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Teotihuacán, Tepeapulco, and Obsidian Exploitation

Tepeapulco obsidian production provides a model for Teotihuacán's Mesoamerican expansion.

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Summary. Current cultural ecological models of the development of civilization in central Mexico emphasize the role of subsistence production techniques and organization. The recent use of established and productive archeological surface survey techniques along natural corridors of communication between favorable niches for cultural development within the Central Mexican symbiotic region resulted in the location of sites that indicate an early development of a decentralized resource exploitation, manufacturing, and exchange network. The association of the development of this system with Teotihuacán indicates the importance such nonsubsistence production and exchange had in the evolution of this first central Mexican civilization. The later expansion of Teotihuacán into more distant areas of Mesoamerica was based on this resource exploitation model. Later civilizations centered at Tula and Tenochtitlán also used such a model in their expansion.

The Valley of Mexico, situated at an altitude of approximately 2250 meters on the central plateau of Mexico (Figs. 1 and 2), functioned as a nuclear area in which pre-Hispanic civilizations developed and from which they expanded to influence in diverse manners cultures in other subareas of Mesoamerica. The last two decades have witnessed a substantial increase in archeological research directed toward an explication of the processes of development, expansion, retraction, decline, and reformulation of those civilizations. Intensive research began with surveys and excavations at Teotihuacán and throughout the Teotihuacán Valley (*1, 2*).

The city of Teotihuacán (200 B.C. to A.D. 750) (Fig. 2 and Table 1) was the locus of the earliest urban civilization in central Mexico. Millon has depicted a well-planned urban center occupied by a population of between 125,000 and 200,000 at the height of its development (*2*). Although a significant proportion of the population was involved in subsistence activities, there is evidence of substantial craft specialization and a well-developed social, political, and religious hierarchy. The growth of the city was based on multiple factors, including control over obsidian resources and trade, the location of the city in a strategic pass leading northeast out of the Valley of Mexico (Fig. 2), the ideology motivating the coordinated labor involved in the construction of public structures within the city, and the cultural-ecological setting, which included significant permanent and floodwater irrigation systems and broad, productive alluvial plains (*2–4*). Obsidian and ceramic fragments, architecture, and iconography, from both Teotihuacán and distant areas of Mesoamerica, indicate a complex pattern of interaction during the expansion of Teotihuacán, involving the control of raw materials, trade route expansion, and political control (*2, 5*).

Intensive archeological survey has expanded to include most of the currently nonurbanized sections of the Valley of Mexico (*6–8*). Similar research outside the Valley, at Tula and the Mezquital valley, Huapalcalco and the Metztitlán valley, Cholula and the Puebla-Tlaxcala area, and Chalcatzingo and the Amatzinac-Tenango valley (Fig. 2) (*9–11*), has provided a substantial body of data on the evolution of complex cultures in the central plateau of Mexico for the period from approximately 1600 B.C. to A.D. 1521.

The Central Mexican symbiotic region model, based on the cultural ecological paradigm of cultural evolution, is the major model guiding research in the Valley of Mexico. Initially formulated by Sanders (*12*) and subsequently modified in detail and emphasis (*1, 3, 7, 13–15*), the model examines the panorama of complex cultural development against the background of an equally diverse and complex environment. Interaction between the cultural and environmental diversity occurs through two productive modes, agricultural and nonagricultural. Interaction between cultures consists of the trade and exchange of those agricultural and nonagricultural products whose distributions are naturally restricted as a result of environmental diversity. The direction and control of these symbiotic relationships form one causal element in the development of complex cultures in the Valley of Mexico. The other element consists of the techniques, intensity, yields, and organization of agricultural production along with the size of population supported by that production (*1, 3, 7, 13–15*).

Although this model has been criticized for neglecting religion and ideology (*2, 16*), I consider another weakness to be a research emphasis on agricultural production and population size to the detriment of studies of nonagricultural

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production and trade within local and regional contexts (*2, 17*). When these are considered, it is usually within the context of contemporary peasant craft production and marketing systems which might be inappropriate for an understanding of pre-Hispanic civilizations (*18, 19*). Considering the stress placed by many archeologists on trade and nonagricultural production in models of the development of civilizations in the Valley of Mexico and the subsequent spread of their "influence" into other subareas of Mesoamerica (*20*), I designed and conducted a research project to collect data specifically related to evaluating the nature of trade during the fluctuating cycles of civilization in the Valley of Mexico (*21*). I shall present in this article aspects of the survey and the results and conclusions as they pertain to evaluating the roles of nonagricultural production and regional trade in the initial development of Teotihuacán and the later spread of its "influence" into distant subareas of Mesoamerica.

Trade Route Survey

In Mesoamerica the archeological definition of prehistoric regional and long-distance exchange networks has rested primarily on physically identifying exotic artifacts and determining their point or points of origin. Studies of the obsidian trade in particular have followed this procedure to determine the extent and intensity of such networks during the Formative period (*22, 23*). In addition, the study of long-distance trade has been approached through an examination of a port-of-trade (*24*), and local symbiotic relationships have been investigated through an intensive microregional survey accompanied by systematic sampling (*25*). To my knowledge, however, there had been no surveys prior to my 1975 survey to examine the probable foot routes over which goods being exchanged were transported in regional or long-distance trade (*21, 26*). Many of these routes pass through areas of limited agricultural and demographic potential between major basins and valleys and, thus, have not been included in research directed through the current application of the Central Mexican symbiotic region model (*6–11*).

The approach included intensive surface surveys of the most likely foot routes through hinterland and mountainous areas situated between previously surveyed regions. Between February and August 1975, I surveyed three routes (Figs. 2 to 6) on a field-by-field basis, recording the data of all occupations on vertical air photographs of a scale of approximately 1:5000. The total area surveyed includes 7 square kilometers along route 1, 22 km² along route 2, and 67 km² along route 3. In order to evaluate field observations of site chronology and site function, I collected artifacts from restricted areas of 20 m² at selected locations within sites. The collections included all cultural materials present. This resulted in the locating of small quantities of somewhat undistinguished body sherds from trade ceramics which, with other more restricted collection procedures, would have been unnoticed and hence uncollected. All of the collections have been studied and the data recorded and quantified.

I selected three routes to survey on the basis of several considerations. In 1969, while walking a Colonial period road from Oxtotipac to Calpulalpan (route 1), I encountered large quantities of Thin Orange pottery, a well-known Teotihuacán period trade ware. This pottery is present in high frequencies at sites in the mountain pass between the Teotihuacán Valley and the Plains of Apan (Fig. 6). Subsequent study of the Teotihuacán period sites revealed a line of sites following natural drainage systems and ridge tops from the East Avenue of the city to the pass. Substantial amounts of Thin Orange pottery are also found in these sites. The pass leads to Calpulalpan, a Teotihuacán period site with substantial ceremonial architecture but little evidence of a large resident population (*27*). On the basis of the data available, I hyothesized that route 1 served in the transport of Thin Orange pottery from Teotihuacán, where it was manufactured, to Calpulalpan, a site at which trade and exchange between Teotihuacán and areas to the east and southeast were coordinated.

Documents and maps provide evidence that route 1 was an Aztec route, which continued in use during the Colonial period. On the basis of the strong indication of continuity between pre-Hispanic and Colonial road systems, I selected a second area, route 2, to survey (Fig. 6). From the eastern Teotihuacán Valley to the northern Plains of Apan runs a now unused road of the Colonial period. Teotihuacán period sites are located at both ends of the road. Tepeapulco (a site comparable to Calpulalpan in size and in ratio of ceremonial architecture to residential structures) is located in the Tepeapulco area at the junction of routes 2 and 3. A smaller site, with a similar disproportionate ratio of ceremonial to domestic architecture, is situated at the southeast end of route 2 in

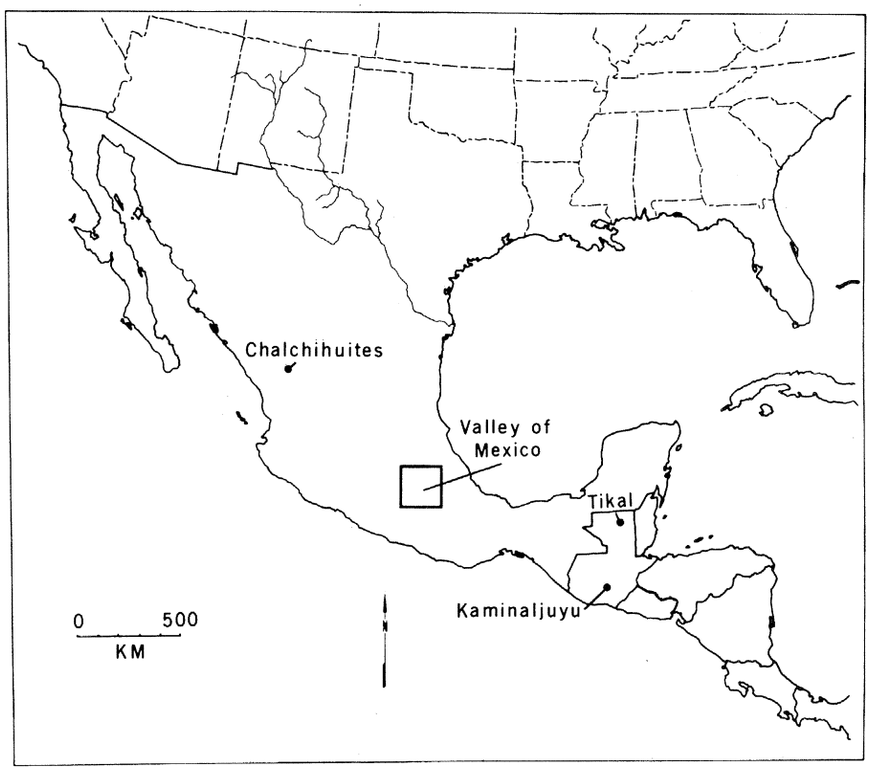

Fig. 1. Location of the Valley of Mexico and archeological sites mentioned in the text.

the Teotihuacán Valley (*21, 28*). Using both the historical and the archeological data, I hypothesized that the Teotihuacán period sites at the ends of route 2 functioned within the context of a network of regional and long-distance trade between the Valley of Mexico and the areas to the northeast.

Route 3 (Figs. 3 to 5) is a topographical extension of route 2, following a natural valley and basin system from the Tepeapulco area to the Metztitlán valley. Pipelines and high-tension power lines today follow this natural pass system. During the Colonial period, a road system crossed route 3, and a very rough contemporary road system still traverses part of this route. In the Metztitlán valley, the site of Huapalcalco is located at one of two natural exits from the valley to the coast. I hypothesized that route 3 was used to move the products of the highland and lowland components of the Central Mexican symbiotic region and that Huapalcalco and Tepeapulco took part in regulating that trade during the Teotihuacán period (*29, 30*).

Table 1. Chronological framework of the northeastern Valley of Mexico. Parsons (*54*) has correlated these phases and periods with a new period framework.

Absolute chronology (estimated)	Teotihuacán phases	Valley of Mexico	
		Periods	Stages
1600	Teacalco	Early Colonial	Early Postconquest
1500			
1400	Chimalpa	Late Aztec	Late Postclassic
1300	Zocango	Early Aztec	
1200			
1100	Mazapan	Late Toltec	Early Postclassic
1000			
900	Xometla	Early Toltec	
800	Oxtotipac		
700	Metepec		
600	Late Xolalpan	Late Teotihuacán	Late Classic
500	Early Xolalpan		
400	Late Tlamimilolpa		
300	Early Tlamimilolpa	Early Teotihuacán	Early Classic
200	Miccaotli		
100	Tzacualli		
0			
100	Patlachique	Terminal Formative	Terminal Preclassic
200	Tezoyuca		
300			
400	Cuanalan	Late Formative	Late Preclassic
500			

The Obsidian Sources

The concentration of four quarried obsidian sources near the routes surveyed is important in an evaluation of the data from the Tepeapulco area and along route 3 (Figs. 2 to 6). Three of these sources, Cerro de las Navajas (Pachuca), Barranca de los Estetes (Otumba), and Pizzarín (Tulancingo) are well known and frequently mentioned in the literature (*31*). I located the fourth source, Paredón, during the survey. To my knowledge, this was the first examination of this source since it was last visited more than 75 years ago (*32*). The unphased aceramic obsidian sites (Figs. 3 to 5) along route 3 and in the Tepeapulco area are composed primarily of obsidian from the Paredón source (*33*). I surveyed the source area to determine its extent and the locations of workshops (*34*).

A similar detailed examination of the Otumba obsidian source during the survey revealed that the major obsidian deposit is located at the base and lower west face of Cerro Soltepec. Additional smaller outcrops occur along the Barranca de los Estetes to the west (*31*). Water-rolled obsidian cobbles are found the length of the two drainage systems (Barranca de los Estetes and Barranca del Muerto) of the source area. During the survey of the major source area, I located pits and workshops that are, to my knowledge, previously unmentioned in

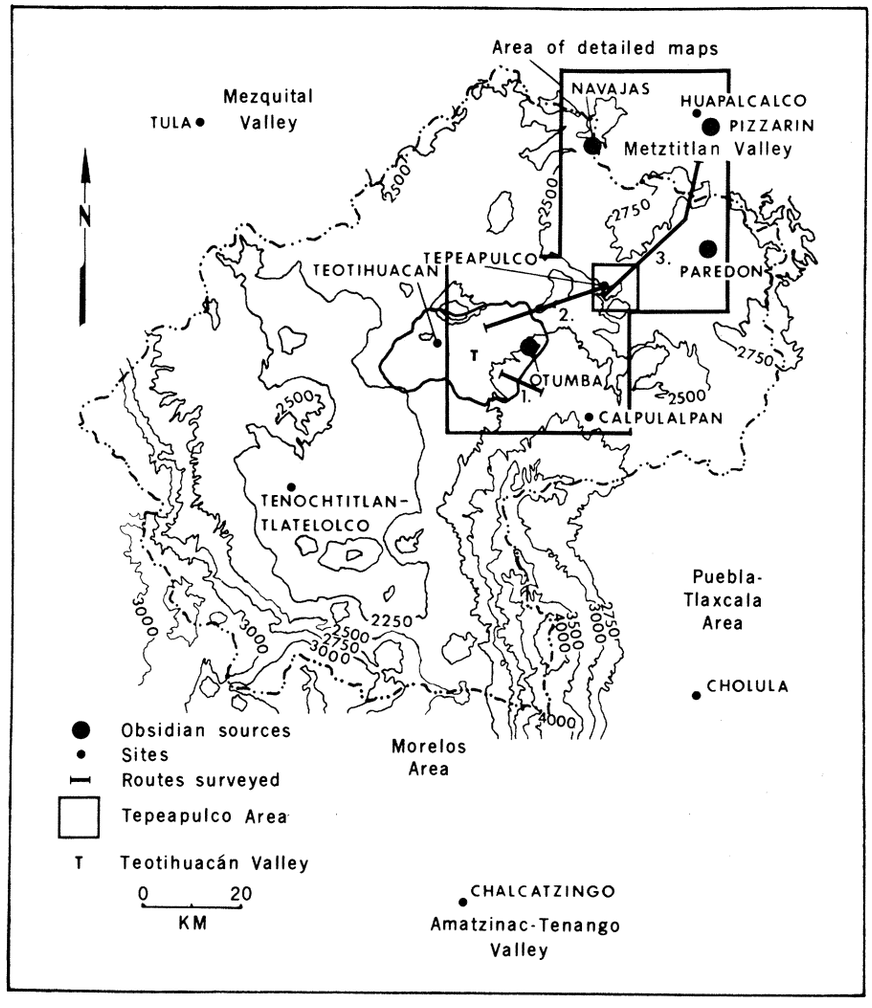

Fig. 2. The Valley of Mexico with major archeological sites, subareas, and routes mentioned in the text.

the literature. As at Paredón, no ceramics are associated with these features.

In the Metztitlán valley, the local Pizzarín source provided most of the obsidian found in sites located there. A brief examination of this source noted the presence of pits and workshops. The Navajas source is well documented although some significant problems remain, in particular the effect of modern exploitation on the pre-Hispanic obsidian debris.

Survey data from the Tepeapulco area and route 3 indicate that obsidian from three sources—Otumba, Navajas, and Paredón—was procured and transported to the Tepeapulco area, where finished tool production took place. These products were then distributed outside the Valley of Mexico. Initial development of this system coincided with the beginning of Teotihuacán. After a hiatus during the Early Toltec period (epi-Teotihuacán states) (*35*) the resources and the distribution system were appropriated first by Tula and then by Tenochtitlán (Fig. 2 and Table 1). At all times, the regional character of both the distribution network and the system of procurement and production was maintained.

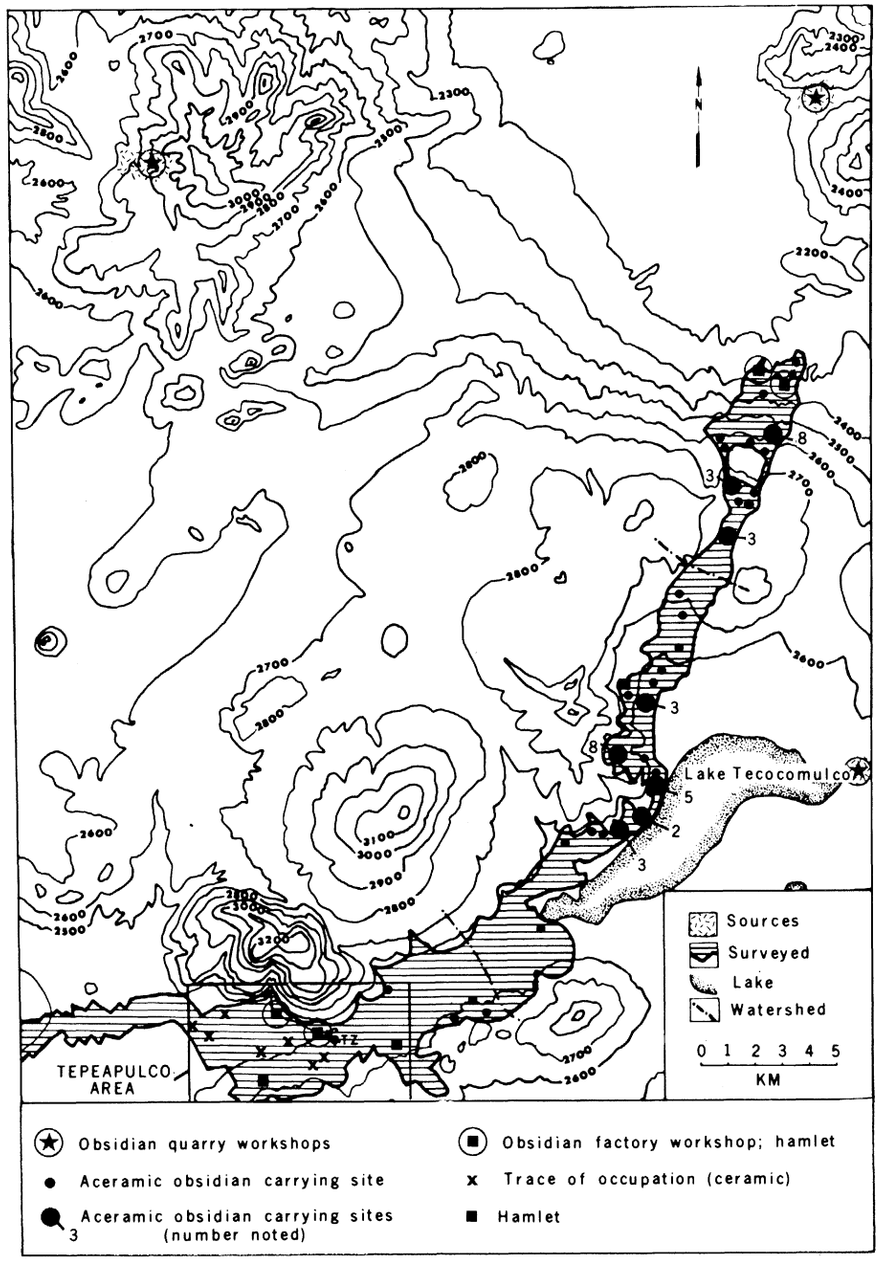

Fig. 3. Tezoyuca/Patlachique phase occupations in the Tepeapulco Area and along route 3. *TZ*, Tezoyuca-phase ceramics. Aceramic obsidian sites are unphased and repeated in Figs. 4 and 5. Contour interval, 100 m.

Obsidian Exploitation

Archeological studies of the exploitation of obsidian have focused on quarries and quarry workshops (*31*) as the loci of initial raw material extraction and preliminary preparation of blanks prior to transporting the materials to factory workshops for the next stage of tool manufacture (*2, 36*). The factory workshops are frequently interpreted as being in or adjacent to the sociopolitical center possessing economic control over the use of the natural deposits of obsidian (*2, 31, 36*). Archeologists have also studied the distribution patterns of manufactured obsidian tools resulting from local, regional, or long-distance trade (*22, 23, 25, 37–39*). The social and economic aspects of the interrelationships, cited as producing the particular distribution patterns, are stressed in these studies. Next to a consideration of the ultimate disposal of the obsidian as garbage (*40*), this aspect of distribution represents the end of a network that began at the geological source. These studies emphasize two approaches: (i) the technology involved in transforming raw materials into finished products (*41*) and (ii) the social, political, and economic ramifications of the network within which the product is distributed (*22, 23, 25, 37–39*).

In examining obsidian exploitation, tool manufacture, and product distribution systems, archeologists deal with two facets of the same reality. In addition to their technological aspects, the studies of quarry workshops and factory workshops deal with systems of nonagricultural production. Such studies consider not only the technological knowledge and stages of production, but also labor, labor organization, and transportation. In Mesoamerica, excepting the technological studies, this facet of obsidian exploitation has not been dealt with effectively. Since such nonagricultural production forms a significant part of the Central Mexican symbiotic region model this is an unfortunate lacuna in our knowledge of pre-Hispanic societies. Studies of the movement of nonagricultural products after they have left the major initial industrial chain of quarry workshop, carrying site, and factory workshop are much better known, although not in detail in central Mexico (*22, 23, 25, 37–39*).

The survey data from the Tepeapulco area and route 3 have provided evidence that allows us to evaluate the organization of the quarry to factory workshop segment of obsidian exploitation. The data are relevant to considerations of the

rise, fall, and reconstitution of civilizations and to the spread of their influence through Mesoamerica.

Interpretive Models

One problem in evaluating the role of nonagricultural production and organization in the context of pre-Hispanic civilizations lies in the emphasis archeologists have placed on ethnographic models that are not directly relevant to those civilizations (*18, 19*). The models are often derived from studies of contemporary peasant craft production and distribution. In Mesoamerica these may have been influenced through Spanish-imposed patterns of manufacture and distribution. Alternatively they may represent culturally devolved systems resulting from conquest. In neither instance do they represent pre-Hispanic civilizations. Technological information from such studies is valuable (*18, 19, 42*). Data on production organization and distributional networks are limited in their direct applicability to pre-Hispanic systems.

I am in general agreement with Hunt's assessment that any cultural persistence has been in "the refuge regions, the marginal cultural and ecological niches of the nation. The information we have about Indians today, thus may not be relevant at all to the past events which took place in the key nuclear areas" (*19*). It is not my intention to quarrel with the judicious use of ethnographic analogies in interpreting archeological data of pre-Hispanic systems of production and distribution. However, I suggest that, although important contributions have been made in recent studies of rural and peasant economic systems (*42, 43*), models for interpreting pre-Hispanic civilizations will be more profitably sought in other fields. One of these is ethnohistory, the other the study of human geography in complex cultures.

In studies of trade, ethnohistorical data have been projected to previous civilizations to interpret and explain trade patterns, processes, and mechanisms (*45–47*). Recent papers have detailed the functioning of markets and systems of redistribution in the Aztec economy (*48*). None of these studies has dealt with the organization of nonagricultural production and the entry of those products into the systems of distribution. It is probable that the obsidian industry did not attract the attention of the Spanish and that, as a result, few records of the primary processes of extraction and manufacturing were made. There are numerous references to the final production and distribution of prismatic blades in markets (*49*) but few comments on other products and their distribution. The available ethnohistorical references to the details of nonagricultural production in the obsidian industry are not sufficient alone to clarify the archeological record (*50*).

In order to offset this problem, I propose that models derived from industrial geography with considerations of factors such as raw material and factory locations, costs, and shipping distances will provide further insights into the operation of nonagricultural production systems in pre-Hispanic civilizations. Such models will take into consideration the available ethnohistorical data, the extent of technological development, and the available modes of transportation. These models are specialized examples of locational analysis (*51*).

Raw Materials to Tools: The Sites

In the Tepeapulco area and along route 3 three types of archeological sites are directly related to the initial stages of obsidian exploitation and tool manufacture prior to the entry of the products into a distributional network: (i) quarry workshops, (ii) transportation or carrying sites, and (iii) factory workshops (Figs. 3 to 5).

1) Quarry workshops at the Paredón source consist of shallow pits from which the obsidian was quarried and the adjacent debris piles containing pieces of obsidian discarded during initial preparation of core and tool blanks. The blanks were subsequently transported to other sites for further work. The materials encountered are similar to items described for other quarry workshops (*31*) that I have observed at the other three sources. At Paredón there are no ceramics or architectural remains associated with the workshops. The quarries were probably visited only temporarily for obsidian extraction and preliminary shaping.

2) Transportation or carrying sites are situated between the Paredón source and the factory workshops of the Tepeapulco area and the Metztitlán valley. These sites occur along natural routes of foot travel and cluster in areas where the topography slows or blocks the movement of persons on foot. The obsidian in these sites consists primarily of small, unmodified flakes and occasional large chunks, with the cortex removed in partial preparation as cores. All of these sites are small (less than 1 hectare in surface area). Obsidian density varies from site to site, ranging from light to heavy. The nearly complete absence of finished tools, the small sizes of many of the flakes, and the absence of ceramics suggest that these sites are distinct from either quarry workshops or factory workshops. To my knowledge, this is the first identification of such sites in Mesoamerica. Similar sites located near Navajas may have been misclassified as quarry workshops (*31*).

Within the Lake Tecocomulco basin and along route 3 to the Tepeapulco area, these sites are composed entirely of Paredón obsidian. I hypothesize that the obsidian was carried by boats across Lake Tecocomulco and then by human bearer to the north and southwest. The survey probably located only part of the carrying pattern, which may have followed all the natural routes out of the basin. Future surveys will resolve this question. In the sites located on the south slope of the Metztitlán valley the obsidian configuration is more complex. Some evidence indicates the movement of Paredón obsidian downslope, and Navajas and Pizzarín obsidians upslope. Intensive survey of the Metztitlán valley, including the major sites of Huapalcalco and Zazacuala, will be needed to resolve the dimensions of the obsidian exploitation pattern in this area. The carrying sites in the Lake Tecocomulco basin and along route 3 to the Tepeapulco area consist of debris left behind when obsidian was being transported out of the Paredón source to the Tepeapulco area workshops during a period of at least 2000 years.

3) Factory workshops are found in the Tepeapulco area and in the Metztitlán valley. These sites are characterized by heavy concentrations of obsidian, the presence of large numbers of unused and unretouched flakes, errors and broken tools, and the nearly complete absence of cores and core fragments. The sites range in size from 2 to 14 ha. Associated ceramics and structural debris suggest permanent occupation. In the Tepeapulco area, obsidian from Otumba, Paredón, and Navajas formed the bulk of the assemblages, with only traces of Pizzarín obsidian (*33*). In the Metztitlán valley at the north end of route 3, Pizzarín obsidian was dominant with small quantities of Navajas, Paredón, and Otumba obsidian present. Neutron activation analyses will be necessary to specify precisely the sources and the frequency of their occurrence in the factory workshops (*33*). Such analyses in conjunction

with a program to date the aceramic obsidian sites through obsidian hydration dating will resolve some outstanding questions on the variations in source use through time. The ceramic data indicate the presence of factory workshops from the Terminal Formative period (Tezoyuca/Patlachique phase) to the end of the Teotihuacán period (Metepec phase) (Table 1). After a hiatus during the Early Toltec period, a time of radical changes in the Valley of Mexico (*35*), factory workshops operated again from the Late Toltec period to the Late Aztec/Early Colonial period (Table 1).

The three types of sites located during the survey form a system of obsidian exploitation and tool manufacture. In the Tepeapulco area, there is evidence for the use of three sources. Since the bulk of the chronologically secure information comes from that area, I shall discuss the development of the system from the Terminal Formative period to the end of the Teotihuacán period (Figs. 3 to 5). Since the later use of the system provides some insights into its earlier operation I shall present selected aspects of Late Toltec and Aztec use of the system.

Tezoyuca/Patlachique Phase

The initial dated occupations in the Tepeapulco area and along route 3 are of this phase. Two small factory workshops are in the Metztitlán valley and two are in the Tepeapulco area (Fig. 3). In addition, there are two definite domestic occupations in the Tepeapulco area and traces of such occupations in seven other locales. Within the Lake Tecocomulco basin, situated high on the western edge near a pass leading to the northwest, there is one small hamlet. With one exception, the ceramics in these sites are Patlachique. In the eastern factory workshop site in the Tepeapulco area are some Tezoyuca-style ceramics (*52*). The surface data alone are insufficient to clarify the chronological or functional differences hypothesized for these two complexes (*53*). From the context, it seems that the Tezoyuca ceramics may represent the initial establishment of a factory workshop followed by a Patlachique expansion.

In the Tepeapulco area, the factory workshops are situated on the steep southern slopes of Cerro Jihuingo, a choice of setting continued by later workshops in the area. The general locale chosen is 22 km from the Paredón and Otumba sources, 30 km from the Navajas source, and 38 km from the Pizzarín source. Preliminary studies indicate that materials from all four sources occur in the factory workshops of the Tepeapulco area (*33*). If the Tezoyuca ceramics indicate chronological priority, changes in frequencies of source material tend to occur between the Tezoyuca and Patlachique subphases. Otumba obsidian decreases from 81 percent to 48 percent. Both Paredón and Navajas obsidian increase in frequency, Paredón from 11 percent to 26 percent, and Navajas from 7 percent to 23 percent. Pizzarín obsidian, always a minor material in the Tepeapulco area, increases from 1 percent to 3 percent of the collections. Similar preliminary studies of the Patlachique phase factory workshops in the Metztitlán valley indicate a heavy reliance on the nearby Pizzarín source (66 percent) with less utilization of materials from Otumba (15 percent), Navajas (10 percent), and Paredón (9 percent). In neither area is there a large population, and all sites are quite small. The domestic debris indicate the presence of small hamlets or isolated homesteads. The factory workshops are best classified as hamlets.

In the central Valley of Mexico, recent surveys have indicated an increase in population at this time, particularly in the Teotihuacán Valley, where it increased from 6,000 in the Late Formative period to 36,000 in the Tezoyuca/Patlachique phase (*54*). Ceremonial architecture was introduced (*54*) and the city of Teotihuacán began its growth, a growth attributed in part to the obsidian industry and trade (*2*). The city is located 22 km west of the Otumba source, the

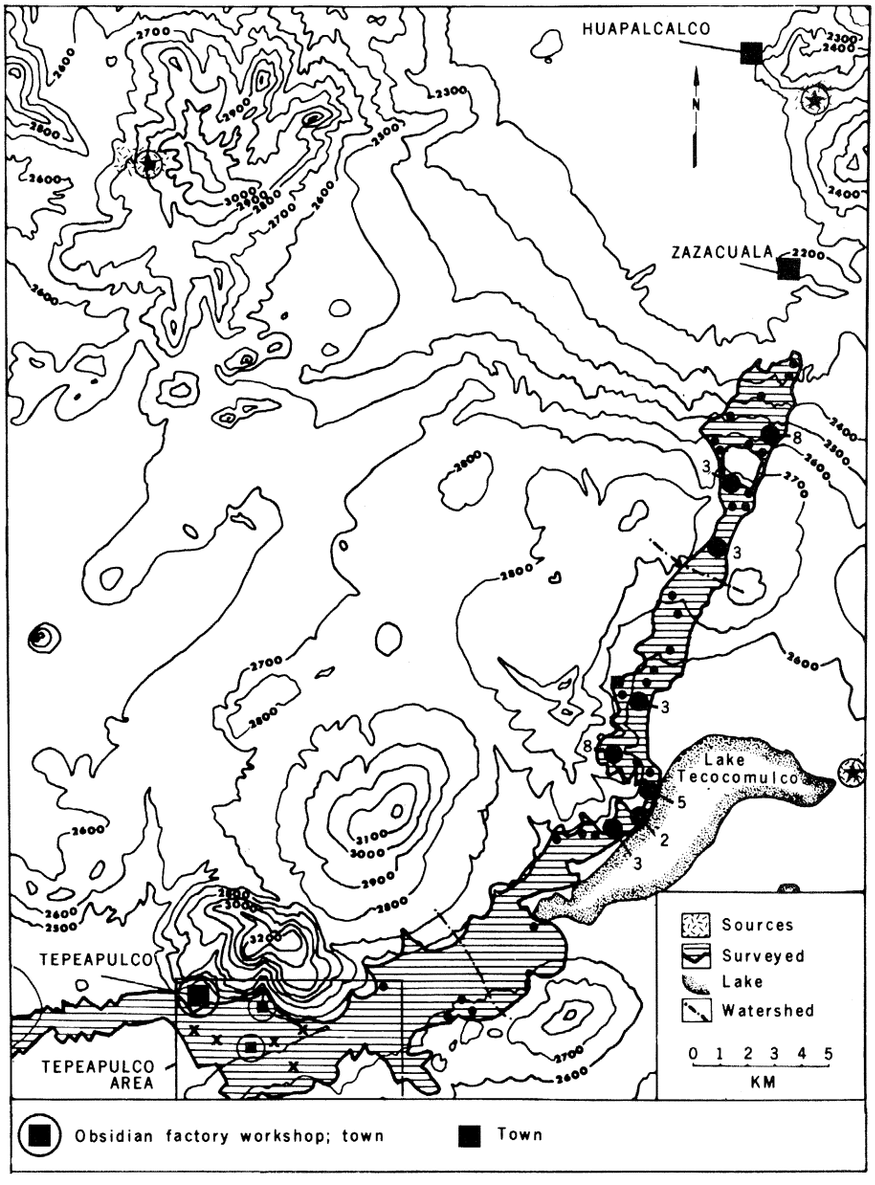

Fig. 4. Tzacualli phase occupations in the Tepeapulco Area and along route 3. New symbols are noted.

same distance the Tepeapulco area lies to the northeast (Fig. 6). Obsidian from the Otumba source is the primary material used at Teotihuacán during this phase. At this time and earlier, the Otumba source may have been the dominant central Mexican obsidian source used in regional and long-distance trade (*22, 23*). Some evidence indicates the early utilization of the Navajas source, and Paredón obsidian occurs at Chalcatzingo during the Early Formative period (*55*). Obviously additional sources had been known and used for hundreds, if not thousands, of years (*56*). It was not their discovery that resulted in increased use, but the changes in the orientation of peoples in the central Valley of Mexico to the organization of their exploitation.

Coincidental with the beginnings of Teotihuacán and its obsidian factory workshops was the establishment of factory workshops in the Tepeapulco area and in the Metztitlán valley. In the Tepeapulco area the workshops drew on three primary sources located almost equidistant from there along natural routes of foot travel. The Tepeapulco area workshops initially depended heavily on Otumba obsidian, but subsequently used more obsidian from Paredón and Navajas. During this phase, Navajas obsidian is not common in the central Valley of Mexico, and Paredón obsidian has not been reported there (*55*). The location of the factory workshops in the Tepeapulco area may best be understood in terms of an efficient exploitation of the three obsidian sources using foot transportation. Not all of the workshop products, however, were destined for the Valley of Mexico markets.

I hypothesize that after the withdrawal of Olmec interests in the natural resources of the central plateau of Mexico (*57*), these resources fell ultimately under the hegemony of an emerging Teotihuacán. The organization of their exploitation and the distribution of the finished products were essential to the development of this civilization and the later spread of its influence throughout Mesoamerica. At the same time Teotihuacán centralized the control of the Otumba obsidian source, it also established factory workshops in the Tepeapulco area for many of the same reasons Ciudad Sahagún is located there today (*58*): transportation, raw materials, and access to markets. In exploiting three obsidian sources and producing finished tools, cultures from the central Valley of Mexico were establishing their initial foray into a type of economic imperialism. They controlled the vertical chain from resource to product in an adjacent area. It is possible that this control was based on an earlier model used by the Olmec; it definitely anticipates later models of exploitation used by Teotihuacán, Tula, and Tenochtitlán.

Of additional importance is the subsequent distribution of the products from this vertically integrated monopoly. The products, in the Tezoyuca/Patlachique and subsequent phases, were not destined for the Valley of Mexico consumer. Those tools produced in the Tepeapulco area probably entered a regional trade network along a route leading south and east out of the Tepeapulco area (Fig. 6). The continuing absence of Paredón obsidian from the Valley of Mexico and the existence there of both Otumba and Navajas obsidian factory workshops sufficient to supply local demand suggest that the Tepeapulco area was geared to production for foreign trade.

Tzacualli Phase

During the Tzacualli phase, the population in the Tepeapulco area increased and was nucleated in the site of Tepeapulco (*21, 28*). One of the factory workshops was abandoned but another was established. There is also evidence of factory workshop debris within the Tepeapulco town site (*21, 28*). The hamlet located on the western edge of the Lake Tecocomulco basin was still occupied (Fig. 4). In the Metztitlán valley, the factory workshops were abandoned and the towns of Huapalcalco and Zazacuala occupied for the first time.

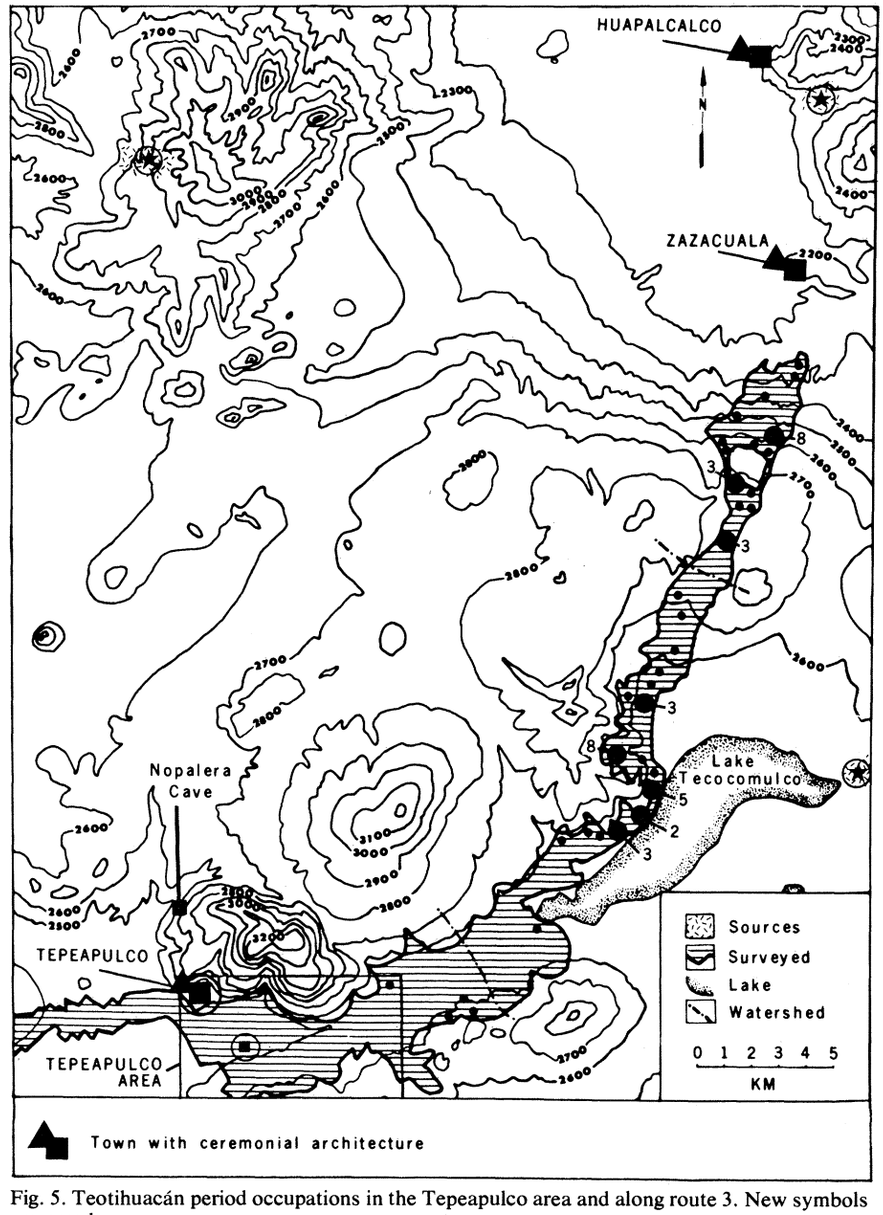

Fig. 5. Teotihuacán period occupations in the Tepeapulco area and along route 3. New symbols are noted.

In the Tepeapulco area during the Tzacualli phase and the later Teotihuacán period, the emphasis shifted to Navajas obsidian (34 percent) at the expense of Paredón obsidian (15 percent). Otumba and Pizzarín obsidian maintained approximately their earlier frequencies (50 percent and 1 percent, respectively). Although not all of the data from Matos's survey of the Tepeapulco town site are yet available (*21, 28*), the population, while increasing and becoming nucleated, retained its primary production activities of obsidian extraction and tool production for nondomestic markets. The changes occurring at Teotihuacán at this time, marked by the building of the Pyramid of the Sun (*59*), may be reflected in the construction of the smaller pyramid and ceremonial plaza and avenue at Tepeapulco; such construction stressed the ideological association with nonagricultural production.

Teotihuacán Period

Teotihuacán control of obsidian tool production centered at Tepeapulco persisted to the end of the Metepec phase (Table 1). Only one workshop existed outside the town site (Fig. 5). There is some evidence of a specialized cave occupation (Nopalera) (*29*). Pending the final results of Matos's survey (*21, 28*), I can only speculate that obsidian tool production was centralized in the town under direct Teotihuacán control. The essential basis for the site had been established during the Tezoyuca/Patlachique phase. Subsequent locations changed, but the functions remained the same for almost a millennium.

Interpretations

The development of Teotihuacán was intimately tied to nonagricultural production and trade activities from the beginning. Although the irrigation system in the Teotihuacán Valley must have been necessary for subsistence agriculture, the emphasis and continuity placed on the exploitation of several obsidian sources in adjacent areas indicates that such nonagricultural production and trade may have been of equal, if not greater, importance in Teotihuacán's development. The efficient, centralized control of a vertically integrated monopoly and the distribution of the products from that system outside of domestic markets indicate a degree of sophistication in resource exploitation comparable to that used today by industrialized societies in Third World countries. The importance is to be found in the degree of control and organization necessary in order to coordinate exploitation, production, and distribution and in the strong religious or ideological content associated with those activities.

Further evidence for the significance of nonagricultural production and regional trade in Teotihuacán's rise and persistence may be found in the Teotihuacán Valley along route 1. The alignment of sites from the Terminal Formative and Teotihuacán periods between the city and route 1, coupled with evidence for the continuous use of that route throughout those periods and the data indicating Thin Orange production in the eastern areas of the city (*60*) and its export over route 1 (*21*) (Fig. 6), delineate an important role for Teotihuacán proper in nonagricultural production for export. This role continued unabated until the end of the city.

Although research at Calpulalpan has been limited, data from several sources (*11, 27, 61*) indicate that this site, located

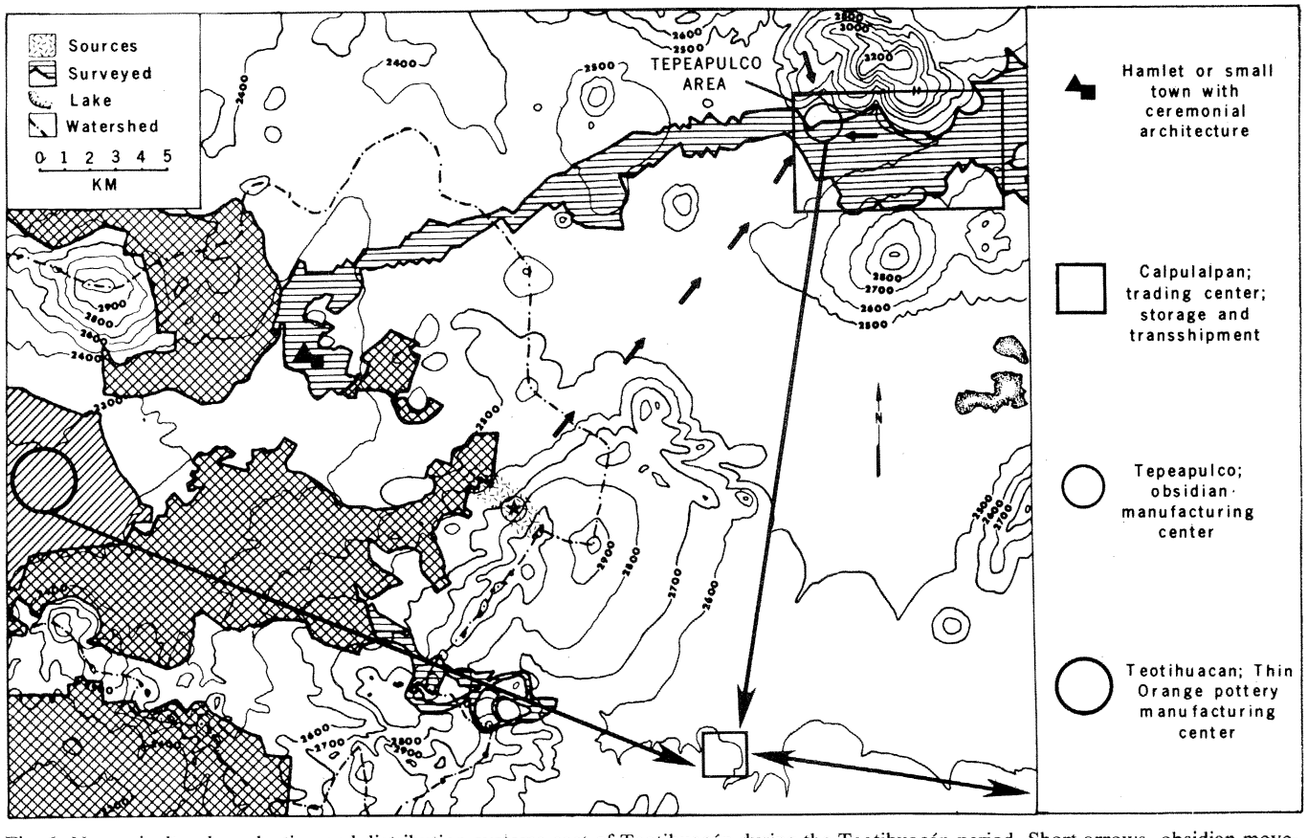

Fig. 6. Nonagricultural production and distribution systems east of Teotihuacán during the Teotihuacán period. Short arrows, obsidian movement from quarries. Long arrows, movements of finished products. Diagonal hatching, city of Teotihuacán survey (*1*). Diagonal cross-hatching, Teotihuacán Valley and Texcoco area surveys (*1, 6-8*).

almost equidistant from the ceramic workshops of Teotihuacán and the obsidian workshops of Tepeapulco, coordinated the movement of these nonagricultural products from the two sites and the import of other (as yet undefined) goods. García Cook (*61*) has defined a "Teotihuacán Corridor" running from Calpulalpan to the east with one branch to the southeast. Future studies will be required to clarify the nature of the movement of goods along this corridor (Fig. 6).

The pattern of obsidian exploitation and trade in an immediate regional context discussed here provided Teotihuacán with a model for the subsequent exploitation of regional resources and the control of regional market systems not directed to the movement of goods to the center of such control, Teotihuacán. The presence of Teotihuacán in sites such as Kaminaljuyu (*15, 62*), Tikal (*15, 47, 62*), and Chalchihuites (*63*) (Fig. 1) should be understood not only in the traditional terms of military expansion and resource exploitation but also in terms of selective colonization (which leaves variable traces depending on the particular colonial situation) in which regional production and marketing are controlled, not for the shipment of all products to Teotihuacán, but for the shipment of profits, in the form of goods available to Teotihuacán only through such economic control. I have hypothesized that this is analogous to the American and European use of the opium trade to China during the 19th century to obtain goods such as tea and chinoiserie desired in the home markets (*64*).

The Tepeapulco data indicate this type of exploitation pattern not only for Teotihuacán but also for Tula and Tenochtitlán. Both subsequently controlled the same network, but neither directed its output to the sociopolitical center (*65*). These later civilizations expanded throughout Mesoamerica using the organized control of regional resources initially developed by Teotihuacán (*10*). The emphasis placed on tribute, recorded by the Spanish for Tenochtitlán, may be only the result of the perceptual biases of the conquerors, in which case a critical reevaluation of the documents will clarify this situation. However, it may represent an early stage in the recovery of the regional resources and precede control of production and marketing in the regional context (*47*). There also remains the possibility that the Aztecs approached the exploitation of Mesoamerican resources from a perspective different from that of Teotihuacán.

Conclusions

The archeological application of interpretive models from industrial geography has provided new insights into Terminal Formative and Teotihuacán period nonsubsistance production and trade systems in central Mexico. The obsidian workshops in the Tepeapulco area are specialized industries located outside of an urban zone (*51*). The Tepeapulco area is a receiving node linked to three obsidian sources in a dendritic transportation network, which minimizes transportation costs (*66*). The obsidian tools produced at Tepeapulco and the Thin Orange pottery manufactured at Teotihuacán were linked in a similarly based transportation network for marketing. The site of Calpulalpan functioned within this network as a gateway city (*57, 66*) linking the Valley of Mexico with regions to the east and southeast.

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67. The field and laboratory research on which this article is based were supported by National Endowment for the Humanities research grant RO-21447-75-138 to the University of Iowa. The University of Iowa provided T.H.C. with a research assignment during the spring semester, 1975, to conduct fieldwork. Professor E. Matos Moctezuma, of the Instituto Nacional de Antropología e Historia in Mexico City encouraged the fieldwork and was helpful in obtaining the necessary permits (Concesión Arqueología No. 4/75). He coordinated his own research at the site of Tepeapulco with ours in the Tepeapulco Area. B. Borg, D. Jones, C. Meyer, C. Rawson, and E. Tenorio C. participated in fieldwork and laboratory analyses. P. Cressey and M. Hotopp aided in data coding. C. L. Charlton prepared all final maps. The Graduate College of the University of Iowa provided research funds to cover illustration expenses. J. L. Lorenzo, Ed. [*Materiales para la Arqueología de Teotihuacán* (Investigaciones 17, Instituto Nacional de Antropología e Historia, Mexico City, 1968), figure 1, p. 54] provided the base map for Fig. 2 in this article. R. Millon, W. T. Sanders, and M. W. Spence read and commented on an earlier version of this article.

Radioimmunoassay: A Probe for the Fine Structure of Biologic Systems

Rosalyn S. Yalow

To primitive man the sky was wonderful, mysterious, and awesome, but he could not even dream of what was within the golden disk or silver points of light so far beyond his reach. The telescope, the spectroscope, the radiotelescope—all the tools and paraphernalia of modern science—have acted as detailed probes to enable man to discover, to analyze, and hence better to understand the inner contents and fine structure of these celestial objects.

Man himself is a mysterious object and the tools to probe his physiologic nature and function have developed only slowly through the millennia. Becquerel, the Curies, and the Joliot-Curies with their discovery of natural and artificial radioactivity and Hevesy, who pioneered in the application of radioisotopes to the study of chemical processes, were the scientific progenitors of my career. For the past 30 years I have been committted to the development and application of radioisotopic methodology to analyze the fine structure of biologic systems.

From 1950 until his untimely death in 1972, Dr. Solomon Berson was joined

The author is Senior Medical Investigator, Veterans Administration Hospital, Bronx, New York 10468, and Distinguished Service Professor at Mt. Sinai School of Medicine, City University of New York, New York 10029. This article is the lecture she delivered in Stockholm, Sweden, on 8 December 1977 when she received the Nobel Prize in Physiology or Medicine, a prize which she shared with R. Guillemin and A. Schally. This article is published here with the permission of the Nobel Foundation and will also be included in the complete volume of *Les Prix Nobel en 1977* as well as in the series Nobel Lectures (in English) published by Elsevier Publishing Company, Amsterdam and New York.

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