# CLASSIC MAYA OBSIDIAN TRADE

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*The obsidian artifact distribution in some 13,000 m$^3$ of excavated fill from 17 Maya sites is analyzed. Large regional centers, characterized by abundant monumental art and architecture, have five times more obsidian per capita than do smaller centers. Central place redistribution, rather than central place market exchange (Rathje 1971), appears to be the best organizational mode for this long-distance trade. That is, obsidian in the Late Preclassic-Early Classic was a status good reflecting religious and political behavior. Its everyday use was largely restricted to elite households. By the Late Classic increases in transport efficiency may have permitted a more widespread usage of obsidian.*

ARCHAEOLOGISTS show increasing interest in the catalytic role of long-distance trade in cultural evolution (cf. Sabloff and Lamberg-Karlovsky 1975; Earle and Ericson n.d.). Lowland Classic Maya culture (A.D. 250-900) in eastern Mesoamerica provides a suitable historical theater for considering this problem, in light of suggestions that both the civilization's rise (Rathje 1971, 1972) and demise (Webb 1964) were interrelated with developments in its long-distance exchange system. This study analyzes the distribution of imported obsidian artifacts, in terms of the artifact mass and distance to source, within 13,000 m$^3$ of excavated fill from 17 Maya sites. It is found that in the Maya lowlands obsidian trade is related to Maya central places. The second phase of the study presents an organizational model for the obsidian exchange system. Despite its seeming abundance at lowland sites, obsidian appears to have served primarily as a high-status good associated with religious and political behavior. Everyday utilitarian use of the commodity would have been restricted to a fraction of the total population.

An organizational reconstruction of Maya long-distance exchange contributes useful information for the ongoing debate as to whether Classic Maya social institutions show a closer evolutionary fit to an "advanced chiefdom" or a "primitive state" (Sanders and Price 1968; Willey 1972b). While the large Maya civic-ceremonial centers are traditionally regarded as the commercial nuclei of Maya culture (Willey and others 1965:13; Thompson 1970:66; Coe 1962), this has not been demonstrated empirically. Economic functions for the centers, however, are suggested by: (1) the presence of long distance imports (Tourtellot and Sabloff 1972:129); (2) ethnographic analogy from Zinacantan (Vogt 1961); (3) the presence of large public plazas (Hammond 1972:87); and (4) central place studies (Marcus 1973; Hammond 1974). Accordingly, the first research phase of this paper will establish an empirical relationship between the import of obsidian and the Maya civic-ceremonial centers. Admittedly one commodity is not representative of the entire diversified exchange system. On the other hand, most Mayanists concede that obsidian was the only non-perishable good that was imported from long distances ($>$ 100 km) in sufficient quantity to warrant this consideration as an everyday utilitarian item.

## MEASURES OF TRADE

Early studies of Classic Maya long-distance trade were, for the most part, lists of items held to be exotic to the sedimentary lowlands or inferences from Postclassic ethnographic data (Blom 1932; Kidder 1947; Thompson 1964, 1970). Later studies took a more quantitative orientation (Webb 1964; Rathje 1971; Tourtellot and Sabloff 1972; Parsons and Price 1971) but data presentation and analysis remained largely qualitative. Problems in methodology also existed. For example, Tourtellot and Sabloff's use of numerical counts rather than mass in their Table 1 (1972:129) causes 38 pearls to be equally weighted with 38 metates. While they do note that mass is relevant to transportation costs, this factor is ignored in their conclusions. A second biasing factor (which they also acknowledge) is their neglect of total excavation volume in making inter-site comparisons. In consequence, Altar de Sacrificios is shown to have the most obsidian, whereas in fact it has much less than most other lowland sites, frequently by an order of about 10:1 (cf. Willey 1972a:208; see also Tables 1 and 2 in this paper).

Clearly the quantitative measure of an artifact's frequency at a site is a critical factor in trade analyses. Frequency may be measured in the following terms: (1) artifact number or artifact mass per unit of excavated volume, (2) a ratio between materials in a single artifact category, and (3) a ratio between artifact categories. These three measures have been applied, respectively, to obsidian in the Near East (Wright 1972); obsidian to chert blades in the Maya area (Urban n.d.); and obsidian blades to sherds at individual Maya sites (Thompson 1948; Parsons 1969:80). Density measures are preferable because they estimate the quantity of mass consumed by a given population. Mass is also preferable to number as the Mesoamerican transport system relied on human manuport. Consequently, mass estimates allow calculations on the number of transport personnel.

Accordingly, the obsidian density (OD) measure is used in this study. It is calculated by the grams of obsidian per cubic meter of excavation fill. The OD index serves as a measure of obsidian per capita at each site. By this I mean an increase in OD represents a true increase in obsidian deposition between comparable residence unit populations (relative obsidian per capita) rather than simply registering the additional deposition of a higher population density. For example, if Site A had a population twice the size of Site B, but both sites had the same OD, then individuals at both sites would have owned comparable amounts of obsidian. The per capita assumption is permissible since the density of residence units is fairly constant between Maya population centers; although Mayapan, and perhaps Tulum are exceptions (Willey 1972b:13). A similar problem is that some of the fill at Zaculeu, Tajumulco, El Baul, Bilbao, and Altar (as picked for the study) comes from large plazas or pyramids that represent public fill deposits, and consequently may bias the total site sample.

The representativeness of the OD estimates must always be carefully considered. For Maya residential structures, artifacts are recovered from "secondary" contexts (cf. Schiffer 1972:159) as it was a common practice to use refuse as fill for house platform (Haviland 1963:76; Willey and others 1965:454). Since the small size of obsidian artifacts insures that they were not deposited as special fill, the samples may be considered representative of normal household midden. Admittedly few of the site samples are representative from the standpoint of strict probability sampling and future OD estimates will likely be somewhat different. A more extensive discussion of specific sampling problems for the Maya area is in Sidrys 1973:20-27. For the OD estimates, all special purpose deposits like caches or burials were excluded.

The obsidian data were obtained primarily from published site reports, including personal clarifications from several of the excavators. Archaeological recovery techniques varied between excavations, but two-thirds of the reports mentioned that special efforts had been made to recover all of the obsidian. Following the determination of the excavation volumes from plans and profiles, the mass of obsidian was estimated in the following manner. The average dimensions of a "fragmentary prismatic flake-blade" (using data from Barton Ramie, San Jose, Zacualpa, Uaxactun, and Yaxha), were found to be: thickness–.3 cm; width–1.1 cm; length–3.1 cm. The mass of this "average" fragment was estimated as a 2 gm standard for converting counts of prismatic blade fragments to an obsidian mass. Similarly cores were estimated to be 25 gm; knife blades at 9 gm; and "waste" flakes at 2 gm. Complete statistical data and methodology for this study is reported elsewhere (Sidrys 1973b:113-41).

The dating of artifacts is greatly complicated by their redeposited context. Refuse piles probably had a high reuse rate in view of incessant Maya constructional activity (Coe 1965) and it may be that redeposited refuse generally was not much older than the construction date of the building, especially for small structures (Willey 1972a:2). At present, however, there is insufficient data to derive an OD for each ceramic phase at any given site. Most of the data in the OD study overlaps throughout the Classic period. The Postclassic sites of Tulum, Mayapan, and Zaculeu had to be included in order to balance the geographic sampling. By excluding time as a factor the general data patterns are somewhat dependent on the assumption that relative site hierarchy was fairly stable through the Classic. The impressive size of the Great Plaza-North Terrace of Tikal from 100 B.C. to A.D. 700 offers support for such an assumption (Coe 1962:504). On the other hand, Marcus (1973) has pointed out that a few regional capitals waned in power during the Classic. The time factor appears to be a problem that can be resolved only by future data collections.

## SOURCE DISTANCE

The present study uses the linear distance from each site to the nearest obsidian source area as the source distance for the final statistical tests. The sources used for the study were the 11 potential sources (cf. Sidrys, Andresen, and Marcucci 1976) that were most likely to have been exploited regularly by the Classic Maya (Fig. 1). The numerous but more distant sources (around 1000 km) in the Central Mexican Highlands are excluded since this obsidian is only occasionally found in the Maya area. For example 1.6% of the obsidian recovered at Tikal (to 1967) is of the green variety probably from Pachuca, Hidalgo (Moholy-Nagy 1974). This report does not incorporate any source assignations based on trace-elemental research. The present state of the art in Mesoamerican "sourcing" research is still uncertain (Stross and others n.d.). The few Maya sites that have been sourced, such as Tikal (Moholy-Nagy 1974), Yaxha (Sidrys and Kimberlin n.d.), and Seibal (Graham and others 1972) tentatively indicate multiple-source exploitation at each site.

The largest known quarries are in the El Chayal region (Coe and Flannery 1964) and on Ixtepeque volcano (Graham and Heizer 1968). Debitage from these quarries as well as at Pachuca, Hidalgo (Spence and Parsons 1967:542) shows that for the most part only rough polyhedral cores were fashioned at the quarries. It is likely that these rough cores were directly transported to lowland sites (Hester 1972:98), despite proposals for the transport of finished prismatic blades (Coe and Flannery 1964:48; Rovner 1973). Cortex remains at lowland sites indicate that the rough cores were further refined at the site, with subsequent pressure removal of the prismatic blades.

## FALL-OFF MODEL

Because of transportation cost the abundance of any commodity falls off with increasing distance from source. Generally this decrease is exponential as shown by modern freight movements (Haggett 1969:34) or in the distribution of Near Eastern obsidian during the Neolithic (Renfrew and others 1968:328). It can be seen that the obsidian data in Table 1 does show a general fall-off as the average OD for the seven highland sites that are close to obsidian sources is four times as large as the average OD for the eleven lowland sites. But regression analysis of the OD (log log) and distance data for the 17 sites showed a low Pearson's r correlation coefficient ($r = -.48$). Clearly this fall-off model does not provide the best "fit" for the data.

Upon reexamination this result was not surprising in view of the different economic functions of the 17 sites that range from undifferentiated agricultural hamlets to nucleated centers. This differentiation suggested a stratification within the data set. Thus, when the major centers were distinguished from the other sites, two discrete but parallel patterns emerge (Fig. 2). Within each group there is a significant negative correlation between source distance and OD (respective Pearson's r is −.79 and −.93). The group of major centers (Line 1 in Fig. 2) includes large sites described as political "capitals" (Tikal, Copan, Bilbao, Kaminaljuyu, Mayapan) or trade ports (Tulum and Cozumel). The other group (Line 2 in Fig. 2) is composed primarily of villages and less important centers (Seibal and perhaps Altar are exceptions).

The major centers have nucleated civic-ceremonial areas (wall-boundaries, acropoli, group-complexes) that average 7.3 times larger than their minor center counterparts, and average 4.5 times as many public monuments (Table 2). In summary the data indicate that major centers were able to import about five times more obsidian per capita than the smaller centers (which had a much smaller average source distance: 205 km versus 386 km). The large lowland civic-ceremonial centers, as suspected, were strongly associated with Classic period obsidian import.

Independent archaeological data such as population estimates verify that the 5:1 average OD

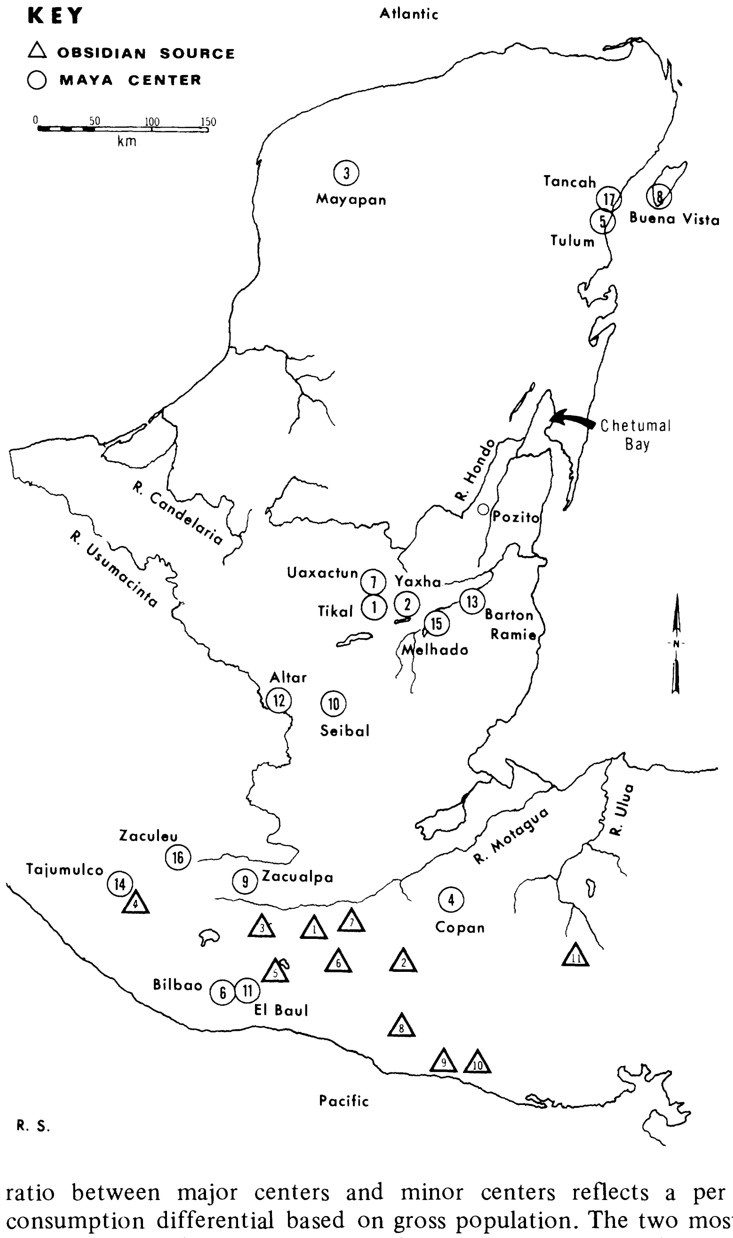


Fig. 1. Maya centers and obsidian sources. Numbers of centers represent Trade Index rank (see Table 2). Numbered obsidian sources: (1) El Chayal; (2) Ixtepeque; (3) San Martin Jilotepeque; (4) Tajumulco; (5) Amatitlan; (6) Media Cuesta; (7) Jalapa; (8) Santa Ana, El Salvador; (9) Zaragoza, El Salvador; (10) Rio Comalapa, El Salvador; (11) La Esperanza, Honduras.

ratio between major centers and minor centers reflects a per capita difference, and not a consumption differential based on gross population. The two most reliable population estimates are for Tikal (Haviland 1972:139) and Barton Ramie (Willey and others 1965:576). The population ratio between them is about 20:1. The ratio of obsidian per capita between the two is about 50:1. Accordingly one would expect Tikal to have a 1000:1 advantage in total obsidian mass. Projected total obsidian mass estimates that are discussed later support the ratio (see Table 3). The Uaxactun:Barton Ramie population ratio is about 4:1 (Adams 1974). Their OD ratio is about 8:1 so one can expect a 32:1 ratio in total obsidian mass between the two sites. Using Table 3, the projected total obsidian mass ratio is on the order of 100:1, which again supports the OD as a per capita measure. Admittedly these numbers and ratios are imprecise; however, as rough indicators they do clearly verify the predicted differences in obsidian per capita between two major centers and one minor center. In both cases the projected total obsidian mass ratios exceed the obsidian mass ratio expected from the population differential.

Table 1. Obsidian Densities and Excavation Data.

| Site[1] | Excavation Volume Used in Study ($m^3$) | Obsidian Mass (g) found in Excav. Vol. | Obsidian Density ($g/m^3$) | Source Distance (km) | Nearest Potential Source[2] |
|---|---|---|---|---|---|
| Altar | 6790 | 3500 | .5 | 195 | San Martin Jilotepeque |
| Barton Ramie | 2213 | 700 | .3 | 315 | El Chayal |
| Zacualpa | 681 | 6116 | 9.0 | 30 | San Martin Jilotepeque |
| Zaculeu | 600 | 565 | .9 | 55 | Tajumulco Volcano |
| Tikal | 544 | 8297 | 15.3 | 285 | El Chayal |
| Tajumulco | 466 | 2143 | 4.9 | 15 | Tajumulco Volcano |
| Cozumel (B. Vista) | 275 | 140 | .5 | 710 | El Chayal |
| Uaxactun | 213 | 481 | 2.3 | 305 | El Chayal |
| Seibal | 197 | 220 | 1.1 | 196 | San Martin Jilotepeque |
| Tancah | 165 | 10 | 0.6 | 682 | Ixtepeque |
| Mayapan | 159 | 583 | 3.7 | 690 | El Chayal |
| Tulum | 150 | 212 | 1.4 | 680 | Ixtepeque |
| El Baul | 79 | 263 | 3.3 | 50 | Amatitlan |
| Bilbao | 67 | 1160 | 17.3 | 53 | Amatitlan |
| Copan | 38 | 1046 | 27.5 | 87 | Ixtepeque |
| Yaxha | 19 | 246 | 12.8 | 280 | El Chayal |
| Melhado | 16 | 3 | .2 | 305 | El Chayal |

[1]Site Obsidian Densities are listed in order of reliability, i.e., according to the size of the excavation volume examined.

[2]The La Esperanza Source may be slightly closer than Ixtepeque for Cozumel, Tulum, and Tancah.

## TRADE INDEX MODEL

A problem in the preceding analysis was that within small data sets a few regional centers could "mask" the normal fall-off pattern in a statistical analysis. The recognition of these major centers, without additonal data, is problematic. Accordingly a Trade Index (TI) was devised that allows the comparison of a small sample of economically dissimilar sites that are at varying distances from the source.

The TI simply weights the OD by the source distance (TI = OD×SD). It is a single measure that couples the relative import mass at a site with the distance that it had to be carried. As such it is a measure of energy expenditure in long distance trade. The TI is analogous to the work equation of classical physics: Work= Force × Distance. That is, the gravitational constant makes Force directly proportional to (obsidian) mass, which is represented in the TI as OD. Weber (see Haggett 1969:142) devised a similar economic index in 1909 to explain the problem of "eccentric" locations of specialized industrial centers. In his analysis the distance a commodity was transported was multiplied by the commodity mass to produce *ton-mile* units.

The TI was calculated for the 17 sites and a rank order was produced (Table 2). The eight major centers have the highest TI, which confirms the earlier finding. As a generalized index of exchange,

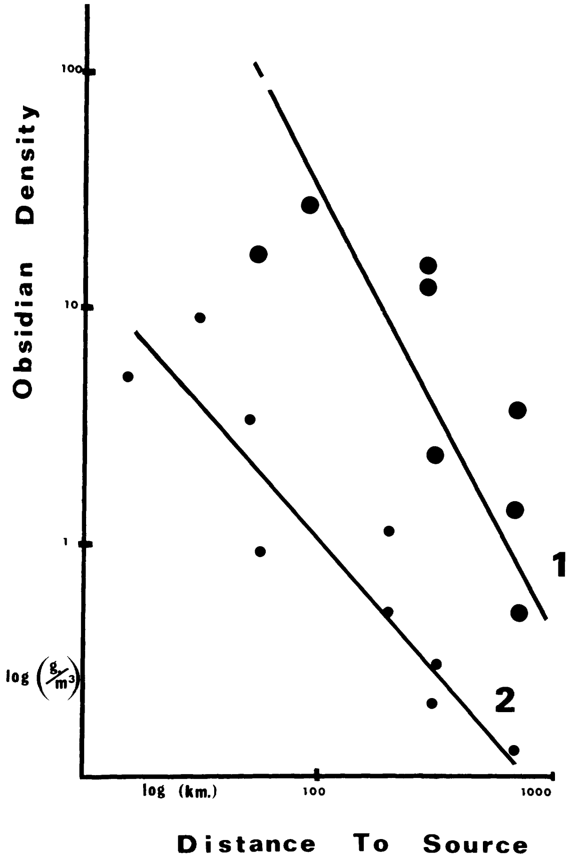


Fig. 2. Fall-off of obsidian density (grams of obsidian/$m^3$ of excavated fill) with increasing distance from source. Line 1 is the estimated least square regression line for the major centers, while line 2 is the regression line for the minor centers. The average OD of the major centers is five times higher than that of the minor centers.

the TI was also used to study other variables of exchange. For example the regression of the log log of TI with the size of the civic-ceremonial area of each site has a correlation of Pearson's $r = 0.70$. Although the explained variability ($r^2$) is not great, at least this analysis is suggestive. Non-parametric statistical analysis showed similar results (Spearman's $r_s = .75$; Kendall's $\tau = .58$). These results tend to support the relationships discussed in the fall-off model. An increase in attributes of "ceremonialism" at a site (which may be equated to some degree to the administrative accoutrements of a managerial group) is apparently related to an increase in trade activity for obsidian per capita. The application of the TI to obsidian exchange in western Mesoamerica is suggested as a further test of its usefulness.

## ORGANIZATION OF THE EXCHANGE SYSTEM

The previous analyses demonstrated that lowland major centers had significantly more obsidian per capita than did minor centers. The organizational correlate to this empirical finding is open to debate. At the outset, two organizational modes appear to "fit" the empirical data well: central place markets and central place redistribution centers. These approximate, but are not equivalent to, modes 6 and 5 in Renfrew's analysis of the spatial correlates of ten organizational trade modes (1975, Fig. 10). Both modes are examined and, on balance, the redistribution center is the best model for Classic period trade.

In the first mode the major center functions as a central place (obsidian) market where specialized merchants provide the low status commodity for everyday use to the majority of the center's population, as well as to the surrounding hamlets (see Fig. 3). This mode is similar to the

Table 2. Trade Index Ranks and Ceremonial Attributes.

| Site | | Trade Index (Obsidian Density x Source Distance) | Civic Ceremonial Area ($km^2$) | Non-Transportable Monuments |
|---|---|---|---|---|
| MAJOR CENTERS | 1) Tikal | 4361 | 4.0 | 206 |
| | 2) Yaxha | 3584 | .6 | 62 |
| | 3) Mayapan | 2553 | 4.0 | 38 |
| | 4) Copan | 2393 | .18 | 82 |
| | 5) Tulum | 952 | .12 | 9 |
| | 6) Bilbao | 917 | .10 | 77 |
| | 7) Uaxactun | 702 | 1.4 | 69 |
| | 8) Cozumel (B. Vista) | 355 | .08 | 1 |
| | MEANS | 1977 | 1.3 | 68 |
| MINOR CENTERS | 1) Zacualpa | 270 | .24 | 2 |
| | 2) Seibal | 216 | 1.1 | 30 |
| | 3) El Baul | 165 | .04 | 30 |
| | 4) Altar | 98 | .08 | 47 |
| | 5) Barton Ramie | 95 | .005 | 0 |
| | 6) Tajumulco | 74 | .006 | 27 |
| | 7) Melhado | 62 | .0004 | 0 |
| | 8) Zaculeu | 50 | .04 | 1 |
| | 9) Tancah | 41 | .13 | 0 |
| | MEANS | 119 | .18 | 15 |

Table 3. Obsidian Mass Estimates for Lowland Maya Sites.

| Site | No. of Structures[1] Major[2] : Minor[3] | Total Structural Volume[4] ($m^3$) | *Obsidian Mass (kg)* Lower Estimate[5] | *Obsidian Mass (kg)* Upper Estimate[6] |
|---|---|---|---|---|
| Barton Ramie | 3:260 | 31,000 | 9.3 | 47 |
| Altar | 40:40 | 242,000 | 121 | 600 |
| Tulum | 20:50 | 122,500 | 172 | 860 |
| Uaxactun | 70:1000 | 470,000 | 1,081 | 5,400 |
| Mayapan | 40:4000 | 440,000 | 1,628 | 8,140 |
| Yaxha | 60:600 | 420,000 | 5,376 | 26,880 |
| Tikal | 200:3000 | 1,350,000 | 20,700 | 103,300 |

[1]The structure count is sometimes estimated from site maps.

[2]A Major structure is considered to be 6000 $m^3$, roughly the size of the average Uaxactun ceremonial mound (Ricketson & Ricketson 1937:20).

[3]A Minor structure is taken as 50 $m^3$, roughly the average house mound volume in Tikal Operation 23 (Haviland 1963:303-306).

[4]The total structural volume neglects the large volume incorporated in causeways and plazas. However, artifacts are infrequent in such monumental structural fill.

[5]Lower Estimate is derived from the Site Obsidian Density given in Fig. 2, multiplied against the total structural volume (TSV). Because most of the TSV comes from Major structures which contain fewer artifacts than smaller structures, the author feels that even the Lower Estimate is actually too high.

[6]Upper Estimate is the Lower Estimate multiplied by a factor of five (see p. 458). It serves as an upper limit, taking into account cache and burial loss, natural breakage attrition, insufficient structural volume estimates, incomplete archeological recovery, and a safety margin.

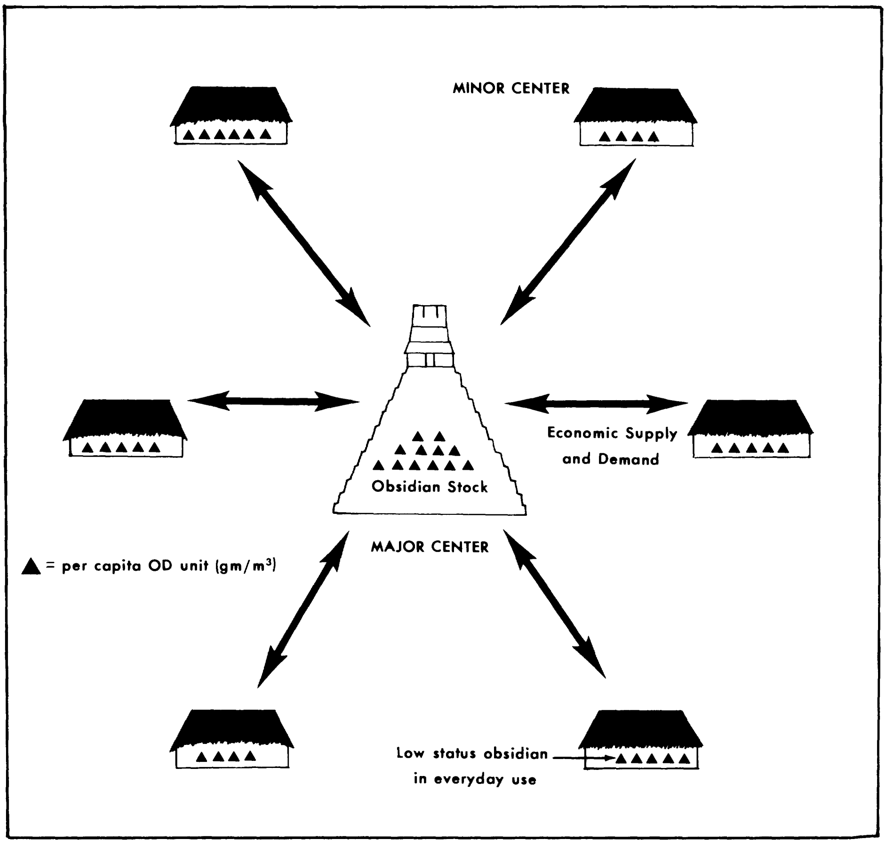


Fig. 3. Major center as a central place market that provides obsidian for everyday household use. Note per capita OD units in major center are about equal to those in the minor centers.

one proposed by William Rathje, which has gained wide acceptance (cf. Moholy-Nagy 1974; Culbert 1974:22-23). The second mode, on the other hand, proposes that major centers are redistribution places where goods are pooled and reallocated by a ruling elite (Fig. 4). In this mode, however, little obsidian would actually be reallocated to the lower classes. Its use, rather, is largely restricted to the elite for the reinforcement of their political status and the concomitant tribute collection.

The two models should not be considered completely polarized. Imported obsidian probably did serve everyday technoeconomic functions such as surgery or fish-cleaning in some regions (Kidder 1948:160; Rathje 1972:389). However to assign functional values to artifacts, for example functional-useful (Tourtellot and Sabloff 1972:129), productive-nonproductive (Renfrew 1975:45), or utilitarian-luxury (Rathje 1971), unavoidably creates ambiguity. Clearly a commodity may possess high value and/or high status and still retain a useful utilitarian function. Luxury cars or diamond watches in modern western society are examples. Analogously, imported obsidian blades may have served some useful tasks and still have been restricted commodities.

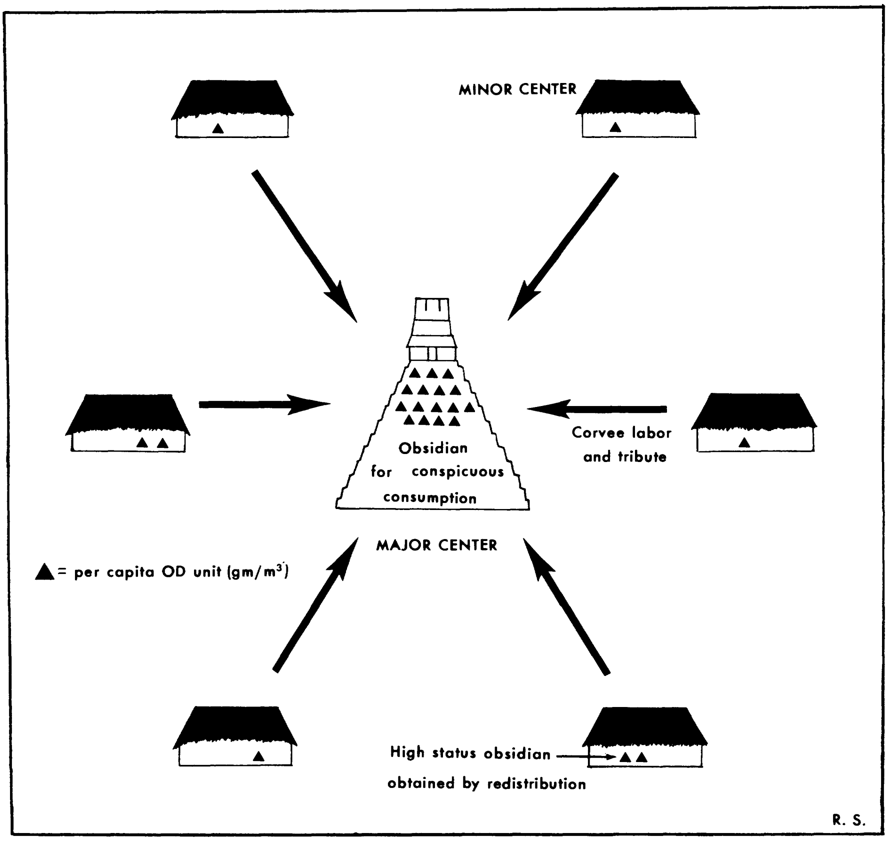


Fig. 4. Major center as a central place redistribution node. While major center receives tribute and labor, few luxury goods are actually reallocated to outlying minor centers or villages. Rather, these items, including obsidian, are part of political and religious regalia within the major center. Accordingly the major center shows far more OD units.

The following section presents six lines of evidence showing that, in general, obsidian was a high status commodity not in everyday use but one that figured prominently in ritualistic behavior. This evidence contradicts Rathje's market exchange obsidian model and concomitantly weakens his trade-oriented hypothesis for the origin of Maya civilization.

## OBSIDIAN IMPORT AS CONSPICUOUS CONSUMPTION

(1) Differential concentrations of obsidian would be expected between a major center and the surrounding villages if obsidian were a high status good not in everyday use. This situation is schematized in Fig. 4, where the little obsidian that exists in the villages has filtered down as gratuities in the redistribution system. Numerous depictions on Maya polychrome vases of tribute being received by seated rulers do suggest a stratified system with substantial corvee labor and tribute being exacted from the sustaining population.

Alternatively, if obsidian were a commonplace item in everyday use, little variance would be expected in the obsidian per capita between the major center and surrounding villages. As shown in Fig. 3, major center merchants would provide a steady flow of obsidian to surrounding villages on the basis of economic supply and demand. A few differential obsidian concentrations might exist because of stock storage areas or specialized workshops.

A simple comparison of a major center's OD to the OD's of the surrounding villages would serve as an excellent deductive test of the problem outlined above. Regrettably, no excavation data of this sort exists in the Maya lowlands. The obsidian per capita differential between major and minor centers that was found earlier in the study is suggestive, however, of the redistribution center schematized in Fig. 4.

(2) Similarly a non-random concentration of obsidian within a site would also be expected if it were a status item or an indicator of wealth. In fact, obsidian is differentially concentrated near the residences of wealthy individuals, as well as lavishly used in caches and burials at many sites. This difference is particularly marked at Tikal (Gr. 4F-1, -2 opposed to Operation 24 house mounds). The small amount of obsidian that occurs in the simpler platforms might represent procurement of fill from an elite-area refuse pile, gifts from wealthy friends, or discarded blades used in bloodletting rituals in all social classes.

Several studies that have emphasized the apparent random distribution or widespread abundance of obsidian as evidence of its everyday use (Rathje 1972; Moholy-Nagy 1974) have confused nominality (i.e., presence/absence) with quantity. While it may be true that obsidian is randomly distributed at a site in the nominal sense, it is not randomly distributed in the quantitative sense.

(3) Estimates of the absolute abundance of obsidian at a site are important in determining the extent to which obsidian was used. Unfortunately, because obsidian is commonly present at some sites, many archaeologists have not bothered to record it adequately. In consequence these subjective reports give the impression of an "incredible abundance" (Rathje 1972:389) of imported obsidian.

Artifact abundance, however, must be analyzed in terms of procurability and use-cycle. From this perspective, estimates of total obsidian mass buried in lowland sites suggest that obsidian was not in everyday household use. Because of the small mass of the individual prismatic blade, some 5000-10,000 fragments of such blades at a site may have been procured during a single journey by one person. In addition, the delicate prismatic blade edge had to be used carefully to retain its sharpness even under such slight mechanical stress as face-shaving (Crabtree 1968:450). The exhaustibility and breakability of obsidian artifacts makes the rate of obsidian artifact consumption very high (Michels 1971:267).

The total obsidian mass per site is estimated by calculating the total structural fill volume and then multiplying the OD estimate derived in this study. As noted previously, the archaeological recovery techniques are fairly reliable, so there remain two biasing factors: obsidian loss through (1) cache deposition and (2) irrecoverable natural attrition. The expended core to blade ratio offers a rough compensatory measure, since it has been determined under experimental conditions that a 700 gm "average" core could produce some 200-300 3 cm-long pieces that represent the average Maya prismatic blade fragment (Sheets and Muto 1972:633). From excavation samples in this study, the core to blade recovery ratio at six lowland sites (Altar, Yaxha, Tikal, Uaxactun, Barton Ramie, Mayapan) ranged from 1:29 to 1:186 but averaged at 1:35. Not all the cores were fully used so this estimate will be corrected to 1:50. This suggests that as many as 80% of prismatic blade fragments could be missing from general refuse areas. Although this estimate may be grossly inflated, it will be used in order to insure a generous safety margin. Table 3 presents a range of total obsidian mass per site. The minimum is based on an actual recovery estimate projection, while the maximum represents the actual recovery (and compensates by a factor of five for cache loss, natural breakage, and safety margin). The lower limit is probably a more reliable projection than the upper one (see Footnotes 5 and 6 in Table 3).

Renfrew and others have commented on similar obsidian mass calculations for the Early Neolithic of the Near East: "in the face of such relatively small quantities of material (80-200 kg per site) it is not, of course, necessary to suggest any well-organized obsidian trade" (Renfrew and others 1968:330). While the masses in Table 3 are larger, it is clear (as a rough heuristic exercise, assume a trade expedition of four porters each carrying 25 kg) that the total maximum amount of obsidian at Uaxactun could represent about 54 trips, or about one trip every 18 years during its millennium of occupation. Similarly, the maximum 103 metric tons at Tikal (if one assumes a minimum use-rate of a small 3 g blade per person a week) would be restricted to only 689 users per year throughout a millennium occupation span. This estimate of 689 users is very close (perhaps fortuitously) to recent estimates for the size of the Tikal elite class: (1) a group of 400-500 is inferred from living space in Tikal vaulted structures (Culbert 1973:69); and (2) 400-800 people are projected from a Uaxactun elite class/total population ratio derived from "bench" sleeping space (Adams 1974). At any rate, less than 700 regular obsidian users in a population center last estimated at 40,000 people (Haviland 1972:138) clearly shows restricted access.

(4) Another measure of obsidian abundance at a site is the obsidian:chert ratio, which was mentioned earlier. The problems with this measure include a poor correlation between numbers of artifacts and their weight; that different breakage rates distort the ratio; and that there is a differential recovery and classification of artifact classes by different researchers, particularly the "unutilized" flake. Brose elegantly demonstrated the last point through several microscopic analyses of experimentally utilized chert and obsidian flakes. In his study no wear-use could be detected on about 40% to 80% of the total sample (1975:88, 92). Consequently the obsidian:chert measure gives inconsistent results. For example, excavations of several house mounds at Yaxha (Sidrys n.d.) showed that the numerical proportion of obsidian prismatic blades within the total lithic complex ranges from 5-17% (depending on the potential usability of individual prismatic blade fragments). By mass this obsidian would constitute less than 1% of the total lithic complex.

On the other hand, Moholy-Nagy (1974) has presented obsidian:chert prismatic blade ratios that appear to show that obsidian was the highly preferred cutting tool at Tikal. A prismatic blade ratio, however, clearly does not give a representative view of lowland obsidian versus chert use. Lowland prismatic blades were overwhelmingly made of obsidian with very few being made of chert, which took a variety of other lithic forms. The Tikal Op. 24 lithic sample shows that chert prismatic blades comprise only 2.2% (54/2469) of all potential chert cutting tools, whereas the obsidian prismatic blades are 93.5% (203/217) of the potential cutting obsidian (Haviland 1963, Tables 152-63; note that in light of the Brose study a .6 correction factor was applied in this study to the "unmodified" chert flakes). In consequence, Moholy-Nagy's study simply restates that obsidian was preferred for the prismatic blade form, and avoids discussion of the wide range of chert tool types that are quantitatively far more abundant than the obsidian prismatic blade.

(5) The size and type of lowland Maya obsidian tools also indicate that obsidian was prized, and used efficiently. The most common artifact in an obsidian collection from 20 Colonial Period Valley of Mexico sites (with very short distances to the source), where obsidian was clearly used for utilitarian functions, was the large rasp end scraper (about 40 gm). Small prismatic blade implements constituted only 26% of the total obsidian industry (Michels 1971:260-67). In contrast, in a Classic period obsidian sample of comparable size from Yaxha, Guatemala, the most prevalent artifact was the tiny prismatic blade, which formed 83% of the total collection. Another indicator that suggests the value of obsidian is the cutting edge length/prismatic blade mass ratio, which generally increases with source distance in the Maya lowlands (Sheets and Muto 1972:633; Sidrys n.d.). The small sizes of expended cores and the reuse of cores as scraping implements also suggests the scarcity of obsidian (Rovner 1973).

With abundant chert sources in the Peten, obsidian use would only be expected for fine finishing work. Obsidian is one of the sharpest substances known, but the crypto-crystalline properties of chert make it far superior in ability to withstand stress. The hard woods of the Peten, for example, could be better abraded by chert than by obsidian (Clay Singer, personal communication). Specialized flint knappers in the lowland area, however, may have procured obsidian to "expand" their range of products. The author has observed dense obsidian debris in three sites that probably also have the most extensive chert workshops in the lowlands (Yaxha and Tikal in Guatemala, and Colha in Belize). Possible interrelations between the chert and obsidian industries should be examined with quantitative data.

Ethnographically known uses for obsidian include ritual bloodletting and sacrifice, shaving, and surgery. It was also fashioned into lip and nose plugs, earspools, figurines, mirrors, ceremonial axes, and eccentrics, and inset into elaborate war clubs (Michels 1971:267). Far from serving a "critically necessary" household purpose (Rathje 1972:368), the function of such artifacts (cult paraphernalia) is to maintain a specific system of social stratification.

(6) There is substantial evidence that obsidian was an integral part of Classic Maya religious and political regalia. Obsidian from ceremonial contexts (i.e., elaborate burials or caches) is nearly always more abundant in Maya excavations than from domestic refuse. A single ceremonial deposit of obsidian at many lowland sites often contains more obsidian than can be found in several months of excavation in general refuse areas. Examples include the Group A tomb deposit of 4,500 pieces at El Pozito, Belize (M. Nievens, personal communication); the Copan Great Plaza cache of 700 large blades; the Yaxha Stela 30 cache of 1,345 blades and fragments; the Altar cache 6 of 677 pieces; and the Early Classic Tikal caches with "pounds" of obsidian scrap (Coe 1962:498). Obsidian in Classic period ceremonial contexts was more abundant than the total obsidian collected as general refuse in the following excavations: (1) Yaxha, (2) Altar, (3) Baking Pot, (4) Copan, (5) Piedras Negras, (6) Tikal, (7) all of Northern Belize (up to 1974). Excavations up to 1967 at Tikal had collected about 37,000 obsidian artifacts, three-fourths of which came from non-utilitarian special deposits. It is true, however, that at Tikal and possibly some of the other sites this phenomenon may be a function of cache-oriented excavations (Moholy-Nagy, personal communication).

The large quantitites of obsidian in major burials and monument caches, as well as its frequent presence in even humble burials suggests that lowland obsidian import evolved to meet religious and political ends. I would speculate that, at least in the Late Preclassic-Early Classic periods (300 B.C.-A.D. 600), obsidian was primarily imported "to lend credibilty" (to use Malcom Webb's phrase) and high status to opposing kin-group leaders competing for newly-developing offices of leadership. Specifically, this would have been achieved through conspicuous public consumption by cache deposition, ritualistic bloodletting, and even by the everyday use of the item in elite households. The lustrous quality of obsidian (associated with gemstones) together with its distant sources made it a fascinating and desirable commodity, irrespective of its potential usefulness.

By the Protoclassic Tikal was beginning to develop religious and political complexity (Coe 1965:1417). Concurrently, or even shortly into the Early Classic, elite cognatic lineages may have merged into clan groups (Haviland 1968:109) with resulting competition for key civic-religious offices. Open social mechanisms (like economic superiority) to resolve status competition might be expected for this period. Many primitive societies include the conspicuous public consumption or display of wealth as demonstrations of economic superiority. Such mechanisms have been defined as "sumptuary regulations" by Service (1971:147) and "levelling mechanisms" by Nash (1962:306). They include the Northwest Coast potlatch (Drucker 1967:488), Oceanian gift feasts (Malinowski 1967:206-20), and the Chiapas-Guatemalan cargo system (Vogt 1961). In each case, accumulated community resources are channeled into non-economic ends.

Late Preclassic-Early Classic obsidian caches suggest such "potlatching patterns" by the intentional removal from potential use of a useful imported commodity during a public ritual. While obsidian is found in the earliest occupations of most of the larger sites, it is fairly rare (Moholy-Nagy 1974; Willey 1972a:217; Graham and others 1972:111). By the Early Classic, however, large quantities were being deposited in stela and structure caches of Tikal, reaching a peak in quantity and variety of types during the Middle Classic (Moholy-Nagy 1974; Coe 1962:498). At Altar, the largest obsidian cache (Cache 6) also dates to the late Early Classic, as do the two largest obsidian caches at Uaxactun (A-6 and A-7).

By the Middle Classic, dynastic marriage alliances linked various centers (Marcus 1973:914) and political status rivalries now were between, rather than within, centers. Conspicuous consumption apparently took a more flamboyant form, shifting from long-distance trade items to a preoccupation with the sheer size and abundance of monumental art and architecture. At Tikal the final discarding of traditional standards of small size in pyramid and monument construction took place around A.D. 711, with each building now commanding more attention than its predecessor (Jones 1969:109). To paraphrase R. E. W. Adams, much of the civic-ceremonial center functioned as a kinship-commemorative monument-complex (this does not necessarily exclude the presence of a functional administrative/residential area). Accordingly, the Tepeu 2-3 cultural "climax" in the Maya lowlands (Willey and Shimkin 1973), if the relatively short time period (5 to 8 generations?) is considered, represents the expected trajectory of an intensive kinship-related status rivalry between centers that manifested itself through monumental sculpture and architecture.

While obsidian became relatively rare in Late Classic Tikal caches, obsidian "potlatching patterns" appear to have persisted. The manufacture of ritualized "incised" and "eccentric" obsidian artifacts is somewhat analogous to the production of geometrically shaped copper plaques named "coppers" that were broken in Northwest Coast potlatch ceremonies. The wealth of symbolic interplay associated with the obsidian "eccentric" (Coe 1959:118-19) is analogous to the names and histories that were attached to highly regarded "coppers" (Drucker 1967:492).

Finally, concurrent with the obsidian decrease in Tikal caches, there is a large obsidian increase in several Late Classic tombs in the form of hundreds of unused crude blades scattered above the tomb (Moholy-Nagy 1974). Similarly, the Late Classic burial at El Pozito was placed on an obsidian deposit that constitutes the largest such cache yet found (up to 1974) in the lowlands. These examples of private ownership of a large obsidian mass may signify that a more regular and widespread use of obsidian had been instituted late in Maya cultural history.

## CONCLUSIONS

Obsidian data from lowland Classic Maya sites was analyzed by measures that considered the imported mass at a site together with the distance from source. It was found that major centers had about five times more obsidian per capita than did minor centers.

Central place redistribution and central place market exchange were compared as possible organizational modes for this long-distance trade. The central place redistribution model appeared to show the best fit with the existing archaeological obsidian data. In this model obsidian is a high status commodity used in political and ritualistic behavior as well as in elite households. This view is supported by the following evidence: (1) the obsidian per capita differential between major and minor centers may be related to the increase in the ratio of full-time "cult specialists" to full-time farmers; (2) the differential concentration of obsidian between elaborate residential structures and small house platforms at Tikal and other sites; (3) the high number of usable chert tools in comparison to obsidian tools at most lowland sites; (4) the tiny, efficient prismatic blade is the most abundant obsidian tool type in the lowlands; (5) estimates of total obsidian mass for lowland sites indicate that, even with modest consumption rates, obsidian in everyday use was restricted to a fraction of each site population; (6) the lavish use of obsidian in monument and building caches, as well as in elaborate burials.

This evidence fails to corroborate the alternative model of central place market exchange, with its concomitant historical hypothesis that lowland centers "developed originally in response to the demand for consistent procurement and distribution of non-local basic resources useful to every household" (Rathje 1972:373). Lowland import of metamorphic metates was abundant but not distant ($<$ 100 km), while obsidian import was distant but not abundant enough to be in everyday use, except in elite households. Undoubtedly obsidian did have some specialized utilitarian functions and some of it did filter down to the peasant-farmer sustaining population. But it was prized as a useful luxury.

The large-scale exchange or reallocation of commodities at Maya centers was most likely limited to local products. This issue has never been studied, perhaps because of the widespread erroneous notion that the lowland environment is "uniform." The growth of an autonomous corporate merchant class within lowland centers, however, would have been suppressed or controlled by the ruling dynastic hierarchies. The status restrictions forced upon Late Postclassic Central Mexican merchants by the Aztec nobility offer an analogy. Maya long distance imports apparently were obtained and then exchanged by the elite of different major centers, probably along with royal marriage alliances or similar mechanisms (cf. Adams 1971; Tourtellot and Sabloff 1972:133; Marcus 1973:914).

Finally, the historical role of Maya central place redistribution is reconstructed. During the Late Preclassic-Early Classic obsidian import was part of the political regalia of kin-group leaders competing for newly developing political-religious offices. The enormous obsidian caches in the Early Classic suggest "potlatching patterns" (the publicized removal from potential use of a useful imported commodity) which may also reflect political behavior. Likewise, the manufacture of Late Classic ritualized "eccentric" obsidian items is somewhat analogous to the production of the geometrically-shaped "coppers" that were used in Northwest Coast potlatch ceremonies. By the Late Classic, however, increases in transport efficiency may have "devalued" somewhat the exotic status of obsidian in the Maya lowlands and permitted a more regular and widespread utilitarian use.

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