Reports

The Paredón, Mexico, Obsidian Source and Early Formative Exchange

Abstract. *In 1975, archeological surface surveys of trade routes located again a pre-Hispanic obsidian source in central Mexico first reported in 1902. Initial trace element studies of the Paredón source through an analysis by neutron activation have been compared with similar studies of the obsidian found at Chalcatzingo 150 kilometers from the source. These comparisons indicate that obsidian from Paredón, rather than Otumba, was of primary importance during the Early Formative in central Mexico.*

During surface surveys of trade routes in 1975 between the central Valley of Mexico and the Metztitlán valley to the northeast, a major pre-Hispanic obsidian source was discovered [(*1*); figure 2 in (*2*)]. The source had been briefly reported in 1902 (*3*) but had not subsequently been studied or examined. As a result, none of the obsidian from the Paredón source has been included in recent obsidian analyses dealing with Mesoamerica (*4, 5*). This is due, in part at least, to the difficulties of access to the source area.

The 1975 survey of the source area did not note any structural or ceramic debris. However, the pattern of aceramic sites recorded by the survey, together with site patterns in the Tepeapulco area, suggest a continuous exploitation of Paredón obsidian from the Terminal Formative to Late Postclassic. A hiatus in exploitation occurs only briefly during the Late Classic. New neutron activation data on obsidian artifacts from Chalcatzingo, 150 km to the south, attest to an even earlier importance for Paredón. Although the Otumba source, 50 km southwest of Paredón, is credited in the literature as the major source during the Early Formative in central Mexico, the Chalcatzingo data suggest that Paredón may have been equal to or greater than Otumba in importance.

The purpose of this report is to describe the location and characteristics of the source area, to detail the appearance and trace-element composition of the obsidian, and to indicate the significance of the relocation of the Paredón obsidian source in a consideration of Early Formative trade networks in Mesoamerica.

The Paredón obsidian source area is situated in the northeast corner of the Valley of Mexico approximately 25 km southeast of Tulancingo, Hidalgo [figure 2 in (*2*)]. The obsidian outcrops and workshops are found on the plateau above Lake Tecocomulco to the east at an elevation between 2550 and 2650 m (*6*). Although situated some distance from modern paved highways, the source area is adjacent to the Colonial road running between Tulancingo and Apam (*3*). During survey, two separate areas of obsidian exposure and utilization were noted. The first of these, described by Breton (*3*), consists of a long ridgetop sloping to the north, where it is cut by a barranca, and to the west, where the lake edge is found. The obsidian occurs in the northern and western drainages as small water-rolled cobbles with a heavy cortex. In eroded drainages on the slope, the obsidian can be seen eroding out of a matrix which appears to have been fluvially deposited. The remains of pre-Hispanic exploitation of obsidian in the ridgetop area include shallow and wide pits, approximately 3 to 4 m in diameter and 1 m in depth, undisturbed by recent use and containing debris from core and tool-blank preparation. The exposed obsidian, pits, and quarry workshop debris occur along a linear distance of approximately 2.25 km varying in width from 450 to 650 m. The approximate surface area is 1.2 km^2. Fortunately, neither area at the Paredón source is covered with trees, which tend to obscure observations as noted for such sources as Navajas (*7*).

The second area of exposed obsidian and workshop debris is situated approximately 3 km southeast of the first ridgetop area and is located near the town of Paredón. The obsidian occurs on two small hilltops, which appear to represent extrusions of obsidian. The obsidian is in large pieces, some ranging as much as 20 cm to a side in unworked form. No quarry pits are noticeable, but the hilltops and sides are covered with core and blank-preparation debris. This second area runs parallel to the first ridgetop and is approximately the same width. The total length was not determined but does extend at least 1.25 km to the west. The total survey surface area is 0.5 km^2.

The obsidian from the Paredón source is gray in color, varying from transparent to translucent with banding (*8*). Neither opaque gray nor black occur in the sample examined. One piece of obsidian was a banded blue-gray color. In addition, a "meca" variety of this obsidian occurs with a color varying from yellow to brown to brown-red within a gray matrix as regular banding or irregular inclusions (*9*). Nearly all the larger pieces collected exhibit white crystalline inclusions, which are characteristic of the Paredón obsidian and which serve to differentiate it from Otumba gray obsidian (*10*). The texture of the obsidian is quite fine and is probably as suitable a fracture plane as the Navajas source material for the manufacture of prismatic blades, if the inclusions could be avoided in the choice of material for core preparation. Even those pieces which on visual examination were judged to be translucent have a fine texture. Their degree of translucency may be attributed in part to their size and thickness and not to variability in structure.

A surface collection of 245 specimens from one workshop area on the edge of a shallow quarry pit was taken from the ridgetop source area. Most of the collection consisted of production *débitage* composed of waste flakes and modified large obsidian fragments (66.9 percent). In addition 27 percent of the sample consisted of large unworked obsidian fragments with most of the hydrated cortex remaining. Those blades (4.1 percent) which occurred were the large crude percussion flaked variety described by Sheets (*11*) as representing the second stage of core preparation. Although no fine prismatic blades were noted, two exhausted cores were found (0.8 percent). The large blades may have been used as knives or as preforms for other tools. Four scrapers and two gravers were found (2 percent). The ratio of production debris to tools at the Paredón source

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(14.5:1) is much higher than the ratios at the Pizzarín source (2.6:1) and at the Otumba source (4.1:1). This may be related to the greater amount of finishing carried out at those two sources, which are closer to settled communities, and the reduced amount of finishing carried out at the Paredón source located somewhat farther from permanent occupations.

Excavations at the Formative period site of Chalcatzingo (*12*) yielded thousands of obsidian blades and chips as well as obsidian workshop debris. Ninety samples were brought to the University of Illinois for neutron activation analysis (*13*). Samples include a select sample covering a wide range of excavated areas of the site, plus a 25-piece random sample taken from the debris of one obsidian workshop. In addition, 28 samples from 17 central Mexican obsidian sources, including four samples from Paredón, were processed for comparative data (*14*).

Table 1. Differentiation of Otumba and Paredón obsidian. All figures except for Na (which is given as a percentage) are parts per million. Ranges are general.

Element	Otumba	Paredón
Mn	360–380	350–370
Na	2.94–3.16	2.92–3.16
Rb	114–133	130–160
Sr	100–125	90–150
Zr	56–105	70–120
As	3–6	8–13
Ba	700–900	<180
Ln	23–30	51–64

Each sample was first ground to a uniform powder. Approximately 75 mg of the sample were weighed into a clean polyethylene bag, and the bag was heat-sealed. A multielemental comparator standard was prepared by weighing approximately 75 mg of National Bureau of Standards standard reference material 1633, "Trace Elements in Coal Fly Ash," whose composition has been well characterized (*15*), and sealing the bag. Ten samples and a standard were sealed into a larger clean bag, and the collection of samples and standard were irradiated for 1 hour at a flux of 3×10^{12} neutron/cm^2·sec in the Illinois Advanced TRIGA Reactor Facility.

The samples and standard were counted for 900 seconds each within 4 hours at the end of the irradiation with a 10 percent efficient Ge(Li) gamma-ray detector having a resolution (full width at half maximum) of 2.10 keV at 1.33 keV. The data were stored in a 4096 channel analyzer and were recorded on computer magnetic tape for processing. The gamma-ray spectral data are reduced to elemental concentrations with their associated uncertainties in a single job by using the program described by Maney, Fasching, and Hopke (*16*).

The samples and standard were recounted for 4000 seconds each after a decay time of at least 24 hours. The samples and standard were then reirradiated for 8 hours at a flux of 4×10^{12} neutron/cm^2·sec. After a decay period of 10 to 14 days, the samples were counted for 5000 seconds. The data from each count were treated as previously described. From this series of irradiations and counts, the concentrations of 30 elements were determined for each of the samples.

Computer programs for cluster analysis using four different dissimilarity matrices (*17*), seven possible clustering criteria (*18*), and 27 chemical elements determined by neutron activation were run on the total of 90 excavated samples and 11 source samples. These data were then compared with additional runs with only eight, then four, elements. In each instance we visually cross-checked the computer-derived clusters against our previous work and against our own observations of patterns. The results of all of the programs were surprisingly close and consistent. They all served to separate clearly the Paredón obsidian source samples from the other source samples and to identify Paredón obsidian as present in significant quantities at Chalcatzingo.

A dendrograph of the cluster pattern using the squared Euclidean distance measure and mean-within-cluster variance clustering criterion and retaining only the Ba, La, As, and Mn concentration data is shown in Fig. 1. As a test of the analysis and clustering procedure to distinguish among different source mate-

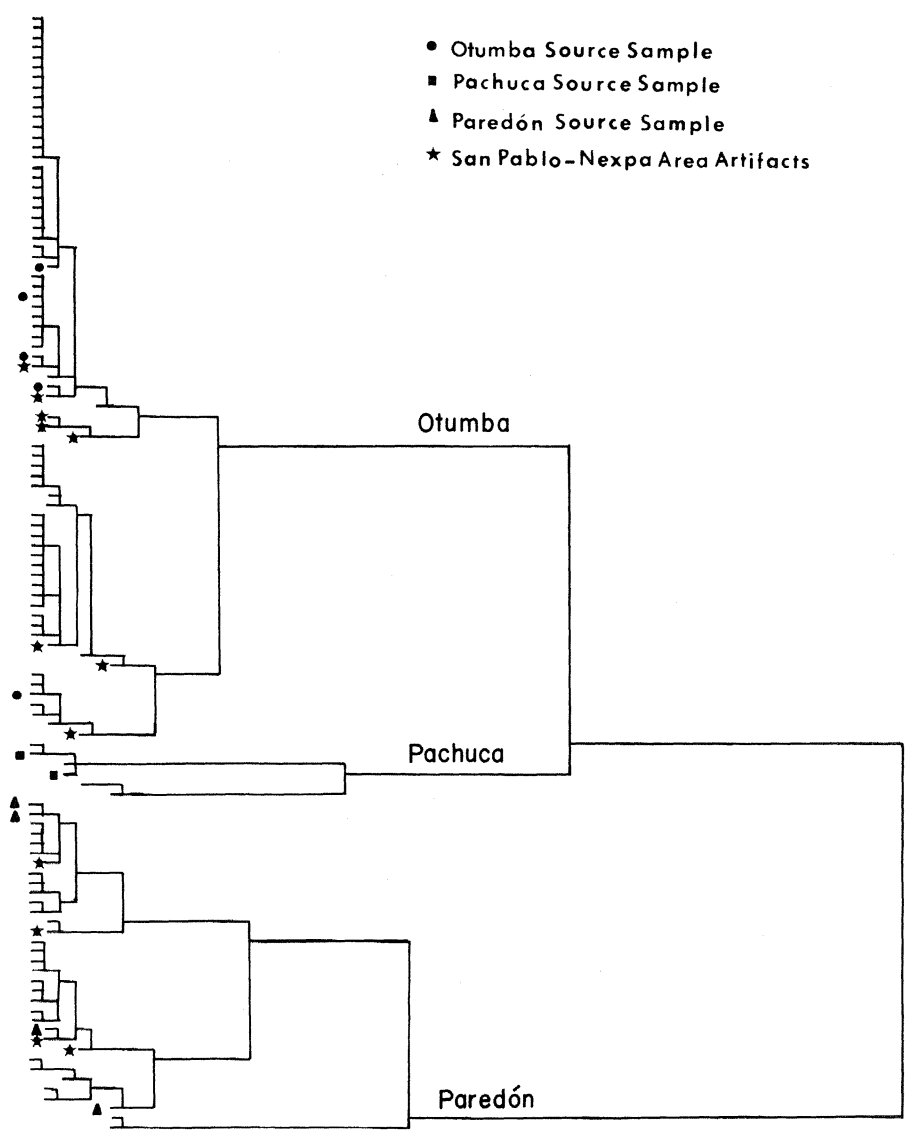

Fig. 1. Dendrograph of the cluster pattern for the Chalcatzingo obsidian artifacts and the source samples. Each line on the left side of the diagram represents an analyzed specimen. Unmarked specimens are artifacts found at Chalcatzingo.

rials, several samples of green obsidian from the Pachuca source were submitted along with the other samples. The analyst was unaware of the clearly different nature of these samples. These samples have been clearly separated from the other two source materials (Fig. 1).

Most published analyses of Mesoamerican obsidian have until now used only a limited number of chemical elements in the characterization. Most have relied on two, three, or four (*4, 5*). Those elements most frequently tested are Fe, Mn, Na, Rb, Sr, Zr, and Y. On the basis of such analyses, the Otumba obsidian source in the Teotihuacán valley has been identified in recent literature as a major obsidian source during the Early Formative (*5*). We cannot now disagree or agree with the effectiveness of using a limited number of elements, for such an approach may be valid for many sources. However, the Paredón obsidian source cannot be differentiated from Otumba obsidian with the elements most commonly used; at least Ba, As, and Ln are also necessary (Table 1).

Of the 90 obsidian samples analyzed from Chalcatzingo, 10 percent (nine samples) were from Early Formative levels. Without a larger number of elements in this characterization, these would have been identified as Otumba; eight of the nine are actually from Paredón. How closely this high percentage of Paredón obsidian in Chalcatzingo Early Formative levels corresponds to sampling versus reality is a matter for future testing. Twelve nonrandom samples from sites of the same time period in central Morelos (*19*) have recently tested out 33 percent Paredón, 67 percent Otumba (Fig. 1). The larger Middle Formative sample from Chalcatzingo indicates a 32 percent Paredón and 68 percent Otumba exploitation pattern. Nevertheless, it is clear that Paredón is an important obsidian source that has gone unrecognized in previous analyses. Its identification indicates that hypothesized Early Formative obsidian networks will have to be reanalyzed. References in the literature to Otumba obsidian (also termed "Teotihuacán valley" and "Barranca de los Estetes") should be read as Otumba/Paredón until further studies have been carried out.

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"To the south of Tulancingo, about four and a half hours' ride on the road to Apam, and beyond the Rancho of Lagunita, there is a ridge of obsidian, which has been worked, partly at so remote a period that a thick lichen has had time to grow on some of the chips in that extremely dry climate.
"There are some small shady caves in the side of a low hill near, to which the workers brought their roughly shaped pieces to finish, and the fragments are strewn down the slope. There are all sorts of bits, broken and half-finished implements, in fact everything except those many-sided objects which hitherto have been called cores, but which are conspicuous by their absence from all the workings I have seen, except one, . . ."
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20. The trade route surveys and laboratory analyses were made possible by a National Endowment for the Humanities research grant RO-21447-75-138 to the Univerisity of Iowa with T.H.C. as principal investigator. The findings and views presented here do not necessarily represent the views of the Endowment. The University of Iowa provided T.H.C. with a research assignment in 1975. Professor Eduardo Matos Moctezuma of the Instituto Nacional de Antropología e Historia in Mexico City encouraged the fieldwork and was helpful in obtaining the necessary permits (Concesión on Arqueología No. 4/75). C. L. Charlton carried out the detailed studies of the Paredón quarry tools and *débitage*. The Chalcatzingo project, under the direction of D.C.G., was supported by NSF grant GS-31017 with supplementary funds provided by the National Geographic Society. The obsidian characterization was assisted by a grant from Landon T. Clay. P.K.H. thanks L. Tills, S. Gribben, and B. Roscoe for assistance in performing the elemental analyses and the operating staff of the Illinois Advanced TRIGA Reactor for assistance with the sample irradiations.

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Amorphous Ice on Saturnian Rings and on Icy Satellites: Its Formation, Stability, and Observability

Abstract. *Saturnian rings and icy satellites may be covered with amorphous rather than crystalline ice. Its likely source is water molecules sputtered by particles in the radiation belts, it may be stable, and its presence could be deduced from the rate of temperature drop in a shadow. Observation of this effect is, however, difficult, especially for the rings. A possible relation to the brightness anisotropy of ring A is pointed out.*

Recently, detailed studies of the structure and of some of the properties of amorphous ice have been made (*1*). The fact that this ice is formed during slow deposition of H_2O vapor at temperatures below about 150°K makes its properties of great interest for certain astrophysical problems (*1a*). In particular, the rings of Saturn and icy satellites are very likely covered with amorphous ice, and this could be verified by observations from spacecraft.

The existence of amorphous ice on the rings of Saturn and on icy satellites depends on the temperature at which the ice was or is being formed and on its stability. Pollack *et al.* (*2*) have discussed the formation and the probable thermal history of the satellites and the rings of Saturn, which condensed, starting with the outermost ring, at the end of the satellite formation period, close to the time when most of the gas in the nebula was being dissipated. There may have been a period of 2 to 6 × 10^7 years, depending on the opacity, when the temperature of the deposits remained above 150°K, and thus they would be crystalline. In any case, molecules condensing later at lower temperatures would form amorphous grains and would cover the earlier ones with an amorphous coating. Lewis (*3*) analyzed the condensation rate of various molecules of the solar nebula when this process is slow (equilibrium) and when it is fast (disequilibrium). For

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