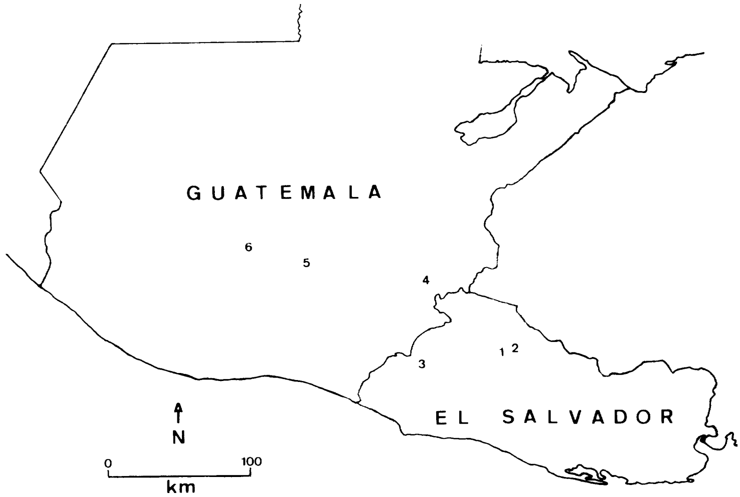

Figure 1. Locations of archaeological sites and obsidian sources mentioned. 1. Cihuatan; 2. Santa María; 3. Chalchuapa; 4. Ixtepeque; 5. El Chayal; 6. San Martín Jilotepeque (Rio Pixcayá).

central El Salvador (Figure 1), provides an excellent example of the broader implications of behavioral/technological typologies and obsidian source determination. These two contemporaneous sites are very closely allied in terms of material culture and layout. They were occupied during the Early Postclassic period (A.D. 900–1200). The weighted average of the calibrated means of the eight most reliable radiocarbon determinations from the sites (seven from Cihuatan, one from Santa María) is A.D. 1037 ± 36 (Fowler 1981:52; Fowler and Earnest 1985). Cihuatan–Santa María radiocarbon chronology and procedures used for calibration and calculation of weighted averages are discussed in detail by Fowler (1981:46–53). The archaeological evidence and related ethnohistoric and linguistic data leave little doubt that the two settlements were inhabited by a Nahuat-speaking Pipil or a Mexicanized group who had migrated from Mexico to Central America during the Late Classic or Epiclassic period (Fowler 1981; Fowler and Earnest 1985).

THE CHIPPED STONE INDUSTRY OF CIHUATAN AND SANTA MARIA

More than 26,000 chipped stone artifacts from Cihuatan and Santa María have been analyzed (Fowler 1981; Kelley 1985) according to a behavioral/technological typology based on those developed by Sheets (1972, 1975a, 1978a) and Clark (1979, 1981a; Clark and Lee 1979). The analyzed collection from Cihuatan consists of almost 5,000 specimens collected by Bruhns (1980) in excavations in 1975, 1977, and 1978, primarily of non-elite residential structures in the northwest and southeast sectors of the site; almost 600 specimens excavated by Lubensky (1978) in 1977 from a small platform of the so-called West Ceremonial Center; more than 10,000 specimens collected by Fowler (1981) in excavations in 1978–1979 of civic-ceremonial structures and an elite residential compound within and adjacent to the West Ceremonial Center; and about 9,900 specimens collected by Kelley (1985) in her 1979 excavations of a domestic zone in the northeast sector of the site. Almost 700 specimens were collected by Fowler (1981) in salvage excavations of Santa María in 1976, from both civic-ceremonial and domestic contexts. For maps of the two sites and locations of excavations see Bruhns (1980), Fowler (1981), and Kelley (1985).

The Cihuatan–Santa María chipped stone tool industry is based almost entirely on obsidian, with non-obsidian raw materials comprising less than 1% of the analyzed collections. There is abundant evidence that obsidian tool manufacture was an important local industry at both centers. Debitage

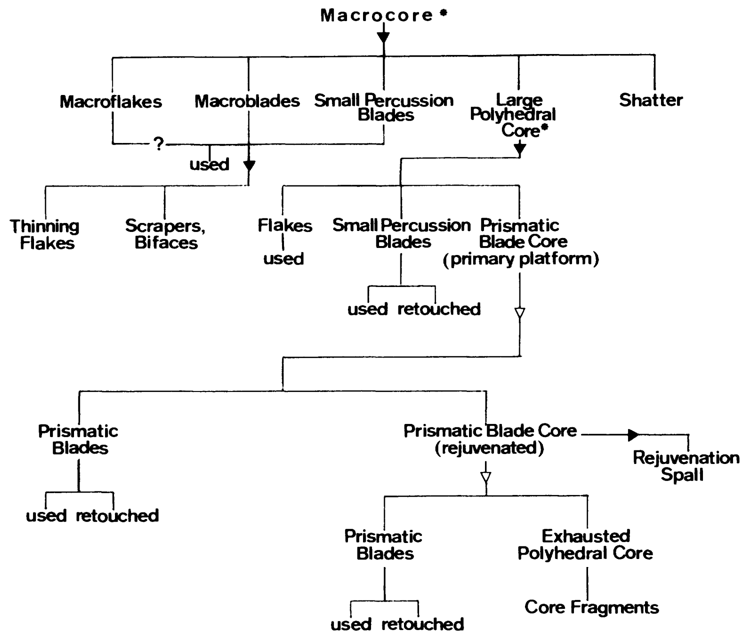

Figure 2. A proposed linear reduction model of the Cihuatan–Santa María chipped stone industry. Note: *—presence inferred; solid arrows—percussion flaking; open arrows—pressure flaking.

(core-blade chipping debris and thinning flakes) is frequently found at both sites, as are exhausted polyhedral cores. Several obsidian workshops have been excavated at Cihuatan, the most noteworthy of which was at Structure P-16 (Bruhns 1980:41). A large number of exhausted polyhedral cores and other evidence of core reduction were found on the surface of a residential zone of Santa María, without doubt the location of one or more obsidian workshops (Fowler and Solís 1977:16).

Obsidian was probably traded to the two sites in the form of macrocores or, perhaps more likely, large polyhedral cores. Obsidian artifacts from the two sites show a very low incidence of cortex (observed on only 20 of the 10,000+ specimens studied in Fowler's [1981] analysis). This fact suggests quarry preforming of the cores. Furthermore, Ixtepeque and El Chayal, two of the sources identified by the geochemical analysis reported here, have yielded evidence of Late Classic and Postclassic macrocore and large polyhedral core production at quarries (Clark 1981b; Graham and Heizer 1968; Hester 1972; Michels 1975; Sheets 1975b).

Typologically, the Cihuatan–Santa María chipped stone industry is composed of a wide variety of implements including polyhedral cores; unretouched macroblades, small percussion blades, and prismatic blades; unifacially retouched prismatic blades, small percussion blades, and macroblades; unifacially retouched scrapers made from macroblade blanks; small projectile points made from laterally retouched flakes, macroblades, small percussion blades, and prismatic blades; and bifacially retouched projectile points, knives, and other tools made mostly from macroblade blanks. Figure 2 presents a proposed linear reduction model of the structure of the industry. Its typological complexity is astounding, but it is probably typical of Postclassic chipped stone complexes of southeastern Mesoamerica. It is very similar in typological composition and diversity to the Late Classic–Postclassic Xival chipped stone complex at Chalchuapa (Sheets 1978a:74–75).

The predominant tool type of the Cihuatan–Santa María chipped stone industry is the prismatic blade, which accounts for approximately 70% of the full analyzed collection. When the blades are considered together with core-blade debitage, retouched forms, and exhausted polyhedral cores, 95% of the industry is referable to prismatic blade production. The importance of this type was

Table 1. Mean Metric Values (cm) of Prismatic Blades from Cihuatan and Santa María.

	Platform		Blade		Length of Eraillure
	L.	W.	W.	T.	
Cihuatan[a]					
N	295	299	299	301	65
$\bar{x}$	.84	.31	1.34	.37	.81
S.D.	.25	.09	.3	.09	.15
Santa María[a]					
N	109	108	109	109	27
$\bar{x}$	.70	.28	1.41	.39	.82
S.D.	.26	.15	.29	.09	.14
Chalchuapa[b]					
N	66	66	66	66	54
$\bar{x}$	.58	.20	1.58	.41	.58
S.D.	.23	.09	.4	.08	.22

Data on Late Classic–Postclassic specimens from Chalchuapa are included for comparison. Note: N—number measured; $\bar{x}$—mean; S.D.—standard deviation.

[a] Fowler 1981:Table 8.

[b] Sheets 1978a:96–97.

undoubtedly due to a number of interrelated factors, most prominent among which was almost certainly the potential in prismatic blade technology to maximize the amount of cutting edge produced from a given amount of raw material.

The maximization of cutting edge is reflected in the very high cutting edge-to-mass (CE/M) ratios of prismatic blades from the sites. The CE/M ratio is an efficiency index that measures the total acute cutting edge produced per unit mass of raw material (Sheets and Muto 1972). Previous studies have demonstrated that the CE/M ratio for prismatic blades from sites in southeastern Mesoamerica tends to vary proportionately with distance from the source of obsidian (Fowler 1985; Sheets 1978b; Sidrys 1976:155–167).

The mean CE/M ratio for Cihuatan, measured on a sample of 7,790 prismatic blade fragments, is 4.38 cm/g. The CE/M ratio for Santa María, measured on a single lot of 235 specimens, is 4.25 cm/g. For comparison, the mean CE/M ratio for Chalchuapa is 2.69 cm/g (Sheets 1978a:11). Chalchuapa is located only 50 km on an easily traversed route from the source of Ixtepeque that probably provided almost all of the site's obsidian (Sheets 1978a:11, 72–73). In contrast, much greater distances and probably tighter controls or limits on obsidian procurement and exchange separated Cihuatan and Santa María from their obsidian sources.

The maximizing tendency is also apparent in the high frequency of rejuvenation of polyhedral cores from Cihuatan and Santa María. Not counting rejuvenation spalls, about 22% of the 106 polyhedral cores from the two sites that were subjected to detailed attribute analysis in Fowler's (1981) study had been rejuvenated. This is almost three times higher than the 8% rejuvenation rate reported by Sheets (1978a:14) for Chalchuapa polyhedral cores. A high frequency of core rejuvenation is expected in a situation in which obsidian was a carefully managed commodity.

Another factor that probably influenced the high frequency of prismatic blades at Cihuatan and Santa María is the versatility of these tools. With their extremely sharp edges, prismatic blades were often used without modification, while others were blanks for the manufacture of other artifacts such as arrow points, drills, burins, and so on.

Socioeconomic factors involving such variables as population size, demand for the blades, and craft specialization probably exerted an influence just as strong as, if not stronger than, the technological factors. Sheets (1978a:74) considers the interplay of technological and socioeconomic

Table 2. Provenience Assignments to El Chayal and San Martín Jilotepeque.

Sample Name	XRF Name	Archaeological Designation	Zr (ppm)	Sr/Zr	Rb/Zr
Samples assigned to El Chayal (N = 7)					
KELL-1	8118-D	I-593-1	127	1.298	1.211
KELL-3	8118-F	I-397-1	128	1.321	1.184
KELL-4	8118-G	I-388-1	125	1.334	1.233
KELL-10	8118-M	I-416-1	122	1.348	1.288
KELL-17	8118-5	1281/4	110	1.318	1.213
KELL-12	8118-Z	1108/5	119	1.299	1.200
KELL-19	8118-7	3015/5	128	1.344	1.229
Mean			122.7	1.323	1.222
RSMD			6.5	.020	.033
Typical counting error for artifact			1.6	.025	.028
Counting error for standard			1.9	.027	.030
El Chayal reference[a]			117	1.31 ± .04	1.27 ± .04
Sample assigned to San Martín Jilotepeque (Río Pixcayá)					
KELL-20	8118-8	3018/6	130	1.633	.910
Statistical error due to artifact and standard			2.8	.046	.035
Representative Río Pixcayá[b]			115 ± 3	1.65 ± .06	1.01 ± .05

[a] Stross et al. 1983:Table B-1.
[b] Stross et al. 1983:Table 2.

factors such as these to have motivated the steady increase in frequency of prismatic blades through time from the Preclassic to the Postclassic at Chalchuapa.

The high frequency of prismatic blades relative to other chipped stone types suggests specialization in blade production at Cihuatan and Santa María. Supporting evidence for specialization, apart from the aforementioned workshops, is the very low incidence of manufacturing errors found in prismatic blades from the two sites. Of the 18,287 prismatic blades analyzed, only 216 (1.1%) had hinged off their parent cores prematurely. Only six blade fragments studied in Fowler's (1981) analysis of 13,428 prismatic blades resulted from outrepassé (plunging) errors. These data indicate a high level of proficiency on the part of the Cihuatan–Santa María knappers, and some degree of occupational specialization in the chipped stone industry is suggested.

It is also interesting to note the very close correspondences in the mean dimensions of platform length and width, blade width and thickness, and the length of eraillure (bulbar scar) of prismatic blades from the two sites (Table 1). These data suggest shared concepts of blade technology among the knappers of the two centers and may be indicative of standardized manufacturing techniques.

The production of prismatic blades at Cihuatan and Santa María, however, was probably not totally in the hands of specialists. Core-blade debitage and exhausted polyhedral cores are found at both sites in domestic contexts that, because of low artifact densities, cannot be interpreted as specialized workshops. These remains would seem to indicate part-time, household- or cottage-level blade production. Thus, a certain amount of casual or nonspecialized prismatic blade production probably accompanied specialized production at the two settlements.

Another important characteristic of the Cihuatan–Santa María chipped stone industry is the occurrence of bifacial retouching and the wide diversity in form and function of bifacial implements. The apparent lack of bifacial retouching in El Salvador prior to the Late Classic period is difficult to explain, for the technique was certainly not unknown (cf. Sheets 1978a:75). All but three of the 112 bifaces analyzed from the two sites were made from macroblade blanks. On the basis of

Table 3. Provenience Assignments to Ixtepeque (N = 12).

Sample Name	XRF Name	Archaeological Designation	Zr (ppm)	Sr/Zr	Rb/Zr
KELL-2	8118-E	I-396-7	192	.909	.551
KELL-5	8118-H	I-397-2	190	.916	.537
KELL-6	8118-I	I-416-4	198	.896	.545
KELL-7	8118-J	I-416-1	195	.899	.550
KELL-8	8118-K	I-390-1	191	.900	.562
KELL-9	8118-L	I-380-7	185	.912	.555
KELL-11	8118-Y	1069/1	179	.884	.505
KELL-13	8118-1	1164/6	171	.909	.513
KELL-14	8118-2	1174 A	179	.916	.550
KELL-15	8118-3	1244/11	186	.907	.527
KELL-16	8118-4	1253/3	178	.907	.595
KELL-18	8118-6	1287/7	176	.890	.567
Mean			185	.904	.546
RMSD			8.4	.010	.024
Typical counting error for artifact			2.0	.015	.015
Counting error for standard			2.8	.019	.014
Ixtepeque reference (outcrop 2-1 of Sidrys)			176 ± 6[a]	.90 ± .02[b]	.57 ± .01[b]

[a] Stross et al. 1983:Table B-1.
[b] Stross et al. 1983:Table 9.

morphology, no fewer than 25 types can be distinguished within this small collection (Fowler 1981: 377–403). Many of the bifacial types have close formal parallels in central Mexico, and their appearance in Late Classic and Postclassic contexts of southeastern Mesoamerica is no doubt related to Nahuat expansion and influence in the region.

SOURCE DETERMINATION

Twenty obsidian specimens from Cihuatan were analyzed for source determination in 1981. The analysis was conducted by Asaro, Michel, and Stross at the Lawrence Berkeley Laboratory. Ten of the specimens selected for analysis were from Fowler's excavations of the civic-administrative center of the site (the "West Ceremonial Center") and an adjacent elite residential compound, and ten were selected from Kelley's excavations of the San Dieguito barrio, a peripheral, nonelite residential zone. The specimens were selected on the basis of contextual and stratigraphic variation and variation in macroscopically observable attributes of the artifacts' chemical composition such as color, banding, translucency, and so on. All specimens submitted for analysis were prismatic blade fragments.

The specimens were first subjected to nondestructive X-ray fluorescence (XRF) analysis. The results are shown in Tables 2 and 3, with reference to the data on Sr, Rb, and Zr abundances. In addition to these elements, Ba, Ce, Fe, Mn, Y, and Nb were considered in the provenience assignments. All the abundances were consistent with the assignments, but statistical or size errors made these measurements less definitive than those for Sr, Rb, and Zr.

Since the artifacts were not destroyed to prepare samples of uniform size, there are errors introduced in the nondestructive XRF method due to variation in sample size and shape. Thinner artifacts will tend to have abundances somewhat higher than the true values; e.g., the average Zr values for the specimens measured in this analysis are higher than the reference values (Tables 2, 3). By taking abundance ratios of elements with nearly the same energy X rays, this error is canceled to a large extent. In Tables 2 and 3 the root-mean-square deviation (RMSD) of the Zr values is considerably larger than the statistical error in counting the X-rays from the artifacts. This is very likely due in large part to the differences in size and shape of the artifacts rather than a true difference in composition. On the other hand, when ratios of abundances are considered, the RMSD is nearly comparable to the counting statistics. Rb is slightly more difficult to measure than Sr, and there may be additional errors of a few percent because of these measurement problems. When comparing the elemental abundances of artifacts with those of the reference groups, the statistical counting errors of the calibration standard (a medium-size chunk of El Chayal obsidian is used as a standard) must be considered if the reference groups are not measured at the same time. These values are also tabulated for the specimens assigned to El Chayal and Ixtepeque.

The XRF source determinations were confirmed by an abbreviated sequence of high-precision, accurate neutron activation analysis (NAA) of three samples—one from each of the assigned source groups. The results are shown in Table 4. The NAA gave accurate values for Mn, Na, Dy, Ba, and K. The XRF source assignments were confirmed.

Although the sample size is relatively small, the XRF/NAA results indicate that the ancient inhabitants of Cihuatan and, by extension, Santa María obtained obsidian from at least three different obsidian sources of highland Guatemala—Ixtepeque (IX), El Chayal (CH), and San Martín Jilotepeque (SMJ). That IX is the most prominently represented source, with 12 of the 20 specimens assigned to it, is perhaps best understood in terms of relative distance to the sources. But it does not necessarily follow that the nearest source will always be the dominant one in a given site's obsidian supplies (see Clark and Lee 1984:241–247). In this case, however, there is a proportional representation of sources corresponding to relative distance from the site, with IX being the nearest, CH the next nearest, and SMJ the farthest source from Cihuatan.

In terms of intrasite variation, it is interesting that the samples assigned to CH and IX are divided almost as evenly as possible between the group of specimens submitted from the nonelite residential zone and that from the civic-administrative center and elite residential compound (in Tables 2 and 3 the archaeological designations preceded by "I" refer to specimens of the latter group). Assuming that these zones of the site were occupied contemporaneously—and they almost certainly were—this distribution pattern argues for tight control of the flow of obsidian into Cihuatan by a centralized administrative authority.

CONCLUDING REMARKS

Behavioral/technological analysis indicates that the chipped stone industry of Cihuatan and Santa María specialized in the manufacture of obsidian prismatic blades. Very high CE/M ratios for prismatic blades and a high incidence of polyhedral core rejuvenation indicate that obsidian was a carefully utilized commodity at the two sites. This inference is supported by the results of the source determination analysis that indicate diversification of sources and supply routes for Cihuatan obsidian.

Several alternative scenarios could be advanced to explain the multiple-source procurement pattern indicated by the geochemical analysis. Chronological variation in source exploitation could be suggested, but since Cihuatan was apparently occupied only during the Early Postclassic such a hypothesis would be stillborn. Direct exploitation by individuals from Cihuatan with differing preferences for obsidian from certain sources could be proposed if such a pattern occurred at an earlier time (for example during the Paleoindian, Archaic, or Early Preclassic period) and among less complex societies, but such an explanation is wildly unlikely for the Postclassic.

A more viable alternative hypothesis would invoke tribute rather than trade as Cihuatan's means of acquiring obsidian. According to this hypothesis, tributary settlements located in different areas could have had relatively greater access to one or another obsidian source, or relatively better exchange ties with traders who handled obsidian from a specific source. This alternative is certainly worth exploring, but we have so little comparative archaeological data from the Salvadoran Postclassic that the evaluation of such an hypothesis would necessarily be limited to general observations. In the first place, there is little doubt that Cihuatan was a powerful regional polity, and it is entirely plausible that tribute from subject settlements formed part of the basis of its economy. On the basis of its size and volume of monumental architecture, Cihuatan appears to have been the primary regional center of the Paraíso (or Cerrón Grande) Basin during the Early Postclassic (Fowler and

Table 4. Abbreviated Neutron Activation Analysis Elemental Abundances.[a]

NAA Name	Sample Name	Dy (ppm)	Mn (ppm)	Na%	K%	Ba (ppm)	Comments
2075-E	KELL-12	2.83 ± .17	653 ± 13	3.21 ± .06	3.81 ± .33	869 ± 58	Confirmation of assigment to El Cha-
El Chayal reference		2.66 ± .11	649 ± 13	3.15 ± .06	3.45 ± .26	915 ± 35	yal source
2075-F	KELL-16	2.62 ± .16	461 ± 10	3.08 ± .06	3.24 ± .30	1,095 ± 59	Confirmation of assigment to Ixte-
Ixtepeque reference		2.30 ± .11	449 ± 9	3.05 ± .05	3.61 ± .26	1,030 ± 27	peque source
2075-G	KELL-20	2.38 ± .16	531 ± 10	2.99 ± .06	3.19 ± .30	1,033 ± 62	Confirmation of assigment to Río Pix-
Río Pixcayá reference		2.03 ± .10	521 ± 10	2.94 ± .05	3.54 ± .25	1,105 ± 32	cayá source

[a] Calibrated vs. standard pottery (Perlman and Asaro 1969, 1971). Errors are estimates of the standard deviation.

Earnest 1985:30). It probably exercised political control over, and possibly received tribute from, secondary regional centers such as Santa María and smaller settlements within the basin. Judging from present data, however, one doubts that Cihuatan controlled an economic access to one or another of the obsidian sources of highland Guatemala. Thus we feel justified in pursuing a model of shifting interregional exchange networks resulting from political and economic instability in the region.

The indications of obsidian procurement from multiple sources by the Pipil of central El Salvador are consistent with our concepts of the Postclassic as a period in which fragile sociopolitical alliances were constantly formed and broken, and exchange networks were often disrupted by interethnic hostilities (see Fuentes y Guzmán 1932–1933:pt. 2, bk. 1, ch. 9, p. 56). The diversification of obsidian sources would have been an effective hedge against the fragility of the alliances and exchange networks. At present, however, little is known or understood of the exact nature of such networks and their operation.

The region surrounding the IX source was held primarily by the Pipil at the time of the Conquest (Fowler 1981:479–480, 1983:353–354). It is possible that IX was controlled for some time by the Pipil during the Postclassic, perhaps by a Pipil state centered on Asunción Mita, Guatemala, who traded the obsidian through a complex network involving many or most major Pipil settlements of eastern Guatemala and western and central El Salvador. Postclassic patterns of exchange involving obsidian from CH and SMJ are also open to speculation. Future research should be directed toward understanding the apparently complex obsidian procurement system in which the ancient inhabitants of Cihuatan and Santa María and other Postclassic communities of southeastern Mesoamerica participated.

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REFERENCES CITED

Bruhns, Karen Olsen
1980 *Cihuatan: An Early Postclassic Town of El Salvador.* University of Missouri Monographs in Anthropology, No. 5, Columbia.

Clark, John E.
1979 *A Method for the Analysis of Mesoamerican Lithic Industries: An Application to the Obsidian of La Libertad, Chiapas, Mexico.* Master's thesis, Department of Anthropology, Brigham Young University.
1981a The Early Preclassic Obsidian Industry of Paso de la Amada, Chiapas, Mexico. *Estudios de Cultura Maya* 13:265–284.
1981b Guatemalan Obsidian Sources and Quarries: Additional Notes. *Journal of New World Archaeology* IV(3):1–16.

Clark, John E., and Thomas A. Lee, Jr.
1979 A Behavioral Model for the Obsidian Industry of Chiapa de Corzo. *Estudios de Cultura Maya* 12: 33–51.
1984 Formative Obsidian Exchange and the Emergence of Public Economies in Chiapas, Mexico. In *Trade and Exchange in Early Mesoamerica,* edited by K. G. Hirth, pp. 235–274. University of New Mexico Press, Albuquerque.

Drennan, Robert D.
1984 Long-Distance Movement of Goods in the Mesoamerican Formative and Classic. *American Antiquity* 49:27–43.

Fowler, William R., Jr.
1981 *The Pipil-Nicarao of Central America.* Ph.D. dissertation, Department of Archaeology, University of Calgary.
1983 La Distribución Prehistórica e Histórica de los Pipiles. *Mesoamérica* 6:348–372.

1985 Lithic Analysis as a Means of Processual Inference in Southern Mesoamerica: A Review of Recent Research. In *Maya Stone Tools,* edited by T. R. Hester and H. J. Shafer. University of Utah Press, Salt Lake City, in press.
Fowler, William R., Jr., and Howard H. Earnest, Jr.
1985 Settlement Patterns and Prehistory of the Paraíso Basin of El Salvador. *Journal of Field Archaeology* 12:19–32.
Fowler, William R., Jr., and E. Margarita Solís
1977 El Mapa de Santa María: Un Sitio Postclásico de la Región Cerrón Grande. *Anales del Museo Nacional Nacional "David J. Guzmán"* 50:13–20. San Salvador.
Fuentes y Guzmán, Francisco Antonio de
1932–1933 *Recordación Florida: Discurso Historial y Demostración Natural, Material, Militar, y Política del Reyno de Guatemala.* 3 vols. Biblioteca Goathemala, vols. 6–8. Sociedad de Geografía e Historia, Guatemala.
Graham, John A., and Robert F. Heizer
1968 Notes on the Palpalhuapa Site, Guatemala. *Contributions of the University of California Archaeological Research Facility* 5:101–125.
Hester, Thomas R.
1972 Notes on Large Obsidian Blade Cores and Core-Blade Technology in Mesoamerica. *Contributions of the University of California Archaeological Research Facility* 14:95–105.
Kelley, Jane H.
1985 Cihuatan: A Study in Intrasite Variability. Ms. on file, Department of Archaeology, University of Calgary.
Lubensky, Earl H.
1978 Mound P-12 at Cihuatan, Ms. on file Patrimonio Cultural, Ministerio de Educación, San Salvador, El Salvador.
Michels, Joseph W.
1975 El Chayal, Guatemala: A Chronological and Behavioral Reassessment. *American Antiquity* 40:103–106.
Moholy-Nagy, Hattula, Frank Asaro, and Fred H. Stross
1984 Tikal Obsidian: Sources and Typology. *American Antiquity* 49:104–117.
Perlman, Isadore, and Frank Asaro
1969 Pottery Analysis by Neutron Activation. *Archaeometry* 11:21–52.
1971 Pottery Analysis by Neutron Activation. In *Science and Archaeology,* edited by R. H. Brill, pp. 182–195. MIT Press, Cambridge.
Sheets, Payson D.
1972 A Model of Mesoamerican Obsidian Technology Based on Preclassic Workshop Debris in El Salvador. *Cerámica de Cultura Maya* 8:17–33.
1975a Behavioral Analysis and the Structure of a Prehistoric Industry. *Current Anthropology* 16:369–391.
1975b A Reassessment of the Precolumbian Obsidian Industry of El Chayal, Guatemala. *American Antiquity* 40:98–103.
1978a Artifacts. In *The Prehistory of Chalchuapa, El Salvador,* vol. 2, edited by R. J. Sharer, pp. 1–131. University of Pennsylvania Press, Philadelphia.
1978b From Craftsman to Cog: Quantitative Views of Mesoamerican Lithic Technology. In *Papers on the Economy and Architecture of the Ancient Maya,* edited by R. V. Sidrys, pp. 40–71. University of California, Los Angeles, Institute of Archaeology, Monograph 8.
Sheets, Payson D., and Guy Muto
1972 Pressure Blades and Total Cutting Edge: An Experiment in Lithic Technology. *Science* 175:632–634.
Sidrys, Raymond V.
1976 *Mesoamerica: An Archaeological Analysis of a Low-Energy Civilization.* Ph.D. dissertation, University of California, Los Angeles. University Microfilms, Ann Arbor.
Stross, F. H., J. R. Weaver, G. E. A. Wyld, R. F. Heizer, and J. A. Graham
1968 Analysis of American Obsidians by X-Ray Fluorescence and Neutron Activation Analysis. *Contributions of the University of California Archaeological Research Facility* 5:59–79.
Stross, Fred H., Thomas R. Hester, Robert F. Heizer, and Robert N. Jack
1976 Chemical and Archaeological Studies of Mesoamerican Obsidians. In *Advances in Obsidian Glass Studies: Archaeological and Geochemical Perspectives,* edited by R. E. Taylor, pp. 240–258. Noyes Press, Park Ridge, N.J.
Stross, Fred H., Payson Sheets, Frank Asaro, and Helen V. Michel
1983 Precise Characterization of Guatemalan Obsidian Sources, and Source Determination of Artifacts from Quiriguá. *American Antiquity* 48:323–346.