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THREE PAPERS ON MESOAMERICAN ARCHAEOLOGY

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Department of Anthropology

University of California

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THREE PAPERS ON MESOAMERICAN ARCHAEOLOGY

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EDITORS' INTRODUCTION

The three papers which appear here were written by students in the Department of Anthropology in the 1973-74 academic year. Velson and Clark worked together in course Anthropology 195, an undergraduate research seminar, given in the Spring quarter 1974. Aaberg and Bonsignore's joint paper came out of the same seminar. Dillon's study of trade represents his Senior Honors Thesis under our joint guidance. All three papers are original and in our opinion good examples of the kind of undergraduate research done in this Department. We think that they are worth sharing with a wider audience.

John A. Graham
Robert F. Heizer

I. TRANSPORT OF STONE MONUMENTS TO THE LA VENTA AND SAN LORENZO SITES

Joseph S. Velson and Thomas C. Clark

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INTRODUCTION

Because monumental stone buildings and sculptures are often the most impressive, readily accessable and best preserved artifacts of a culture, archaeologists have long been interested in the technology associated with the quarrying and transportation of large stones.

Working with the problem of a "heavy" lithic technology need not offer only information about ancient engineering practices, but also a point from which some demographic and socio-political implications may be explored.

The complexities of an ancient heavy transport operation are more readily seen by breaking the operation down into its component parts. It then becomes possible to assign quantitative values such as man-power and man-hours to each of these components: quarrying operations, construction of transportation aids, land and/or water travel, maintenance and supplies, etc.

The total amount of manpower involved can then be estimated. If we can determine how many individuals were engaged in a project, we may be able to estimate the size of a minimum support population. It may also be possible to say that a certain number of these individuals were full-time non-agricultural specialists, and that a certain number of other individuals were part-time workers normally engaged in other presumably subsistence related activities.(1)

Because it appears that so much can be learned from such studies, we have selected one particular New World culture on which to focus our attentions. Specifically, we are considering the various stone monuments--including the altars, stelae and colossal heads--that are characteristic of the Olmec culture of southern Veracruz, Mexico.

<u>Geography and Climate</u>. The Olmec culture area was concentrated in that part of the tropical lowland Gulf Coast plain bordered by the Papaloapan River on the west, the Tonala River on the east, the highland area to the south, and the Gulf of Mexico to the north (Drucker 1947).

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(1) Parenthetical numbers refer to <u>Notes</u> at end of text.

This area covers between 6,200 and 7,000 square miles (Coe 1962:86; Bernal 1969:17), although the area surrounded by the four major sites comes to not more than 2,500 square miles (Heizer 1968).

With the exception of the intrusive volcanic highland of the Tuxtla Mountains, the Olmec coastal lowland area has been described as a plain which "varies between slightly undulating in most places to gently rolling as the elevation limit is approached" (Poleman 1964: 31). The coastal plain is composed mainly of the alluvial deposits from the river deltas and flood plains of three of the largest river systems in Mesoamerica--the Papaloapan, the Coatzacoalcos, and the Tonala-Blasillo. The Tuxtlas are a small isolated range whose highest peak does not exceed 6,000 feet. Here lies the source of much of the stone material used by the Olmec (Williams and Heizer 1965). Much of this coastal plain is flooded during the rainy season with the exception of some uplifted Pleistocene domes overlying salt and oil deposits. All, or nearly all, of these islands are known to have had Olmec sites on them (Heizer, personal communication).

The heavy tropical jungle growth was the most prevalent vegetation formation in pre-Columbian times, but has been severely restricted by intensive logging operations and extensive use of grazing lands. The rain forest consists of essentially three stories of trees which range up to 50 meters in height. The dense canopy forest with the taller trees includes laurel, tinco, Ceiba, and mahogany. The intermediate and lower stories consist of palms, magnolia, fig, rubber tree, immature members of the upper story, numerous bushes and shrubs. The forest is characterized by many climbing plants, some of which achieve lengths of fifty meters or more. There are several other vegetative and faunal adaptive zones in the area--savannah, beach, mangrove forest, and river levee forest to name a few--but none are nearly as extensive as the tropical rain forest. (West, Thom, Psuty 1969; Wagner 1965).

The climatic variation in the area is due largely to its geographical position between the middle and lower latitudes of the northern hemisphere. The land below 1,000 meters elevation is often called "tierra caliente" and has average yearly temperatures between 20 and 30 degrees Centigrade. The relative humidity is well over 80% for most of the year. The rainy season runs from late May to January with a peak period in June and a maximal peak in September. The entire area receives over 2,000 mm. of rainfall annually, and some portions of the Tuxtlas receive over 5,000 mm. During this time many of the rivers over-run their banks and flood the surrounding countryside for many miles, making almost impossible any kind of prolonged construction project. The area is blanketed by a dense network of seasonal streams which make overland travel during the rainy season very difficult. The dry season, which extends from early February to late May, is not really "dry" as the rains never actually stop completely. This is the time of <u>nortes</u>, storms characterized by high winds and intense rains which are caused by large masses of polar air which have penetrated far south.(2)

La Venta and San Lorenzo. The Olmec culture is known essentially from four sites: La Venta, San Lorenzo, Tres Zapotes, and Laguna de los Cerros; and is dated to the first millenium B.C. Only La Venta and San Lorenzo have been excavated in sufficient detail to aid our consideration of ancient heavy transport, so this inquiry will be limited to these two sites.

The La Venta site is located on an island to the east of the Tonalá River about 12 miles from its mouth. The island itself is an emergent salt dome with a dry land surface area of about 2.1 square miles. The mounds of La Venta are oriented in a bilaterally symmetrical manner along a center-line which runs 8 degrees west of north. Most of the investigations at the site have taken place in the northern-most areas--centering around the 100 foot fluted pyramid of Complex C and the area to the north of that designated as Complex A (Drucker, Heizer, and Squier 1959). Excavations have revealed a large number of stone monuments (ibid; Heizer, Graham, and Napton 1968) as well as extensive evidence of large massive offerings (Drucker, et.al. 1959). The site appears to have been continually maintained and modified over a period of 400 years, from about 1000 to 600 B.C. (Berger, Graham, and Heizer 1967). The constructions are apparently of a religious nature as no occupation or trash debris has been found within the site area (Heizer 1961:45). The massive offerings, the fact that much of the materials for sculpting and for refurbishing the site were transported from great distances (Williams and Heizer 1965), and the large amount of manpower that would have been required for general maintenance and construction indicate a large, well organized labor force which was continually involved in the up-keep of the site (cf. Drucker 1947; 1961; 1952; Heizer 1959; 1962).

San Lorenzo is one of three sites clustered along the banks of the Río Chiquito, a branch of the Coatzacoalcos River about 50 miles upriver from the modern town of Coatzacoalcos (Stirling 1955). The site, which is only 1.2 km. long, is situated on a plateau which rises above the surrounding savannas. The florescent Olmec occupation at the site is known from the San Lorenzo Phase, which has been placed within the 1200-900 B.C. time span (Coe, Diehl, and Stuiver 1967). The site is also characterized by a large number of stone monuments in the Olmec style (Coe 1968:69; de la Fuente 1973; Clewlow 1974), as well as major earthworks. The entire plateau has been modified and tremendous amounts of earth moved to construct the artificial ridges on which the site rests. The presence of what appears to be a complex drainage system represents another example of the tremendous expenditure of labor at the site (Coe 1968:57). The site has been extensively mapped and photographed by Coe and unlike La Venta, it appears to have had a resident population of not more than 1,000 individuals who were probably supported by the farmers of the surrounding area (Coe 1967; 1968; 1969).

Stone Monuments. The number of stone monuments known from San Lorenzo and La Venta is quite large. Recently Clewlow (1974) has subjected over 200 of these to a stylistic and chronological analysis. These range in size from sculptures weighing only a few pounds to La Venta Altar #1, the largest of known Olmec pieces, which weighs 36.5 tons. The maximum weight which could have been lifted by the ancient Olmec is uncertain. Monument 34 at San Lorenzo, which weighs 1,000 pounds, was carried by 17 workers on a litter made out of poles (Coe 1965:79). Heizer (1966: fig. 6) shows 35 men carrying the weight of a 1.5 ton andesite column at La Venta. Perhaps a weight of 3 tons could be lifted, but the number of men involved would, due to sheer numbers, be so far away from the weight being raised that the entire litter might collapse due to the concentration of the great weight in the center. However, the majority of Olmec stone monuments do fall within this "portable" category, i.e., less than three or four tons.

We have arbitrarily limited our inquiry to consider only stones which weigh over five tons. With stones of this size there is little doubt that they would have been dragged. By working with the idea of dragging a large stone we hope to better visualize the planning and logistics that would have characterized such an operation.

The large monuments moved by the San Lorenzo and La Venta Olmec include eleven colossal heads, three stelae, and over a dozen altars and other stone monuments (See Appendix A.).

Source of Stone. Basalt was the most common material used by the Olmec for their monumental artistic endeavors, although andesite and schist were also known. Although the basaltic lavas used could have come from several sources, the place of origin of most of the material was in the area of Cerro Cintepec, an extinct Plio-Pleistocene volcano located along the southern flank of the Tuxtla mountains a few kilometers southeast of Lake Catemaco (Williams and Heizer 1965). Along the slopes of the Cerro Cintepec, the basalt used by the Olmec occurs as naturally formed boulders already detached from the rock.(3)

Other Olmec monuments had their origins at other places in the Tuxtlas. Cerro el Vigia, a volcano located about 4 kilometers west of Santiago Tuxtla, appears to be the source of much of the basalt used at the site of Tres Zapotes (Heizer, Smith, and Williams 1965). Although a number of columnar basalt exposures have been examined in the Tuxtla Mountains, none of these prove to have been the source for those used at the La Venta site. Other lithic materials were obtained from Volcán La Unión, over 100 kilometers southeast of the La Venta site. Limestone slabs from Chinameca, approximately 60 kilometers west of La Venta were transported to the site (Williams and Heizer 1965:6-8).

The Olmec thus appear to have acquired their lithic materials from several locations, some of them over 100 kilometers from the site to which they were transported. For the purposes of this paper, it is not possible to deal with each site and each lithic source known. We have decided to limit our inquiry to the large stone monuments of San

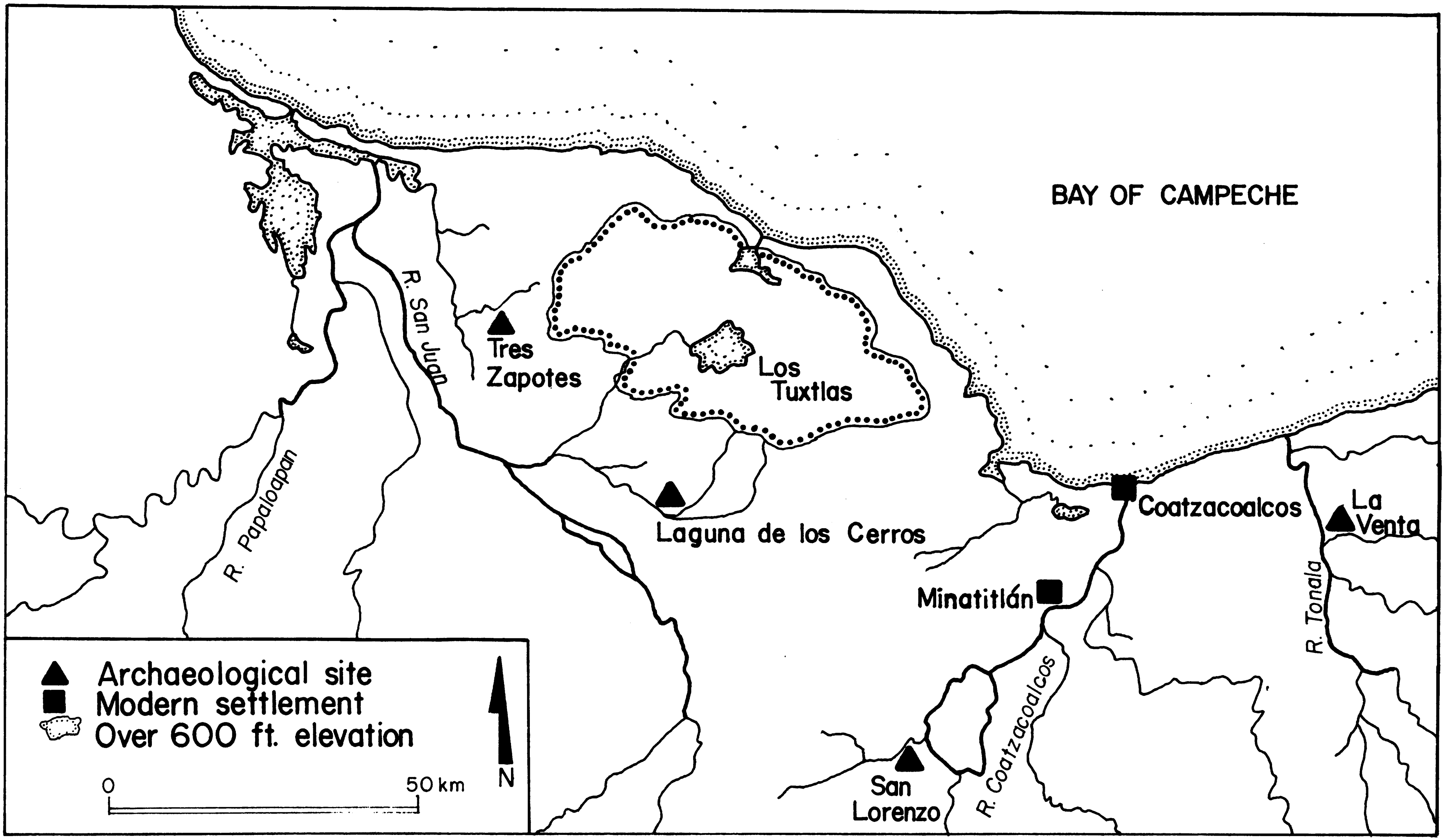


Figure 1. The Olmec Region (After Bernal 1969: 16)

Lorenzo and La Venta which came from Cerro Cintepec. The La Venta and San Lorenzo materials are the best documented so we can work with the most accurate physical descriptions of the stones. The Cerro Cintepec source was probably used extensively throughout the Olmec period.

For our calculations regarding La Venta, we have selected the largest monument from that site, the 36.5 ton basalt "Altar" #1. By using the largest possible stone, we can calculate the maximum amount of effort and planning that would have been taken into account at any one time.

At San Lorenzo the largest monument known is Monument 14. This is an andesite monument which weighs between 30 and 40 tons. It is not possible to determine its exact weight due to the discrepancies in the various accounts of its dimensions (cf. de la Fuente 1973; Clewlow 1974; Stirling 1955). This stone did not come from Cerro Cintepec, but it was undoubtedly transported to San Lorenzo in the same manner as other large stone monuments. So that we are not in danger of under-estimating the manpower necessary, it would appear feasible (and make our calculations easier) to also use the weight of Altar #1 at La Venta as that of the maximum size stone that would have been transported to San Lorenzo from the Cerro Cintepec.

Transport Routes. We have estimated that approximately 575 tons of basalt stone monuments were transported to La Venta and San Lorenzo. This figure does not include the massive stone offerings or the columnar basalt at La Venta (See Appendix A).

The transportation of this large amount of material over a long period of time required calculated forethought which presumably included the selection and development of routes over which the monuments would have been transported to their destination.

Cerro Cintepec to San Lorenzo. The technology of transport cannot be considered without knowledge of the physical barriers to be overcome, that is, the actual nature of the route of transport.

A review of available topographic maps, aerial photographs, and written accounts of the local geomorphology has suggested three possible routes from Cerro Cintepec to San Lorenzo and two from Cerro Cintepec to La Venta. These are shown on figure 5 and numbered according to the following descriptions.

Route 1 is a direct overland route from the Cerro Cintepec to the San Lorenzo site. The route follows the contours of the Tuxtlas in a southeasterly direction to the alluvial plains of the Coatzacoalcos River and on to the site. Some small rivers or gullys would have had to have been crossed by temporary measures such as rafts or crude bridges built by felling tall trees along the river. (This method is occasionally employed modernly, see Standley 1920). It is conceivable that the quarrying, transport, sculpting and erection of monuments played an important enough role that permanent thoroughfares of earth might have been established. These would have doubtlessly served a multiple function in the practical development of trade and communication routes.

This overland route would have been the most economical in terms of distance, 65 kilometers in all. However, San Lorenzo is not situated on the level alluvial plain but on a plateau which rises to about 340 feet above sea level (Coe 1967). This means that a heavily laden sledge would have had to be drawn up steep irregular inclines to reach the site.

Route 2 is suggested by M. Coe who believes that the stones "must have been floated down on rafts to the Gulf of Mexico and along the coast to the mouth of the Rio Coatzacoalcos, and dragged from the river up to the San Lorenzo Plateau with ropes" (Coe, Diehl, Stuiver 1967). It is not clear what is meant by "floated down on rafts to the Gulf." If this means drawing a heavily burdened sledge over a ridged volcanic landscape to the San Juan-Papaloapan River system, the route is so difficult to negotiate that it may be readily discarded. Traversing the mountains to the east to gain access to the Gulf is likewise improbable. The only really feasible route utilizing the Gulf of Mexico would be to descend from the Tuxtlas in a southeasterly direction and then turn due east. The mountainous terrain would be avoided, and though longer in distance the route may have seemed attractive because less energy would be spent dragging the stone on level ground or transporting it on water. One difficulty presented by this model is that of approaching the Gulf from the Veracruz coastal plain. Surrounding Laguna Ostion are expansive swamps abetted by the drainage of the Rio Chalcalapa. Though this obstacle might have been eliminated by draining the marsh or crossing with an earthern causeway, this would involve a large labor expenditure the fruits of which would not have lasted through the rainy season. Drucker (personal communication) suggests that during the rainy season the Rio Calzadas, which enters the Coatzacoalcos near its mouth, would have enough water to serve as a possible avenue of transport. Coe's concept of water transport is useful though this particular route presents some difficulties.

Transport on water is advantageous for several reasons. The surface of a large river (or the sea when calm) has fewer obstacles. Less manpower is required to move the cargo. A river may not always be the most direct route but is often the only possible route. Bernal notes that "the rest of the (Olmec) area with the exception of a few humid plains and the swamps, was and is still covered with tall vegetation which in reality is an impenetrable jungle whose only open spaces are those cut by the rivers that form the only possible means of communication." (Bernal 1969:18-99).

Route 3 appears to be the most feasible. This involves leaving the Tuxtla highlands following the easiest contours in a southeast direction, crossing the coastal plain in the same direction to arrive at the banks of the Rio Coatzacoalcos perhaps upstream of Minatitlan. From there the monument would be transported up the river to the site. This route is approximately 114 kilometers in length. Though it is 49 kilometers longer than the first route, the journey on land is more consistantly level and the advantages of water travel are exploited.

The first part of this route, the overland trail from Cerro Cintepec to the Rio Coatzacoalcos (58 km.), might have been cleared specially in anticipation of the stone movement. This assumes that Cerro Cintepec basalt may have been quarried at irregular, perhaps quite lengthy, intervals. Because it seems that the stone was removed at periodic intervals from its source (Heizer 1961), it appears more probable that the route from the mountains to the river was a well established "road".

Cerro Cintepec to La Venta. We have examined two transport routes from Cerro Cintepec to La Venta.

Route 4 is the least probable, consisting simply of a straight line overland route. This route is complicated by having to cross two major rivers, numerous smaller ones, as well as the watery swamp surrounding the island of La Venta. The rivers are too wide to be bridged, so rafts would have to have been constructed to ferry the stones from one side to the other and finally up to La Venta. We concur with Drucker who discredits this route: "There are some swampy sections that couldn't have been traversed by heavy loads, and some rather rough (though not terribly high) terrain between the Coatzacoalcos and the Tonalá rivers that would be difficult to roll or drag big stones across," (personal communication).

Route 5 takes full advantage of the two large rivers and the Gulf Coast waters. It appears to be the easiest and quickest route. The monument would have been dragged from the Cerro Cintepec to the Coatzacoalcos, perhaps along the same path described for route 3. At that point it would have been transferred to some water-transport structure to be paddled or towed to the Gulf. The route then follows the coastline to the mouth of the Tonalá where it turns inland to the La Venta site. The distance from quarry to site would be approximately 139 kilometers, only 33 kilometers longer than the direct overland route.

There are certain conditions which are most favorable for aquatic transport. During the months of rainy season the rivers are flooded because of the heavy rainfall. Today as much as 122 inches of rain annually falls on Minatitlán (Bernal 1969). During this season river travel as well as travel on land is difficult. The rivers are not just swollen and raging, but encumbered with tree trunks and debris. The rainy season overlaps with the nortes which intermitantly hinder travel on land and particularly on water. The time which appears optimal for transport of heavy monuments is dry season. Navigation on the open sea would have been most likely when weather hazards were least likely to have occured, perhaps just after a norte. Depending on the stability of Olmec marine craft there may have been comparatively few brief periods in which sea travel could have been negociated.

Mode of Land Transport. An important part of the problem of transportation of monoliths is the mechanism used to carry the heavy stones on the land. Not having access to wheeled vehicles or domesticated beasts of burden that might have facilitated carriage, Olmec engineers had to rely on resources locally available to move stones over the routes previously discussed. Of course men can double as draft animals and must have done so in the movement of Olmec sculpture. It is possible that monuments were dragged overland without any sort of helping device, but this is hard drudgery. Conducting a many ton boulder which rests directly on the earth by hitching many teams of men to it would have been wasteful of time and energy, due to the problems that would have been incurred by friction, irregular terrain, and possible damage to the stone itself.

Sledges. The simplest perhistoric device to move large monuments on land was the sledge. Atkinson suggests the use of sledges in Neolithic England and documents the use in modern times, despite the advent of the wheel, in the British Isles and among the Naga people of Assam (1961). Heyerdahl observed the use of miro manga erua (a sledge device) on Easter Island and concludes that a similar idea was used anciently in the dragging of the monolithic sculptures (Heyerdahl 1958: 149). Sledges were also employed by Assyrians and Egyptians in their transport of monumental sculpture (see plates 1-3).

Heyerdahl (ibid.) describes the sledge on Easter Island as a Y-shaped figure with crosspieces. This seems nearly identical to the ancient model described by Atkinson in which "the strongest form would have been one whose main longitudinal members were formed of a natural pair of forked tree trunks, in the shape of a modern tuning fork, joined by nature at their bases and braced transversely by cross-members morticed and pegged" (1961).

While this might have been a useful design for some areas it may not have been for the Olmecs. The difficulty in locating forked trunks of the desired thickness, length, and shape far outweigh the advantages of strength. Transporting such a "natural" sledge to the quarry site would involve considerable difficulties if the wood were not available locally.

A sledge made up of two parallel beams reinforced with a series of cross-members could be transported to the quarry and assembled there with much less effort.

In the case of La Venta Altar 1 (which we have estimated to weigh 38 tons before final sculpting), three runners might have been used to provide additional support.

We have developed a hypothetical model (Figures 2 and 3) of a sledge similar to the Egyptian example described by Solver (1940). The sledge measures 12 ft. X 11 ft., while the base measurements of Altar 1 are 8-1/2 ft. X 9 ft. The sledge is slightly longer and wider to leave room for wedges which may have been provided to prevent the monument from slipping. The idea of a long, narrow sledge seems unfeasible due to tne danger of uneven support beneath the runners. Should the two ends of the sledge become suspended on high points along the track, the midsection might collapse due to inadequate support. The ends of the runners are tapered upward to facilitate the introduction of sleepers beneath the sledge while dragging is in progress. The wood had to be strong and hard. For our calculations we have used the data for mahogany.

To be carried successfully, the stone would have to have at least one flat surface--this would be the side that would rest on the sledge. Some boulders may have had a naturally flattened surface (this could have been a factor in selection of potential monument material) but if they did not, one had to be prepared.

Using levers and pulling with ropes, the stone could have been turned on its flat side (if it wasn't already) and dragged onto the sledge, which might have been approached by a slight ramp of earth. An interesting alternative may have been easier: assuming the flat side was vertical to the ground at some point after being planed, the sledge would be assembled onto that surface affording a custom fit. Then with levers and hauling with gangs and ropes the monolith was rolled over so that it sat securely on the horizontal sled. Turning the monument on its level side could have been aided by jamming stones under the side being jacked up as the Easter Islanders did in the erection of their monoliths (Heyerdahl 1958).

Once the monument was laid in its most stable position shims might have been slipped into the interfacing area of rock and sledge. The monolith would have been securely lashed to the sled with fiber ropes, sinew, or vines. These bindings (like the ropes for pulling) would have been replaced as strain and wear broke them. Once the monolith was mounted on the sledge it probably remained there until it was unloaded at the destination, which in the case of Altar 1 was La Venta.

Sledge Dragging and Manpower. Sledge dragging no doubt involved a large number of men; to make an estimate as to the manpower required we have looked at other similar examples of stone transport.

In experimenting with a copy of the bluestone weighing 1.5 tons and placed on a simple wooden sledge, Atkinson (1959) found that 32 schoolboys could just pull the sledge and its load up a four degree grade. This works out to 109 pounds of pull per man. Heyerdahl (1958) describes an experiment in which 180 men drag a 12-ton Easter Island monument without a sledge. This required 133 pounds per man. An account of the construction, transport, and erection of the Seringapatam obelisk in the early 19th Century tells that "the number employed at one time, on the drag-ropes...was about 600 men." (Wilkes quoted in Kennedy 1821: 312). This stone weighed about 35 tons, thus requiring 116 pounds pull per man (cf. Barber 1900). A 132-ton Egyptian obelisk and sledge required 5,585 men to transport it across the desert. Adding a minimum of 5 or 6 tons for the weight of the sledge we see that each man had to pull 49 pounds. King Mehthuhotpe IV of the XI Dynasty sent an expedition to the Wady Hammamat quarries, numbering 10,000 men, to quarry stone for a large sarcophagus. The lid was dragged to the Nile by 3,000 sailors. Although sources differ as to the weight and size of the lid, the range is such that each worker would have had to exert between 12 and 20 pounds of pull (Erman 1894; Clark and Engelbach 1930: 32; Breasted:vol.1:448). Wilson (1888:584) calculates the weight of the Menhir of Lochmariaquer at 347 tons, and Salmon believes that 4,500 men each pulling 165 pounds were needed to drag it. Grant cites an example involving the removal of a two ton statue from Eleusis using 150 men to drag it (27 pounds/man), but also describes the transport of an 11-ton marble sculpture found by Newton near Cnidus. There, 100 sailors were said to have moved this weight, which would have required a tremendous pull of 200 pounds per man (Grant 1966:131,180). Wilson (1882:226) describes a 7.5 ton stone transported by 92 men at 113 pounds per man; and Kida (1912:5) recounts how, in 1908, a 155-ton Japanese megalith on a sleigh was dragged by 550 men using iron chains. This required 58 pounds of pull per worker. An example from the New World is given by Howells (1960:161) who quotes Cowgill (1957) as saying that the 8-ton Stela 18 at Uaxactun was dragged by 160 men at 100 pounds per man.

We have presented here a broad range of figures, the discrepancies in which may be attributed to a variety of factors ranging from the incorrect recording of data and poor observation technique to the failure to mention the use of mechanical devices or the physical condition of the workers. Most of these examples refer to short range transport: a few hundred yards to a mile or two at the most. Maschet made a study of the continuous potential pulling power of man and concluded that "for steady pulling at the rate of 1-1/2 miles per hour for 8 hours per day, it falls as low as 30 lbs," (Maschet in Barber 1900:41). The figures obtained from the Egyptian examples would seem to be more indicative of the manpower necessary for long distance hauling (i.e., 12-50 lbs./man). For this reason we will use the figure of 50 lbs./man as the <u>maximum</u> for long distance continuous dragging of heavy stone monuments.

If we accept the figure of 50 pounds per man, then 1,626 men would be required to pull the sledge and stone; but this cannot be accepted as a final figure for the totality of men involved in the land transport of the monolith. There are other factors to consider, some of which add to this number of men and some of which will reduce it. A careful study of the Egyptian and Assyrian depictions of land transport scenes offers some clues as to the complexity of the problem (see Plates 1-3).

Plate 1 is an Egyptian representation of the dragging of the 60-ton alabaster statue of Djehutihetep, from a 12th-Dynasty tomb painting at El Bersheh (from Wilkinson 1842).

> One hundred and seventy-two men, in four rows, of fourty-three each, pull the ropes attached to the front of the sledge; and a liquid, probably grease, is poured from a vase, by a person standing on the pedestal of the statue, in order to facilitate its progress as it slides over the ground; which was probably covered with a bed of planks, though they are not indicated in the painting. (Wilkinson 1842:325-326).

The lubricant question is especially interesting (cf. Takahashi 1937). There is little doubt that the Egyptians had knowledge of sleepers, but none are shown (cf. Layard 1853:115). If rollers were used, then a lubricant would not be necessary. Hence, Wilkinson's interpretation would seem to be suited to the evidence at hand. He goes on to describe the scene surrounding the dragging of the stone:

> Some of the persons employed in this laborious duty appear to be Egyptians, the others are foreign slaves, who are clad in the costume of their country; and behind are four rows of men, who, though only twelve in number, may be intended to represent the set which relieved the others when fatigued.
>
> Below are persons carrying vases of the liquid or perhaps water, for use of the workmen, and some implements connected with the transport of the statue, followed by taskmasters with their wands of office. On the knee of the figure stands a man who claps his hands, to measure cadence of a song, to mark the time and ensure their simultaneous draught; for it is evident that, in order that the whole power might be applied at the same instant, a sign of this kind was necessary (ibid.).

Plate 2 is an Assyrian relief from Nineveh showing the King supervising the transportation of a winged-bull statue. This particular monument probably weighed about 30 tons. In addition to the men on the ropes there is also shown the use of the lever, of sleepers, and the presence of supervisory personnel. The sculpture itself is on its side, roughly blocked out with blocks of wood placed beneath the statue to keep its weight evenly distributed on the sledge.

Plate 3 is another scene in the same series from Nineveh. This shows the statue now in the final stages of transport. It is held upright by "beams, held together by cross bars and wedges" in addition "to blocks of stone, or wood, piled up under the body." Note also the "cables (which) appear to be of great length and thickness, and ropes of various dimensions" (Layard 1853:113-114).

In these three scenes there is a wealth of evidence on the many facets of ancient stone transport. In addition to the men necessary to drag the stone there are men to work the levers, move the sleepers, supervise the operation, provide replacement for fatigued and injured workers, and the supplying of food. From this we can see that there must also be men to maintain and replace broken rope and cable, as well as manufacture and repair levers and sleepers. There must be workers to grade the roadway so that it is as level as possible, and there must be those who are continually supplying the lubricant and applying it as the sledge progresses.

The transmission of power involved in these transport scenes can be broken down into essentially three categories: ropes, reduction of friction, and simple mechanical devices (Atkinson 1961).

Ropes of leather, animal hair, or vegetable fiber were probably known in the Old World (Atkinson 1956; 1961). According to one informant, the natives of Easter Island used to make "thick ropes from the tough bark of the hau-hau tree" (Heyerdahl 1958:149). The Olmecs apparently had rope, as shown on Altar No. 4 of La Venta and Monument 14 from San Lorenzo (Stirling 1955). Plant fibers would have been available in abundant quantities for use by the Olmec, and it strikes us as logical to assume that the numerous vines and crawlers that literally tie the rain forest together could have been braided into ropes of sufficient strength for such a project.

Ropes were probably attached directly to the front parts of the sledge and perhaps around the stone itself and then run out to the towing crews. Though there is no evidence of it, it is possible that towing bars were attached to the ends of the rope to afford the draggers a good hold. However the representations of Assyrians and Egyptians show men pulling at every point of the tow ropes. This last idea is more fruitful, because more pull can be exerted per foot of rope by men being stationed along the length of the rope than by a few men hauling at a tow bar.

Reduction of friction would certainly reduce the number of men necessary to pull the sledge, and it would seem that this would have been a matter of prime concern to the ancient stone movers. Mulloy (1970) notes that totora reeds or dry grass could have been used to reduce friction in the transport of the Easter Island statutes. He cites one source which recounts one tradition telling of a "paste of taro and sweet potatoes" that was used to reduce friction (Metraux 1940, cited in Mulloy 1970:12). Speaking of the transport of the Egyptian obelisks, Barber believed that "with wood, well lubricated with oil, and operating upon fine sand, a reasonable traction was obtained"

(1900:91). Even wood on wood reduces the friction--for example, a sledge running on sleepers as opposed to running directly over the ground.

It seems probable that the Olmec did consider the question of friction reducing agents, though we cannot know for certain whether any were employed. Use of the wheel and rollers has been well documented for the Old World, but there is nothing in the New World to suggest that this development ever extended beyond use in toys or games.

Any lubricant which would have reduced the number of men pulling a heavily laden sledge would have been a great help. Even running over wooden sleepers would reduce the number of men from 1,626 to 618. Wood on wood has a coefficient of friction of approximately .38, though there is a range depending on the type of wood used. With soap, the figure would be reduced to 244 men, and with tallow it drops to 114 men. Even if these substances were known, difficulties would probably have arisen in obtaining sufficient quantities to last for several days, weeks, or months of hauling.

It is tempting to assume that mud, clay, or perhaps leaves were used in this capacity with a subsequent reduction in the manpower requirement to 450-550 men. If the assumption that some sort of friction reducing device was used is valid, then it is possible to suggest a range of from 500 to 1,000 men as being necessary to drag the sledge. One thousand men will be used as a maximum figure here.

In addition to the possible use of sleepers, other simple mechanical devices may have been known to the Olmec. These might include the simple folcrum lever and perhaps the tourniquet (cf. Atkinson 1961; Plate 1). It is difficult to gauge the effect of the lever on the long distance transport of the Olmec stone monuments. A lever might have been used in conjunction with each "heave" to ease the burden on the dragging crew, and was probably employed in helping to move the sledge up and down steep grades.

Another interesting question regarding dragging large stones is the degree to which a regular cadence will increase the effective pulling power of the workers. We know of no way to calculate the effect of such an organized effort, though Barber (1900:94) points out that "when hauling a weight...a 'one, two, three and a surge' will produce a momentary force represented by nearly the weight of the whole mass of men, or several times their ordinary pulling force." If this is true, then a 150 pound man would have the potential to pull 150 pounds of weight. The 40.6 ton sledge and monument would then have required only 206 men to pull it without lubricant. However, it seems unlikely that such a maximum effort could be exerted continuously over a period of several hours.

We have from 500 to 1,000 men to drag the sledge, but more are necessary for other related tasks. If the sledge were run on sleepers, then there would be men required to constantly replace these if they broke and to move them regularly to the front of the sledge. If the sleepers were each 12 feet by 6 inches by 6 inches and made of mahogany, each would weigh 96 pounds. If one were necessary for every foot of sledge runner, then 12 sleepers would be under the sledge at a time. It seems reasonable to say that 12 or 13 additional sleepers were always on hand if some broke or splintered. In addition to the pulling crew, about 25 men would be required for the functioning of the sleeper system. (The sleepers under the sledge do not require men, therefore a total of 25 sleepers requires 25 men).

Men would also be required to level the road in front of the sledge, to be constantly providing mud, clay, or whatever lubricant was used and to be gathering and braiding ropes to replace frayed or broken ones. All totaled it seems that these tasks could easily have required an additional 100 men, and probably at least 200. Add to this a dozen or so supervisory personnel and the entire procession would consist of between 700 and 1,200 men. If we assume that the workers actually pulling the sledge would have been periodically relieved by a member of the road gang or the sleeper crew, then no more men would be needed. If however, a separate crew of perhaps 50 men were kept rested and then periodically rotated into the hauling schedule, then we would have between 750 and 1,250 men. This would then be the total number of men actually accompanying the sledge along its overland journey, but many more persons would be indirectly involved in the land transport (those working in food production). This will be discussed later.

The rate of progress of this procession was probably fairly slow. We have only one example of dragging a monument on a sledge which gives some idea as to the time involved. Kida (1912:5) in describing the transport of a 159-ton Japanese megalith using a sleigh and iron chains, notes that it took seven days to travel slightly less than two miles (3,318 yards). If we convert to metric, this works out to 431 meters/day.

Here we must digress momentarily and consider the probable length of the work day. Erasmus (1955:330), in his study of Mayo work patterns determined that the "total working time of...males... was between eight and nine hours a day, of which between six and one-half and seven hours were dedicated to what we have called 'economic' pursuits." It should be noted that this study took place in the summer time when the days are longer. If the Olmec moved stone monuments during the dry season the days would not have been quite as long. If the total work time was reduced one hour due to the length of the winter day, this would leave us with a seven to eight hour day. Assuming a maximum eight hour day, we must make adjustments for delays that no doubt would have occurred regularly--fatigued workers, broken ropes, readjusting the position of the monument on the sledge, etc. A more accurate estimate of the amount of time actually spent in dragging might be closer to 6 hours per day.

There is great danger here of anthropocentrically imposing our own 8-hour day on the Olmec; just as it must be realized that the Mayo observed by Erasmus may have already been victims of such Western work schedules. Had the Olmec been highly motivated in their stone working endeavors, it is not inconceivable that they may have worked for ten or twelve hours a day, or at least as long as there was daylight. In light of this it seems best to suggest a range of between 6 and 12 hours of work per day. Using the lowest figure (which gives the maximum travel time involved) in conjunction with Kida's data, the rate of transport works out to 71.8 meters/hour.

The distance from the Cerro Cintepec to the Coatzacoalcos River is 58 kilometers. With our rate of 431 meters per day, the journey would have taken 13.5 days. This does not include the time necessary for loading the sledge--only the actual time on the road.

Water Transport Mechanism. Clinton Edwards (1965) in his exhaustive investigation of aboriginal watercraft on the Pacific coast of South America documents the use of the following in aquatic transportation: reed bundle floats, hide floats, sewn bark canoes, dugouts, gourd rafts, and log rafts. As tantalizing as they may seem we will discard the potential use of floats of reeds and hides, bark canoes, or gourd rafts from our study. There is no ethnographic evidence that these mechanisms were employed by peoples in the Veracruz-Tabasco area anciently or recently, and the presence of the necessary materials such as *Scirpus totora* for the bundle rafts, sealskin for the hide floats, and the large *Lagenaria* gourds are lacking in the natural environment. Even if the natural resources for construction were on hand, as possibly in the case of bark canoes, the feeble little crafts were not sturdy enough to carry more than a couple men, much less several tons of basalt. Canoes and logs bound for rafting, however, are potential means of heavy transport on the water and will be considered each in its turn.

Log Rafts.

> For the sea journey the raft has some marked advantages over the boat, in that it is unsinkable and cannot be swamped. On the other hand a raft to support a given weight is very much larger and heavier than a boat, or composite of several boats lashed together, to carry the same burden, and is therefore more maneuverable in an emergency. Moreover, while it is very doubtful if they would be practical for the inland part of the journey (Atkinson 1956:111).

Both forms of water transport must be considered as a method employed by the Olmec to move their large stone monuments. It is possible that both rafts and canoes with support structures were used, one for the sea part of the voyage and one for the river transport; but the effort involved in transferring the monument from one to the other makes it seem improbable.

We assume that for a raft a light wood which was easily available to the Olmec would have been selected. Ceiba sauraums is a very light wood found today throughout the tropical rain forests of the Olmec heartland. The introduction of cattle has greatly increased the amount of grazing lands, but as a result the forest lands are much smaller today than they were in prehistoric times. Ceiba was probably much more common then than it is today. This tree grows up to heights of 150 feet and can be found up to ten feet in diameter. It has a specific gravity of 0.089 (dry) and weighs 23 pounds per cubic foot. With water weighing 60 pounds per cubic foot, one cubic foot of Ceiba will support a maximum of 37 pounds without sinking below the waterline.

Using Altar 1 from La Venta as a sample, we can make a theoretical model of a raft with varying dimensions. Assuming that Altar 1 weighed 38 tons before being carved into final form, the Olmecs would have required a minimum of 2,054 cubic feet of ceiba to support the stone. 2,000 cubic feet of Ceiba can take many forms from an almost square 25 ft. X 27 ft. X 3 ft. to an elongated 50 ft. X 8-1/4 ft. X 5 ft. The possibilities are limited only by the size of trees available.

The raft would have probably been made of two layers of Ceiba lashed at right angles to each other. For lashings numerous vines and crawlers from the forest were always available, although other materials may have been used for rope. The logs may have been slightly notched so that they rested in place more securely.

A raft with a five foot draft might be too much for some of the shallower parts of the slow moving Gulf Coast rivers. Perhaps three feet would be more reasonable. The raft would actually have to be larger than 2,054 cubic feet for several reasons: (1) to allow for an increase in weight of some men on board to attend to the lashings and help with steering (and perhaps even paddling); (2) to allow for an increase in weight due to prolonged exposure to the water; and (3) to allow for some freeboard above the waterline. With these considerations in mind, we can construct a model raft.

Starting with a raft 35 feet long by 20 feet wide by 3 feet deep, we see that it contains 2,100 cubic feet of Ceiba, enough to support 77,700 pounds. With the addition of the stone, the sledge, and ten men, this raft will sink below the surface of the water. To support this weight and allow a one foot clearance above the waterline, a raft 35 feet long, 20 feet wide and 4.2 feet deep would be required. A total weight of the raft, plus the monument, plus the sledge, sleepers and ten men would be 75.3 tons (see Appendix C for calculations).

This is the largest raft that would have to be built for any single monument, and if individual rafts were built for each stone, then the smaller monuments would require proportionately smaller craft. It is possible that a large raft such as the one described was constructed and then reused for other monuments; but again, considering the effort that would be involved in returning the raft to the point of debarkation, drying it out, replacing worn lashings, etc., this also seems rather unlikely. Perhaps such a raft--if ever built at all--was used only for the very largest monuments, a canoe structure being more suitable for the smaller ones.

Canoe Rafts. The most feasible alternative to a log raft is the dugout canoe. The use of the dugout seems almost universal. Atkinson (1956) mentions the use of 35-55 foot oak dugouts in his reconstruction of the transport of the bluestones from their source to Stonehenge. Joseph Ames, a shipping foreman with experience in Micronesia, observed a 60 foot dugout war canoe rowed by 40 men with a carrying capacity of 5,000 pounds of cargo in the Fijis (personal communication). Pizarro noted the use of three large dugouts with sixty paddlers in the Gulf of Darien (Edwards 1965). Columbus encountered a large Mayan seagoing dugout used for trade near the Bay Islands. He described it to be the length of a galley, eight feet wide (beam), and manned by 40 men. Thompson (1954) remarks that canoes are depicted in murals dating from 1150 A.D. in Chichén Itzá, and adds that the Chontal Maya used forty-man canoes. At Tikal mythological beings ride in a large canoe incised in bone.

As anciently, the dugout canoe has continued to be used in river basins of the Coatzacoalcos and the Tonalá, though they are now more frequently powered by outboard motors than by oars. Bernal believes that one jade carving from Cerro de la Mesas is a representation of an Olmec canoe (1969:plate 68a).

Drucker reports that most dugout canoes made today are fashioned from either Ceiba or mahogany. Though Ceiba is convenient the wood is not particularly strong. It cracks and weathers rapidly unless treated with resin as a preservative and sealer. Mahogany (*Swietania macrophylla*) is much preferred because it is strong, durable, hard (yet carves well), and it is decay resistant.

Atkinson proposed the joining of several canoes side by side to carry stones to Stonehenge from distant quarries, and even conducted a replicative experiment by building a raft consisting of three canoes (1960). The stone rested on the pole superstructure which also served to link the elm canoes.

This idea also has the support of Heizer who suggests that the canoe structure is the only logical alternative not only in terms of manuverability but also in ease of construction (Heizer in Bernal 1969:52).

Drucker feels that such a canoe "barge" is unfeasible because of decreased manuverability and the time-consuming nature of canoe carving (personal communication).

The time and labor-intensive nature of canoe construction may not have been a problem. Instead of engaging in a major canoe construction project in conjunction with large stone transport, Heizer has suggested that the canoes used in everyday life were also used in heavy transport (personal communication). Workers would travel in their canoes to the staging area where the dragged stone would eventually be brought. The raft of canoes could then have been assembled on the spot. At journey's end, the super-structure assembly would be removed and the workers would return to their homes in their individual canoes.

In our reconstruction of a canoe-raft, the assumption is made that mahogany (Swietenia macrophylla) was used. S. macrophylla has been used extensively for canoes throughout the riverine communities of Veracruz and Tabasco in the recent past. It is admirably suited to canoe construction because of its hardness, strength, shock resistance and relatively high dimensional stability (Lamb 1966). The tree itself is usually over 100 ft. in height with a straight cylindrical bole before branching of 40 - 60 ft. (ibid.). Canoes carved from a mahogany log could have been 50 ft. long.

Canoes observed in Veracruz and Tabasco today exhibit a wide range of sizes. Heizer (personal communication) had an opportunity to measure four canoes at Villahermosa ranging in size from 42 ft. in length to 18 ft.

Length	Interior Depth	Beam
42'	24"	45"
30'	22"	29"
26'	24"	46"
18'	12"	20"

A canoe measured by Drucker was 26-1/2 ft. long, 1-1/2 ft. deep, and 2-1/2 ft. wide. It had a carrying capacity of 3/4 ton with three inches of freeboard (personal communication).

Though big canoes 50 feet or more in length could be made today, Drucker (ibid.) explains that shorter canoes are more manageable; the larger forms may not have been constructed except for special purposes. Also, the availability of mahogany has been reduced in coastal areas due to intensive logging operations. Large trees needed for larger canoes are becoming increasingly unavailable.

If canoes similar to that noted by Drucker were joined in a raft, more than 51 of them would be needed to carry the monument alone. Doubling the length and width of a canoe roughly quadruples its capacity, so a dugout 50 ft. long with a 5 ft. beam would probably have a capacity of about 3 tons. Fourteen canoes of these dimensions would be needed to carry a 38-ton monument (see Fig. 3).

A mahogany superstructure to join the canoes and bear the monument would weigh about two tons. The weight of as many as 120 men for rowing (and perhaps bailing) would add an additional 8.4 tons to the load. The monument still rests on its sledge and sleepers, another 3.2 tons. These additional items could add as much as 13.6 tons to the total load, or 52 tons in all (see Appendix D).

In these calculations it has been assumed that the depth of the canoe has been a constant variable, but in all likelihood as the dugouts were made longer and wider they would have been made deeper. We are not certain how much deeper they may have been, but if the depth was doubled the capacity of the canoe would have been more than doubled. Perhaps for a 50 foot dugout the depth would be 2-1/2 feet. A combination of 14 canoes 50 ft. by 5 ft. by 2-1/2 ft. deep could easily carry Altar 1 and all its attendant men and equipment. This model approximates the minimum number of dugouts needed and a possible design of the canoe raft. Smaller monuments would have required fewer canoes and less men, but we are interested here in the greatest numbers of men and equipment needed.

To construct a canoe-raft, the individual canoes would have met at the termination of the land transport route somewhere along the shores of the Coatzacoalcos River and there been fitted together to form a raft.

The sledge carrying the monument may then have been pulled and pushed across some sort of ramp onto the canoe-raft and lashed into place. The details of the loading operation can not be known, but it is of interest to note Barber's description of Egyptian obelisk loading. The embarkation was probably effected as follows:

> A dry dock was dug out at a short distance from the river bank at Assouan, in a position at right angles across the road along which the obelisks were to be dragged from the quarry. In this dock the lighter was built, and was afterward floated so that its deck was the exact height of the roadway. The obelisk was then hauled from the quarry and turned half around just before reaching the lighter, and launching skids were led to the deck. In this position forty drag ropes could be made fast to the obelisk and led over the ship's deck to the roadway beyond, where one-hundred fourty men could be harnessed to each, and the obelisk dragged on board. The dike separating the dock from the Nile was then entirely cut away and the lighter floated into the river. When the boat reached Thebes the operation was reversed. (Barber 1900:94).

It is questionable that this complex procedure was used by the Olmec. Possibly the raft was loaded while stranded on low tide or while the river was lowest during the dry season in anticipation of the rising tide or the swelling of the river during the rainy season. It is not known whether our theoretical embarkation point was effected by tides, nor can we say that the rainy season was best for water transport. Coe, et.al. (1967) consider riverine transport to San Lorenzo as being possible only during the rainy season, but it must be noted that rain-swelled rivers are particularly hazardous to negociate because of floating debris.

The task of moving the canoe-raft on the river was probably accomplished by a number of towing canoes which were connected to the raft by towlines of fiber or sinew rope. The dugouts intended for towing might have been brought from surrounding areas as the large 50 foot canoes were. They were probably not of a certain specified dimension and were not made specially for use in monument transport but were the dugouts used in daily life conscripted for the project. These canoes probably varied in size and therefore in the number of paddlers in each one. The idea of towing is utilized in ancient Egypt to tow obelisk barges. Solver (1940) discusses three lines of towing crafts--the center being chiefly concerned with pulling and the outer two had the primary objective of steering the barge and keeping it midstream. This was surely the case with the Olmecs; some of the towing canoes were for drawing the raft through the water while others were intended to conduct the raft past obstacles and through bends in the river. It is not known if a rudder was used. It is likely that men on board the raft could help propel it by paddling from the canoes on the perimeter. The idea of towing from the shore may be rejected as the margins of the river are either too steep or swampy and densely overgrown in either case. We assume that the same mechanism and manner of propulsion and steering was used in marine as well as riverine navigation.

Rate of Progress in Aquatic Transport. Twelve hundred men might have been able to drag the sledge carrying Altar 1 from the highlands to the Coatzacoalcos River in 14 days, using the Japanese monolith moving data as a basis for calculations. Meanwhile a smaller crew of perhaps some 100 workers could have been assembling the canoe-raft. It is possible that the men involved with dragging also assembled the raft upon arrival. One way or the other, probably not more than one or two days were spent in construction. Another day would have been required to load the monument with its sledge onto the raft and to secure it for the voyage.

It has been our assumption that the laborers involved in the whole project of developing a ceremonial center such as La Venta or San Lorenzo, importing stone from the Tuxtlas and other sources, as well as collecting of other materials were furnished by the population living in the support area adjacent to that center. Thus quarrying, dragging, towing, carving, and supervising intended for the edification of La Venta would have been done by the men who used that center, or those who were benefited by it. The same is true for San Lorenzo.

Most of the 1,200 men involved in dragging Altar 1 to the Coatzacoalcos River would have then returned to the support area from whence they came. Some might have remained to aid in the water transport, but the manpower requirements of this phase would have been much less than those of land transport.

There could have been as many as 120 persons on board the canoe-raft itself (the maximum number of individuals that could fit comfortably in rowing or paddling positions). This leaves over 1,000 additional workers. Some of these undoubtedly continued on in the towing canoes, but many were no longer needed and must have returned to their homes.

Heizer and Drucker (personal communications) believe that the Coatzacoalcos river flows at a rate of 1-2 miles per hour. The La Venta water transport route (Fig. 1, route 5) involves 32 km. of travel down the Coatzacoalcos with the current, and 49 km. against the current along the coast and up the Tonala. The canoe structure would require 72 men to move it at a rate of 1.5 knots while bucking a current of 1.5 mph.(4) Since there is ample room for this number of men on the canoe structure itself, there would be little need for towing canoes other than for steering purposes. The canoe structure would require only directional control while moving down the Coatzacoalcos because the current would move it along at the desired rate. At the rate of 1.5 knots (which is approximately--for our purposes--1.5 mph., 1 knot equals 1 nautical mile per hour, which is slightly more than one land mile) the canoe-raft with its load would reach La Venta in about six days (still assuming a six hour work day). Going up the river in San Lorenzo the manpower requirements are the same, but the time necessary would be only 4 days. The total manpower requirements for the Cerro Cintepec to La Venta transport of Altar 1 would be 110,592 man-hours. The San Lorenzo route would involve a little less, something on the order of 107,328 man-hours. Should additional canoes have been used for steering and extra towing, we might add 120 man-hours per canoe (20 men per canoe at 6 hours each) per day. Ten canoes for 6 days of water transport would increase our La Venta figure to 117,792 man-hours. So as not to underestimate, we will use this as our figure for the Cerro Cintepec to La Venta route, and 114,528 man-hours for the trip to San Lorenzo.

There is always a danger that the ocean part of the journey might have been plagued by rough seas, <u>nortes</u>, or other unexpected hazards, but this would not greatly effect our overall calculation. For every additional day on the water, only 432 man-hours would be added for those on the raft. If 10 towing canoes were being used, the total daily figure would be 1,632 man-hours.

<u>Conclusion</u>. We have tried to make a reconstruction of the most probable means of transport of a large stone monument in ancient Olmec times. We have tried to incorporate into our calculations a maximum of ethnographic and archaeological data and a minimum of speculative reconstructions. If our model is a valid one in light of what we know of Olmec organization, we might ask what more can we infer about the Olmec.

It appears that something on the order of 117,792 man-hours would have been required to transport the single largest stone monument from the quarry to the site. This seems to be divided roughly into 1,200 men working for 14 days and 472 men working for 6 days. These figures represent the maximum amount of time and labor involved. We assume that the Olmec workers were normally engaged in agricultural pursuits, as there is no evidence to suggest a permanent working laborer class.(5)

There is the question of whether there was sufficient time available for these farmers to work on something besides their fields. The requirements of slash-and-burn agriculture are such that the milpero may find himself with up to 100 continuous days of free time in a year (Heizer 1961). This 100 days follows the harvesting of the old milpa and the cutting of the new one, but preceeds the burning of the fields. It coincides with the dry season, from late January to mid-May. Using La Venta as an example, we can see that there was apparently a large agricultural population occupying the lowland area between the Tonala and Coatzacoalcos Rivers. Heizer (1960:219;1961; 1962) has calculated that the area probably contained about 18,000 individuals. Using the figure of 4.5 persons per average family (Cook and Borah 1960) we see that there were probably 4,000 family heads available for this work. To move a stone such as we have described, the manpower and time were apparently available; but how does this fit in with the total scheme of Olmec construction projects and the overall time involved?

Heizer (1968:23) has postulated that the origins of the Olmec culture might have come from a mutually beneficial arrangement between the local farmers of the southern Veracruz-Tabasco lowland and an organization of ritualists. He suggests that ritualists would provide religious information relating to the proper time to burn the fields, plant the crops, etc.(6) While the farmers would contribute to the support of the administrative priesthood by supplying food and goods as well as labor and men to be trained as craft specialists.

From this it is possible that a "highly innovative" and perhaps "dynastic" group of small numbers arose and directed the energies of the farmers towards the construction of the sites and the transportation of the stone monuments (ibid.), perhaps as a token of devotion and in remuneration for the ritualists religious-calendric advice.

Such a social structure would probably have sufficient control to engage in periodic massive public work projects, but not enough control to require this type of service regularly.

The Olmec farmer, in return for the religious ceremonies and blessings, could have repaid the hierarchial class regularly with food and perhaps small amounts of labor at the sites; but at the time of a great religious event--the end of a cycle, for instance--the importance of starting and continuing large religious projects, along with encouragement from the hierarchy, could have been enough to motivate the farmers to perform such tasks. These endeavors would, of course, be in their own self-interest as well because they wanted to guarantee the continued support and advice of the priests.

Such a ruling class would be able to plan in advance the major undertakings that would be required at each major religious ceremony, and could thus inform the agriculturalists well in advance that some of them would have to work at the La Venta site, or that some would be required to quarry limestone at Chinameca for a massive offering. The mechanical aspects of this part of the social organization really cannot ever be known. Some sort of voluntary community service is expected of the farmers in many modern communities in the area, and this type of community obligation in conjunction with a corvee labor operation perhaps similar to the Inca mit'a might have facilitated the procurement of the necessary labor force.

Heizer (1961) has estimated a total of 2,000,000 man-days as being necessary for the total construction of the site of La Venta. This estimate was made before the exploration of the Stirling Acropolis (Heizer, Graham and Napton 1968), and we feel that it would not seem excessive to add an additional 1,000,000 or more man-hours for the construction of this complex alone. (It should be kept in mind that additional mounds may yet lie undiscovered, so additional manpower may have been required). Of course, if all family heads worked for 100 days for several years in succession, they could have built the entire site in 7 or 8 years! This is totally irrelevant, for we know that the site was constructed in four major efforts spread out over 400 years (Drucker, Heizer and Squier 1959), but it helps to emphasize the point that it is not what could have been done, but what is normally done that is important to know (Sanders and Price 1968:55).

The Olmec "invention" of the earliest calendric system in the New World has been suggested (Coe 1957). As it appears to be the forerunner of the better-known Maya calendric system with its 52-year cycle, Heizer (1960:218+; 1961:47) has argued for the four major construction periods at La Venta being spaced at 104 year intervals throughout the 400-year occupation of the site. If the La Venta fluted pyramid required 800,000 man-days of labor to build, this could have been accomplished in eight work periods--one every 52 years. This works out to 1,000 men working 100 days every 52 years (Heizer 1960:220). If the general mound building at the site required 300,000 man-days, this could have been separated into four 100-day work periods, one every 104 years, involving 750 men each time (ibid.). If we add to this the 1,000,000 man-days for the Stirling Acropolis, this would require the addition of 2,500 more men every 104 years. This brings the total manpower requirement for every 104-year interval to a bit more than the maximum capacity of the support population. Of course, there is nothing to prevent work in "off" years, and perhaps every 52 years the entirety of the work was evenly divided instead of having the emphasis placed on the 104-year interval. If all of these constructions were being attempted at once, we would have 4,250 men at work during one season. It seems more probable then, that the work was somewhat spread out, with peak production periods probably correlated with the cycles of the religious calendar. If 118,000 man-hours were required to move the largest stone monuments, it would seem that this undertaking, too, would have been planned for a propitious religious moment. Stirling (1955) has suggested that the massive heads represent chieftans and were carved perhaps only once a generation (or once every 52 years?), which might coincide with the calendric cycle.

As nearly as can be calculated, the total weight of all La Venta stone monuments appears to be approximately 325 tons (see Appendix A). At 118,000 man-hours per 38 tons, all of the Olmec sculpture brought to the site would have required c. 1,015,000 man-hours in transportation time alone. If all monuments were transported at such cyclical intervals, this would be another factor which would overload the 4,000 men per year capacity. It seems likely that smaller stones could have been transported at almost any time; but that only the largest monuments were commissioned for a 52-year cycle ending. It would seem that the La Venta Olmec support population was, at least every 52 years, working at or near its maximum capacity.

We might ask here what they did the remaining 51 years when there was little work going on at the site. There was apparently a large amount of "free" time available, but as Kaplan points out with reference to the Maya culture:

> To show that the Maya only had to farm two or three months of the year and had plenty of spare time for community development, given social differentiation and increasing power at the top, presents a picture of bored aboriginals wandering aimlessly through the brush in search of a power structure to put them to work (Kaplan 1965:280).

Thus, although there was ample free time available, it is not enough to just say that the farmers got together and decided to build a ceremonial center. The underlying forces that motivated the work force at the end of each 52-year period to engage in such major undertakings did not suddenly appear at these intervals and then disappear. They were always present, though perhaps not in sufficient quantity or to a sufficient degree except when they worked in conjunction with the religious-calendric cycle.

This is not to say that this is the way it was, but when dealing with a group of individuals with the capacity for 160 million man-hours of work over 400 years, there must be some reason why only a fraction of this capacity was ever used. Because any 400-year effort requires continued control over the factors involved, the ritual leadership probably planned the entire venture in advance. If the degree of control were such that the dynastic rulers couldn't demand a certain output except on special occasions, this might explain how such a great work capacity existed without being fully utilized. A point may have been reached:

> beyond which the common people refused to go to meet what they considered intolerably heavy demands for their services, goods, and time. A bare suggestion of this in the La Venta site is the occurrance in its final phase, or large tombs and sarcophagi which may be interpreted as the material expression of the ultimate development of class differences in the form of burials of high priests within the ceremonial precinct (Heizer 1961:54).

It would be interesting to speculate as to the manpower requirements of the San Lorenzo site, but unfortunately no support population estimates have been published. Using our figure of 118,000 man-hours per 38 tons; plus the estimate of the weight of all San Lorenzo monuments as being between 200 and 250 tons, we can suggest that a labor force of at least this capacity must have been available. Coe (1968) describes a survey of a 75 sq. kilometer region surrounding San Lorenzo in which he says not more than 2,500 individuals could have supported themselves, but beyond this we have no information regarding whatever limitations--geographical or otherwise--that there might have been on the San Lorenzo support area. We would like to assume a similar type of ruling class and work pattern, but until we have some concrete evidence as to what went on at San Lorenzo, we will have to continue to work with the La Venta materials for much of our inferences.

Returning to the problem of transporting the stone monuments, it appears that the only limiting factor (in terms of the quantity of stone transported) was the availability of labor. Stone was always available in abundant quantities, and apparently there was enough time to move even the largest monument in one dry season. The hierarchial social structure did not inhibit the transport of smaller stones, and was a valuable support mechanism in the transport of the larger ones because of its value in planning ahead and controling large numbers of people. The only limitation we can see was in the availability of labor during peak periods. If we take Heizer's estimate regarding the population of the La Venta support area as correct, there were only 4,000 individuals available at any one time. If all the work was actually done at 52-year intervals, then something on the order of 4,500 workers, or a total population of 20,250 individuals was required.

Our reconstruction of Olmec heavy stone transport is in many ways highly speculative. In applying historical and ethnographic examples and the results of modern-day replicative experiments to the

Olmec we have tried to use caution, but the inherent uncertainties of analagous reasoning leave many unanswered questions.

It has been said that we know now perhaps 90% of all that we will ever know about the Olmec. The La Venta site alone has been almost completely destroyed by the expansion of the town of La Venta and the nearby oil refinery.

Though much of the material presented here can neither be confirmed nor denied, the uncertain future of Olmec studies may soon pressure many scholars into similar methods of analysis.

We hope that with carefully formulated models students of archaeology and history will continue to investigate the mysteries of ancient heavy transport as one tool in the reconstruction of ancient civilizations.

NOTES

(1) The number and distribution of such large stones in sculpture and architecture throughout the world is quite large and diverse. A description of each monument, its location and condition, would not be properly discussed in a paper such as this. There is abundant information concerning almost all phases of large stone transport which will be referred to when applicable. For a general discussion of the evidence for ancient heavy transport see Heizer (1966).

(2) For more information on climate see West, et.al. 1969; Poleman 1964; Vivo Escoto 1965.

(3) Just as Monument 19 at La Venta shows how the Olmec artisan adapted to the medium with which he worked, it is interesting to speculate that the shape of some of the colossal heads might have been predetermined by the configuration of the boulder as found at its source. A similar observation has been made by Hawkes and Woolley (1963) for the Old World:

> For important sculptures the Sumerians imported diorite (and sometimes trachyte), a hard stone capable of taking a fine polish... It would appear that this was not quarried but came in the form of boulders, and the size and shape of such could not but influence the sculptor's work. ...it is curious how frequently a seated Sumerian statue suggests the shape of the natural boulder from which it was economically carved (Hawkes and Woolley 1963:775).

(4) Our special thanks to Mr. Charles L. Wickers, Jr., Chief Engineer of the Port of San Francisco, for these calculations. Our thanks also to Mr. Mark Rasmussen for his work on the maps (Figures 1 and 5).

(5) Were there evidence for such a permanent working class, the question arises as to whether a large non-producing population could be supported by the Olmec agriculturalists. The La Venta support area contains about 900 sq. kilometers (Heizer 1961; Drucker 1961). With a population density of 20 persons per square kilometer (Sanders 1953), this comes out to 18,000 individuals. Slash-and-burn agriculture demands that approximately 5/6ths of the land be in fallow at any one time. Still, the potential land under cultivation in any one year would be 1/6th of 900, or 166 sq. kilometers. If a family of 5 can live on 1.5 hectares under cultivation (Drucker and Heizer 1960), then this area has the potential to support well over 45,000 individuals...well beyond the 18,000 we get using Sander's population density figure. An additional fraction of a hectare

per farmer would provide the surplus necessary to feed 4,000-5,000 additional individuals. Thus, if the need arose, a large non-agricultural class could be supported by the primary producers (see also Heizer 1960;1962).

If the workers used for transport were normally farmers, they would have already produced enough food to feed themselves during the course of their normal agricultural year. The problem would be in transporting the food to the place of work. Some could have been brought by the workers who went to the work area by canoe, but overland transport of as much as 75 kg per man would have been difficult. (753 g/day X 100 days = 75.3 kilos. See also Sanders 1953). This, then, would have been a factor taken into consideration by the priestly class when the work was commissioned, and perhaps the agricultural producers along the transport route were told to plant more corn the previous year to feed the additional people who would be passing through their area in the next dry season.

(6) Ritual plays an important role in the agricultural practices of modern inhabitants of the southern Veracruz-Tabasco area today, and may have its origins in these earliest ceremonies (cf. Foster 1942).

Appendix A: HEAVY BASALT MONUMENTS FOUND AT LA VENTA AND SAN LORENZO

La Venta Monuments	Weight in short tons
Colossal Head #1	24.0
*Colossal Head #2	11.8
Colossal Head #3	12.3
Colossal Head #4	19.8
Stela #1	5.5
Stela #2	10.5
Stela #3	25.5
*Altar #1	36.5
Altar #2	5.5
*Altar #3	13.7
*Altar #4	33.7
*Altar #5	18.6
*Altar #6	2.7
Altar #7	4.3
Monument #8	9.9
Monument #68	8.3
	242.6

Note: A rough calculation of the total weight of all the Olmec monuments known from La Venta based on dimensions given in Escultura Monumental Olmeca (de la Fuente 1973) is 325 tons. Not all of the monument dimensions are given, so calculations of their weights is not possible. For the sake of calculation, all monuments were assumed to be made of basalt with a weight of 180 pounds per cubic foot (3.183 short tons per cubic meter). This is only a rough estimate, but the range of 300 to 350 tons is probably fairly accurate.

San Lorenzo Monuments	Weight in short tons
*Colossal Head #1	25.3
*Colossal Head #2	11.8
*Colossal Head #3	9.4
*Colossal Head #4	6.0
*Colossal Head #5	9.9
Colossal Head #6 (Mon. 17)	9.0 (8-10)
Monument #14	35.0 (30-40)
Monument #20	16.3
Monument #51	12.3
Monument #60	6.2
	141.2

Note: The total weight of all the San Lorenzo monuments listed in Escultura Monumental Olmeca was 181 tons.

Appendix A (continued):

An unknown percentage of the Olmec monuments from this site may yet be undiscovered so an arbitrary addition of 40 or 50 tons would not seem unreasonable. Thus the range for San Lorenzo is probably between 200 and 250 tons. The possibility of many more as yet undiscovered monuments does exist (Coe 1968:55).

* monuments made of basalt from Cerro Cintepec.

Some of the weights above were calculated by the authors using the dimensions given in the following sources:

Clewlow *et.al*. 1967
Clewlow 1974
de la Fuente 1973
Williams and Heizer 1965

Appendix B: SLEDGE MECHANISM (see Fig. 2-3).

Runners: 2 runners for smaller monuments
3 runners for heavier monuments (LV Altar 1)
12' X 1-1/2' X 1-1/2'
therefore each runner has 27 $ft.^3$, and all 3 runners have 81 $ft.^3$.
if mahogany weighs 32 $lb./ft.^3$, then weight of 3 runners is 2,592 lbs.

Crosspieces: 6 crosspieces (1 for every two feet runner)
11' X 1' X 1'
therefore each beam has 11 $ft.^3$, and all 6 beams have 66 $ft.^3$, and weigh 32 X 66 = 2,112 lbs.

Bracing blocks: 2 bracing blocks
9' X 1' X 1'
therefore each block has 9 $ft.^3$ and all blocks have 18 $ft.^3$ and weigh 32 X 18 = 576 lbs.

Complete sledge weighs 5,280 lbs. or 2.6 tons

Sleepers: 25 sleepers (12 always under sledge)
12' X 1/2' X 1/2'
therefore each sleeper has 3 $ft.^3$ and weighs 96 lb. each.

Weight of complete sledge plus LV Altar 1 = 2.6 + 38 = 40.6

Appendix C: RAFT CONSTRUCTION

Weight of unfinished LV Altar 1	76,000 lb.
Weight of sledge and sleepers	5,280 lb.
Weight of 10 or 12 men	1,700 lb.
Total weight that need be supported	82,980 lbs.

1 $ft.^3$ of dry Ceiba can support 37 lbs.

82,980/37 = $ft.^3$ needed to support sledge, etc. = 2,242.7 $ft.^3$

Volume of raft + 700 $ft.^3$ for freeboard = total vol. of raft

2,242.7 + 700 = 2,942.7 $ft.^3$ of ceiba

2,942.7/(35' X 20') = 4.2 feet of draft

2,942.7 X 23 (weight of $ft.^3$ of ceiba) = 67,682.2 lbs.
Total wt. of raft

Final dimensions of raft: 35' X 20' X 4.2'

Final weight of load:	41.5 tons (82,980 lbs.)
Final weight of raft:	33.8 tons (67,682 lbs.)
Total weight	75.3 tons (150,662 lbs.)

The raft will support 41.5 tons with a 3 ft. draft and 1.2 ft. of freeboard.

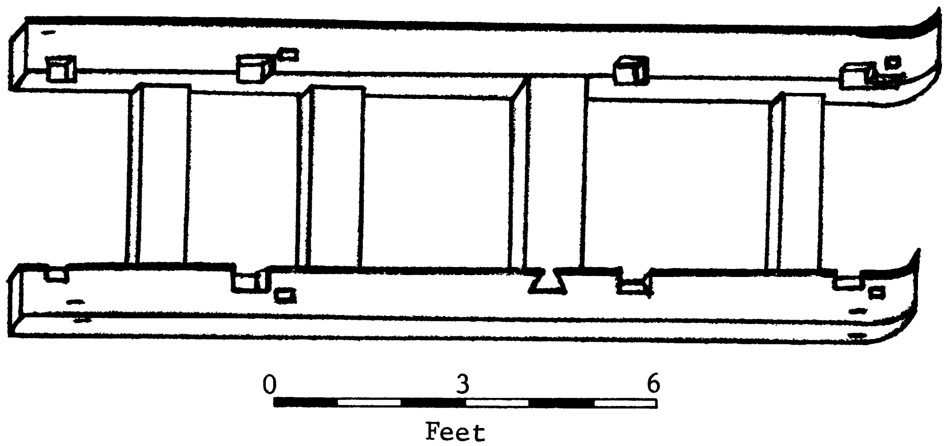


Figure 2: Egyptian Sledge (Solver 1940)

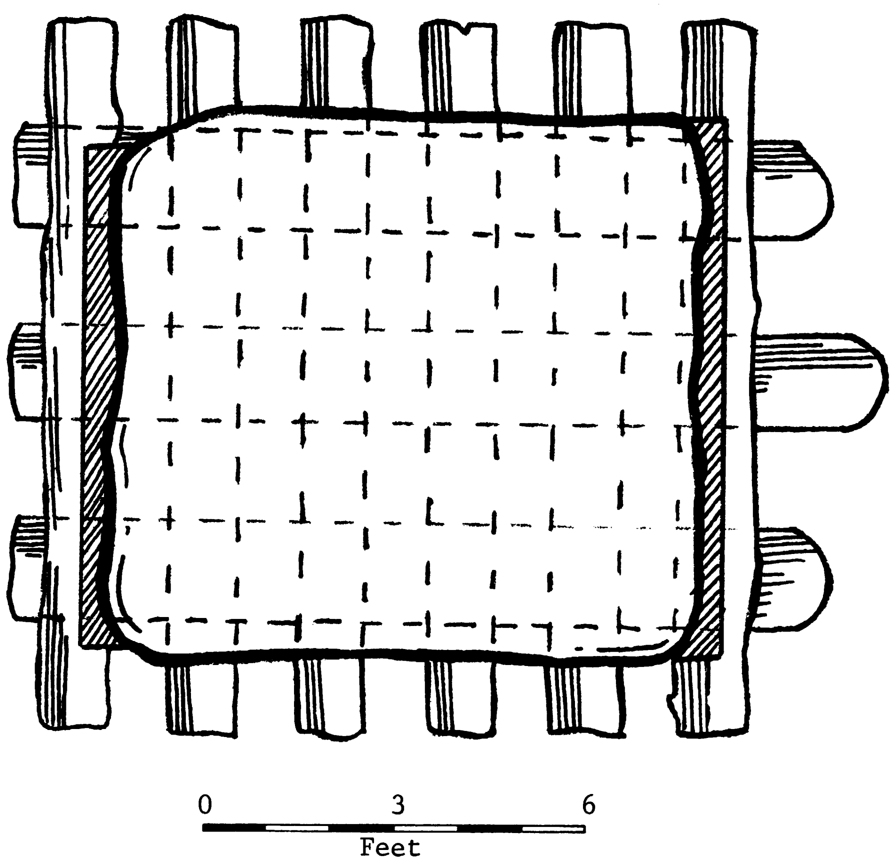


Figure 3: Hypothetical Sledge for Olmec Transport

Appendix D: CANOE-RAFT CONSTRUCTION (see Fig. 4).

Weight of LV Altar 1: 38 tons (unfinished)

Dimensions of Drucker's Canoe: 26-1/2' X 2-1/2' X 1-1/2'

Capacity of Drucker's Canoe: 3/4 ton

Number of canoes the same as Drucker's to carry LV Altar 1 = 51

Possible canoe length: 40-60 ft.

Capacity of 50 ft. canoe (with beam of 5 ft.) = 2 X 2 X 3/4 = 3 tons

Capacity of Canoe-Raft made of 14 50' canoes = 3 X 14 = 52 tons
(The capacity is greater because canoe depth increased).

Superstructure: all poles are 6" X 6" thick and are 50', 20', or 30' long (each pole may not be that long; but poles are lashed to span the raft.)
total weight of superstructure: 3,750 lbs. or 1.9 = 2 tons

Total length of full raft: 150'

Total width of raft: 30'

Depth: 2-2-1/2'

Anticipated freeboard loaded with stone and men (120) = 6+"

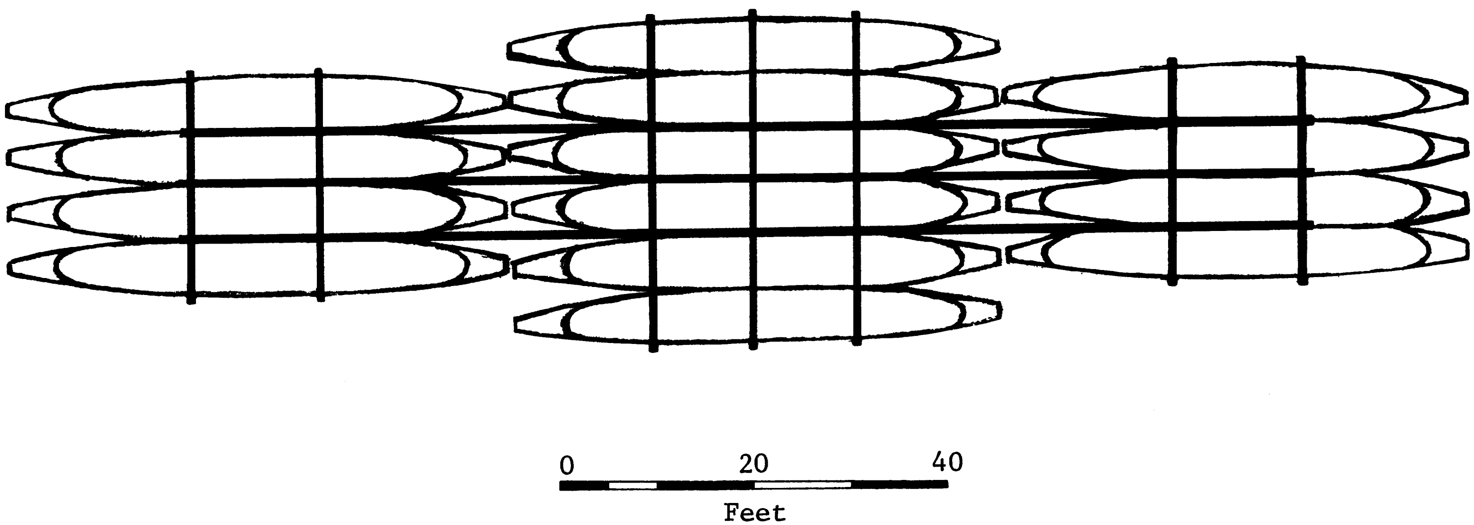


Figure 4: Hypothetical Canoe-Raft for Olmec Transport

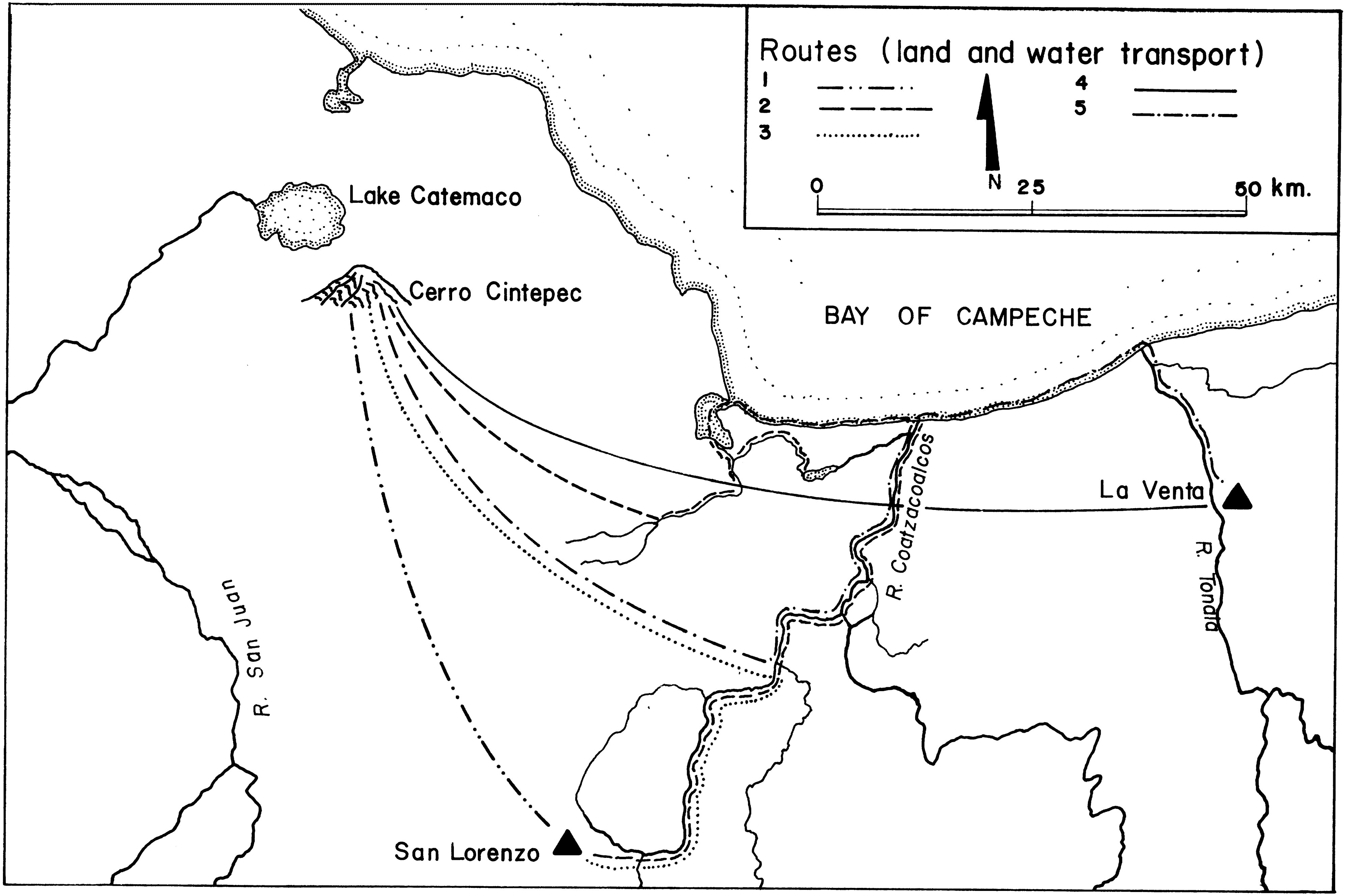
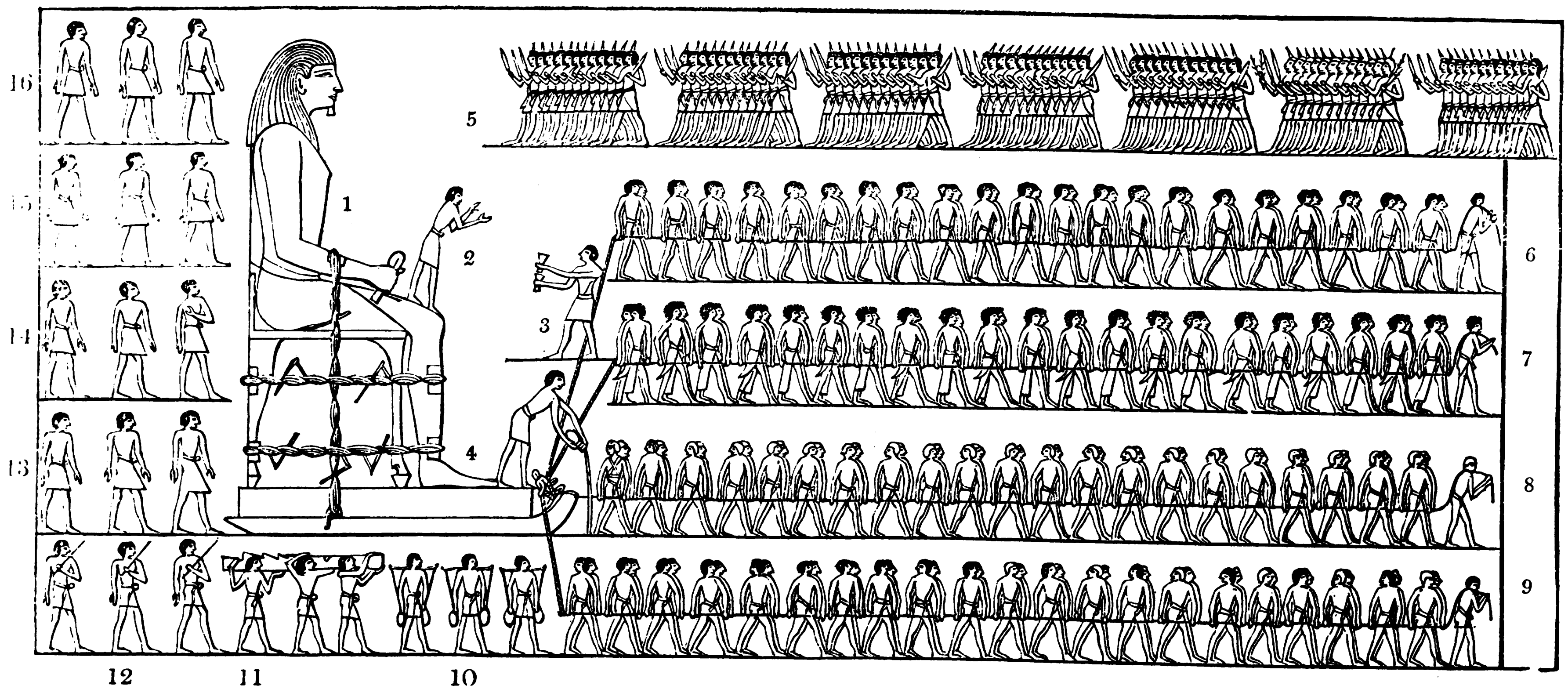


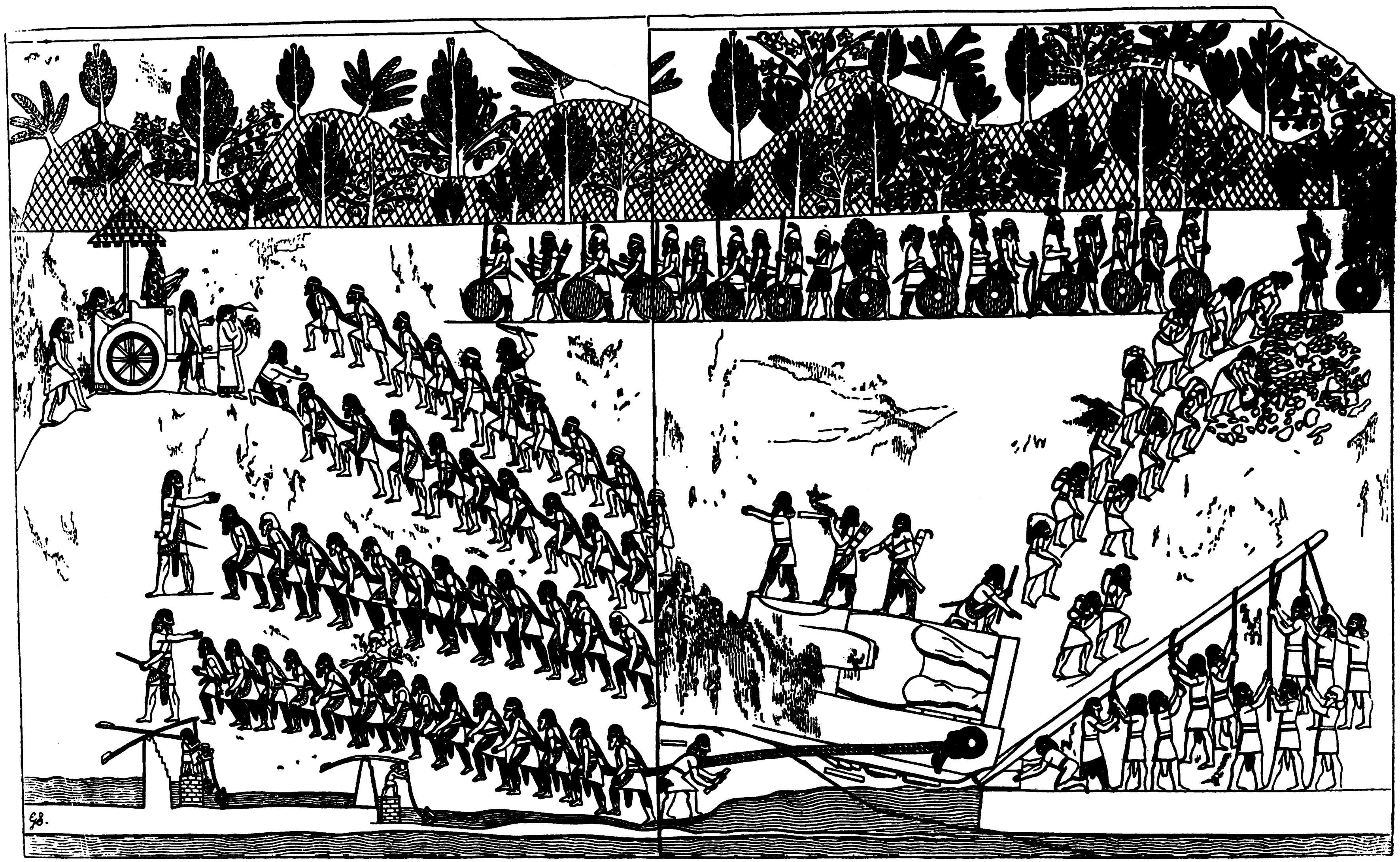
Figure 1. Projected Transport Routes for Olmec Lithic Material



No. 390. Mode of transporting a colossus from the quarries, from a lithographic drawing, by Mr. Bankes. *In a grotto at El Bersheh.*

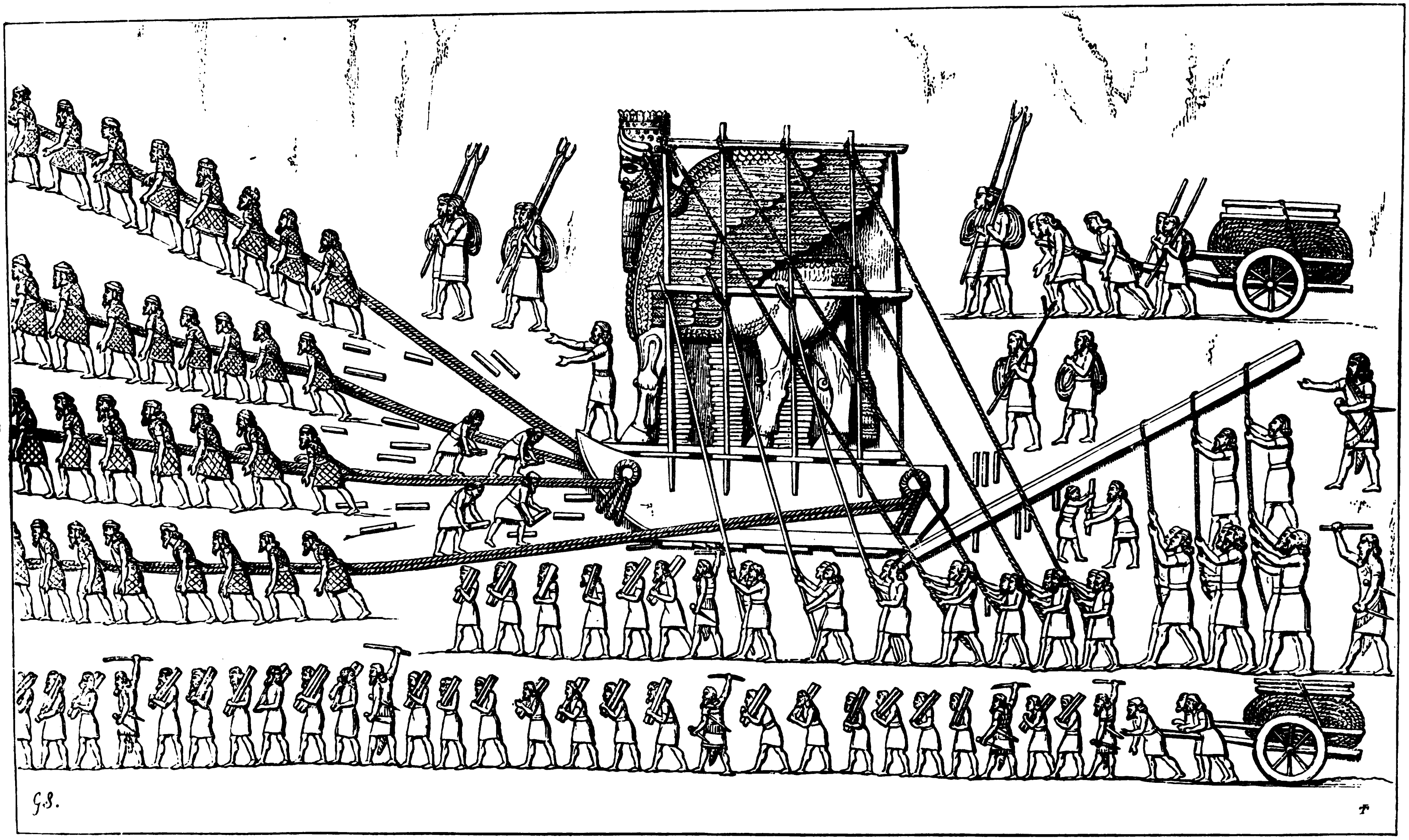
1. The statue bound upon a sledge with ropes. It is of a private individual, not of a king, or a deity.
2. Man, probably beating time with his hands, and giving out the verse of a song, to which the men responded; though 3 appears as if about to throw something which 2 is preparing to catch.
4. Pouring a liquid, perhaps grease, from a vase.
5. Egyptian soldiers. 6, 7, 8, 9. Men, probably captives and convicts, dragging the statue.
10. Men carrying water, or grease. 11. Some implements.
12. Taskmasters. 13, 14, 15, 16. Reliefs of men.

Plate
1



King superintending Removal of colossal Bull (Kouyunjik).

Plate
2



Assyrians placing a human-headed Bull (partly restored from a Bas-relief at Kouyunjik).

Plate
3

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II. A CONSIDERATION OF TIME AND LABOR EXPENDITURE IN THE CONSTRUCTION PROCESS AT THE TEOTIHUACAN PYRAMID OF THE SUN AND THE POVERTY POINT MOUND

Stephen Aaberg and Jay Bonsignore

II. A CONSIDERATION OF TIME AND LABOR EXPENDITURE IN THE CONSTRUCTION PROCESS AT THE TEOTIHUACAN PYRAMID OF THE SUN AND THE POVERTY POINT MOUND

Stephen Aaberg and Jay Bonsignore

INTRODUCTION

In considering the subject of prehistoric earthmoving and the construction of monuments associated with it, there are many variables for which some sort of control must be achieved before any feasible demographic features related to the labor involved in such construction can be derived. Many of the variables that must be considered can be given support only through certain fundamental assumptions based upon observations of related extant phenomena. Many of these observations are contained in the ethnographic record of aboriginal cultures of the world whose activities and subsistence patterns are more closely related to the prehistoric cultures of a particular area. In other instances, support can be gathered from observations of current manual labor related to earth moving since the prehistoric constructions were accomplished manually by a human labor force. The material herein will present alternative ways of arriving at the represented phenomena. What is inherently important in considering these data is the element of cultural organization involved in such activities. One need only look at sites such as the Valley of the Kings and the great pyramids of Egypt, Teotihuacan, La Venta and Chichen Itza in Mexico, the Cahokia mound group in Illinois, and other such sites to realize that considerable time, effort and organization were required.

In this paper, the focus of attention will be on two sites, each of which provides information concerning the construction activity at each site. The Poverty Point site in northeastern Louisiana, 20 miles west of the Mississippi River, is one of the selected sites. The features of interest here are the earthen mounds (one of which is the second largest in North America) and the extensive, geometric system of earthen ridges that is associated with the largest mound. The other site that will be considered is Teotihuacan in Mexico. Emphasis here is upon the largest construction at the site, the Pyramid of the Sun.

TEOTIHUACAN

The Valley of Mexico in the Mesa Central of Mexico has been an important cultural center in Mesoamerica since man first arrived in Mexico. The Valley and surrounding areas witnessed the rise and fall of numerous native civilizations, climaxing with the destruction of the Aztec empire by the Spanish in the early 16th century. Among the civilizations which arose in the Valley was one centered in the small sub-valley of Teotihuacan. Although it was not the first civilization in the Valley, Teotihuacan, beginning in the last century B.C., grew to become the major political and cultural center of the Valley and, most likely, of a considerable area outside the Valley as well. Typically, Oaxacan remains appear at Teotihuacan as early as the first century A.D.; later, Teotihuacan influences are seen as far south as the Mayan site of Tikal. At present, Teotihuacan appears to be the Mesoamerican site at which true urbanism first appeared. During its heyday, Teotihuacan grew into a city with an estimated population of 85,000. The city was well-organized with a planned street pattern and districts. Present were large, airy homes for the powerful, crowded apartment complexes for the plebes, and an elaborate ceremonial and political center (Weaver 1972).

The ceremonial center, with its long, broad Avenue of the Dead and two large pyramids, is the better known part of the site; the larger of the two pyramids, the Pyramid of the Sun, is the second largest structure in the Americas. The site, especially its pyramids, has long fascinated men and has stimulated considerable research into its origins. Although the site had been abandoned for over 700 years, the Aztecs were still worshiping at the pyramids when the Spanish arrived. The Aztecs attributed the pyramids to the Toltecs, the legendary ancestors, who in fact did not achieve prominence until well after the city was abandoned. The Spanish, for lack of any other information, accepted the idea that the Toltecs were founders of Teotihuacan and that belief persisted into this century. Leopold Batres (1889), who directed the first "archaeological" excavations at Teotihuacan for the Mexican government at the end of the 19th and the beginning of the 20th centuries, described the site as the "Sacred City of the Toltecs".

It is now known that the occupation of Teotihuacan entirely predates that of the Toltecs, but much uncertainty remains concerning the site despite, and partly as a result of, the fact that it has been known and studied for so long. A major area of uncertainty concerns the Pyramids of the Sun and Moon. A major problem with the Sun Pyramid is that even its physical characteristics are in doubt. Batres' main project while he was working at Teotihuacan was the excavation and reconstruction of the Pyramid of the Sun. In the course of his work, Batres altered the original form of the pyramid and, because he did not record the excavation and reconstruction processes, he made it extremely difficult to determine what the pyramid looked like before he started or what he did to change its appearance. Apparently, when Batres started, the outer surface of the pyramid was a disintegrating mass of adobe and stone, as the Teotihuacanos used adobe rather than mortar to bind the face of the pyramid. Batres probably expected to find an earlier structure within the pyramid, as is the case with many other Mesoamerican temple mounds which were enlarged by accretion. Unfortunately for Batres and the pyramid, the

Pyramid of the Sun was basically built in one stage.* Before he realized his mistake, Batres had already removed several meters (probably 4-6 meters, although the exact amount is unknown) of mortar. The surface Batres had exposed when he stopped soon began to disintegrate because of the lack of lime mortar, so Batres had the surface rocks cemented together (Linne 1934; Weaver 1972). As it stands today, the pyramid has five major recesses or steps at various heights. On one side, the remains of brackets which helped hold the outer facing in place can still be seen. Linne states that Batres' reconstruction "obtained-with more or less accuracy- the original shape of the pyramid, albeit reduced in size". Others (J. Graham, personal communication) believe that Batres altered the appearance of the pyramid considerably, including changing the angle of the sides. Weaver (1972) states that the pyramid followed the typical talud-tablero style architecture of Teotihuacan: "a rectangular body (tablero) with recessed inset, which rests on an outward sloping basal element (talud)...at Teotihuacan, the tablero always was larger than the talud." The Pyramid of the Sun was faced with volcanic stones set in clay and plastered over with a coating of lime plaster, not ordinary lime and sand mortar (Linne 1934; Weaver 1972).

Because of Batres' methods of reconstruction, the exact original dimensions of the pyramid are not known. However, Alexander von Humboldt, a Frenchman who visited Mexico at the beginning of the last century, recorded in 1803 that the Pyramid of the Sun was found to have a base of 208 meters (682 feet) and a height of 55 meters (180 feet) (v. Humboldt 1811). These dimensions are at variance with those of Batres' (1886) who measured the pyramid as 224 meters square at the base and 68 meters high. Nevertheless, v. Humboldts' (1811: 64-7) observations about the pyramid are of some interest as they shed light on its original form and are more accurate in some respects than are modern observations:

> The nations whom the Spaniards found settled in New Spain attributed the pyramids of Teotihuacan to the Toltec nation; consequently this construction goes back as far as the eighth or ninth century;... The faces of these edifices are to within 52 feet exactly placed from north to south and from east to west. Their interior is clay, mixed with small stones. This kernal is covered with a thick wall of porous amydaloid. We perceive,

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* R. Millon (The Teotihuacan Map. Part I. University of Texas Press, 1973) says (Caption for Fig. 17b) that the pyramid was built in at least two stages. The earliest construction was in the Tzacualli Phase (A.D. 1-150) in Terminal PreClassic times when the structure reached to within about 2 meters of its present height. The uppermost 2 meters was added either in late Tzacualli or post-Tzacualli times. No reference is made to enlarging the outer shell of the pyramid.

> besides, traces of a bed of lime which covers the stones... They formed four layers of which three are only now perceivable,... A stair of large hewn stones formerly led to their tops... Each of the four principal layers was sub-divided into small gradations of a meter...
>
> It would be undoubtedly desirable to have the question resolved whether these curious edifices of which the one (the Tonatiuh Ytzaqual) (Pyramid of the Sun)... has a mass of 123,970 cubic toises (33,743,201 cubic feet) were entirely constructed by the hand of man or whether the Toltecs took advantage of some natural hill... Their situation in plains where no other hill is to be found renders it extremely probable that no natural rock serves for a kernal to these monuments.

Two tunnels, one dug by Manuel Gamio in 1917 and the other dug by Eduardo Noguera in 1933, were driven through the base of the Pyramid of the Sun to answer v. Humboldt's question. As he suspected, the pyramid is entirely man-made. Millon, Drewitt and Bennyhoff (1965) re-studied the tunnels to determine the nature and age of the fill of the pyramid and whether the pyramid was built in successive stages. While their investigation did uncover possible traces of earlier structures, these structures were insignificant in bulk when compared to the pyramid as a whole (Millon and Drewitt 1961). The single stage construction of this pyramid clearly demonstrates, despite arguments to the contrary, that Meso-American cultures did attain a level of social integration, be it officially a "civilization" or not, that permitted the construction of monumental public works. Further, the midden which comprises the vast majority of the interior of the pyramid indicates that it was constructed during the Tzacualli (or Teotihuacan I) phase, dating from the first century A.D. (Weaver 1972), 200 years before the official "Classic" period when Teotihuacan flourished.

It is frequently stated (cf. Weaver 1972; Linne 1934; Acosta 1963; et.al.) that the pyramid fill consists of "adobe brick." Millon, et.al. (1965) demonstrated that this assertion was incorrect. While they did find evidence of adobe brick within the pyramid fill, the major portion of the pyramid consists of midden, mainly in the form of loose soil that contains some rock and huge quantities of sherds. The adobe brick that does appear might have served as a structural feature designed to contain the loose fill while the pyramid was being constructed.

If the early reports of the pyramid's dimension are uncertain, present day measurements are only slightly more precise. The most recent measurement available from Millon, et.al.(1965) gives the pyramid's volume as 1,175,000 cubic meters, but does not include basal dimensions or height. Linne (1934) lists the most detailed dimensions: 211 m. by 207 m. by 215 m. by 209 m. at its base; and

64.5 m. high. He gives its mass at 2,980,000 (presumably) metric tons. His volume of 993,000 cubic meters is quoted by Cook (1947) and others and it agrees with the volumes listed by Acosta (1963) at 1.5 million cubic yards and by Judd (1948) at 35,067,596 cubic feet. Heizer (1966) gives a volume of 840,000 cubic meters, but does not provide any dimensions.

Another major question concerning Teotihuacan is the nature of the subsistence base of its population, especially at the time of the construction of the pyramids. Of course, agriculture was the foundation upon which Teotihuacan existed. But did the Teotihuacanos rely on natural rainfall for their farming or did they practice some form of irrigation, either via stream diversion and canal networks or via chinampa farming? The question is central to the understanding of the nature of Teotihuacan society. Irrigation that involved the thousands of people in and around Teotihuacan implies a high degree of centralized power capable of maintaining a large irrigation system. Irrigation also increases dramatically the potential production and reduces the risk of farming, the effects of which allow for an increase in population and/or the possibility of the maintenance of a body of non- (food) productive leaders, priests and craftsmen. That is, irrigation would have permitted the achievement of that level of social integration and diversification which has been labeled "civilization". Palerm (from Graham 1966) states:

> It seems rather obvious that a rainfall agriculture, never extensive in Mesoamerica, could not accumulate an adequate and constant surplus to maintain the urban centers... (p. 31)
>
> ...a strong socio-political organization seems to be the only way open to people with a poorly developed technology to have and run large-scale public works (p. 39).

Armillas (1948) states that rainfall in the Valley of Mexico today is sufficient for only one crop of maize; irrigation is necessary for a second crop. On the other hand, Gamio (1922) states that irrigation is now necessary for farming in the sub-valley of Teotihuacan. However, it is likely that a drop in rainfall has occurred since the pre-Classic because of man's activities in the area, including the deforestation of the sub-valley and the draining of most of the lakes in the region, a situation which does not obtain to as great an extent in the Valley of Mexico. The difference in rainfall is slight, but significant; it, therefore, seems at least possible that rainfall farming was possible at Teotihuacan before deforestation and land reclamation. Millon (1954) and others point to an analysis of pollen profiles from the Valley of Mexico by Sears (1951) which seems to indicate a dry period beginning in the late pre-Classic. This indicates to Millon that irrigation was necessary at Teotihuacan. Sanders (1962) states that Sears' data are "highly suspect".

Evidence does indicate that during the Tzacualli phase, when the Pyramid of the Sun was being built (A.D. 1 - A.D. 150), people were moving from the hills near Teotihuacan to the alluvial plains and piedmont (Weaver 1972) thus indicating a shift in agricultural pattern. But as of the present time, no direct evidence for irrigation during this period has been discovered (Sanders 1962). Sanders and Price (1968) believe that irrigation can be demonstrated for the Classic (A.D. 300 - A.D. 900). Weaver (1972) infers that irrigation was practiced at Teotihuacan by the late pre-Classic, though she admits to a lack of data. Regardless of whether there are data for that time period, the Pyramid of the Sun had already been built by a people for whom there is no evidence of irrigation. The Pyramid of the Sun is ample evidence of a high degree of sophistication and organizational ability for these same people. There is no evidence of a highly developed, tightly controlled irrigation system which Palerm and Sanders seem to require as a pre-condition for the construction of a public work as monumental in scale as the Pyramid of the Sun.

Assuming there was no irrigation during the Tzacualli phase at Teotihuacan, or at least not an extensive, centralized system, farming would have been limited to the rainy season from May through November, a period of approximately 200 days. For the purposes of this study, it will be assumed that the remaining 160 days were, more or less, "surplus" time that would have been available to some extent for public work. Erasmus (1965) cites a study by Ian Hogbin of the Wogeo chiefdom in New Guinea which states that each household averaged 40 to 45 days of community work per annum. The important fact there is that the Wogeo are not a "state" level society. The chief has no coercive power to force people to work. Erasmus' figure, then of 40 days per annum per household will be taken as the minimum number of work days in this study. At the other end of the scale, 200 days per annum per household will be used as the maximum number of days of community work; this figure assumes that members of the households other than that of the adult male head would also perform community service, thereby raising the number of work days per family. One hundred days a year will be used here as an intermediate figure; 100 days a year seems a likely amount of community service, given a project as great and compelling as the construction of the Pyramid of the Sun. Weaver (1972) gives a population of 30,000 for the end of the Tzacualli phase; using this population as the maximum population available for the construction of the pyramid, 6,000 households would be contributing work to the community (accepting five as the average family size).

As the Mesoamericans were without draft animals or vehicles and relied entirely upon human labor for all construction tasks, factors affecting the output of manual labor become important in any time-labor estimate. Factors which must be considered are the manpower required for excavation and transportation of fill materials (loose, sandy earth, clay, rock, and lime for the pyramid), the manpower (mp) required for construction of special sections of the structure (i.e., the stone-faced outer layer), the manpower for the production of lime plaster; length of the work day; distance raw materials had to be transported; density of materials transported; weight carried on each trip; available work-force; and number of work days per year.

For this study, the man-days necessary for excavation was calculated using data Erasmus (1965) collected from a study of the Mayo Indians of Sonora. Using a hardwood digging stick, Erasmus' informants could excavate 2.6 cubic meters of earth a day. The rate of excavation would necessarily depend upon the type of soil. A loose soil is assumed for the pyramid as a midden full of sherds would not be expected to pack. Erasmus' figure, then, is probably too low for the rate of fill excavation; however, the same figure is used for the rate of the exterior clay, which would probably require more manpower to excavate. The two rates are assumed to average to the 2.6 cubic meters of output per day given by Erasmus.

Manpower required for transportation was calculated using the daily output and manpower formulas and tables in United Nations publication ST/-ECAFE/SER.F/17 (Earthmoving by Manual Labour and Machines, hereinafter referred to as UN) and the Economic Commission for Asia and the Far East publication E/EN.11/WRD/Conf.3 L.1 (Manual Labour and Its More Effective Use in Competition with Machines for Earthwork in the ECAFE Region, hereinafter referred to as ECAFE). Manpower for transportation on the level, with a loading height of 0,

equals $q \dfrac{1}{\frac{L}{V} + \frac{L}{V'}} H$, where H = work hours per day, q = capacity of the container used for transportation expressed in cubic meters or kg, L = average transport distance, and V and V' = average velocity, of the basket carrier, loaded and unloaded, respectively. The loading and unloading time are not considered, nor is the time lost per trip. It was assumed to be five hours as the most likely average time actually spent per day (see Erasmus 1955, 1965); nine hours was used as a maximum work day. A seven hour work day was also used in the calculations as an intermediate figure. However, a nine or even a seven hour work day was probably unlikely. The warm temperatures of the Valley of Mexico during the middle part of the day would probably have precluded such long work days, particularly for such strenuous work as voluntary earth moving. Indeed, when Erasmus (1965) conducted his experiment, he found that productivity dropped so dramatically that he eliminated the sixth hour of work from his calculations. In this paper, seven and nine hour days were used to compute the time necessary for construction only for the volume of the Pyramid of the Sun given by Linne (1935) and others to illustrate the range of variation in estimates when different length work days are introduced into the calculations. When expressed as a volume, q (capacity of container) is calculated by multiplying the density of the transported material times the weight of a basket load of material. For the fill, Erasmus' density of sandy Sonoran earth of 1.3 was used; for the clay, a density of 1.7 for light clay (taken from UN Table 45) was used. The rock in the adobe and rock outer coating was native basalt that is abundant in the Teotihuacan area and need not be excavated or broken up (cf., Castaneda 1925, footnote on p. 53). A density for basalt of 3.0 was taken from Braumeister's Standard Handbook for Mechanical Engineering (1958).

Three values for the mass of basket loads were used: 15 kg. as a minimum mass (based on Shetrone's (1930) measurement of preserved basket loads from Monk's Mound). Forty kg. was used as a maximal value, as suggested by the ECAFE value for weight carried by Indian workers who were affected by heat. Twenty-two kg. was used as an intermediate and most likely value as suggested by Ford (1955a), Fowke (no date) and Erasmus' 1965 experiment. Values for L (average transport distance) vary with each substance used. The fill was assumed to have been excavated within a 1 kilometer radius of the pyramid, with an average transport distance of 750 meters. Clay was assumed to have been excavated within 750 meters of the pyramid, with an average lead (transport distance) of 500 meters. Rock was assumed to have been collected within a 3 kilometer radius of the pyramid, with an average lead of 2.25 kilometer. Lime, with a density of 1 (from Braumeister) was arbitrarily assumed to have been manufactured 5 kilometers from the pyramid. All materials were assumed to have been transported in two stages: Stage one--from source to a stockpile at the base of the pyramid, with no lift; and Stage two--from the stockpile to the pyramid with an average lead of 30 m. and an average lift of 18 m. (18 m. is the height of the first layer of the pyramid which contains approximately half the total volume, (c.f. Millon 1965). Lift introduces an additional manpower factor; an average, constant value of .342 manpower (mp) per cubic meter for a five hour day was extrapolated from ECAFE. Man-days necessary for the manufacture of lime was taken from Erasmus (1965). Again using Erasmus' 1965 data, an extra component of required man-days was added to the total manpower requirement to take into account the work needed to fit the stones in the outer layer of the pyramid. Work force was calculated at 6,000 (one per household) for all equations, except for the manpower requirement for rock transportation. Since the rock is ubiquitous and is available in various sizes, it was assumed that other members of a household would contribute some time to its collection, thereby yielding an estimated two additional workers per family or a work force of 1,200.

The details of the calculations using the above variables and formula are presented in Appendix 1. Table 1 below gives a portion of the final results. The estimates range widely from a maximum time of 61 years to a minimum time of 4.4 years. As was mentioned previously, 22 kilogram per load probably best approximates the ancient load size. If 100 days per year is taken as the time spent on such a major project as the Pyramid of the Sun, the estimated time for construction for the pyramid ranges from 10 to 20 years, with the

Table 1. Time in Years Necessary to Build the Pyramid of the Sun.

Load size / Volume ↓ / days work	15 kg			22 kg			40 kg		
	40	100	200	40	100	200	40	100	200
$1.17 \times 10^6 m^3$	61.8	24.7	13.4	51.8	20.7	10.3	43.9	17.6	8.8
$9.93 \times 10^5 m^3$	48.2	19.3	9.7	42.5	17.0	8.5	26.1	14.4	7.4
$8.40 \times 10^5 m^3$	20.4	12.2	6.1	26.3	10.5	5.2	22.3	8.9	4.4

Workday = 5 hr.

inconsistencies in pyramid size from modern reports remaining as the only uncontrolled variable.

The time and labor estimates given in Table 1 and in Appendix 1 were calculated on the basis of the assumption that labor was voluntary, or at least not coerced physically. People would be expected to be motivated to work by "the desire for public approval and prestige, duty to the community, religious sentiment, pleasure, and pride in craftsmanship" (Erasmus 1965). The size of the pyramid, the complexity of organizing such a long term project, and the amount of time involved (most likely around 15 to 20 years) strongly suggest that some specialists were present at Teotihuacan in the opening century of this millenium, probably in the person of priests who also functioned as architects, organizers, and engineers. The estimates derived here do not, however, suggest the presence of full-time craft specialists. If Weaver's (1972) population estimate of 30,000 for the Teotihuacan locale by the end of the Tzaculli phase is accepted, then construction of the pyramid by the number of specialists which could have been supported by such a population would have taken vastly longer than by community effort. Cook (1947) estimated that 300 full-time specialists worked on the Pyramid of the Sun. To support such a population of non-subsistence workers and the other functionaries associated with the project, Cook estimated a population of 150,000, a much greater number than the evidence suggests. Further, 300 specialists working even 300 days a year would still have required 10 to 12 years to construct the pyramid (assuming 22 kg. loads and a five hour work day). As can be seen in Table 1, such a time for construction is only slightly less than that possible for a citizen work force (using Linne's volume and 22 kg. as the load size).

Brainerd (1954) and Erasmus (1965), on the basis of very crude data, estimate the man-days of labor necessary for the construction of the pyramid at roughly three million. The data and controls presented in this paper yield a man-day estimate of 5 to 15 million, with an estimate of 10 million man-days as the most probable figure.

POVERTY POINT

Of the three mounds at Poverty Point, the largest is the Poverty Point mound. It has an elevation of 70 feet and overall basal measurements of 640 feet north to south by 710 feet east to west. From the summit, a flattened area about 15 feet in diameter, running east to west on both the north and south side of the mound, are several narrow stepped ridges 180 feet long. On the east side of the mound summit is a gently graded slope that Ford and Webb (1956) suggest could have been used as a platform that provided easier access to the summit, since the west side of the mound is extremely precipitous. This slope drops to a flat rectangular portion of the mound that is 23 feet high and measures 240 by 300 feet. Ford and Webb (1956) later note that this mound "is aligned rather closely to the cardinal directions" and that it lies directly west of the octagonal ridges of the site, all of which may reflect the organization and planning necessary to construct the earthworks. From what can be determined by a core drilling of this mound and by excavation of the other mounds at the site, Poverty Point Mound was constructed mostly of brown and yellow clay with some occurrences of loam and whitish topsoil.

Of the information available on the Poverty Point site at the time of this report, none revealed any excavation that had been carried out on the Poverty Point Mound itself, other than the drilled core taken by Ford and Neitzel in 1953. The precise nature of the mound is, therefore, in question. It is not known definitely whether the mound is an effigy mound or a burial mound, though its artificial nature is not in doubt. The core drilled to a depth of 61 feet from the mound summit showed continually changing soil color (and texture) and a flint chip at 56 feet. Later investigations of eroded cuts in the lower platform on the east side of the mound showed evidence of basket loading. Impressions of basketry were found here (Ford and Webb 1956; Ford 1954, 1955a, 1955b, 1955c). Ford gives the volume of the Poverty Point Mound as 185,000 cubic yards (141,221 cubic meters).

The second largest of the three mounds at the Poverty Point Site is the Motley Mound, about 1-1/2 miles north of the Poverty Point Mound and the octagonal ridges. It is similar in shape to the Poverty Point Mound, but is considerably smaller. Ford and Webb (1956) say of the two mounds:

> If the peculiar shape of the Poverty Point Mound is considered to be oriented towards the west, away from the center of the octagonal arrangement of ridges, then the Motley Mound is oriented towards the north, always away from the center of this figure. The summit is formed by a high, narrow, east-west ridge. Again, a small flattened platform lies at the highest point, near the center of the ridge. The crests of the ridges on either side of the platform descend by poorly defined steps, and a slight sinuosity of the ridge line is observable.

The Motley Mound has basal dimensions of 400 feet by 600 feet and is 56 feet high. This mound and the small 21.5 foot high conical mound 740 yards north of the Poverty Point Mound contain 265,000 cubic yards (202,291 cu. m.) of earth (Ford 1955a).

The small conical mound, though not nearly so large or structurally impressive as the other two, disclosed some important information on mound construction when several test trenches were run through it by Ford and Webb. Upon excavation it was found that this mound had been built in stages and contained four floors, one of which held the remains of a number of containers of earth. From these "basket-loads" preserved on this floor, Ford was able to determine the average size of the load (50 pounds), the weave of the basket and the basket design, thus providing good evidence as to how the earth was transported to the mound. Later, Ford and Webb state that "the containers full of clay found on Building Level 4 clearly were intentionally placed. In this stoneless alluvial valley they are possibly analagous to the layers of gravel or stone that cap primary stages of many of the Hopewell Cultural Mounds of Ohio". Impressions of basketry came from other areas at the Poverty Point Site also and it is assumed that they were considered in Ford and Webb's conclusion that 50 pounds was the average load size.

The Geometric ridges contain over half the total volume of earth in the mounds at the site. There are six ridges, concentrically arranged, that form half of an octagon, with four "aisles" radiating out from the center, cutting across the ridges. The ridges are, on the average, six feet high, although the original height is difficult to determine because of erosion and cultivation. These ridges, approximately 80 feet across, stretch to the very edge of a 15 foot bluff that overlooks Bayou Macon. Webb and Ford (1956) later say that they "think that the excavations in the concentric ridges that form the portion of an octagonal figure three quarters of a mile in diameter have demonstrated that the dwellings of the inhabitants were arranged along the crests of these ridges, although no direct evidence of the dwellings was found". Following this, they make a statement regarding population size at Poverty Point;

> In the absence of evidence as to the size and arrangement of houses at this site, an estimate of the population is difficult. If the octagonal figure were symmetrical and complete in the eastern portion, which is now erased, about 11.2 miles of artificial ridge was built and occupied. If houses were arranged along these ridges at 100 foot intervals, there would have been about 600 houses in the town. There were probably several times this number. In any event, a population of several thousand people is indicated.

The archaeological record seems also to indicate that the 530,000 cubic yards (404,581 m^3) contained in these ridge structures came from the spaces between the ridges, in which case the work required for construction of the ridges would have been sufficiently less than if the soil had been transported any distance.

A consideration of some cultural phenomena and the subsistence pattern is necessary here as they are directly related to the work force and organization that would have been necessary in the construction of the earthworks at Poverty Point. Ford and Webb (1956) say of the Poverty Point peoples:

> Culturally the Poverty Point Complex seems to belong at the end of the Eastern Archaic phase. The diagnostic traits that define its cultural position are: cooking with heated stones (artificial stones of baked

> clay), crude adzes or hoes, celts, tubular pipes of clay and stone, steatite vessels, two-baled flat gorgets, bar atlatl weights, bannerstones (rare), plummets of hematite and magnetite, copper (two pieces), stone beads, and a substantial proportion of corner-notched projectile points.

They also note similarities between certain Poverty Point traits to some of those from the Adena and Hopewell cultures of the Upper Mississippi Valley. The subsistence pattern would had to have been based on agriculture to insure a staple food source for the large population necessary for the construction that was performed at Poverty Point.

There is no evidence of any other staple food source at Poverty Point, such as the shell middens that have accumulated in some areas of the Southeast. The only direct evidence for agriculture at the site is the one bit of fired clay into which a corn cob was pressed, leaving an impression (Ford 1955a). Possible indirect evidence of agriculture is the celts and adzes or possibly hoes. These people most probably depended on hunting and gathering for a good part of their diet as did most agricultural groups of the east. There was no mention of faunal remains in the site report; however, tools related to a hunting economy were found that included cutting, scraping and perforating tools and substantial number of projectile points.

The first element considered in the discussion of time and labor involved with mound construction at the site is population. Using Ford's figure of 600 houses that were built on the geometric ridges at the site, a population of 3,000 people can be assumed in the vicinity of the Poverty Point mound. Quite possibly a population was distributed in the outlying areas around the site. Taking this into consideration, using the average maximum family size as five and assuming all of the houses were occupied at the same time, a maximum population at the Poverty Point site at any one time is set at 6,000 people. Accepting S.F. Cook's figures of 173,000 for the population of the Teotihuacan area and requiring 25,800 acres of corn at 40 bushels an acre yield, a population of 3.5 per cent (6,000) of Cook's total would only require around 900 acres of corn to support themselves (Cook 1947). There is adequate land available for cultivation on Macon Ridge, the site of Poverty Point, and the required acreage may have been even less if the people had a secondary dependency on hunting and gathering. An alternative, smaller population figure will be considered, assuming that only half of the houses were occupied at any one time and assuming that an equal sized population existed in the outlying area around the mounds. This yields a figure of 300 household heads in the ridge area and 300 in the outlying area. Using a minimum family size of five (any lower would result in a decreasing population or ZPG), the total population in this alternative situation would be 3,000.

In determining the cubic content of the structures at Poverty Point, the figures Ford (1956;1955a) gives were accepted and used in computations. The cubic contents of the features at Poverty Point are:

Poverty Point Mound	185,000 cubic yards
Motley Mound	
Conical Mound (Mound B)	265,000 cubic yards
Octagonal Ridges	530,000 cubic yards
Total	980,000 cubic yards
	(748,092 cubic meters)

The total weight of the earth in these structures is 3,305,817,585 pounds (1,502,644,357 kg.), using a weight of 2.0 metric tons per cubic meter of heavy clay (UNESCO 1961). It is assumed that the bulk of the soil used in construction was of a clay-like nature, since this was the case in Mound B which was more extensively tested than any of the other mounds. The soil in the mounds was extremely hard packed; this is another reason for using the weight and density of heavy clay.

The time required to construct the mounds at Poverty Point must have been considerable. The time the people had available for non-essential labor would have largely been dependent on the labor requirements for subsistence. Erasmus (1965), in reviewing the literature on primitive technologies and agricultural societies derived an average minimum figure of 40 days of work contributed by each head of family in pre-state societies. This figure will be used for one set of time-labor calculations.

In the area around Poverty Point, the average growing season, determined by the earliest killing frost in the fall and the latest killing frost in the spring, is 220 days (USDA 1944). If the assumption, that some agricultural activity was going on during this time, is accepted, 145 days remain to be devoted to other activities. Bowen (1961) says there are six basic requirements for all agriculture. They are:

1. Ground must be broken up
2. A seed bed prepared
3. Animals kept away from the growing crops
4. The harvest taken
5. Crops prepared for storage use
6. Crops stored

Considering all of these activities, it seems that there would have been adequate time to devote to other activities during the growing season. The artist DeBry, in 1564, noted that a group of Florida Indians, after planting their crops, left the fields alone from the twenty-fourth of December until the fifteenth of March (Fundaburk

1958). Here is a case in the southeastern United States where, for an 81 day period, no agricultural maintenance was necessary at all. Waddell (1972), in his study on the Aruni, an agricultural people of the New Guinea highlands, states that 49 percent of the Aruni's time at home is spent in food production. Here, too, considerable time would have been available during the growing season to devote to other activities. The 49 percent figure included activities such as fencing and the care of pigs, a factor that would not have been involved in food production at Poverty Point. Taking into account the above mentioned information and realizing that there were other tasks also to be done, such as hunting and gathering, house maintenance, socializing and religious activities, a maximum of 150 days contributed by each house-head is used here. This figure is used in a separate calculation of time-labor. In yet another set of calculations, a figure of 100 days contributed by each house-head is used. This figure was reached very arbitrarily and is used to show a medium range in the effort required on construction of the earthworks. It will also represent a figure that is between Erasmus' minimum man-days and the maximum man-day figure.

Erasmus (1965) also conducted experiments with the Mayo Indians of Sonora in Mexico concerning manual labor that was involved in excavating and transporting earth. He found that a five hour work day was the most efficient when a man is involved in the fairly strenuous work of excavation and transportation. Also in his observations of the Mayo, Erasmus noted a maximum nine hour work day. The reason that efficiency was reduced after five hours of earth moving, Erasmus feels, was due to the effects of the extreme heat of the Sonora region which rose from 84 degrees at 6:30 A.M., the beginning of the work day, to 110 degrees at 11:30 A.M. However, the temperature in northeastern Louisiana should not have been much of a problem since the temperature rarely goes above 100 degrees and usually does so only in the late summer months. Both work-day figures (5 and 9) are used in our calculations, as is a median day of seven hours.

The soil of Macon Ridge, upon which Poverty Point is built, was formed from earlier stages of the Mississippi and Arkansas Rivers and seems to be the source for the soils contained in the mounds (Webb and Ford 1956). As mentioned earlier, the soil used for the construction of the geometric ridges was obtained from the area between the ridges, according to evidence disclosed by excavation of several test areas among these ridges. The soil for the mounds must have come from the plains surrounding the site as there is no single "quarry" source. There would have been a considerable depression made in the landscape if 450,000 cubic yards of soil had been removed from one spot. In 1591, DeBry (Fundaberk 1958) observed preparation for the construction of an earthen altar by some Florida Indians, which included leveling the land. In leveling an area for mound construction, not only was the surface prepared for the structure, but the soil removed from the leveling could also be used in construction. A maximum limit of 600 yards distance for transporting soil to the mound sites will be used. Any distance further than this would have reduced efficiency greatly. The average speed of a laborer carrying a load of soil has been determined by a UNESCO study on manual labor as 3 km. an hour (UNESCO 1957). At this rate, it would take 10 minutes just to transport a load 600 yards. It is improbable that the soil sources would have been located much further away. Using a radius of 600 yards for a soil source around the three mounds, the average transport distance would be 400 yards. This distance is computed by taking the radius of a smaller circle containing half the volume of the larger circle and half the volume of the soils in the mounds. An area of this size would have yielded enough soil for construction of the mounds by removing only 1.2 feet of the soil covering.

To establish the labor involved in the transporting of the soil, the average basketload size must be determined. As mentioned earlier, Ford and Webb (1956) determined an average load size of approximately 50 pounds for the Poverty Point site. They arrived at this figure by noting the basketloads and impressions that were exposed during excavation. Shetrone (1930) says that he carefully observed and measured basketloads in his investigations into primitive mounds and found that workers seldom carried over 20 to 25 pounds in a load. Jewell's (1963) experiment, in which English students actually constructed a mound using primitive tools, pointed to 30 pounds as the most economical load. Fowke (n.d.) says a man can easily carry half a bushel or 5/8 of a cubic foot in one load. The weight of 5/8 cubic foot of common soil is between 45 and 50 pounds (Braumeister 1958). Erasmus, whose experiments with earth moving were mentioned earlier, determined that the average load for the Mayo Indians in that experiment was approximately 20 kilograms or 44 pounds. The three figures used in the calculations show a range of effort that includes the loads discussed above. The three basket sizes used are: 15 kilograms (33 pounds), 22 kilograms (48.4 pounds) and 40 kilograms (a maximum load of 88 pounds).

There are two basic processes that occur in mound construction and for these processes several equations are used. Atkinson (1961) says:

> All earthwork building processes can be broken down into two parts: loosening of subsoil and the filling of baskets in the ditch, and transport to and dumping of basket loads on to the bank. In the former, rate of production is independent of size and varies only as to hardness of material being dug; the latter is related directly to the size of the earthwork being built.

Erasmus' figure of 2.6 cubic meters of soil excavated per man per day was used. The Erasmus observations were mentioned earlier in the paper. This figure of 2.6 was obtained by observing Mayo Indians excavate and fill containers using a digging stick and their hands to perform the activities during a five hour work day (Erasmus 1965). This figure provides only for excavation and not for transportation.

The time-labor figure for transportation of earth is determined by the use of an equation obtained from a UNESCO (1961) study on manual labor. This formula is given in the data on Teotihuacan elsewhere in this paper. The formula is based on the soil being transported and then stockpiled to be carried up later and placed on the mound. A separate figure is used to determine the work necessary to carry the loads up onto the mound. This figure is mentioned next.

The labor required for lift (vertical distance) in transporting the soil is determined from a table obtained from a study carried out by the Economic Commission for Asia and the Far East (1957). The study included calculations on the manpower required for 40 kilograms at various lifts and leads. These figures are obtained by interpolating from this table and calculating ratios for the other basket sizes used in this paper. The figure presented in the table is given in terms of the manpower required for the lift of one cubic meter in one work day. The table includes figures for the various types of soil, including hard clay, that are used in these calculations. The lift figures are average lift heights determined by the percentage volume contained in the mounds at that particular height (height at which half of the volume is contained). The average lift height for all the mounds is 6 meters and for the ridges 1 meter.

A summary of all the variable used in calculations for time-labor involved in the Poverty Point earthworks is tabulated below.

	Volume	
	Cubic Yards	Cubic Meters
Poverty Point Mound	185,000	141,221
Motley Mound Mound B	265,000	202,291
Geometric Ridges	530,000	404,580
Total	980,000	748,092

Total Soil Weight - 3,299,085,720 pounds 1,496,184 metric tons

	Proposed Population	
	Total	Number of Workers
a.	6,000	1,200
b.	3,000	600

DAYS OF MOUND LABOR/MAN/YEAR

a. 40
b. 100
c. 150

LENGTH OF WORK DAY

a. 5 hours
b. 9 hours
c. 7 hours

TRANSPORT DISTANCE FOR BASKET LOADS

For All Mounds Excluding Ridges

Maximum distance	600 yds.	(545 meters)
Average distance	400 yds.	(360 meters)

For Ridges

No transport distance - lift-lead figure 1 m. lift 12 m. lead

VELOCITY

Loaded - 3 km./hr.
Unloaded - 5 km./hr.
Average - 4 km./hr.

LIFT HEIGHT (VERTICAL TRANSPORT DISTANCES)

Mounds - 20 ft. (6 m.) average
Ridges - 3.3 ft. (1 m.)

BASKET SIZES

a. 15 kg. (.008m^3) = 33 lbs.
b. 22 kg. (.011m^3) = 48.4 lbs.
c. 40 kg. (.020m^3) = 88 lbs.

CALCULATIONS

A. Mandays required for excavation of all soil at Poverty Point =

$$\frac{\text{Total volume of earthworks}}{\text{output } (m^3)/\text{day}} \quad \frac{748{,}092 \ m^3}{2.6 \ m^3 \text{ (from Erasmus' study)}} =$$

278,728 man days

B. Output/man/day for transporting soil (P.P. Mound, Motley Mound and Mound B only) = $q \dfrac{1}{\frac{L}{V} + \frac{L}{V'}} H$: where q = basket capacity in m^3, L = transport distance in kms., V = velocity loaded, V' = velocity with no load and H = hours in work day:

$$\text{output} = q \frac{1}{\frac{.360}{3} + \frac{.360}{5}} H = q \frac{1}{.192} H = \underline{q\ (5.2)\ H}$$

(a)	$.008m^3(5.2)5$ =	.008(26) =	$.208m^3$/day/man	=	1,651,500	man-days		
(b)	$.008m^3(5.2)7$ =	.008(36) =	$.288m^3$/day/man	=	1,192,750	man-days		
(c)	" " 9 =	" (47) =	.376 " " "	=	913,595	" "		
(d)	$.011m^3$ " 5 =	.011(26) =	.286 " " "	=	1,201,091	" "		
(e)	" " 7 =	" (36) =	.396 " " "	=	867,455	" "		
(f)	" " 9 =	" (47) =	.517 " " "	=	664,433	" "		
(g)	$.02m^3$ " 5 =	.02 (26) =	.520 " " "	=	660,600	" "		
(h)	" " 7 =	" (36) =	.720 " " "	=	477,100	" "		
(i)	" " 9 =	" (47) =	.940 " " "	=	365,438	" "		

Man days in each of the above calculations was determined by dividing total volume of the mounds (not ridges) by the output/man/day.

C. Manpower required for removal from stockpile and placement in mounds and ridges at Poverty Point (lift and lead): (figures determined from ECASFE study)

a. Mounds (P.P. Mound, Motley Mound, Mound B) - 6 m. lift - 12 m. lead for hard clay requires .252 manpower/m^3/day

b. Ridges (Octagon) - 1 m. lift - 12 m. lead for hard clay requires .170 manpower/m^3/day

c. Total manpower for lift and lead of all soils from stockpiles = Ca + Cb = .422 mp/m^3/day

d. Output/man/day for lift and lead = $\frac{1}{.422}$ = 2.4m^3/m/day can be removed from stockpiles and placed in mounds.

e. Total Man-Days required for lift and lead from stockpiles at Poverty Point = $\frac{\text{Total Volume in Earthwork } (m^3)}{\text{output/man/day (Cd)}}$ =

$$\frac{748{,}092\ m^3}{2.4\ m^3} = 311{,}705 \text{ mandays}$$

D. Total Man-days required for excavation of earth and removal from stockpiles to mounds = Ce + A = 599,433 man-days

E. Total Man-days work in Poverty Point Earthworks, with alternate basket size and length of work day:

	Basket Size	Day Length	Total Man-Days
a	15 kg	5 hours	Ba+D = 2,250,933
b	15 kg	7 hours	Bb+D = 1,792,183
c	15 kg	9 hours	Bc+D = 1,513,028
d	22 kg	5 hours	Bd+D = 1,800,524
e	22 kg	7 hours	Be+D = 1,466,888
f	22 kg	9 hours	Bf+D = 1,263,866
g	40 kg	5 hours	Bg+D = 1,260,033
h	40 kg	7 hours	Bh+D = 1,076,533
i	40 kg	9 hours	Bi+D = 964,871

F. Total Work Days Contributed by Poverty Point Alternative Population Figures:

	N No. Family Heads	n Work-Days/Year	N.n Total Man-Days/Year
a	1200	40	48,000
b	1200	100	120,000
c	1200	150	180,000
d	600	40	24,000
e	600	100	60,000
f	600	150	90,000

G. Time (in years) for completion of Poverty Point Earthworks with alternative populations, work days, and basket size =

$$\frac{\text{Total Man Days}}{\text{Man Days Per Year}}$$

Man-Days/Year	Fa 48,000	Fb 120,000	Fc 180,000	Fd 24,000	Fe 60,000	Ff 90,000
Total Man-Days						
Ea=2,250,933	46.9	18.8	12.5	93.8	37.5	25.0
Eb=1,792,183	37.3	14.9	10.0	74.7	29.9	19.9
Ec=1,513,028	31.5	12.6	8.4	63.0	25.2	16.8
Ed=1,800,524	37.5	15.0	10.0	75.0	30.0	20.0
Ee=1,466,888	30.6	12.2	8.1	61.1	24.4	16.3
Ef=1,263,866	26.3	10.5	7.0	52.7	21.1	14.0
Eg=1,260,033	26.3	10.5	7.0	52.5	21.0	14.0
Eh=1,076,533	22.4	9.0	6.0	44.9	17.9	12.0
Ei= 964,871	20.1	8.0	5.4	40.2	16.1	10.7

Webb and Ford state in their site report for Poverty Point excavations in 1952 that:

> The few examples of chronological information that have been secured from excavations in various parts of the earthwork suggest that probably all of it was built and inhabited at about the same time. The same conclusion might be drawn from a casual view of the air photograph, for it is obvious that the figure was constructed according to an integrated plan that probably would not have prevailed if the town had grown by accretion over a long span of time.

It seems that, in view of this statement, the most probable rate of construction for the Poverty Point earthworks falls in the ranges given for a population of 6,000 with the head of each household working 150 days. As shown by the table accompanying calculation (G), the range in time for construction of the mounds is from 5.4 years for a population of this size. The range, of course, arises out of consideration of variables that include basket size and length of working day. In considering the smaller population of 3,000, the work could have been accomplished under optimum working conditions presented in this paper with a completion time of between 10.7 years and 25 years.

It is unnecessary to mention any more about the organization and planning necessary for constructing a site such as Poverty Point. It is interesting to think about the dates of the site, tentatively placed at between 800 B.C. and 600 B.C., an estimate that is 1,000 years earlier than the greatest mound complex in North America at Cahokia in Illinois. Very little is known of the Poverty Point peoples as compared to the extensive picture that is available for Hopewellian and Adena peoples who left a rich record for archaeologists to associate with cultural phenomena. Until more archaeological evidence is obtained from the few Poverty Point type sites, there is little that can conclusively be stated concerning their level of integration and type of organization. Webb and Ford speculate on possible influence from the Upper Mississippi Valley by a group that may have evolved later into Hopewell and Adena cultures. Other than that, little can be said specifically about how the Poverty Point peoples may have accomplished such a major engineering and construction feat.

Research carried out on this paper revealed very little concerning specific methodology for arriving at time-labor figures for some primitive architectural features that quite obviously represent major and remarkable engineering feats. At the most others have mentioned cubic content (there is even variability on a matter as fundamental as this) and have suggested the amount of work a man can do in a day and correlated that to cubic content. The work a man can do in a day is not a constant. There was very little discussion on the variables of time-labor in the data investigated during research for this report.

Demography is a matter that is better treated in Meso-America where there exists a current population that lives on a relatively primitive subsistence level. From this living population and from the extensive ethnographic record accumulated through history, a valid population figure can be determined for Teotihuacan. In eastern North America there was very little ethnographic material collected on the aboriginals until after they were dominated and their cultures modified by Europeans. The Meso-American data on demography lends itself to the Poverty Point discussion on population when the assumption is that both areas were engaged in some level of pre-state horticulture.

Once the labor force is established the element of working time must be established to carry out time-labor calculation. The major factor affecting time available for non-essential labor (monument building) is subsistence pattern. There are interacting phenomena that make up subsistence regimes and allot time to tend to other matters. These phenomena were investigated and controlled.

There are also interacting elements that affect work output involved in the construction process. Although many of these elements vary from culture to culture and area to area, it is felt that the energy expenditures and construction processes were similar enough at the two discussed sites to allow use of some of the same equations and figures to establish control. The list of variables has by no means been exhausted; however this paper is a step towards ending mere speculation on how prehistoric peoples, such as those at Poverty Point and Teotihuacan, accomplished engineering and construction feats represented by monumental architecture.

Time-labor studies as those presented in this paper are far removed from the romantic aspects of archaeology such as finding ancient treasures or speculating as to possible extraterrestrial origins of various civilizations. However, they do yield useful information as to the social and political integration of a society, based upon existing archaeological and experimental data. Time-labor studies can also serve as tests of other hypotheses. This study, for instance, indicates that monumental public works need be either a sure sign or the exclusive domain of state level societies. This study demonstrates that the construction of the Pyramid of the Sun and the Poverty Point complex was possible for a society which was not necessarily rigidly organized, nor did its construction necessarily depend upon coerced labor. Further, this study yields a picture of a people who believed in their own power to undertake and complete such a task and who were dedicated enough to their ideals to bring it to fruition.

In conclusion, this paper suggests a range of possibilities for time and labor consumption by considering variables over which some degree of control can be achieved. There are some elements that could conceivably affect working time about which we can only speculate; these include for instance, such factors as illness, mourning, socializing, inclement weather, and religious festivals. Perhaps when more is known of the respective peoples, an entirely different and more valid time-labor calculation method can be developed.

APPENDICES 1 AND 2

FOR

TEOTIHUACAN

APPENDIX 1: Calculations of the manpower and time requirements for the construction of the Pyramid of the Sun.

1. A. Volume of Pyramid:

Millon: $1.17x10^6 m^3$; Linne: $9.93x10^5 m^3$; Heizer: $8.40x10^5 m^3$

Load Size Material s	15 kg	22 kg	40 kg
fill 1.3	.015 m^3/load	.017 m^3/load	.031 m^3/load
clay 1.7	.008	.013	.024
basalt 3.0	.005	.007	.013
lime 1.0	.015	.022	.040

Volume of outer shell removed by Batres; = 25% volume

M: $2.8x10^5 m^3$; L: $25x10^5 m^3$; H: $2.1x10^5 m^3$

M = Millon; L = Linne; H = Heizer

Volume of clay; if clay = 25% to outer layer

M: $7.0x10^4 m^3$; L: $6.3x10^4 m^3$; H: $5.3x10^4 m^3$

Volume of rock in outer shell

M: $2.1x10^5 m^3$; L: $1.9x10^5 m^3$; H: $4.6x10^5$

Volume of lime coating, assuming 30 cm. thick = 1%

M: $1.17x10^4$; L: $9.93x10^3$; H: $8.40x10^3$

2. A. Man-days required for excavation of fill, using $2.6m^3$/day from Erasmus (1965)

M: $4.1x10^5$ days; L: $3.8x10^5$ days; H: $3.2x10^5$ days

B. Assuming a work force of 6,000; required man-days =

M: 68 days; L: 63 days; H: 53 days

C. Assuming a 6,000 man work force; days required for clay excavated =

M: 18 days; L: 16 days; H: 14 days

D. Erasmus states that 300 man days of labor, including excavating limestone, cutting firewood, transporting firewood and limestone, and stacking wood, yields 8,140 kg. lime which .037 man-days per kg. of lime.
of lime = 1000 kg/m^3. Mass of line covering =
M: $1.17x10^7$kg; L: $9.93x10^6$kg; H: $8.40x10^6$kg

Man days for lime plaster preparation =
M: $1.17x3.7x10^5 = 4.3x10^5$ days; L: $9.93x3.7x10^4 = 3.7x10^5$ days; H: $2.0x10^5$ days

E. Assuming a work force of 6,000 days required for lime preparation =

M: $\frac{4.3x10^5}{6x10^3} = 72$ days; L: $\frac{3.7x10^5}{6x10^3} = 62$ days;

H: $\frac{2.9x10^5}{6x10^3} = 48$ days

F. Total days required for all materials before transport = 2(B+D+F)

M: 158 days; L: 141 days; H: 115 days

3. A. If fill collected within 1 km. with av. lead = 75 km.; output =

$$.015 \quad \frac{1}{\frac{.75}{3} + \frac{.75}{5}} \quad 5 \quad \text{or} \quad .017 \quad \frac{1}{.25 + .12} \quad 5 \quad \text{or}$$

$$.031 \quad \frac{1}{.37} \quad 5 \text{ and } 40 \text{ kg.} = .418 \text{ m}^3/\text{day}$$

B. Days required for transport of fill to stockpile = volume ÷ output per day

	Load Size Volume	15 kg	22 kg	40 kg
M	$1.17x10^6$	$5.8x10^6$ days	$5.1x10^6$ days	$2.8x10^6$ days
L	$9.93x10^5$	$4.9x10^6$	$4.4x10^6$	$2.4x10^6$
H	$8.40x10^5$	$4.2x10^6$	$3.7x10^6$	$2.0x10^6$

C. Assuming 6,000 workers, required day for fill transport =

	15 kg/load	22 kg/load	50 kg/load
M	9.70 days	8.50 days	4.70 days
L	8.20	7.30	4.00
H	7.00	6.20	3.30

D. Manpower for transport of fill from stockpile to pyramid with an average lift of 18 m., which yield an mp factor of .342 mp/m^3, and average lead of 30 m., which yield

$$mp = {}^{1}/_{c} \frac{1}{\frac{.03}{3} + \frac{.03}{5}} 5 = {}^{1}/_{5c} (63.5) = {}^{1}/_{312.5c} \frac{.0032}{c}$$

for

c = .015; .017; .031m^3, (for 15 kg. = .213 mp; for 22 kg. = .189; for 40 kg. = .103) equals mp for lift + mp for transportation = for 15 kg. = .655; for 22 kg. = .531; for 40 kg. = .445

E. Output per man per day for transport from stockpile to pyramid =

$$\frac{1}{\text{total mp}} = \frac{1}{.655} ; \frac{1}{.531} ; \frac{1}{.445}$$

for 15 kg. = 1.5 m^3/day; for 22 kg. = 1.9 m^3/day;

for 40 kg. = 2.2 m^3/day

F. Days required for transport of fill from stockpile to pyramid =

$$\frac{m^3}{m^3/\text{day}}$$

	Load Size Volume	15 kg.	22 kg.	40 kg.
M	$1.17x10^6$	$7.1x10^5$ days	$6.2x10^5$ days	$5.3x10^5$ days
L	$9.93x10^5$	$6.6x10^5$	$5.2x10^5$	$4.5x10^5$
H	$8.40x10^5$	$5.6x10^5$	$4.4x10^5$	$3.8x10^5$

G. Assuming 6,000 available workers, required days =

	15 kg.	22 kg.	40 kg.
M	120 days	100 days	90 days
L	110	90	75
H	90	70	60

H. If clay collected within .75 km. of pyramid with an average load of .5 meters, output =

$$c \frac{1}{\frac{.5}{3} + \frac{.5}{5}} \quad 5 = 5c \frac{1}{.17+.1} = 16.50c$$

for c = .008 m^3/load; c = .013 m^3/load; c = .024 m^3/load for 15 kg. = .132 m^3/day; for 22 kg. = .214 m^3/day; for 40 kg. = .406 m^3/day

I. Days required for transport of clay to stockpile = volume ÷ daily output

	Load Size Volume	15 kg.	22 kg.	40 kg.
M	$7.0x10^4$	$5.3x10^5$ days	$3.3x10^5$ days	$1.7x10^5$
L	$6.3x10^4$	$4.8x10^5$	$2.9x10^5$	$1.5x10^5$
H	$5.3x10^4$	$4.0x10^5$	$2.4x10^5$	$1.3x10^5$

J. Assuming 6,000 available workers; days required =

	15 kg.	22 kg.	40 kg.
M	90 days	55 days	28 days
L	80 days	50 days	25 days
H	67 days	40 days	22 days

K. Manpower required to transport clay from stockpile to pyramid

w/average lift of 18 m. and average lead of 30 m. Lift factor = .342 mp/m^3; lead component = $\frac{.0032}{c}$ - (c.f. 3D) for 15 kg. = .400 mp/day; for 22 kg. = .245 mp/day; for 40 kg. .133. Total mp = .342 + $\frac{.0032}{c}$ = for 15 kg. = .742 mp; for 22 kg. = .587 mp; for 40 kg. = .475 mp

L. Output per man per day for transport from stockpile to pyramid =

$$\frac{1}{\text{total mp}} = \frac{1}{.742\text{ mp}} ; \frac{1}{.587\text{ mp}} ; \frac{1}{.475\text{ mp}} =$$

for 15 kg. = 1.3 m^3/day; for 22 kg. = 1.7 m^3/day; for 40 kg. = 2.1 m^3/day

M. Days required to transport clay from stockpile to pyramid = $\frac{\text{volume}}{\text{output}}$

	Load Volume	15 kg.	22 kg.	40 kg.
M	$7.0x10^4$	$5.4x10^4$ days	$4.1x10^4$ days	$3.3x10^4$ days
L	$6.3x10^4$	$4.8x10^4$ days	$3.7x10^4$ days	$3.0x10^4$ days
H	$5.3x10^4$	$4.1x10^4$ days	$3.1x10^4$ days	$2.5x10^4$ days

N. Assuming 6,000 workers; required days =

	15 kg.	22 kg.	40 kg.
M	9.0 days	7.0 days	5.5 days
L	8.0 days	6.0 days	5.0 days
H	7.0 days	5.0 days	4.0 days

O. Assume basalt collected within 3 km. of site, with average

lead of 2.25 km. output = $5c \dfrac{1}{\frac{2.25}{3} + \frac{2.25}{5}} = 5c \dfrac{1}{.75 + .45} =$

$5c \dfrac{1}{1.20}$

for 15 kg. = .021 m^3; for 22 kg. = .029 m^3; for 40 kg. = .054 m^3

P. Days required for transport of basalt to stockpile = volume ÷ output

	Load Volume	15 kg.	22 kg.	40 kg.
M	$2.1x10^5$	$1.0x10^7$ days	$7.2x10^6$ days	$4.0x10^6$ days
L	$1.9x10^5$	$9.0x10^6$ days	$6.5x10^6$ days	$3.5x10^6$ days
H	$1.6x10^5$	$7.6x10^6$ days	$5.5x10^6$ days	$3.0x10^6$ days

R. Assume 1,200 workers; required days =

	15 kg.	22 kg.	40 kg.
M	830 days	600 days	330 days
L	750 days	540 days	290 days
H	630 days	470 days	250 days

S. Manpower required to transport rock from stockpile to

pyramid = .342 mp for lift + $\frac{.0032}{c}$ for mp for transport

with 30 m. lead
transport mp = .640 for 15 kg.; .457 for 22 kg.; .262 for 40 kg.
total mp = .982 for 15 kg.; .799 for 22 kg.; .604 for 40 kg.

T. Days required = mp · Volume =

	Lead Volume	15 kg.	22 kg.	40 kg.
M	$2.1x10^5$	$2.06x10^5$ days	$1.68x10^5$ days	$1.27x10^5$ days
L	$1.9x10^5$	$1.88x10^5$ days	$1.52x10^5$ days	$1.15x10^5$ days
H	$1.6x10^5$	$1.57x10^5$ days	$1.28x10^5$ days	$9.70x10^4$ days

U. Assume lime transported 5 km.

$$\text{output} = 5c\ \frac{1}{\frac{5}{3}+1} = 5c\ \frac{1}{2.67} = 5c\ (.375) = 1.88c$$

for 15 kg. = .029 m^3/day; for 22 kg. = .041 m^3/day; for 40 kg. = .075 m^3/day

V. Assume 6,000 workers for rock

	15 kg.	22 kg.	40 kg.
M	34 days	28 days	21 days
L	31 days	24 days	19 days
H	26 days	21 days	16 days

W. Days required for lime transport = volume ÷ output

	Load Volume	15 kg.	22 kg.	40 kg.
M	$1.17x10^4$	$4.0x10^5$ days	$2.8x10^5$ days	$1.6x10^5$ days
L	$9.93x10^3$	$3.4x10^5$ days	$2.6x10^5$ days	$1.3x10^5$ days
H	$8.40x10^3$	$2.9x10^5$ days	$2.0x10^5$ days	$1.1x10^5$ days

X. Assume 6,000 workers for lime transport

	15 kg.	22 kg.	40 kg.
M	67 days	47 days	27 days
L	57 days	43 days	22 days
H	50 days	33 days	18 days

Y. Manpower for transport of lime from stockpile to pyramid =

$$.342 \text{ mp} + \frac{.0032}{c} = .342 + (.213 \text{ or } .145 \text{ or } .080)$$

total mp = .555 for 15 kg.; .487 for 22 kg.; .422 for 40 kg.

Z. Days required for transport lime from stockpile to pyramid

	Load Volume	15 kg.	22 kg.	40 kg.
M	1.17×10^4	6.5×10^3	5.7×10^3 days	4.9×10^3
L	9.93×10^3	5.5×10^3	4.8×10^3 days	4.2×10^3
H	8.40×10^3	4.7×10^3	4.1×10^3 days	3.5×10^3

AA. Assume 6,000 workers

	15 kg.	22 kg.	40 kg.
M	1.1 days	1.0 days	.8 days
L	.9	.8	.7
H	.8	.7	.6

BB. Total days required to transport pyramid materials.

	15 kg.	22 kg.	40 kg.
M	2222 days	1678 days	972 days
L	1857	1485	837
H	1571	1260	701

4\. A. Using Erasmus' (1965) figure of 10 hr/m^3 of masonry = 2 days/m^3 rock and adobe exterior of pyramid would require M: 5.6×10^5 days; L: 5.0×10^5 days; H: 4.2×10^5 days

B. Assuming 6,000 workers, outer coat would require M: 93 days; L: 73 days; H: 70 days

5\. A. Total days required to construct pyramid with a 5 hr. day

	2F + 2BB + 3B 15 kg.	22 kg.	40 kg.
M	2473 days	2071 days	1756 days
L	1929	1699	1445
H	1223	1051	886

B. Total time in years assuming 40, 100, 200 days of community labor per year

	15 kg.			22 kg.			40 kg.		
	40	100	200	40	100	200	40	100	200
M	61.8	24.7	13.4	51.8	20.7	10.3	43.9	17.6	8.8
L	48.2	19.3	9.7	42.5	17.0	8.5	26.1	14.4	7.4
H	20.4	12.2	6.1	26.3	10.5	5.2	22.3	8.9	4.4

C. Total time in years required when work day varied but load kept constant at 22 kg. (the most likely carrying load) for 5, 7, and 9 hours.

	40 days/yr.			100 days/yr.			200 days/yr.		
	5 hr.	7 hr.	9 hr.	5	7	9	5	7	9
M	51.8	36.6	29.0	20.7	14.5	11.6	10.3	7.2	5.8
L	42.5	29.8	23.8	17.0	11.9	9.5	8.5	6.0	4.8
H	26.3	18.4	14.6	10.5	7.4	5.9	5.2	3.6	2.9

APPENDIX 2: Some dimensions, volumes, and weights for the Pyramids of the Sun and Moon at Teotihuacan.

Acosta, 1963
Pyramid of the Sun: 735 ft. at base; 210 ft. high
volume = 1,500,000 cubic yds.

Pyramid of the Moon: 490x390 ft. at base; 135 ft. high
volume = 252,000 m^3

Batres, 1889
Pyramid of the Sun: 224 m. square at base; 68 m. high

Cook, 1947
Pyramid of the Sun: volume = 993,000 meters cubed

Heizer, 1966
Pyramid of the Sun: volume = 840,000 cubic meters

Humboldt, 1811
Pyramid of the Sun: 208 m. square at base; 55 m. high
volume = 33,743,201 cubic feet

Pyramid of the Moon: 44 m. high

Judd, 1948
Pyramid of the Sun: 692 ft. square at base; 212 ft. high
volume = 35,067,596 cubic feet

Linne, 1934
Pyramid of the Sun: 211 m^{x}207m^{x}211m^{x}209m at base
64.5 m. high
volume = 993,000 cubic meters
weight = 2,980,000 tons

Pyramid of the Moon: 150mx120m at base; 42 m. high

Millon, 1960
Pyramid of the Moon: 500 ft. x 400 ft. at base; 100 ft. high
volume = 250,000 cubic yards

Millon, 1965
Pyramid of the Sun: volume = 1,117,000 cubic meters
volume of 1st stage = 600,000 cubic meters

Weaver, 1972
Pyramid of the Sun: 700 ft. square at base; 200 ft. high

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III. NOTES ON TRADE IN ANCIENT MESOAMERICA

Brian D. Dillon

III. NOTES ON TRADE IN ANCIENT MESOAMERICA*

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INTRODUCTION

The subject of "trade" in pre-conquest Mesoamerica has long intrigued (or plagued) archaeologists, culture historians, economists and historical geographers alike. The role it played in the individual ancient cultures and the effects it exerted upon them to change over time have often been studied. Questions about what was traded, in what volume, from whence to where, the status of "trade" in the overall regional or interregional economies, and the influence or lack of influence of politics, markets, demand and supply and percentage of production destined for export have often been addressed, but seldom very fully answered. In view of the great volume of literature on the topic, I confess that I cannot hope to contribute much in the way of answers to these pressing questions. My aim, rather, is to impart a feeling of the scope of some of the general implications of trade; the diversity, known or assumed, of products traded, as well as a familiarity with some of the misconceptions that have "guided" some of the research carried out in the field, and through their perpetuation, have tended to work against a more complete knowledge of the subject.

To this end I will attempt to establish what can be meant by the term "trade", and offer some brief examples demonstrating the value of studying "trade" relative to the archaeological reconstruction of Mesoamerican culture. A short selection of approaches to the topic, both the descriptive and the explanatory, will be discussed and evaluated. In order to better assess the factual basis of the theories described I will take a detailed look at a few selected resource items that were of importance in aboriginal times. By doing so, I hope to demonstrate that the basic data utilized is inconsistent with some of the hypotheses that have been proposed and nonexistent for others. Finally, I will offer a very few suggestions for work that might be done in the future, and how it ought to be carried out.

This overview makes no pretentions of being exhaustive; doubtless I will have omitted as many important points as I have included. However, I feel that the examples presented will be sufficient to support the contentions I wish to convey.

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SOME DEFINITIONS OF "TRADE"

Hole and Heizer (1973:342) observe that "it is easy enough to recognize 'foreign' objects in a site, but much harder to demonstrate that they were traded and to pinpoint their origin." However, some students of Mesoamerican archaeology have tended to immediately project cultural institutions of historic trading peoples back to societies known only from excavations upon discovering such "foreign" items in their digs, or sometimes even when artifacts were found without provenience. Caso (1965:928) cautions us that "objects pass from one place to another by trade, tribute or pillage, so that the provenience by itself can be only a very uncertain indication that the object was a local product." How much more remote is an accurate assessment of origin when no provenience data exists at all, to say nothing of the means by which the object moved.

If it is possible to establish that "trade" might have occurred in an archaeological society or between societies, the next logical step has often been to determine its cultural role. "Trade" studies, when applied carefully and with discretion, have been very successful as tools in the empirical examinations of dead cultures and in archaeological reconstructions. However, the most common failing in Mesoamerican studies of trade has been an overeager ascription of patterns discernible in the Postclassic period to earlier times, a hazardous undertaking at best. Quite often the actual model of "trade" based on late times is poorly understood as well, and utter chaos may well be the result. Silva-Galdames (1971:42) should be heeded when he suggests that: "Trade must not be inferred; it has to be demonstrated."

Parsons and Price (1971:180) observe that "the 'formative' demographic, settlement, agricultural and other productive systems, on the basis of archaeological evidence, were demonstrably different from those of the Classic and Post-Classic; it seems reasonable to assume that these observed differences may be closely correlated with other institutional differences." Therefore, we can most likely never know the actual form that trading organizations took in all but the latest of Mesoamerican cultures, and assigning models of dubious value in attempts to clarify the situation cannot help but obscure it further.

There has been much speculation in recent years on the cultural and social implications of Mesoamerican trade, especially in the Preclassic period. The lack of actual contextual evidence to support claims of far-reaching trade routes and other such cultural manifestations is equaled, in my opinion, by the degree of confusion engendered by the imprecise use of the term "trade".

Chapman (1971:208) warns of valuable results being "nullified when the terminology is not respected, when it is deprived of its specific meanings and reduced to everyday vernacular." Yet many treatments of the subject consider "trade" as a given element, without bothering to explain what exactly is meant by the word. Some authors seem to assume that there is a common consensus on its definition, which there is not. "Trade" is offered to indicate tribute, exchange, plunder, procurement and even communication. Some writers employ the term interchangeably with, or to represent one or all of the above words. The variety of meanings associated with the term points to the fact that in reality, there is little agreement on the definition of "trade".

Some students have recognized that "trade" is not equivalent to the other meanings popularly associated with it and have attempted to clarify the situation. Flannery (1968:102) suggests that: "exchange is not 'trade' in the sense that we use the term, but rather is set up through mechanisms of ritual visits, exchange of wives, 'adoption' of members of one group by the other and so on." Hole and Heizer (1973:342) strike the same chord by stressing the need to reject preconceived notions in studying the phenomenon: "exchange may literally be non-economic in the sense that no gain is expected nor any economic necessity fulfilled." There are, it becomes apparent, numerous ways in which, or reasons why, objects should move from place to place without any necessary connection with what we consider "trade".

It is therefore much better, when foreign objects are found in dateable archaeological contexts or described in early histories, to account for them with a less loaded term than "trade". Perhaps we should adopt a culturally neutral expression such as "movement", but the word "trade" is so imbedded in the literature that such a measure would be unlikely to succeed. In any case, if and when the word "trade" is used, it should be qualified.

APPLICATIONS OF "TRADE" STUDIES TO MESOAMERICAN CULTURE HISTORY

Despite the confusion that some treatments of the subject have generated there have been others that have increased our understanding of ancient Mesoamerican culture in important ways. This interest tends to be manifested in two basic directions. "Trade" has been studied as a means of obtaining a greater knowledge of cultural integration at individual points in space and time, and also has been examined as a causal factor in cultural change. The contributions of "trade" studies to Mesoamerican archaeology as a whole have been many and varied.

In constructing relative chronologies, trade pieces, especially pottery, are of the utmost importance. The concept of "horizon styles" (Kroeber 1944:108) helps to establish the sequence of the regional traditions that it comes into contact with, and serves as the anchor in local sequences that otherwise might not be subject to cross dating. The ideal horizon style, according to Kroeber, would embody the following characteristics: an extremely short life-span; broad spatial distribution; stylistic components distinctive enough as to preclude the possibility of confusing it with other styles of non-contemporaneous times. Examples of the application of this concept to Mesoamerican archaeology are the association of "plumbate" pottery (Shepard, 1948) with the Late Classic and Early Postclassic periods, and that of Mixteca-Puebla style decoration with the Late Postclassic (Nicholson, 1971).

The movement of articles through tribute or trade has been studied in attempts to determine the political boundaries of specific ethnic groups, as well as in establishing cultural parameters. Expansionism in the Postclassic period was effected through both "Military force and tribute exactions" (Willey, et.al., 1964:493). Barlow (1949) correspondingly defined the limits of the "Empire of the Culhua Mexica" by using a listing of direct tribute to Tenochtitlan, on the individual town level, to represent Aztec domination. In arriving at their estimate of central Mexican population in the Late Postclassic of 25.2 million persons, Borah and Cook (1963) make extensive use of the Matricula de Tributos from the Codex Mendoza. The authors reach their figure by counting the number of individuals tributary to the Mexica per town as family heads, and then multiply by 4.5, the estimated family size. Without the detailed tribute books, such a figure might not have been suggested.

Hole and Heizer (1973:339) suggest that one of the most important contributions of "trade studies" has been the illumination of the types of interaction engaged in by contemporaneous peoples. "Precise knowledge of the geographical limits of trade enables us to plot the areas of effective intercommunication or interaction for each group of prehistoric people; this knowledge in turn lets us make reasonable guesses about the sources of influence and the nature of contacts between areas." The authors elaborate: "a careful analysis of trade in a prehistoric context can inform us perhaps more quickly than any other means, of the scope and nature of interaction in which the people who lived at any one site were participating" (ibid.:342).

Willey, et.al., (1964:492) ask the basic question about the internal organization of early Mesoamerican civilization: "What were the political, social, religious, and economic ties that bound these societies together?" And to what extent was external and internal trade, among other institutions, "significant integrative factors?" The increase of long-distance trade would work towards augmenting the wealth of those involved in it, encourage production of more specialized items and upgrade the level of workmanship, and create new demands for products or resources that previously had been limited to localized areas because of ignorance of their existence by the neighboring populations, and as such would be an important focus in any society. Trade between major centers of cultural innovation could have had larger effects on the development and spread of new ideas:

"Trade in objects and commodities would have been accompanied by the diffusion of the religious and sociological complex common to the Mesoamerican co-tradition" (Parsons and Price, 1971:169). It is interesting to note, however, that there were apparently four regionally distinct merchant's religious cults in the Late Postclassic period, and that substantial differences existed between them (Thompson, 1966b). Thus we must not be too quick to assume that there was any common form of institutionalized cultural association with trading organizations at this or any other time.

The role of "trade" as a vehicle for cultural communication and diffusion has often been considered by Mesoamericanists: Flannery (1968:101) links the Olmec with the Preclassic peoples of the Valley of Oaxaca; Bernal (1969:87) suggests "commercial consulates" of the Olmecs in their dealings with peoples outside of the Tabasco-Veracruz heartland; Classic Teotihuacan is represented as maintaining "embassies" at Tikal (Silva-Galdames, 1971:52-53); and Millon believes he found a Huaxtec enclave at Teotihuacan (1973:35) in addition to a barrio with close relations to the Valley of Oaxaca (ibid.:41-42), both of which existed presumably to engage in trading relations.

A logical concomitant to determining the importance of trade as an agent of cohesion between separate cultures is to evaluate the influence of the absence of trade as well. Silva-Galdames (1971:58) accounts for the "marginality" of certain areas within Mesoamerica proper to this cause: [since] "trade is guided by commerical interest it follows that when a region is too far from cities or it does not have a commodity attractive to cities, it will remain outside of trade networks. It will therefore be beyond those relationships that are generated in cities which bring about cultural transformations."

Some students even see trade as the raison d'être for "cities", cultures, or entire civilizations. Hammond (1972:44) in his short sketch of Lubaantun, suggests that the site's probable manipulation of the cacao "industry" in that portion of Belize "enabled it to trade with other parts of the Maya area, and by trading and other contacts tied in to the general development of Classic Maya civilization." Grove (1968:184) urges us to believe that "trade was the major force to which we should attribute Olmec presence in the Mexican central highlands." Others extrapolate that assumption back to account for the Olmec presence in the Tabasco-Veracruz heartland itself (M. Coe, 1965:123, Parsons and Price, 1971: 174-178), and it does not stop there.

Even the Classic Maya are represented as living or dying on their foreign commerce, easy prey for the "business-minded" central Mexicans: "The fact is that the Maya of both highlands and lowlands have never been isolated from the rest of Mesoamerica, and that Mexican influences have sporadically guided the course of Maya cultural history since very early times..." (M. Coe, 1966:52).

"It was...trade that linked Mexico and the Maya, for they had much to exchange...[and in Postclassic times] it was probably the smooth business operations conducted by the Chontal that spared the Maya from the Aztec onslaught that had overwhelmed less cooperative peoples in Mesoamerica" (ibid.:142). Chapman (1957:132) had previously voiced the same general attitude: "The Maya social and political stratification, internecine warfare, as well as the economics of production and consumption, was to a large extent dependent on the maintenance of trade relations beyond their ethnic frontiers." She further claims that the "fall of Tenochtitlan, the center of economic and political power", also guaranteed the collapse of trade networks throughout all the rest of Mesoamerica. For the Aztec state itself, Acosta Saignes (1945) sees trade as crucial to an understanding of the Tenochca rise to power, and as an important element in the development of Aztec society.

A theoretical view that has been gaining many adherents lately has been the thesis that long-distance trade is a direct concomitant, if not a causal factor in the development, of a more complex culture or civilization. Two basic distinctions must be made before any assessments of the consequences of movement of items can be advanced: whether we are talking about local or long-distance movement, and whether the articles in question are of an essential or non-essential nature. Most studies of Mesoamerican trade have been concerned with the long-distance trade in luxury items because of its importance in understanding cultural diffusion, but more recently attention has been paid to the effects of local trade in "essentials" on cultural development.

The basic difference between local and long-distance trade is that long-distance trade usually necessitates a supra-familiar organization to insure success in the undertaking. Fried (1967:204) sees trade in luxury items playing a vital role in the emergence of the "state" by exerting pressures towards social stratification in egalitarian societies. Parsons and Price (1971:188) envision the genesis of ranking as promulgated and reinforced by trade in luxuries, and Tourtellot and Sabloff (1972) promote the view that Classic Maya society could not achieve "statehood" status without economic intervention from central Mexico. Voorhies (1973), in criticizing the latter suggestion, proposes that no foreign impulse was necessary for the development of a complex trading organization to ultimately be instrumental in state formation. It can certainly be argued that articles symbolic of the distinctions of rank are useful in maintaining social distance in a classed society, but more questionable is the view that a classed society necessarily evolves out of the ability of certain individuals to obtain such luxury goods.

Exotic materials used in dress, ritual or in other contexts work to reinforce the notion of separate and powerful status for those people equipped to procure them. They serve to accentuate the differences between their possessors and the masses, as well as providing opportunities for the privileged group to "flex their muscles" in obtaining more of them. This is not to suggest that the evidence of luxury items in archaeological contexts always is an indication of warlords, chieftains, priests or traders, but merely to reinforce the view that non-essential luxury items probably served a very real function in their own social context. Flannery (et.al., 1967:454) comments that when luxury trade was carried on between "elites, such contact probably stimulated exchanges of the 'lore' known only to the elite-calendrics, hieroglyphic systems, and symbolic art-thus widening the gap between farmer and chief." It is important to note, however, that the "elites" are considered to already be in existence.

Following the same basic idea, but calling upon a different kind of evidence is the thesis that would attribute the development of complex society not from a trade in luxury goods, but in utilitarian items for common consumption. Here the generation of an institutionalized organization monopolizing "essential" resources is seen as a precursor to a more complex social structure. Rathje (1971) suggests that the origins of Maya lowland civilization resulted from the organizational development required to procure resources that he feels were essential for survival, and also suggests the applicability of his model to the formation of Olmec civilization as well. An underlying tenet of this hypothesis is the opinion that the Central Maya area is both extremely uniform in terms of ecological and economic potential, and extremely poor in valuable or even "essential" resources. Both of these assumptions are subject to question, and an examination of the natural situation in the Peten will be likely to disprove them. Perhaps the seeming lack of resources deriving from the Peten as represented by the archaeological record can be attributed to the possibility that the majority of them would have been of an impermanent nature.

Silva-Galdames (1971:63) sums up the importance of "trade" to hypotheses concerning cultural development perhaps in the most succinct way possible: "Trade...promotes civilization and it is not, in our opinion, a consequence of it." In considering trade to be a causal factor in the creation of "civilization" one must assume that trading systems were in existence prior to the actual development of complex political and social systems. "Trade" probably throughout the history of its presence in Mesoamerica was firmly rooted in extremely complex and culture-specific matrixes incorporating religious, political and social factors, and it would seem to be misleading at best to divorce it from that larger context so as to consider it an independent variable in order to account for the system as a whole.

Organized "trade" probably played roles of varying importance in different societies over time and space, but doubtless was prominent in all of those that we have come to consider civilizations. Willey, et.al., (1964:490) attempts to outline basic features which one could recognize the existence of a "civilization" from purely archaeological contexts, and enumerate seven, of which the last is "extensive foreign trade." We seem to be at present no closer to a strict definition of how to establish the actual means by which movement of resources and manufactured goods took place, but few would contest the fact that such movements did occur. Taken in sum, perhaps the greatest overall contribution of Mesoamerican "trade" studies has been to sharpen our awareness of the quantitative and qualitative differences to be found throughout Mesoamerican culture history.

APPROACHES TO THE TOPIC

Conquest-Era Descriptions

One of our greatest sources of knowledge of Mesoamerican cultures in their most diverse aspects derives from the records kept by the European conquerors. When the first Spanish came into contact with the flourishing native civilizations, they were impressed by the lively trade in items from all known regions of the Mesoamerican "world", in the diversity of things traded and in the strangeness of the more exotic items.

Possibly the earliest exposure to the remarkable phenomenon we are concerned with here was the frequently cited meeting in 1502, during Columbus' fourth voyage, of the great seagoing trading canoe off Bonacca island in the Gulf of Honduras. Usually represented as Chontal Maya (the most famous long-distance traders of Mesoamerica), the identity of the canoe's paddlers is still in some doubt. Lothrop (1924:13) suggests that the merchants, who were carrying axes of copper, cotton cloth, obsidian blades and many other objects, were actually from Honduras (Paya?) instead. Regardless of the "nationality" of that specific canoe, it does serve to illustrate that there was considerable movement of goods by sea in the Caribbean at the time of the conquest. Oviedo (1959:Vol. III, book 32:422) reports that "along said coast [eastern Yucatan and northern Honduras] there is an extensive trade...canoes go from Yucatan loaded with clothing and other goods to Ulua and from there they return with cacao."

If the long distances covered in the interest of trading surprised the Spanish, they were no less impressed with the distinctly Mesoamerican type of market. The great open-air market at Tlatelolco was described in much detail by Gomara (1966:160-163), as well as Bernal Diaz (1956:215-217), the latter relating: "we were astounded at the number of people and the quantity of merchandise that it contained, and at the good order and control that was maintained, for we had never seen such a thing before." The garrulous conquistador then proceeded to describe each type of ware or product, food or resource offered for sale, and concluded: "One could see every sort of merchandise that is to be found in the whole of New Spain." The staggering array at what must have surely been the largest market in Mesoamerica left Diaz for once, at a loss for words: "why do I waste so many words in recounting what they sell in that great market? for I shall never finish if I tell it all..."

Another well-known description is that of Ximenez (1926:128) for a market day in the Guatemalan highlands some years after the conquest: "The selling and buying is the exchange which is the most natural form of trade; they give maize for black beans and black beans for cacao, exchanged salt for spices which were aji or chile...Also they exchanged meat and game for other things to eat, they swapped cotton cloth for gold and for some hatchets of copper, and gold for emeralds [sic], turquoise and feathers..."

Lest we imagine that commerical enterprise and regular markets were characteristics mainly of the highland regions, Landa (1941:94) reassures us that for the lords of northern Yucatan, "The occupation to which they had the greatest inclination was trade." The bishop duly reports on the "considerable amount of barter between those living in the interior and those on the coast. From the former came flint, cotton cloth, and some maize in exchange for fish and salt." As well as major sea-routes, overland trails played an important role in the movement of goods from one area to another. That the entire land route from Tabasco to Nicaragua was commonly known to merchants in Postclassic times is attested to by the bark-paper map that was prepared for Cortes by traders from Xicalango to aid him on his epic march to Honduras.

With the drastic demographic collapse of the native population (Borah and Cook, 1963, estimate that there was a population decline of around ninety percent in the hundred years following the Spanish entry into Mesoamerica) and the culture shock of conquest and subjugation, accounts of purely native commerce tapered off until all that was being recorded was the outright taxation of the indigenous peoples by the colonial government.

More Recent Approaches

With the birth of the archaeological study of Mesoamerican culture, new generations of scholars tackled the subject of "trade" from the purely descriptive viewpoint, building on or uncovering more of the earlier historical data, and making use of new skills derived from their different respective disciplines.

The fields of geography and historical geography have done much to increase our understanding of the natural context and resource potentials of areas which in pre-Hispanic times engaged in "trade" with other locales. West, Psuty and Thom (1969), in their excellent survey of the Tabasco lowlands, describe in detail the landforms, resources and ecology of the area and, with an eye towards the archaeologist, attempt to plot out centers of habitation and routes of commerce.

Scholes and Roys (1948) in their ethnohistoric study of the Chontal Maya, describe the closest thing to a "race of merchants" in Mesoamerica, doing much to reduce the anonymity of "trade" during the

Postclassic period in regions as far distant as Tabasco and Honduras.

Of a slightly different nature are those studies firmly rooted in the present. McBryde (1947) describes the human ecology of western highland Guatemala among the descendents of the Quiche, Cakchiquel and other ancient tribes, providing possible clues to pre-Hispanic settlement, environmental exploitation and exchange. The modern ethnographic approach is used in understanding the present-day regional market systems and economy, and in separating the introduced features from the indigenous ones by Tax (1953) for Panajachel and McBryde (1933) for Solola in the same region.

The trend towards an holistic approach to the study of Mesoamerican culture history and archaeology has brought many talented people from different disciplines into the area, and produced a great amount of data that is useful to those interested in the phenomenon of "trade". In examining the topic today, one cannot afford to ignore the work of the ethnographers, geographers and ethnohistorians whose efforts have so rounded out our information on the possibilities of ancient trade.

Explanatory Models

When descriptive information on the nature of "trade" in ancient cultures is incomplete or lacking, there has been a recent tendency to project hypothetical models based on relatively more secure conquest-period data back in time in order to provide an explanation. Of the several currently in vogue, I will deal only with the two that have received the most attention and caused the most confusion: the Pochteca and "Ports of Trade". These two constructs have been often used, either singly or in combination, when some students have sought to portray a specific mechanism to account for foreign objects at sites, cultural diffusion, or other "problem" situations. Although both their applicability and accuracy appear subject to question, their popularity seems to rest on the assumption that the path which Mesoamerican cultural development took was of a relatively simple and undifferentiated nature, continuous and not very different at any one time in its progression to its final expression.

The Pochteca Model

At the time of the Spanish conquest of Tenochtitlan, merchants were a favored and influential group. At the top of their social ladder was a category that has long been generically labeled as pochteca, who "are not to be confused with peddlers and petty traders who sold their wares in the market places of the Valley [of Mexico]. The pochteca engaged only in foreign trade" (Vaillant, 1972:147). Aztec military expansionism often went hand in hand with the activities of certain elements of the pochteca, and several students (i.e., Parsons and Price, 1971:171) have pointed out that the Aztec "long-distance trade pattern" cannot be understood outside of the context of the peculiarities of the Mexica political and military organization. Acosta Saignes (1945) goes so far as to consider the pochteca as the primary agents of Aztec "imperialism", and so important that the Aztec state as we know it could not have existed without them.

Sahagun (1959:book 9) describes the different kinds and activities of pochteca at some length, and one can distinguish between the broad categories of traders who dealt in merchandise from beyond the limits of Aztec influence: the puchtecatlatoque, or "principle traders" who were the patriarchs of the trading "families" or corporations (ibid.:3), and who usually stayed at home to administer the receiving end of trade and deal with red tape; the slave-traders, who generally obtained their foreign wards by buying them directly from the warriors who had captured them, and who were recorded as being present at Tochtepec as well as at Tlatelolco. Sahagun describes them as the most important of all merchants, which, given the Mexica penchant for blood and human sacrifice, is not surprising. The teucunenenque, or lordly outpost traders (ibid.:8), represented the Aztec nobility in their transactions with foreign merchants. The naoaloztomeca, or "trader-spies", the type most often associated with the pochteca label (ibid.:4), who went in heavily armed groups to foreign parts, and probably filled the lowest position in the hierarchy.

The exact status of the pochteca in Aztec society has been the subject of much debate. Sahagun tells us that they formed a separate, semi-autonomous political unit within the social structure, that they lived in their own barrios separated from the bulk of the population, that their status was transmitted hereditarily, and that they possessed their own special god, Yacatecuhtli, or "he who guides". The pochteca are said to have had their own courts dealing in both civil and religious matters, with the power to punish offenders.

The degree of privilege relative to the rest of Aztec society probably increased in direct proportion to the distance from Tenochtitlan. Although Vaillant's (1972) description of Mexica society was strongly influenced by Bandelier's earlier study (a la Lewis Henry Morgan's kinship scheme) and by all of its inaccuracies, the placement of the pochteca in a separate social class is probably correct. Acosta Saignes (1945) studies the pochteca as a distinct caste within the Aztec state, and feels so strongly that they were different from the rest of society that he proposes that they were actually foreigners from the gulf coast residing in Tenochtitlan-Tlatelolco.

Perhaps Chapman (1957:120) strikes closest to the mark when she suggests that "their status seems nearly to approximate that of some skilled crafts-workers", (a connection indirectly made by Sahagun as well) and cites similarities between them and the prestigious feather-artisans in the types of favors and exemptions granted, and in their familiarity with luxury goods. The *pochteca* most likely enjoyed their greatest freedom and power when they were on journeys to foreign lands, and their privilege of autonomous judicial action probably was only exercised when they were the only representatives of the Aztec state in the area. It should be remembered that when the *pochteca* returned to Tenochtitlan laden with much wealth, they were required to slink into the city in the rags that they had set out in, to dispell any fears the nobility might have of encroachments on their power.

In addition to their role as spies, some *pochteca* groups acted as *agents provocateurs*, furnishing the Aztec state with a "valid" excuse for attacking hitherto friendly or neutral powers. Vaillant (1972:149) states that "often the *pochteca* deliberately provoked the local population in the hope of starting a war, and in the time of Ahuitzotl a group of Mexican traders had to withstand a four-year seige in the city of Quahtenanco on the Pacific coast. When eventually the ruler sent an army...he learned that the merchants had fought their way out of the town and had conquered the surrounding district by their own efforts." The *pochteca* were often simply sacrificed in the power plays of conquest; the first campaign of the triple alliance in the Huaxtec area, during the reign of Moctezuma Ilhuicamina, was precipitated by the convenient murder of Aztec traders in or around Tuxpan.

Expansion of the *pochteca* model, and therefore perhaps misuse of the term *pochteca*, which we have seen to have represented various functionally different groups with poorly understood social standings within the Aztec state, possibly begins in earnest with Chapman (1957). Here *pochteca* is used generically to refer to "the various types of full-time professional traders who carried on trading relations exclusively with peoples beyond the frontiers of the Aztec empire" (ibid.:120). The peculiar characteristics of one of the *pochteca* groups, the *naoaloztomeca*, is then ascribed to all long-distance traders of Aztec times, and thenceforth to earlier cultures as well. In much of the literature today, *pochteca* has been used to refer to any kind of organized, socially distinct group of traders in Mesoamerica, and such a definition is certainly misleading.

The *pochteca* model, in which traders double as spies or warriors, has been suggested for just about every pre-Hispanic culture in Mesoamerica at some time or another by someone. Michael Coe, perhaps making the most liberal use of the construct, extrapolates it back to explain the "Olmec presence in central Mexico" (1965:122-123) and to account for the collapse of classic Maya civilization after the establishment of a "Teotihuacan hegemony" spearheaded by *pochteca* in southern Maya area (1966:81), with a Teotihuacan-dominated Kaminaljuyu functioning much as did the later Aztec Xoconocho. A suggestion of some of the shortcomings of the explanation is revealed (ibid.:84) when it is proposed that even Tikal came under the grip of the *pochteca*. "Perhaps it was the resplendent, gold-green tail feathers of the shy quetzal that they were seeking, to adorn the headdresses of the Teotihuacan nobles." The central Mexicans would hardly go to the low-lying Peten to search for a bird that lives exclusively in the high cloud forest (see Pelts and Plumes), certainly not if Kaminaljuyu was already under a "Teotihuacan hegemony". Coe concludes by explaining the presence of the Cotzumalhuapa culture (ibid.:90) as the result of another pochteca group traveling in the area in Preclassic times.

Other students use the pochteca model with some modification: Grove (1968b:184) proposes it to account for the sites in Morelos that he labels as "Olmec", and Parsons and Price (1971:205), while carefully stipulating that they do not assume a pochteca-like organization for the Olmec, show no compunction at ascribing the model back to Teotihuacan, despite their own criticism of Coe's usage: "the Aztec long distance trade pattern cannot be understood except in the context of the Aztec state and its policy of militarist expansion" (ibid.:171). Wiegand (1968:59) has suggested the pochteca were responsible for the distribution of the products of the mines of the Suchil branch of the Chalchihuites culture, Ferdon (1955:26-27) calls in the pochteca to account for "Mexican" influences seen in the Hohokam and Anasazi peoples of the American Southwest after the fall of Tula, as do Hedrick, Kelley and Riley (1974:7,67) for the "wave of Mesoamerican ceremonialism" seen in the Southwest at the end of Pueblo III times. Many other examples could be cited as well.

Strictly speaking, it seems highly questionable to project the institution of the pochteca backward to cultures that are known only from archaeological remains without implying that those cultures also had the same social, political, military, and economic structures and orientations as the Aztec. Acosta Saignes (1945) notes that there is no mention of any kind of pochteca organization in the "Toltec" histories, so it would seem extremely doubtful that it would be found elsewhere if not even present among the antecedents of the Aztec themselves. Due to the complexity and ambiguity of the Aztec situation with respect to the definition of what a "pochteca" really was, his social standing, and the variety of implications that the word conveys, it would seem most unwise to use the term out of its Aztec context.

The "Ports of Trade" Model

If the pochteca cleared the way for the Aztec conquests of foreign areas and the adage that "tribute follows trade" is correct, then it is necessary for us to better understand the nature of the "free trade" that preceeded the military takeover of distant lands. To this end, Chapman (1957) proposed a hypothetical construct labeled the "port of trade", in the context of assumed relations between the Aztec and Maya civilizations.

What might be called an "economist school" looked at

Mesoamerican trade with a view to fitting the New World phenomena into a universal evolutionary schema. A three-stage sequence was visualized in the evolution of the economy and therefore of society and culture itself: from the reciprocity characteristic of "primitive" cultures through the various forms of redistribution found in the context of the "emerging state", finally ending with the modern "price making market" that is characteristic of our own civilization (Polanyi, et.al., 1957). The "port of trade" was suggested as a necessary step in the progression of the economy from simple to complex in the second stage of the schema, and Chapman (1957:116) states that "independent trade areas of this kind, harboring numbers of warehouses, storing the goods of distant trading peoples, while the local population of the area itself did not engage in trading expeditions, have been found to exist in widely different places of the globe."

Chapman locates six "ports of trade" within Mesoamerica proper: Acalan in west-central Peten, Chetumal on the east coast of Yucatan, Naco and Nito on the gulf of Honduras, Xicalango on the Laguna de Terminos, and Xoconocho on the south Chiapas coast. An idea of the strategic placement of these areas can be gained from Scholes and Roys' (1948:318) description of one of them, Xicalango, as being the "convergence point of (1) the coastal sea route from Yucatan, (2) the land and river route across the Peten of northern Guatemala from the Caribbean coast of northern Central America, and (3) the river route that tapped the rich Usumacinta valley and its tributaries."

The "port of trade" is described as a city or town located in a neutral or politically weak area intermediary to two or more strong powers, functioning as a tension-relieving device to facilitate interaction without direct contact between the populations involved. Exchange was administered by backers and carried out by their upper-crust merchant representatives, who met on peaceable terms. The basic difference between the kind of exchange that took place in the "ports of trade" as opposed to all other kinds of trade was that here the merchants dealt only in luxury items, they were a distinct social group of relatively higher social standing then the local merchants, and that they, in keeping with their status, did not involve themselves in trade in the local markets at all.

For these reasons, Chapman totally disassociates the "ports of trade" from the local markets and even bases part of her argument for the existence of the "free ports" on the assumption that markets were not common in pre-Hispanic Mesoamerica. In these "neutral" areas it is claimed that the contractual nature of the "marketless" business is reinforced by the "existence of factors and warehouses, both of which were notably lacking within the Aztec empire proper as well as in Yucatan" (Chapman, 1957:146). The argument for the presence of "ports of trade" in Mesoamerica is rendered dubious on two counts: by reason of contradictions in the internal logic of the construct, and by misrepresentation of much of the evidence of an important nature relative to trade and markets in pre-Hispanic times.

The title of the book (Polanyi, et.al., 1957) in which the Chapman article is found implies that the economic systems being studied are to be found in "early empires", but neither of the two civilizations that Chapman deals with would fall under that term. The Aztec "empire" really was more on the order of a city state maintained by tribute from other cities or towns allied to or conquered by the capitol, Tenochtitlan. The Mexica do not seem to have consolidated their "subjects" once these had been vanquished, but rather to have pursued a policy of minimal interference as long as the tribute kept coming in. In the main, the local customs, religion, language, and socio-political structure was kept status quo, although the calpixqui (or resident Aztec tribute collectors) and Aztec garrisons, if present, assuredly introduced an element of Nahuatl and slid to the top of the existing social order. Chapman senses the unsuitability of the term "empire" in her treatise, and offers "militarily powerful metropolitan units" (1957:116) instead; but one can hardly characterize the Maya of Late Postclassic northern Yucatan, who were divided into eighteen tiny and jealous provinces (Roys, 1972: 11) as being militarily powerful or metropolitan on the same order of magnitude as the Aztec state.

Highly questionable also in the inclusion of Xoconocho as a "port of trade" as it was certainly not "politically weak" or "neutral", but directly under the control of the Mexica. Chapman rationalizes its inclusion in her schema by stating that "goods flowed to the center [from that location] not only as tribute or tax, but were also traded by the pochteca" (Chapman, 1957:120), although this is subsequently contradicted in part by her statement (ibid.:122) "Once a territory was conquered and therefore subject to tribute payments, the pochteca ceased to trade there." If Xoconocho was indeed a "port of trade", then certainly any number of other Mexica dominated cities or areas could likewise be labeled as such. The great town of Tochtepec on the southern boundary of the Aztec area of influence proper in addition to dispatching calpixqui to the towns nearby also served as a jumping-off place for all pochteca groups desirous of traveling farther south, who no doubt engaged in commerce with those nearby peoples not under the Aztec yoke. The variety of goods coming from the province of Tochtepec as seen in the Codex Mendoza exceeds that of any other location, and many items of tribute are not native to the region, necessarily being imported from some distance. The corrolary comes even closer when we note that Vaillant (1972:149) reports that in Tochtepec "all the corporations [of pochteca] owned storerooms and rest houses for their members."

Warehouses also must have existed in northern Yucatan to cope with the extremely seasonal salt harvest (see Salt) that would have called for storage throughout the rainy season. Roys (1972:47) comments on the practice of building fires on top of the newly collected piles of salt in order to form a "hard crust which the rain did not penetrate," which hardly points to anything other than keeping it for some time.

Chapman (1957:116) notes that all of her proposed "ports of trade" were located in "regions where cacao cultivation was predominant, a significant fact, since the cacao bean was the universal money in the Mesoamerican and Central American regions" (see Cacao, for fuller discussion of "cacao as money"). She (ibid.: 134) also claims that "the long-distance traders used only the cacao bean as money. The traders carried a kind of pocketbook filled with cacao beans." Yet the contradictions in the argument are obvious: "How would the pochteca and ppolom [the Maya long-distance trader] trade in the absence of markets? Obviously nothing but barter in kind was feasible..." (ibid.:135), and if their "ports of trade" seemed always to be located in "regions where cacao cultivation was predominant," of what value would cacao beans be to them as "money"? The "coals to Newcastle" implications are self-evident.

The most questionable assumption in the entire argument is the case made for an absence of markets in much of Mesoamerica, specifically the Maya area (ibid.:132), and the position that the long-distance traders did not frequent them when they did occur. It is admitted, however, that "some pochteca did purchase goods in the markets of Tenochtitlan-Tlatelolco which they traded in foreign ports" (ibid.:125). M. Coe (1966:142) perpetuates this assumption and makes a questionable asessment of the ecological situation to boot: "Markets are rarely mentioned where the lowland Maya are concerned, in contrast to Mexico where they were so large that the Spanish were astonished, and it is probable that they were unimportant in this very uniform land." (But one wonders at what he means then by his comment on page 24 of the same book on the "agricultural potential of the lowlands, which is by no means uniform.")

Gomara, however, reports that "each district and parish has its square for the exchange of merchandise, Mexico and Tlatelolco the largest...[in the rest] one every five days is customary, and, I believe, in the whole kingdom and territory of Moctezuma" (1966: 160). Spores (1965:972) extends the range of markets further: "the entire southern Zapotec area was devoted to extensive commercial enterprises. A great weekly market was held in Miahuatlan... Nearby Amatlan seems to have been a village that was largely devoted to commerce" and "Tehuantepec was of course a great market center, and goods and traders went from here to all parts of preconquest Mesoamerica." For the Maya area in Postclassic times, Thompson (1964:25) states that "we can suppose that every fair sized town had one [a market] and, in earlier times, they were probably a feature of every important ceremonial center. Presumably they did not differ, except in importance, essentially from the great markets of Central Mexico, about which there is ample information." In Roys' (1972:51-52) very chapter that Chapman uses to support her no-market argument we find the following notation: "Large market places were established at Cachi and Chauacha, important commercial centers in north-eastern Yucatan. At the former...there was a market-court at one corner of the square, where disputes were settled by certain officials. In the latter town a part of the market was housed in stone buildings with thatched roofs. Similar markets were likewise organized at other large towns... In the interior of the country none of the markets seem to have impressed the Spaniards sufficiently to elicit a description, but they are mentioned and they evidently existed in the more populous communities." Landa (1941:96) comments that the Maya, when "at their markets...traded everything which there was in the country" and also reported a strict regulation of commerce by the civil and religious authorities.

One would assume that weekly markets held in the open air would leave very little in the way of remains that could be discovered archaeologically. If there really is a dearth of markets mentioned in the early conquest accounts, perhaps it is due to the impermanence that is characteristic of markets in the Mesoamerican area today. It would be expected that markets might cease to be held under any kind of threat to traditional behavioral patterns, and the Spanish conquest qualifies in the first degree. The most significant clue we have regarding this possible situation comes from the pen of Gomara (1966: 345) who records that on Cortes' march to Honduras, merchants sent to guide him informed him that "they no longer went to the fairs [markets] as they had formerly done, because the people had fled to the forests, the wandering Spaniards having burned many towns." The drastic decline in the native population, especially in lower altitudes (Borah and Cook, 1963), that resulted from introduced diseases that were part of the European's cultural baggage would certainly have affected the continuation of the traditional pattern of regular market days, and commercial congregations would have been ideal centers for the contraction and spread of such diseases.

The "port of trade" model has been invoked for, in addition to the Late Postclassic period, the Olmec (M. Coe, 1965:122), Teotihuacan (Parsons and Price, 1971:182), and various cultures by others. If "ports of trade" have but questionable validity in the context of the Maya and Aztec areas in Protohistoric and early historic times for which they were originally proposed, there seems little justification for projecting the construct back to cultures for which we have no historic accounts whatsoever.

PERISHABLE RESOURCES

The greatest weakness of many of the existing theories concerning ancient Mesoamerican "trade" is that they either ignore or do not specify the articles which were being imported and exported. "Movement of articles" can only become "trade" when one class of objects is exchanged for another, and both can be identified. The use of models, heuristic or otherwise, can be helpful in illuminating and reconstructing the possible social and economic mechanisms of ancient trade, but only a familiarity with what was, or could have been exchanged over distances can bring the study of "trade" out of the realm of pure speculation.

Numerous imperishable "trade items" are known archaeologically in Mesoamerica, principally pottery, precious stones, metal items, and a few other categories of objects that were able to withstand the ravages of both time and the tropical elements. But assuredly, the perishable items that were imported into consuming areas must have constituted a large, if not the largest proportion of the total "trade". There are many historic examples from Mesoamerica of the movement of coveted items that would leave no archaeological trace. Perhaps that which comes most quickly to mind is the Aztec preoccupation with capturing candidates for human sacrifice. In Protohistoric times, the successfulness of Aztec warfare was perhaps guaged by the numbers of captives taken, rather than the acquisition of new territories. Given the sanguinary nature of the Tenochca, their stock of war captives were probably in need of constant replenishment, and human lives were undoubtedly a precious commodity.

The detailed but albeit fragmentary accounts of the early conquistadors, coupled with the modern work of ethnologists and geographers, have enabled us to catch a glimpse of the wide variety and importance of perishable items that were and are involved in trade in Mesoamerica. In the absence of firm archaeological preservation, we are forced to rely upon the histories, on representational art and iconographic studies, and on analogies from the current ecological situation of the area and the resources that it offers for our primary sources of information.

In the following sections of this paper, the characteristics, uses of, and geographical distributions of five perishable resources that may have played an important part in the exchange systems of ancient Mesoamerica are described. The archaeological intangibility of these items (as well as the seeming lack of value of some of them to the western mind) may account for the lack of references to them in much of the literature. When they are mentioned, often they become poorly understood or misrepresented. For these reasons, I wish to demonstrate that they indeed had an importance in the ancient cultures in which they existed, and that by studying them we can better understand the needs, desires, and values of the people involved. Most to the point, we can then begin to appreciate their cultural value as tradeable items.

In choosing salt, quetzal plumes, feline pelts, rubber and cacao as the five resource items for study, I have of course omitted countless others that deserve to be represented. The five selected, however, range in nature from the absolutely indispensible to the purely non-essential, yet all are possessed of the common characteristic of perishability.

My lack of attention to all other potentially tradeable items is not meant to imply a value distinction, merely my own preference in selection. There is no argument being presented against the importance of cotton, copal, dyes, slaves, foodstuffs, textiles, tobacco, honey and wax, seashells, fish, stingray spines, rope, body paint, pitchpine, spices and herbs, bark cloth and paper, tortoiseshell, animal teeth and bones, lime, cinnabar, hematite, ilmenite, pyrites and mica, and other precious or semi-precious stones, weapons, beads, copper and gold, volcanic tufa, obsidian, flint, metates, pottery, amber and many others in the ancient Mesoamerican cultures; quite the contrary, they all are in urgent need of being studied in detail. It becomes apparent that virtually every item under the sun that could have possessed an intrinsic or arbitrary value, no matter how obscure to us, surely moved about by human means from place to place in ancient times. The items that I have chosen to study are no more or less important than those few enumerated above.

Salt

Salt is absolutely necessary for the continuation of human metabolic processes; without it we die. Salt may be ingested in pure mineral form, or through a secondary food source high in saline content. Grains are notoriously low in this respect, vegetables and root crops are somewhat higher. Of the secondary sources, meat has the highest salt concentration, and therefore hunters and pastoralists, owing to their diet, seldom suffer from the lack of it.

The economic basis of Mesoamerican civilization, as most indications suggest, was predominently agricultural, but a few domesticated animals were known. In addition to the staples of corn, beans, squash and other plant foods, turkeys and dogs were eaten, no doubt helping to offset the chronic salt-deficiency that must have accompanied the basically vegetarian diet. The role that domesticated animals played in the diets of ancient Mesoamericans, however, is still poorly understood.

Indications are that the average peasant farmer seldom had an opportunity to eat meat. Benedict and Steggerda (1936) in their study of modern Maya from northern Yucatan discovered that over 70 per cent of everything eaten was derived from maize, and McBryde (1947:10) states that "The present inhabitants of [highland] Guatemala, especially the Indians, are essentially vegetarians. Maize supplies perhaps as high as 80 percent of the total food consumed." Archaeological information is much harder to come by, but Haviland (1965:17) comments on the "Paucity of bone fragments in...middens" at Tikal, suggesting that either domestic dogs "scavenged discarded bones. Or perhaps meat was not important in their diet."

In most of the sedentary civilizations extant at the time of the Spanish conquest, meat was reserved for the noble class as a luxury food, possibly because of its scarcity. In the regions of extremely high population density poaching wild game would have been a near impossibility, as the animals would have tended to have been outcompeted by the sheer weight of the human population. Yet salt would remain a crucial concern, as Roys (1972:53) states: "Its importance as an article of diet among agricultural peoples who eat comparatively little meat can scarcely be exaggerated." The major source of salt then, would of necessity have to be in mineral form.

As mineral salt can only be produced in certain geographically restricted areas, it must have been a primary (if not the first) article of "trade" from the beginnings of sedentary life in Mesoamerica. Those people with their own salt supply would be in a much more favorable position than those who had to trade for it. Mendizabel (1929:209), in his comprehensive study of the salt sources in prehispanic Mexico suggests that in order to be independent politically, pre-conquest populations had to have control of their own salt resources. In earliest times, however, before population pressures became too pronounced, the situation may have been different.

Political conditions often must have contrived to disrupt the movement of salt into consuming areas that could not produce it, and there are several accounts of this occurring. The classic example is that of the Tlaxcalans, who were surrounded and virtually isolated by their Aztec enemies for many years. When the Spanish arrived on the scene, the people of Tlaxcala were partially cajoled into joining in with the Europeans by a speech of Xicotencatl the elder's: "...the Mexicans make war on us every year...we are hemmed in in our own lands, so that we do not dare to go outside even to seek for salt, so that we have none to eat..." (Bernal Diaz, 1956: 136). Later, when making obeisance to Cortes, the old leader apologized for his country's poverty, suggesting the lack of salt, and his people's practice of eating dirt in attempts to obtain it, as the best possible indication of it.

A similar situation existed in Yucatan at the time of the conquest, and Landa (1941:40) writes of squabbling between the "Chel, who lived on the coast [and] would not give fish and salt to the Cocom, making them go a long distance for it...". The Spanish conquerors were also affected upon occasion: on Cortes' march to Honduras in 1524-1525, there was much suffering from the lack of salt, particularly in the Tabasco and Chiapas lowlands, and the Europeans had to rely on traveling merchants for their meagre supply.

In those regions where salt exploitation was most feasible, it must have been a major item of "trade". Foreign items in archaeological contexts in such areas would provide the evidence for what might have been traded in return. Weaver (1972:190) makes this connection for the large salt-producing portion of northern Yucatan: "...for each Peten polychrome pot [found there], its equivalent in salt made the return trip to the central core region."

Perhaps in later times the wealth of Mayapan was based on its proximity to the saltpans of the north coast. Tozzer (1957:226) reports that the rights to salt exploitation were jealously guarded in that region by the local chiefs, and that "to these all who came for salt made small offerings, either of the salt itself or of things from their own land...". Weaver (1972:188) in speaking of Dzibilchaltun, suggests that it must have had a population "far greater than could be maintained by outlying agricultural settlements. Trade undoubtedly flourished, and the fine salt deposits nearby provided an exchangeable commodity."

The Yucatec Maya were not the only peoples who were blessed with large and productive salt resources, for in Aztec times "The salt lake of the Valley of Mexico produced sufficient salt for the large [Mexica] population and even for an active commerce, particularly with the Otomies...and the Chichimecas" (Mendizabal, 1929:193). The Tarascans were also aided in maintaining their political independence by their own ample reserves of salt within the boundaries of their "empire".

But even among those people who could command as much local salt as needed, the substance was apparently brought in from other areas upon occasion. The Mexica imported salt from the country of the Matlazincas in the form of tribute (Codex Mendoza, 1938: folio 34, the only mention of salt in the document) because they preferred its taste to that of their own. It is possible that the Matlazincas obtained this salt in turn from the Pacific coast by trade or other means. The Tarascans apparently had also had the same predilection for foreign salt, as "a favorite [south] eastern raid had as its goal the fine salt deposit of Ixtapan" (Weaver, 1972:270) on the Pacific coast of Guerrero. Weaver (Ibid.:219) even suggests that a motivation behind the establishment of the Chalchihuites outposts of Mesoamerican civilization by the "Toltec" was to take advantage of the salt playas or bolsones of Durango and Zacatecas, but noting the proximity of Tula to the Lake Texcoco source, this is rather improbable.

Throughout Mesoamerica, it seems that sea-salt was much preferred to the highly nitrous products of the inland salt wells and solution basins. While these were decidedly important, "such sources could hardly compete with the Yucatecan salt, which needed only to be shoveled from the beds at the proper season and could be transported for much, if not for all, of the distance to its foreign market by canoe" (Roys, 1972:53). Before we can talk about the role of salt as a "trade" item, we must know more about how and where it occurred, and of the methods of obtaining it.

Salt was acquired from three general geographic loci: salt lakes, salt wells or streams, and from the sea itself, and mineral salt was extracted from brine either by solar or fire evaporation, or simply by surface collection of natural salt concretions or impregnated earth.

Salt lakes may be only seasonally occurring, as in the north of Mexico, or permanent with occasional cycles of shrinkage and replenishment, as are most of those found within the neo-volcanic axes. Salt lakes are formed in the bottoms of basins of interior drainage, with either limited or no outlets. Highly mineralized soils contribute a variety of salts in solution which "migrate with the water table" (Stevens, 1964:286) and ultimately end up in the lake water. The accumulation is highest in the halomorphic soils which are characterized by greater evaporation than precipitation, and the haloids of sodium, potassium and several nitrates become impregnated into the soil in high percentages. Sometimes seasonal playa lakes upon receding will leave a deposit of nearly pure sodium salts around their margins, called <u>tequezquite</u> in the basin of Mexico (Apenes, 1944:37), but more often the crystallized "salt" will be haloidal soil where extreme salinization and evaporation has occurred.

To extract salt from the waters of salt lakes involves a specialized technology, either the building of solar evaporation pans around the lake edges, or in the use of fire and ceramics. The processes of extracting salt from inland lakes by these measures are best known from numerous accounts and studies centered on Lake Texcoco. Gomara (1966:138) describes the salt industry of Ixtapalapa: "They have a rich trade in salt, which they make and sell there, or ship out to fairs and markets. They draw the salt water from the lake through ditches and collect it in pits, in which the salt crystallizes, and with it they make balls or loaves. They also distill it, which is a better method, but more laborious. Moctezuma derived a great income from it." Mendizabal (1929:187) makes the case for the primacy of the strictly solar method in the development of salt extraction technology, but probably both were used contemporaneously from the beginnings of ceramic times onwards. A selection of one method over the other would most likely be a result of other variables than time of invention and subsequent diffusion, such as availability of firewood, length of dry season and, especially, the relative salinity of the brine to be used.

During the time of Tylor's visit in 1860, large portions of Lake Texcoco were still being walled off and salt extracted by solar evaporation, and Apenes (1944:40) found a still-active "folk industry" of salt extraction in existence in this century. Although the recent hydrologic re-organizations of major scale have contrived to make Lake Texcoco many times more saline in modern times than anciently, Apenes found extraction processes continuing, in his opinion, unchanged from prehispanic times. He describes the methods of extraction and the different native categories of salt resulting from the variations in the "solubility of various salts at different termperatures", each of a distinctly different quality.

Tolstoy (1958) believes to have found the archaeological remains of a prehispanic salt industry at Texcoco, where he suggests that the <u>tlateles</u>, or earthen mounds on the lake margins served as loci for the evaporation of brine by fire in conjunction with a distinctive pottery type, which he labels Texcoco Fabric-Marked. The structural characteristics of "TF-M" however, bear little relation to the large, flat clay pans or pailas described by Apenes (1944:39) that seem to be the best shape for water evaporation, and Nunley (1967:521) states bluntly that "There is no evidence to support the hypothesis that TF-M [as well as the tlateles themselves] was involved with the salt-making industry..." Nunley has in turn been rebutted by Charlton (1969), who affirms that the distribution of Tenochca communities specializing in salt extraction coincides with Tlateles, which are in fact the "wastage" from the extraction process itself, and that Texcoco Fabric-Marked pottery is indeed a useful kind of vessel in salt making. In spite of the contradictory evidence for the exact mechanism of extraction, there is a general consensus of opinion that Lake Texcoco did support a large salt making industry in pre-conquest times.

In most cases the small salt wells or streams that are found sprinkled throughout the highland areas could produce only enough salt to support the populations immediately proximate to them. In pre-ceramic times salt most likely was obtained by immersing porous organic materials in the brine and then burning them to retrieve the salty ash. Later, salt was extracted principally through distillation with fire, and with few exceptions, production was on a small scale. Modern ethnographies of highland native groups indicate that salt extracted from small wells is still of religious and economic importance (i.e., Cancian, 1965:36-37), and McBryde (1947: 59-60) reports that the major source for the Guatemalan highlands in ancient times, Sacapulas, is a going concern even today.

An indication of the probable magnitude of the salt industry of the Yucatan peninsula has already been mentioned. Many early European observers commented upon its operation, and the Spanish were not slow to appreciate the economic potentialities for themselves. The natural conditions most favorable towards sea-water salt extraction anywhere in Mesoamerica are found on the northern coast of Yucatan, where the littoral is ringed with long barrier beaches and reefs that create salt lagoons and tidal swamps of shallow depth. In addition to having a much longer dry season than the rest of the peninsula (Koeppen's Aw to Bs in the west, as opposed to Am-Af in the east) which makes for better evaporation, the karst landscape of northern Yucatan gives birth to no rivers that may dilute the highly saline sea water. On the Pacific coast similar conditions exist in places, but the saline content of the water is lower, and the shoals and shallows that are pre-requisites for the construction of successful salt-pans are few and far between.

The process of solar evaporation of sea-water in Yucatan was described by Ciudad Real (1932:307) in 1588, and although the region had been under Spanish domination for some years, the methods were most likely little changed: "On almost all that coast, from Campeche to the Rio de Lagartos and further, there are wonderful salt-beds, which without being worked give quantities of coarse and very white salt of great value...ship loads of it are carried to New Spain, Havana, Honduras and Panuco and other parts. [They]...stretch along the coast, following the sea-shore, and with rain-water when it falls, the salt coagulates in them and at that time the Spaniards and Indians repair to them and in the water they pile all the salt they can. Afterwards they take it from there and make large mounds on which they put fire which makes a thick and strong crust that does not melt although it rains for days and nights upon it... From these mounds [they make] loads and carry it inland..."

In pre-conquest times, the weight of raw salt probably insured that it would travel principally by canoe, and most students (Blom, 1932a:535-536; Benson, 1967:69; and Thompson, 1964:16,36) suggest that salt was carried in this manner from Yucatan to, among other places, the Gulf Coast, Honduras, and the Peten. The extraction process, as indicated, must have been highly seasonal, and large amounts probably were stockpiled the year round if a continual "trade" was to be kept up. Ciudad Real's earlier mention of "rains for days and nights" suggests nothing other than storage over the rainy season, when weather and water conditions would not allow for efficient evaporation of brine.

One would expect that little of the aboriginal constructions for salt extraction such as dikes, platforms and the like would have survived the colonial period unchanged, for Yucatan at a later time provided much of the salt demanded by the "patio process" of silver refining in the Chichimec region. Tylor (1861:84) in 1859 commented upon the great quantities of salt that were brought to the Valley of Mexico from the "Salinas of Campeche" by water via Tuxpan. The finer Yucatecan salt was used as food in Mexico City, the coarser being sent north to the mines. Roy's (1972:53) claim for prehispanic times: "Yucatecans enjoyed what was virtually a monopoly of the salt business on the Atlantic seaboard" perhaps was just as applicable to the situation discussed by Tylor in the 19th century.

Throughout Mesoamerica are localized regions with either an overabundance or dearth of salt. Those areas generally lacking natural sources are the better part of the Peten and other low-lying regions such as portions of the Gulf Coast, and river valleys on the Pacific litteral, and isolated highland country including the southern reaches of the Chichimeca, much of the southerly portion of the neo-volcanic axis, and most of highland Guatemala.

In addition to Yucatan on the Atlantic coast, several other localized sources of varying productive capacity exist: in Tabasco and southern Veracruz are a few salt wells and "piles" associated with salt deposits at Tlacotalpan, Iztapangajoya and Iztapan (Mendizabal, 1929), and in the shallow waters of Chila lagoon in the Huaxteca solar evaporation took place. The sea-salt extraction complex extended up the Pacific coast, with important works at Iztapa in Guatemala, Salina Cruz in Oaxaca (Spores, 1965), Ixtapan in Guerrero, and at Barra de Navidad on the Jalisco-Colima border. Less important sources occur intermittently, and no coastal area is very far removed from a salina of one order or another. The only major source in the Maya central area is at Salinas de los Nueve Cerros (Thompson, 1970:23,29) on the Middle Chixoy in Alta Verapaz, which was surely of great importance in classic times.

In the Mexican highlands the major salt-producing areas, besides the basin of Mexico itself, were in the Colima basin, centered around Lake Sayula, the Tonalan, near modern Guadalajara, and two in the present state of Michoacan, the first directly to the east of Lake Chapala, a district of salt-springs and wells, and secondly, the salt pans of Lake Cuitzeo. In the Oaxacan highlands, north of the Altas de Miahuatlan, was the largest concentration of salt wells and streams outside of the volcanic highlands, fairly evenly distributed throughout the area. The highlands of Chiapas and Guatemala are relatively poor in salt, but San Mateo Ixtatan and Sacapulas in southwestern Guatemala possibly could have produced enough for the entire region.

Most areas rich in salt supported large and vigorous populations that are known from conquest-era accounts or archaeological excavation. The numerous other civilizations with inadequate salt sources must have been engaged with them from very early times on in order to obtain this precious commodity, but the role that salt and salt trading played in the rise of Mesoamerican civilization remains to be seen.

Pelts and Plumes

The largest carnivore in Mesoamerica is *Felis onca*, the jaguar. Impressive in size (males can attain a maximum weight of around 250 pounds), demeanor and power, the great cat has been represented in art and figured in ideology from the very beginnings of civilization in Mesoamerica. The feline motif has also been one of the longest-lived; it pervades the art of the Olmec culture in all mediums, and Kubler (1971:19) notes that the jaguar image is incorporated into the art and iconography of Teotihuacan, Tula and Chichen Itza by itself or in the form of a composite cult symbol that he refers to as the "jaguar-serpent-bird icon". The importance of the jaguar in Mesoamerican conciousness and expression was such that in 1970 a conference (see Benson, ed., 1971) was held to discuss the various implications of feline motifs throughout Mesoamerican culture history.

During the Classic period, a high mark of prestige was a breech-clout of jaguar or ocelot (*Felis pardalis*) skin. At Teotihuacan, "by far the largest class of jaguar images consists of human beings wearing jaguar costumes. Sometimes the costume is an entire pelt with head and claws and tail..." (Kubler, 1971:25). The "militarist" peoples of the Postclassic period often likened their warriors to jaguars in terms of fighting ability and ferocity, the military orders of "jaguar knights" in Aztec times being the best known example. Moctezuma even imported jaguars from the lowlands and kept them in his private "zoo" in Tenochtitlan, and Bernal Diaz (1956:212) compared the fearsome collection of animals and the noises that they produced not infavorably with "a hell". In the Protohistoric period the highly prized skins of the big cats served as symbols of the importance of those who wore them, and their use was almost certainly restricted to the "privileged" classes. Among the Quiche (Carmack, 1968:73) puma and jaguar skins were used to cover the "thrones" of rulers, and the eagle and jaguar skins sculpted in stone in the rock-hewn structure 1 at Malinalco probably represented a similar practice of associating authority with the jaguar seat.

Puma skins are known from late times to have been likewise favored, but their exact identification in the representational art is difficult, as there are no distinguishing marks (such as the jaguar's "rosettes") to set them apart from more mundane clothing. Unlike the puma (Felis concolor), whose range throughout Mesoamerica closely approximates that of its principal prey, the ubiquitous white-tailed deer, the jaguar and ocelot are rather restricted in their distribution. They are "most at home in the tall shady forest along streams and watercourses that traverse the coastal lowlands" (Leopold, 1972:446). The jaguar will hunt and kill whatever form of animal life is most available in its locality, and although it sometimes ranges into the sub-tropical monte of the foothills, it generally remains in the tierra caliente where game is more abundant. The greatest concentrations of jaguars and ocelots was through the hot lowlands of southern Sinaloa and coastal Nayarit to Xoconocho, the southern gulf coast regions and most of the Yucatan peninsula as well as the coastal lowlands of Honduras, Nicaragua and Costa Rica.

Much movement of the skins of F. onca, and to a lesser extent, those of the smaller F. pardalis must have taken place in ancient times. Since it is not always possible to distinguish the individual species of cats represented in Mesoamerican art, some students prefer to label those depictions of indeterminant nature merely as "felines", while others continue to call all cats "jaguars". In any case, the native peoples made distinctions along species lines; most indigenous groups in direct contact with the big cats were found, at the time of the conquest, to have had separate and distinct names for jaguar, puma, and ocelot.

In maintaining status distinctions by dress and adornment, feathers have also played an important role in Mesoamerica. The practice of using feathers in this way is likewise very old, probably as old as religious and secular authority. In the vestments of important personages from pottery, stone sculpture, and murals from the earliest times on, feathers of rare or geographically restricted origin are in evidence. Capes, canopies, fans, fringes of cloth, embroidered textiles, headdresses, crests, robes shields and standards as well as many other objects were decorated with or constructed wholly of a multiplicity of valuable feathers.

Virtually all feathers used in such elaborate applications were from the tierra caliente, or from the tropical river valleys that dissected some highland areas. In Aztec times, those of the toucan, parrot, macaw, and hummingbird were worked by the members of the prestigious "guild" of feather-artisans, but the most valuable ones were harder to obtain. The striated red, white, and pink body feathers of the roseate spoonbill (Ajaja ajaja) could be secured from the peoples of the gulf coast, but the emerald-green irredescent tail plumes of the quetzal were to be found only in the cloud forests of the highlands to the south.

The feathers of the latter bird were in constant demand due to their impressive length of two to three feet as well as their "precious" green color. Quetzal plumes were probably reserved for only those people of great rank and honor. It is hard to find a Classic Maya stela without great splays of quetzal plumes decorating the personages depicted, and in highland Mexico, far from the source of these feathers, their representation in art is common in both Classic and Postclassic times. An extremely elaborate headdress, sent back to Charles the fifth by Cortes is still preserved in Vienna; the piece, reputed to have belonged to Moctezuma himself, has been variously estimated as containing either five-hundred (Nuttall, 1888: 27) or six-hundred (Morley, 1946:440) tail plumes. Since these plumes are only present on the male of the species, and only two, or at most three, are grown annually, this single remaining example represents a massive amount of quetzal-plucking.

In Protohistoric times, the people of highland Guatemala, Honduras and even Nicaragua and Costa Rica sent as tribute or trade items both feathers and live birds to Tenochtitlan. The greatest tribute in "quetzal" plumes listed in the Codex Mendoza comes from Tlaxiaco in the Mixteca Alta, but today the bird is almost unknown north of the Chiapas highlands. Xoconocho contributed eight-hundred handfuls of quetzal feathers periodically, and Cotoxtla the same amount, but these were almost surely imported from the Alta Verapaz region or elsewhere. Nuttall (1888:39) in interpreting early historic accounts notes that the "extensive aviary in Montezuma's "palace" was constantly supplied with living specimens...Indians...administered to each want and bestowed special care on the raising of young broods." So between the influx of plumes from distant lands, and those that were "farmed" at home, the Tenochca nobility must have had an ample supply.

Protohistoric peoples practiced a form of "wildlife management" that guaranteed the continuation of breeding stock in its natural habitat. Both Bernal Diaz and Gomara report that birds of precious plumage were caught in the wilds at the right season, plucked, and then set free again, and that killing the quetzal was a capital crime. This annual tail-feather harvest probably took place immediately before the nesting season, as the quetzal incubates its eggs in cramped nests in hollow trees, much to the detriment of its plumes. The breeding male uses his feathers to attract his mate, and they reach the peak of their excellence right before the eggs are due. So accordingly, the "harvesting" of tail plumes must have occurred at a very rigidly determined annual time.

The quetzal is still very much sought after today, and perhaps the popularity that its feathers "enjoyed" in Europe during the last century effectively eliminated it from areas in which it had previously been common (Oaxaca?). Over a hundred pairs of live birds are reputed to be smuggled out of Costa Rica alone annually. Stuart (1964:323) suggests that this practice of recent times, coupled with the "greatly accelerated destruction by man of its [cloud forest] habitat in the twentieth century", have rendered the quetzal "rare and local".

The bird is an inhabitant of the upland cloud-forest, seldom found at elevations below 4000 or in excess of 9000 feet. They are omniverous but seldom if ever descend from the trees, being easy marks for predators. The northern bird, Pharomachrus mocinno mocinno, is the larger of the two subspecies called "quetzal", and consequently has the longer plumes. His smaller southern cousin, Pharomachrus mocinno costaricencis, can live at slightly higher altitudes due to the higher temperatures in its range. Stuart (ibid.:323) reports that the birds live in the "humid mountain cloud forests from Oaxaca to Panama", but many students place the northernmost extent of P. mocinno mocinno in the Chiapas highlands. The great numbers of plumes listed as coming from the Mixteca Alta in Aztec times, as well as the presence of the cloud-forest configuation in parts of the Oaxacan uplands (West, 1964b:373) lends credence to the possibility of a large quetzal population in this region during ancient times.

No doubt exists, however, that the birds were "endemic to the Central American highlands" (ibid.:375), and assuredly both subspecies were exploited. The yearly replenishment of the male's tail feathers probably ensured a continual supply of these delicate items so treasured by the ancient Mesoamerican civilizations. One has only to examine Proskouriakoff's (1950) study of Maya sculpture to gain an impression of the imagination with which perishable items such as feline skins and quetzal plumes were put to use, and of their importance that accrued to them in Classic Maya society. Perhaps quetzal feathers better than any other resource of ancient times qualify as a completely non-essential item of prestige value alone, a value hard to imagine from our western viewpoint.

Rubber

A well-established tradition of rubber use existed in ancient Mesoamerica and its environs. By the time of the Spanish conquest, the area of rubber utilization had far exceeded its natural distribution, and large quantities were moving from the producing to the consuming areas. Rubber was put to use in both strictly functional applications as well as in many other ways relating to religion, ritual, and curing.

The development of an indigenous rubber technology is considered by some students to be a diagnostic trait of Mesoamerican culture itself.

Of the more than fifty species of plants (Polhamus, 1962:61) present in Middle and North America that yield rubber, only two can be considered as potentially important sources in pre-hispanic times. Most of the others, due to the meager quantity and quality of their "latex" were not, from what is known, exploited. The two visible sources, that of the sap from trees of the genus Castilla found in the tropical lowlands and littorals, and that from the roots of the xerophytic desert shrub Parthenium argentatum, or guayule, were utilized because a large percentage of their weight is represented as rubber latex.

Of these two plants, extremely different morphologically as well as in geographical distribution, Castilla was pre-eminent in importance. Castilla rubber was used in all areas of Mesoamerican influence (the stability of its latex made it the more desirable in all contexts of use) and was preferred over guayule if and when a choice existed. Significantly, both guayule and castilla rubber are found within the sphere of Mesoamerican cultural influence, a condition that no doubt led to the primacy of the Mesoamerican peoples in rubber technology (Stern, 1950:4).

The major interest the colonial period Spanish had in the various applications rubber was put to by the conquered peoples chiefly concerned its use as an element used to impregnate fabrics, to stiffen them and make them water repellant. Using native rubber for impermeating raingear continues among some indigenous groups in southern Mexico and Guatemala to this day; Covarrubias (1947:photo 31) illustrates rain slickers so treated in the Tehuantepec region. In ancient times, soldiers and travelers most probably were the major consumers of rubber put to the purpose of waterproofing, and no doubt contributed in some way to its adoption throughout Mesoamerica. Raingear in general, as well as sandals, were coated with a protective layer of rubber latex. Banners were stiffened with it, as were war-shields, and although it is not reported, it is probable that the obsidian blades set in the edges of macanas or sword-clubs were anchored in a rubber mastic which could be more easily melted out by heat for replacement of dulled blades than, for example, pine-pitch. Cooking utensils were covered, canoes were caulked, drumsticks padded and rubber was also put to a myriad of other strictly utilitarian applications.

Rubber also enjoyed a great popularity as an intermediary with the supernatural in worship and in curing. In certain circumstances, modelled figurines or "idols" of castilla rubber have been preserved in nearly their original form; several have been recovered from cenotes in the Maya lowlands (Davalos Hurtado, 1961:548-549). As with copal or pom, rubber was burnt as incense or offered up as a sacrifice in hardened cakes in devotionary practices among the Maya (Landa, 1941:142-143). In areas of close proximity to the major concentrations of castilla rubber, the latex was drunk in its semi-liquid form; in places farther removed, it was eaten or swallowed in its solid state. An indication of the possible variety of ancient applications in curing can be gained from the mention of rubber being used by historic Maya peoples in treating common dysentery (Roys, 1931:49), "poisonous snake dysentery" (ibid.:52), minor burns (ibid.: 69), "swollen knees" (ibid.:121) and slivers or splinters in the foot (ibid.:204), to note but a few. The Nahua peoples of conquest times times also ascribed all manner of cures to the ingesting and administration of rubber to various parts of the body, generally concerned with physical betterment and in increasing "suppleness". Castilla rubber was used by priests in ritual body painting and for daubing on statuary in addition to functioning as glue in the manufacture of mosaic masks for ritual use.

Undoubtedly the best known use of rubber in ancient Mesoamerica was in the fabrication of balls for the ritual ball game. Ball courts are characteristic features of most major sites of the classic and postclassic periods, and most students consider the ball-game to be a hallmark of Mesoamerican civilization (i.e., Kirchhoff, 1971:8-9). The different forms that ball-courts can assume have been studied by a number of students, and A.L. Smith (1961) convincingly demonstrates that temporal seriations are indeed possible in certain areas.

Rubber balls were manufactured in a number of different ways, usually by mixing herbs or other solid matter with the latex to harden it and give it greater cohesion. Isabel Kelley (1943) describes the particulars of ball making in modern Nayarit, where a modified form of the ancient ball game still persists, using local castilla rubber.

The ball game is known from the area to the north of the Mesoamerican heartland by the presence of several ballcourts as well as by a few actual balls themselves that have been preserved through dessication. During the northward expansion of Mesoamerican culture via the Chalchihuites groups, rubber use reached its greatest extent, spreading through the "Gran Chichimeca" and beyond. Ball courts are found at La Quemada, Zacatecas, the Schroeder site in Durango, and at Casas Grandes, Chihuahua. It is probable that at this time the Chichimec nomads of the area were playing a variant of the game without ball courts, as they were at the arrival of the Spanish. Courts are known from several Hohokam sites in Arizona; Snaketown and Wupatki both have archaeologically reconstructed examples.

The development of a tradition of rubber use in this area far from the northernmost castilla stands probably led to the large-scale exploitation of the second, and closer source; guayule. The original rubber ball in the arid region stretching from Zacatecas to central Arizona must have been made of latex from castilla, and imported from the south. Uncertainties of supply, compounded by distance and the intervening "hostiles" must then have prompted the exploitation of guayule, a plant most likely already familiar to the northern cultivators, as an alternative source. Although much closer than castilla, Parthenium argentatum still is extremely localized in its distribution, and likewise had to be imported into some of the consuming areas. Production of rubber from guayule on a scale applicable to the demands of the ball-game constitutes an important regional specialization, but probably not the original introduction of a rubber technology of advanced proportions in the area.

Of the ten known species of Castilla, five are found within the Mesoamerican region: C.fallax, C.guatemalensis, C.lactiflua, C.nicoyensis, and C.elastica. Most of the differences between the five are so minor as to be insignificant in the context of rubber exploitation, and the modern species distinctions are based primarily on variations in bud formation, flowering and in geographical restriction. C.elastica is the most widespread and so references to "castilla" rubber generally imply that it is elastica that is being utilized. Polhamus (1962:100) makes the point that in pre-conquest times these different species were probably not distinguished, and selection was most likely made on the basis of the individual merits of each tree as a producer.

Castilla bleeds freely with the first tapping, but seldom can more than one extraction of latex be made successfully. The proportion of actual rubber content in the sap increases with age; the non-rubber element being as high as 50 percent in the first few years of life, but dropping to around one-tenth after eight or nine years. Most botanical studies suggest that castilla is not a true canopy forest tree, but rather inhabits specialized zones within the rain forest configuration. West, et.al., (1969:61) in Tabasco locates the elastica as scattered throughout the second story of secession, and does not mention it in any other context. Pittier (1909:251) however, states that its "natural habitat is in the clearings and other open spots of the virgin forest...in company with cecropia, or in the fertile, sparsely wooded alluvial flats of the valley bottoms". Castilla appears then to grow "wild" in a number of closely corresponding ecologic situations, tolerating shade but preferring sunlight. Polhamus (1962:99) notes that "trees that grow in the thickest forest... [their] latex is very thin and easily collected, containing less rubber than that of others, whilst trees that grow in full sun exposure have...a very thick, highly coagulated latex."

The general impression received of pre-hispanic rubber exploitation, if and when the topic is discussed, usually concerns wild trees being "hunted" out of the forest, tapped, and then abandoned. In light of some of the characteristics outlined on the previous pages, this view may not be entirely correct.

A semi-intentional form of cultivation may have existed as a concomitant of swidden agriculture in the lowland areas, with castilla growing up in resting milpas as a fallow crop. The practice of raising "cash crops" in the fallow period of fields is known from the modern Totonac area (Kelley & Palerm, 1952) where vanilla is planted in milpas immediately after their abandonment. The presence of castilla in the fallow field would have encouraged an adherence to the necessary period of time for the regeneration of soil nutrients by precluding burning until the optimal tapping age of the trees (eight or nine years) had been reached. The "one shot" nature of castilla tapping would tend to argue against intensive cultivation, but encouragement of the trees in the weed invasion following abandonment of cornfields would certainly allow for a greatly increased production of rubber over that of collection in the wilds. Castilla can certainly get along without the aid of man, but would tend to benefit from the creation of a cultural landscape that approximated the ideal natural one described previously by Pittier.

Castilla will grow at elevations as high as six or seven hundred meters (especially C.guatemalensis) but rubber content in the sap begins to become insignificant at a much lower altitude. The geographical occurrence of castilla in Mesoamerica follows the Pacific coast from the Nicoya Peninsula to San Blas, primarily in the humid river valleys interspersed along this area of Koeppen's Aw climate; the Atlantic coast from the southern Gulf of Honduras across the Peten to the Tuxtlas and southwestern Veracruz, with the northernmost stand being a discontinuous and isolated element in the Huaxteca. Of these areas, the most important were the Peten, Tabasco, and Veracruz, where the rain forest was most exuberant. The Pacific and Huaxtec areas saw little large-scale production, as most of the rubber found in these locales was of poor quality and consumed locally. Across its entire extent, castilla is not evenly distributed. There are heavy concentrations of trees in some areas, a dearth of them in others, with a general sprinkling throughout.

Stern (1950:75-76) places the time of diffusion of the ball game over all of Mesoamerica at the end of the "formative period", and the ball court at the Schroeder site has been tentatively dated to the middle classic (Ayala phase). The playing of the ball game must have provided a constant demand for rubber in those areas where rubber was hard to obtain, and almost assuredly the ball game was not merely restricted to those sites with recognizable ball courts. Such rubber would have had to have come from either the far away lowland sources within the nuclear area, or from the small stands of guayule in the arid bolsones. The supply of castilla rubber from the south probably was curtailed by the retraction of Mesoamerican influence from the northern area after the fall of the "toltec" groups, and the people of Zacatecas, Durango and Arizona most likely had to rely on guayule exclusively.

Several rubber balls have been excavated in the American southwest. A ball found at Snaketown was analysed by Haury (1937) who tentatively identified it as composed of guayule. The people of the arid north were probably familiar with the properties of guayule long before the introduction of the ball game, with its concomitant increased demands for rubber. In historic times, guayule was used by country children within its area of natural distribution in making small rubber balls or was chewed as gum (Altamirano, 1906:1100) and the latex was extracted from the pulp by constant mastication of the plant's roots (Lloyd, 1911).

Guayule does not give up its latex in a flow of sap, but rather contains it in isolated pockets in its extensive root system. The extraction of the rubber therefore necessitates the total destruction of the plant, but since guayule can generate its maximum rubber content in a single year, the yield is immediate. The rubber element increases throughout the year until the greatest proportion is reached immediately before the start of the rainy season, whereupon it might constitute up to a quarter of the plants dry weight.

Parthenium argentatum, as with castilla, is present in isolated patches within its area of maximum distribution, and there are few concentrations of major proportions. It is usually found on limestone ridges and other calcareous soils, at elevations of approximately five to six thousand feet, in areas possessing less then ten annual inches of rainfall. The parameters of guayule distribution encompass portions of the states of San Luis Potosi, Nuevo Leon, Coahuila, Chihuahua, Durango, and Zacatecas, with a slight extension across the Rio Grande into the Big Bend region of Texas.

Blom (1932b:540) expresses a conviction that the rubber used in the highlands of Mexico and Guatemala "was grown exclusively in the tropical lowlands, and brought to the highlands...by traders." But the exact mechanism of movement for this rubber is unknown. The best known example of the actual workings of any mechanism of movement is found in the Aztec tribute lists of the Codex Mendoza (1938, Clark), which is still at best ambiguous and subject to varying interpretations. An example of this ambiguity is shown by the debate over the actual quantities of rubber that are represented in the codex and the form in which they were transported.

The Codex Mendoza lists Cosamaloapan, Tochtepec, Michapan and other towns of the gulf coast, twenty-two in all, that contributed rubber as part of their "protection" to the Aztec state. Clavijero (1958,Vol. II:214) describes this tribute as 16,000 (Aztec numerical notation) pelotas, a term that has been interpreted as either "balls" as in the finished product for the ball game, or "loads" (cargas) referring merely to the shape of a large amount carried. Blom (1932b:540) demonstrates that the Nahuatl word for rubber olli is a derivative from the Maya term for "round thing" or uollic, and infers that the form of traded rubber was that of the small, finished ball. Lowe and Ries (1948:37) however, consider them to be loads of 100 pounds each, giving a total listing of 1,600,000 pounds. Furthermore, this interpretation places the tribute as being exacted from each of the twenty-two towns, not from the area as a whole. After citing some dubious figures for "individual annual yield" per tree (12 oz.) the authors conclude that "the busy Olmeca may have worked as many as 2,133,333 trees each year in order to pay taxes to their overlords" and, "The Nahua merchant man must have done a rush business in distributing the Olmeca tribute" (Lowe & Ries, 1948:37-38). This assessment of the amount of rubber is almost surely excessive, but the staggering outlay of time and resources is proposed, one feels, in order to account for the vast amount of rubber that was known to have been consumed in Postclassic times solely by means of tribute exactions.

"Free trade" leaves no written records, yet the rubber contributed by sources other than strict tribute must have been of no little consequences. Furthermore, there is no way of knowing how much of the rubber taken as tribute from the towns of the Veracruz region might have come from other major producing areas (i.e., Tabasco and the Peten) primarily, only to then be seconded to Tenochtitlan by the subject towns themselves. The cautions necessary in examining the tribute lists for the presence of rubber apply no less to any other item, and the Codex Mendoza best serves to illustrate the type and range of political contacts of the Aztec state rather than as an accurate guide to the actual sources of supply.

The remarkable properties of rubber, whether from castilla or guayule, lent themselves to many uses of major import to the Mesoamerican and related peoples. Perhaps the greatest number of which, when one considers the diversity of applications known to us, remain solely in the realm of conjecture. Likewise, the mechanisms by which the rubber to fill those needs moved are unknown, and subject, as are those of all other resources described in this paper, to all manner of speculation.

Cacao

Virtual oceans of ink have flowed from the pens of those interested in the phenomenon of cacao cultivation in Mesoamerica. The first accounts by the Spanish regarding this product are speculative and relatively unreliable, but a few of the early chroniclers took the trouble to record their observations with some concern as to time, place and ethnic affiliation, so we are not totally in the dark. The status that cacao occupied in Mesoamerican society and economy is still a poorly understood and much debated topic.

Thompson (1956:109) in probably the most ambitious statement regarding the function of cacao yet written, suggests that it played an important role in cultural development. Besides "stimulating trade throughout Middle America and, with trade, the spread of ideas," Thompson sees the possible origins of the complex Maya system of reckoning time and arithmetic and ultimately, the development of the Long Count dating system in the familiarity with large numbers gained from transactions involving cacao beans.

Cacao was used as a common religious offering at the time of the conquest, and in parts of rural Mesoamerica is still important in that context today, as a direct sacrifice, or to solemnify contracts of marriage, compadrazgo, and the like. The numerous examples from Roys (1931) for the modern Yucatec Maya, together with those listed by Thompson (1956:106) for Mesoamerica in general in which cacao is used in a medicinal way point up a probable analagous function as a curative in pre-Hispanic times. Cacao was taken for general pains, or more specific ailments such as snakebite, poisoning or burns, and was either ground into powder and mixed with honey and/or spices in hot water to be drunk as the nahuatl chocolatl. More serious wounds were dressed with the "butter" extracted from the beans by pressing.

Assuredly, the leading means of consumption was in the form of the luxury beverage chocolatl. Millon (1955:220-221) sees the development of an "almost universal demand for cacao, as evidenced by the wide use of cacao as a luxury food, [which] seems to have been instrumental in the development of inter-provincial trade in ancient times." Thompson (1956:101-102) notes that cacao was of such importance that depictions of it in the architectural sculpture, "stelae" and murals of Santa Maria Cotzumalhuapa, Copan, El Baul, El Tajin, and Teotihuacan are fairly common. The wide distribution of possible producing and receiving areas points to the probability that cacao was well known throughout these regions of its ultimate extension by at least the early classic period.

There are indications that in the non-producing areas cacao was reserved for the upper strata of society, and the notion of cacao's sovereignty as the "universal" currency of Mesoamerica has been often suggested as the common denominator in poly-ethnic interaction anciently. Millon (1955) however, sees the role of cacao as money in a subordinate position to its major function as a food restricted to those in control of cacao groves, or the wherewithal to secure it by trade or tribute. He concludes (ibid.:221) that the economy of ancient Mesoamerica as regards cacao was "based primarily on production for consumption rather than production for exchange." This view is shared by Benson (1967:62) who suggests that "for the most part cacao was a luxury, as most of the cacao crop went to the priests and nobles and the surplus was traded to other areas."

As mentioned previously, many other students are not of like mind, preferring to consider cacao as a medium for tribute or exchange, often, one feels, in the hopes of discovering a "true" monetary system comparable to those of modern times, where every object can be assessed in terms of a single standard of value. Blom (1932a:538) speaks of "regulated currency" in the form of cacao beans existing as the "international monetary unit of the Aztec, Maya, Chorotega, and other nations" and Bergmann (1969:86) echoes this view by claiming that "nearly all goods and services were obtainable in exchange for cacao beans." These rather broad assumptions are based largely on well-documented accounts of two areas in which cacao did serve as a kind of money and also on the subsequent practice of the colonial Spanish of paying Indian wage-laborers in cacao.

The first of the two conquest period examples is that of the famous market center of Tlatelolco, described by Cortes, Bernal Diaz and Gomara, which is too well known to be repeated here. The second is for Nicaragua, a major cacao producing area, in which Oviedo (1959: book 42, 363-364) states that "everything is bought with cacao, however expensive or cheap, such as gold, slaves, clothing, things to eat...", even going on to relate the going price for the attentions of the "public women" in cacao terms. Oviedo describes the method of counterfeiting the beans by filling old skins with clay (Thompson, 1956:100-101 lists other methods), and this practice certainly reinforces the case for a "cacao currency".

As a medium of exchange, cacao would have had several inherent advantages over other items. With careful curing the beans will keep for at least a year, and not lose their value for making chocolatl. The individual beans would be low enough in value to make for ease of small purchases, and their relative durability, small size and ease of storage would make them ideal for use when traveling. Finally, the constant consumption as food or drink would guarantee a continuing market for them, and likewise function as an automatic inflation control.

It must be remembered that cacao was still an article restricted to the upper strata of Mesoamerican society, a point which the chroniclers cited above all make clear. As a prestige item, it would have been coveted by those who would not have normally had an opportunity to obtain it, and if the elite upon certain occasions allowed cacao to trickle down to the common people to be used in rituals as offerings, or payed them for purchases with it, this only underlined the monopoly that the upper classes held in controlling cacao.

The use of cacao beans as "money" by the Spanish in dealing with Indians has been well documented. Thompson (1956) devotes the better parts of five pages to the fluctuations of areal and temporal value of cacao used as currency in New Spain. The conquistadores learned early that recalcitrant Indians could be bribed with presents of cacao, workers paid in it, and that it could be sold to them at a great profit. Thus it behooved the early encomenderos and settlers to foster the cultivation of a crop that was primarily directed not for export to Spain, but for domestic consumption. O.F. Cook (1916) reported that as late as the time of his writing in Guatemala cacao was still one of the few articles that could be sold to the natives for money, and that the coffee growers were importing it from Ceylon and the West Indies in order to meet the demand. Thus the possibility that the social disorder created by the Spanish conquest and subsequent developments enabled more classes of people than previously to gain access to cacao would not be discounted. The European colonial practice of using cacao for payment instead of money has done much to give the impression that cacao circulated through all classes in pre-conquest times, and most who have treated the subject consider it to be a survival of the state of affairs at contact. As I hope to have pointed out, the matter of "cacao as money" is by no means settled.

From any standpoint, cacao was an extremely valuable resource in Mesoamerica, and was cultivated by all peoples living within its natural range. It was even in one recorded instance transplanted to an area not suited to its cultivation, and kept alive by artificial means. Millon (1955:176) suggests that this wide distribution by human agency is indicative of the great age of its cultivation in Mesoamerica. At the time of the conquest, cacao was moving between widely separated groups, some of it in the form of tribute, other represented a barter commodity exchanged for goods.

The subject peoples of the Mexica who lived in the tierra caliente paid a substantial portion of their "protection" in the form of cacao. The kind of relationships that existed between Tabasco and Tenochtitlan is not well understood, but the area does not seem to have been tributary to the Aztecs. It is known that great quantities of cacao came from Tabasco in the form of trade, and therefore were not listed in the Mexica tribute rolls, and perhaps some of the Veracruz cacao in the _Codex Mendoza_ may have originated in Tabasco. Bergmann (1969:85) claims that "areas producing on a large scale for trade [he means tribute] with the Mexican plateau were restricted to a few districts, principally those of Soconusco [Xoconocho] and Tabasco." This statement is misleading, for whereas Tabasco did trade with the Mexica (West, Psuty and Thom, 1969:99-101; Scholes & Roys, 1948:29-31), Xoconocho was a subject area and produced cacao as tribute. The fundamental importance of this distinction is that "free trade" is relatively hard to document whereas tribute must be compiled exactly to be a successful operation.

There are two different species of cacao, _Theobroma cacao_, the "cacao proper", and _Theobroma bicolor_, commonly called patashte (from the nahuatl _patlaxli_) and is the less desirable of the two. There are furthermore two distinct forms of _T. cacao_; the first and favored is the "crillo" variety, whose fruit is milder and less bitter than the second, or "forestero" type. A criollo seedling takes five years to begin to yield, and is especially susceptible to disease; forestero yields in only three years and is much hardier. Both types need constant care and protection from the numerous insects and small animals that have a taste for their fruit. The most destructive are red ants, monkeys, parrots, squirrels, and rats, and parasitic plants also pose a threat to cacao. The crop, to be economically successful, must therefore be tended continuously by man.

The individual pods of the tree contain from twenty to fifty separate seeds or "beans", depending on whether they are "branch" or "trunk" pods, and the size and quality of the bean varies with the species, rainfall, soil conditions and seasonal length. Cordero (1884:20) states that the Xoconocho crop took twice as long to mature as the Chontalpa type (probably because of lower rainfall). The two annual yields from Chiapas, taken immediately before and after the rainy season, were superior in quality to the four annual crops from Tabasco.

Cacao grows best in rich, well-drained soil, preferably of alluvial or volcanic origin. It is the soil, not the tree, that must be shaded, and kept constantly moist, as the humidity of the earth is more important than the amount of annual rainfall. According to Erneholm (1948:269-273), cacao can tolerate a minimum of forty inches of precipitation per year and a dry season of up to four months if irrigated. It will not grow where the average annual temperature is below seventy degrees fahrenheit and does best in areas of extremely high humidity (90 percent plus). In regions of lower rainfall, cacao is limited to the narrow valleys of streams and rivers, or in the karst landscape of northern Yucatan, to the occasional silt-filled cenotes.

Most students agree that the central area of cacao cultivation was within the limits of Maya speech. With the increasing centralization of power in the highland areas during classic and postclassic times, cacao began to expand in its distribution. From the core area it was spread north and south, probably by Nahua speaking peoples, along the coastal areas that would support it. The single occurrence of cacao growing in the highlands (Duran, 1951:252-253) is for Huaxtepec in Morelos, where Moctezuma II ordered cacao seedlings to be transplanted from the Cotoxtla region of Veracruz. Bergmann (1969:88) mentions that the northernmost extension of cacao on the Pacific coast reached to the Rio Ameca, and Paso y Troncoso (1905: Vol. 1) mentions the northernmost Atlantic groves as located at Tuxpan. Production in these peripheral areas was never on the same scale as that of the central region, and the Pacific coast north of Chiapas as well as the Huaxteca were particularly insignificant. Bergmann (1969:88) says that in these places the cultivation of cacao was at most an adjunct to gardening, and that it was raised primarily for local use. The Aztec in late postclassic times thus had to look to the south and east for their major supply of cacao.

Sauer (1950:538) states that cacao was grown on the Pacific coast from the Nicoya peninsula to Tepic, and that on "the Atlantic side it had a similar latitudinal extent, but its cultivation was in fewer localities and in general less significant." He suggests that the principal producing areas were on the Pacific slope, in spite of its longer dry season than the Gulf coast, and his neglect of the Atlantic side (perhaps due to the absence of volcanic soils?) is puzzling. Perhaps Sauer received his stimulus from Acosta, who wrote in 1590 (1604:295) that "Guatemala was recognized at that [pre-hispanic] time as the chief center of production of cacao." This position is highly debatable.

Xoconocho was _a_ but not _the_ major producer of cacao for the Mexica, as the tribute lists from the _Codex Mendoza_ (1938:fol. 46-47) show that the production from this area was less than half of the total for the entire cacao tribute of the empire. Borah and Cook (1963:151) in rating the overall values for items of tribute, rank the cacao exacted from Xoconocho as equal to either that from Huatusco or Cotoxtla, and only one-fifth more valuable than that from

Cihuatlan. The impression that the Guatemalan and Xoconocho areas were the primary producers probably is due in part to the Spaniard's predilection for temporate highland abodes over the steaming swamps of the Gulf coast, and to the biased and distorted view of affairs given by Aztec informants. The early importation of European diseases and parasites decimated the people in the lowlands (Thompson, 1970: 52-54) but were not nearly so destructive at higher altitudes. The continuation of the Xoconocho and Pacific Guatemalan crops from the pre-conquest through colonial periods can be explained by the fact that there are cool highlands right behind the boca costa that laborers in the lowlands can retire to if their health is threatened. Until the recent anti-malarial campaigns in the tropics, the coffee and banana plantations on the Pacific lowlands used labor that migrated seasonally from the highlands, or was able to live immediately above the malarial zone.

Despite its early depopulation, Tabasco must have also been a producer at least as large as Aztec Xoconocho. Roys (1972:106) makes the point that only in Tabasco was cacao production on such an intensive level that food had to be regularly imported to feed the pre-hispanic laboring population. The rulers of this area, being free of direct Aztec domination, might have had an incentive to produce more cacao than a subject people under threat of force. Thus there is good reason to doubt that the Xoconocho coast was the major producer in pre-conquest times.

Cordero (1884:3) states that the principal centers of production during the colonial and independence periods in Mexico were Tabasco and Chiapas, in that order. Millon (1955:175) is of the opinion that the most important "aboriginal areas of production" were "Tabasco, closely followed by northern Oaxaca, central and southern Veracruz, southern Chiapas, south-western Guatemala, and Honduras..."

The opposite view, however, continues to receive attention: Bergmann (1969:95) claims that "there is no evidence to suggest that cacao production in [north] eastern Guatemala and northern Honduras, the areas which supplied Yucatan [he omits Tabasco altogether], was ever on a scale approaching, much less equal to that of the Pacific side of the isthmus." This statement is equivocal, as both of the areas were known to have had a large "trade" in cacao with merchants from the west, and also because he ignores the other great Atlantic growing areas. To suggest that the highland Mexicans consumed more cacao than the lowland Maya is hazardous at best.

Millon (1955:282) relates that "it is in the Maya languages that the most extensive terminology for cacao products seems to have existed. Conversely, Nahuatl provides the greatest terminology for the cacao trade." The tradition of cacao use among Maya speakers was much more widespread at contact than among the highland peoples, and one must assume a consumption of fairly large proportions. The <u>Relacion of Merida</u> (1885:70-71) reports that the inhabitants of northern Yucatan used a "great quantity of cacao which is brought from the province of Tabasco and from Honduras..." Landa (1941:40) says that cacao was also grown near Chetumal, "the only province of Yucatan where it was produced on any considerable scale." Roys (1972:52) reports a cacao producing area on the Rio Hondo, from which originated an overland trail for the export of that crop to the north. Hammond (1972:42-44) suggests that the very reason for the existence of Lubaantun in coastal Belize was the proximity of the site to the "largest zone of prime cacao soil in the whole of southern British Honduras". Ciudad Real, in 1588, spoke of the area near Asencion Bay; "the Indians say a great river runs through it, and on both its banks there are many people to convert and conquer and that they have many plantations of cacao trees..." (Ciudad Real, 1932:325). Finally, the royal questionnaires to all holders of Spanish land-grants in 1579 and 1581 requesting information on local conditions, including trade, were answered almost unanimously from Yucatan with reports of cacao from Tabasco and Honduras being imported in large quantities. Faced with such evidence, it is most probable that the production of cacao on the Atlantic coast was as viable a concern, or superior to that of Xoconocho.

It seems that the misrepresentation of producing areas therefore is the result of post-conquest alterations in the pre-existing patterns. It has been shown that there was an impetus for the Spanish to continue cacao production, even before the development of an European market for it, but with the catastrophic drop in the native population in the lowland regions, there is little doubt that the patterns of cacao cultivation were radically changed.

Bergmann (1969:91) however, claims that "there is nothing in the early documentation to suggest that the earliest Spaniards caused any change in the distributional pattern of cacao prior to 1548. [The year that official records were first collected in Guatemala that deal with cacao.] There is no evidence that new areas were planted to cacao where cacao had not previously been cultivated, nor that production was eliminated from an area during...the campaigns of conquest." It becomes evident that the closer one looks at the contrast between pre and post-conquest culture it is seen that major changes did occur, and this applies specifically to the question of cacao. Certain areas of production, like Tabasco, were largely ignored, and other areas of previously little importance, were, because of their closeness to the nucleated settlements of the Europeans, much expanded. In some cases it appears that the Europeans fostered an intensive cultivation of cacao where one had not previously existed. In other situations, entire areas were depopulated and cacao production dwindled away to a mere vestige of its former importance.

The changes in exploitation of cacao as a resource after the conquest have contributed in large measure to the uncertainties and confusion as regards to the aboriginal experience. That cacao was an item of great worth in ancient Mesoamerica is unarguable, but its role in the societies and economies in which it appeared cannot be studied with much hope of reaching accurate conclusions until the more basic concerns are met squarely. When so much confusion exists regarding where cacao was grown and in what proportions, it seems premature to speak of it as having a common universal value and importance wherever it was found.

CLOSING REMARKS

The perishable resources considered in the preceding pages would only in very unusual circumstances be preserved in archaeological contexts. In order to formulate hypotheses concerning patterns of movement and interaction based upon empirical data, some archaeologists have turned to substances that are prone to preservation. A most promising development in the recent study of Mesoamerican culture as it relates to "trade" has been the work undertaken in determining the sources of obsidian for many important sites.

The feasibility of such studies in Mesoamerica was demonstrated by Weaver and Stross (1965) when a basic typology was begun by comparison of the varying percentages of chemical trace elements that could be detected by rapid-scan x-ray fluoresence. Heizer, Williams, and Graham (1965) began the plotting of the different obsidian sources and the corresponding artifacts that could be "fingerprinted", and since that time, obsidian from the sites of Tres Zapotes (Hester, Jack, and Heizer, 1971), La Venta (Jack, Hester, and Heizer, 1972), San Lorenzo (Cobean, et.al., 1971), Cerro De Las Mesas (Hester, Heizer, and Jack, 1971), Seibal (Graham, Hester, and Jack, 1972), Cholula (Hester, Jack, and Heizer, 1972), Cempoala, Quiahuiztlan and El Tajin (Jack, Hester, and Heizer, 1972) and several other sites have been subjected to analysis. Cobean, et.al., (1971) list twenty-five separate geological sources for obsidian in Mexico and Guatemala, and the list is still growing. The obsidian studies have provided us with the first real archaeological data that can be tested in hypothetical reconstructions of "trade". The work done in this area has demonstrated that an intimate familiarity with the basic data is necessary before hypotheses can be formulated, and that such an approach is the best insurance against careless speculation.

"Trade" is one of the most popular panegorics in use today when problems of causality are being considered. It is perfectly suited to that role for, as we have seen, the term is not really subject to a strict definition and can be invoked without much concern for substantiating evidence. My feeling is that the point has not been reached where one can begin to construct models of interaction and movement of articles, because the corpus of archaeological data is too small. The limitations presented by the accidents of preservation have almost guaranteed that complex models of interaction in the past will be narrow, and represent only a part of the situation as it existed.

Although my criticisms at times may have seemed overabundant, I confess that I have very few specific suggestions calculated to illuminate the murk that has obscured the problems of Mesoamerican "trade" for so long. Certainly the obsidian studies should continue, and it is to be hoped that with time, a complete inventory of all sources will be possible along with a corresponding refinement of laboratory technique. Despite the attention to analyzing the samples from archaeological sites, surprisingly little work has been done in establishing the cultural sequences and associations at the obsidian "mines" themselves. The earliest accurate report for a major source that was concerned with more than sample collection is that of Holmes (1900) for Cruz Del Milagro in Hidalgo. A hiatus in the interest in the "workings" existed from that time until relatively recently, until the studies by Coe and Flannery (1964) for El Chayal, Graham and Heizer for Papalhuapa (1968), and Spence and Parsons (1972) at Cruz Del Milagro and other nearby deposits.

Most ideas concerning the actual mechanisms through which "trade" was effected have been derived from the historic descriptions of Protohistoric peoples in Mesoamerica, yet many of the great commercial centers of Protohistoric times have never been adequately excavated (Tochtepec is a case in point) and we would learn much if they were. The exact location of the trading town of Xicalango is still in doubt; Ruz Lhuillier (1945) identifies the site of El Aguacatal as such, but it has no Late Postclassic occupation, Scholes and Roys (1948) place it under the town of Cerillos, and others suggest that it lies to the east or south.

In order to understand the phenomenon of ancient Mesoamerican trade, one must consider questions of the influence of space, time, and distance, the individual desires of the specific peoples involved, the availability of the items desired, and the political, physical, and cultural barriers that existed and how they could have possibly affected the nature of the assumed trade. The only conceivable way in which such questions may begin to be answered is by careful excavation and recording, coupled with a selective consideration of all historical, ethnographic and geographic sources. Needless to say, these suggestions could only apply to the Postclassic period and in earlier times a different kind of <u>modus operandi</u> would be required.

A suggested procedure to be followed before discussions of the socio-cultural aspects of trade in early societies could be made would entail the following: (1) adequately defining and describing the article in question by botanical, mineralogical, metallurgical, or other means; (2) determining whether or not it is actually "foreign" in the context found by establishing the limits of its "natural" occurrence; (3) plotting the overall distribution of the supposedly "foreign" object in all known archaeological associations; and finally, (4) researching all available ethnographic or geographic and ecological sources that could possibly contribute information of a clarifying nature. It will be quickly observed that perishable resources do not lend themselves to such an analytical framework easily, but to ignore them would guarantee inaccurate results. The very real results that can be derived from studying perishable resources have been demonstrated by Puleston (1971), and it is to be hoped that more research will be directed towards them.

One must review the possibilities suggested by the information gleaned from all courses of study, and consider them to be only that, not probabilities. I submit that the only precept to be followed to the letter in attempting to understand "trade" in archaeological cultures is that which should be called to mind whenever an attempt is made to create the tangible from the intangible: the only rule is that there is no rule. In dealing with as unknown a quantity as Mesoamerican trade, where hard evidence is so noticeably lacking yet theories so abundant, attempting to work with preconceived ideas cannot help but obscure what little information we may be able to gain by all of our other efforts combined.

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Abbreviations Used

AA	American Anthropologist.
AAnt	American Antiquity.
CIW	Carnegie Institution of Washington.
HMAI	Handbook of Middle American Indians, University of Texas Press, Austin, Texas.
INAH	Instituto Nacional de Antropología e Historia de México.
MARI	Middle American Research Institute, Tulane University, New Orleans, Louisiana.
UCARF	University of California Archaeological Research Facility, Berkeley, California.

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