Settlement Hierarchies and Political Complexity in Nonmarket Societies: The Formative Period of the Valley of Mexico

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Archaeologists have long recognized that increases in political centralization often coincide with the growth of regional settlement hierarchies. Here I develop a theoretical model which explicitly relates certain aspects of political complexity to variation in settlement size. This model applies specifically to hierarchical societies without well-developed market economies—societies which Service would classify as chiefdoms and (perhaps) simple states. Using settlement data from the Formative Period Valley of Mexico, I show how this model is useful in measuring (1) the number of levels in a regional hierarchy, (2) the degree of political centralization, and (3) the relative amount of surplus food mobilized to support the political establishment. [location theory, political evolution, political economy, chiefdoms, Valley of Mexico]

INTRODUCTION

ARCHAEOLOGISTS STUDYING THE EVOLUTION of politically complex societies have sometimes relied exclusively on a typological approach in characterizing the sociopolitical forms they observe. Especially utilized in this manner have been the general evolutionary typologies of Elman Service (1962) and Morton Fried (1967). On the basis of synchronic ethnographic comparisons, Service suggested that nonegalitarian societies could be classified into "chiefdoms" and "states," while Fried proposed a threefold classification consisting of "rank societies," "stratified societies," and "states." Each author's types can be arranged in a sequence that represents increasing sociopolitical complexity. Thus, these typologies have in many cases been adopted as ordinal scales, with reference to

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which the archaeologically observed processes of cultural evolution have been measured and described.

Although the typological approach has been (and still remains) useful in many ways, it also harbors certain disadvantages. One particularly troublesome aspect is that the types themselves are so broad. The categories were originally formulated at such a high level of generality that the societies included within each exhibit a very wide range of variation. For example, Service's rubric "chiefdom" subsumes such relatively simple polities as Tikopia on one hand, and also includes the multitiered, considerably more centralized political systems of Hawaii on the other. One reaction to this problem has been to subdivide the categories, to recognize new types based on more fine-grained distinctions (e.g., Taylor 1975; Hatch 1976). Yet however helpful such attempts may be, they at best can provide only a partial solution, for political evolution is a process that need not take place in a series of discrete steps. Imposing static types on what is actually a continuum will always mask a certain portion of the variability that is of interest (Kottak 1977).

Types, moreover, are usually defined in terms of several attributes simultaneously, such as social differentiation, political centralization, and others. Though such attributes are certainly interrelated, they should not be assumed a priori to vary always in perfect correspondence. Measuring sociopolitical evolution purely with reference to a single ordinal scale inevitably collapses numerous variables into one, and prevents us from clearly detailing the manner in which these variables interact through time.

I therefore suggest, and attempt to illustrate in this paper, that political complexity should (wherever possible) be viewed in terms of several analytically separate dimensions. In addition, I wish to show that it is archaeologically feasible to measure directly some of these dimensions along a continuous scale. Although the number of potentially relevant dimensions is large, I will focus on three in particular: (1) the number of levels in the political hierarchy, (2) the degree of centralization at the uppermost level, and (3) the relative amount of surplus food mobilized to support the political establishment. Variables such as these have long been recognized as being theoretically important (e.g., Orans 1966; Sahlins 1963, 1972; Flannery 1972; Johnson 1973; Wright and Johnson 1975; Taylor 1975), but measuring them archaeologically has often been difficult. At least some of the practical difficulties have stemmed from the lack of appropriate models linking these variables to their material correlates.

In this paper, I will develop a theoretical model which explicitly relates certain aspects of political complexity to the growth of regional settlement hierarchies. This framework will apply specifically to hierarchical societies without well-developed market economies—societies that in Service's terms would be classified as chiefdoms and (perhaps) simple states. The amount of full-time craft specialization in such societies tends to be highly limited, and most households consume the food that they themselves produce. The nonfood-producing specialists who do exist are for the most part connected with the political establishment, and owe their support, either directly or indirectly, to tribute extracted from the commoners (Earle 1973, 1977; Peebles and Kus 1977; Wright 1977; Steponaitis 1978). The settlement model to be developed will in no sense be comprehensive, for it will not encompass all possible factors that influence the configuration of a settlement hierarchy in such societies. It will, however, form the basis of a method which under certain conditions may be useful in measuring the political variables I have noted above.

The plan of this paper is as follows: first, I shall explicitly define what I mean by political centralization, discuss its relationship to political economy, and suggest ways of measuring centralization archaeologically. Second, I will develop a mathematical model which shows how systematic differences in settlement size relate to aspects of political complexity. Finally, I will apply the model in describing the development of political systems during the Formative period in the Valley of Mexico.

POLITICAL CENTRALIZATION AND THE FLOW OF TRIBUTE

As a point of departure, let us briefly consider the interesting framework that Adams (1975:206-217) proposed for the study of political evolution. Rather than presenting an ordered series of static models, Adams's framework emphasizes the cyclical "growth sequence" by which political hierarchies may develop. The first step in the sequence is "coordination," which takes place when a number of distinct political units begin to interact and coordinate their activities in some formal way, but do so in a state of relative equality. This step is then followed by a gradual process of "centralization," as one of the units acquires more and more power in relation to the others, and becomes increasingly able to make decisions that are binding on the rest. Each time this "growth sequence" of coordination and centralization is repeated, an additional level of political control emerges in the hierarchy, and a larger, more inclusive political unit results.

Adams's idealized model of growth is instructive, for it brings to our attention two issues of relevance to the present discussion. First of all, since the *process* of centralization at any given level can in theory take place gradually, this implies that the *degree* of centralization is an attribute which intrinsically varies along a continuous scale. Second, it is important to note that the process of centralization involves one unit's gaining more and more power relative to a set of other units which were formerly coordinate. This clearly suggests that the degree of centralization can be measured as a ratio of the power wielded by the decision-making unit at the uppermost level, relative to the average amount of power wielded by decision-making unit in the level immediately below.

Indeed, such a definition of centralization is not entirely new. Similar notions of what constitutes centralization have appeared from time to time, particularly in the body of literature dealing with comparisons among African political systems (Kaberry 1957:233; Lewis 1959:60-61; Vansina 1962:331-332). Lloyd (1965:81), after having critically reviewed this literature, specified the three criteria that he felt were most important in assessing the degree of centralization: (1) the "sphere of competence" of the central government, i.e., the range of activities over which it is regarded as having legitimate control; (2) the degree to which the constituent units of the kingdom can act independently of the king; and (3) the degree of control exercised by the king over the appointment of officeholders in the administrative hierarchy. Of these, (2) and (3) are both factors which, in essence, measure the relative amount of power wielded by the central authority in comparison to that of the immediately subordinate levels.

Yet the foregoing discussion still begs the question: how are we to measure the degree of centralization archaeologically? Ethnographers can observe the distribution of various decision-makers' sphere of competence, and they can gauge the extent of compliance to any given command. What, then, is the archaeologist to look for? I suggest that part of the answer lies in recognizing that " 'power' is control over resources, whether human or material . . ." (Nicholas 1966:52). Social power in a formal political/administrative hierarchy is manifest in the officeholder's access to some specified portion of his subordinates' surplus goods and labor, usually extracted in the form of tribute. It is reasonable to expect that, in general, the degree of political power will be closely related to the amount of tribute that can be extracted, for these two variables are intrinsically interdependent. A chief commands the payment of tribute by virtue of his political power; at the same time, much of the chief's power rests on his access to a sufficiently large pool of tribute (Sahlins 1963, 1972). These are facts of political life that have been documented in numerous ethnographic cases. Among the Suku of the Congo, for example:

> The formal political system is based on the delegation of power by the paramount chief to region-

> al chiefs and sub-chiefs. *One of the principal expressions of this power is the periodic collection of tribute* in each region and its flow, at least ideally, upwards to the MeniKongo through the successive links in the chains of delegated authority. [Kopytoff 1964:84; emphasis added]

And among the Tswana (Ngwato Reserve),

> *The chief's power is further dependent upon the uses to which he puts his wealth.* As head of the tribe, he formerly received tribute from his subjects in corn, cattle, wild animal skins, ivory and ostrich feathers, retained most of the cattle looted in war, and kept all unclaimed stray cattle and part of the fines imposed in his court . . . [Schapera 1940:76; emphasis added].

The list of examples could be expanded almost indefinitely, but these two are sufficient to make the point.

I suggest, therefore, that it should be possible to measure the degree of political centralization, at least approximately, by determining the ratio between the amount of tribute controlled by the central decision-making unit, and the average amount of tribute controlled by a decision-making unit in the administrative level immediately below. I use the term "tribute" in a loose sense to refer to all goods and labor allocated by the domestic (producing) sector to the purposes of the political establishment, including regularized unsolicited offerings, various solicited extractions, fines, and spoils gained in war. The actual goods and services that constitute tribute are generally of many kinds, commonly including (1) comestibles, and the labor invested in their transport and production; (2) labor invested in public architecture; (3) craft items, and the labor invested in their production and transport; and (4) labor invested in military service. The material correlates of such tribute will surely differ in archaeological visibility from one category to the next, as well as from one society to the next. However, it may be feasible to make quantitative relative estimates of tribute flow within each of these categories but the last.

Usually the most visible archaeological manifestation of tribute flow in chiefdoms and simple states is the existence of public and monumental architecture. With reasonable chronological control and an adequate amount of excavation, it may sometimes be possible to estimate, for a given unit of time, the amount of labor mobilized for such construction at sites of different levels in the hierarchy. Such estimates might be cast in person-days, the volume of fill moved, or whatever else seems most appropriate in the case at hand (see, for example, Kaplan 1963; Erasmus 1965; Muller 1978). The degree of political centralization (as defined here) could then be assessed by taking the ratio of the amount of labor mobilized at the paramount central settlement, relative to the average amount mobilized at a center of the next level down.

Assessing the relative control over tribute in the form of craft items would be considerably more difficult with archaeological data. It might be possible to attempt such an estimate if a large sample of burials with grave goods were available from sites at different levels in the regional hierarchy. However, even if one could identify the relative quantities of craft items which moved as tribute, one would still be faced with the problem of assessing their relative value (cf. Winters 1968). The way in which different kinds of craft items are evaluated against one another is a cultural phenomenon that would be very difficult to measure archaeologically.

A third approach, and the one to be explored most fully in this paper, is to estimate the relative quantities of comestibles controlled as tribute at different levels. Such an estimate must, of course, be made by indirect means, for the comestibles themselves leave little distinctive trace. Yet food obtained as tribute is used to support people, and systematic differences in the amount of food available at settlements of different levels in the hierarchy may, in some cases, result in systematic differences in the numbers of people living there. Differences in the numbers of inhabitants can, in turn, be reflected by differences in site size. The potential feasibility of this sort of analysis was initially suggested by the work of Brumfiel (1976) (see also Peebles 1978). In an attempt to test for the existence of population pressure during the Late and Terminal Formative periods in the Valley of Mexico, Brumfiel constructed scatter plots of site size (and index of population) versus the agricultural productivity of the land within a certain distance of each site. Expecting to find a single linear relationship for each period, she was surprised to find two distinct lines on each plot (Figure 1). Speaking specifically with reference to one of the periods, she interpreted her results as follows:

> I would suggest that the two-tiered nature of [the scatter plot] during the Terminal Formative is better explained by sociopolitical factors than by demography or by the conditions of agricultural production. . . . I would suggest that the larger and smaller Terminal Formative sites followed different regimes of production and consumption, and that these differences were based on the ability of the large "secondary regional centers" to draw produce from the smaller settlements in the form of taxes, tribute, or payment for special services rendered. The collection of such tribute by a regional center would constitute a kind of "productive activity," the yields of which would be unrelated to the agricultural productivity of the catchment area immediately surrounding the center. [Brumfiel 1976:247]

In subsequent sections of this paper, I will construct a mathematical model that more precisely accounts for the relationship between site size and productivity observed in Brumfiel's plots. I will then apply this model in reanalyzing the data from the Valley of Mexico, in order to show how measuring centralization in this way may be feasible.

Of course, it must be emphasized that measuring the degree of centralization archaeologically will always be a matter of approximation, rather than absolute determination. In any particular archaeological setting, only a subset of all the goods and services allocated as tribute will be visible, and then only a subset of what is visible will be quantifiable in terms of the ratio that I have proposed. On the other hand, it seems reasonable to expect that, in most cases, a major portion of the total tribute extracted will consist of labor invested in public architecture, and of comestibles to support the political establishment. Though these two categories may constitute only a part of the total, they

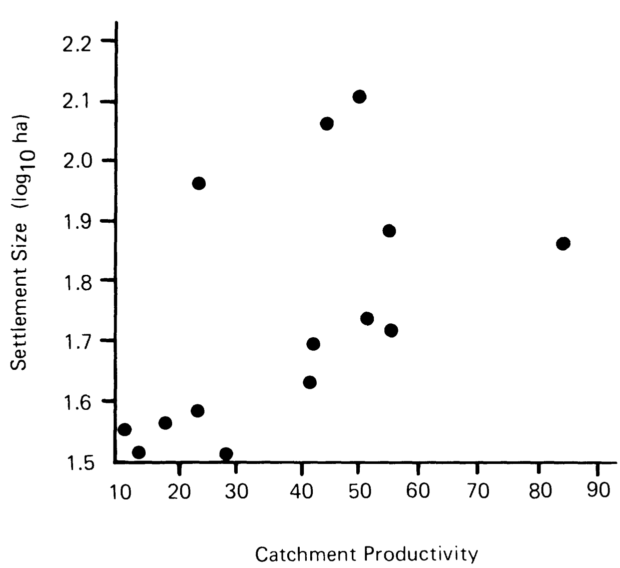


Fig. 1. Scatter diagram of site size versus catchment productivity, Valley of Mexico sites (after Brumfiel 1976: Fig. 8.12).

should still reflect, in a general way, the pattern of tribute flow within the hierarchy. Yet the potential for inaccuracy should always be kept in mind, and the results interpreted accordingly.

THE MODEL

In order to see how patterned variation in the flow of tribute can create systematic differences in settlement size, it is useful to construct an idealized model. Let us begin with a premise—true in many real-world situations but not necessarily in all—that the size of any settlement is directly related to the amount of food it has available. If the society is politically centralized, but lacks a diversified market economy and extensive full-time craft specialization, then the amount of food to which a settlement has access will depend principally on two things: (1) the productivity of the settlement's catchment (i.e., the annual yield of the productive zone directly exploited by the settlement's inhabitants), and (2) the flow of food as tribute either into or out of the settlement. Along the same lines, it is convenient to regard the general populace as being made up of two segments, either or both of which can exist within a given settlement. One segment is that of the *producers,* people belonging to households which must engage in subsistence production to fulfill their own needs. Another segment is that if the *nonproducers,* people whose livelihood depends on surplus food extracted as tribute from the producers.

From these basic premises, two corollaries follow. In any settlement: (1) the number of producers is directly proportional to the annual yield of that settlement's catchment, minus the food that is allocated as tribute; and (2) the number of nonproducers is directly proportional to the amount of tribute in food to which that settlement has access. Obviously, then, the size of any given settlement will depend on the productivity of its catchment *and* on its position within the regional political hierarchy.

The model can now be developed in a series of three steps which, in effect, simulate the growth of a regional hierarchy of settlements.

Case 1

Consider a region where the villages that exist are politically autonomous. Because they are autonomous, there is no movement of tributes from one village to another. If we envision these settlements as being inhabited solely by producers, then the size of each village (V_j) is simply proportional to the productivity (annual yield) of its catchment (P_j). The relationship is expressed algebraically as follows:

$$V_j = k\, P_j \qquad (1)$$

where k is a constant expressing the number of people that can be supported per unit productivity.

If one were to plot on a scatter diagram the size of each village against the productivity of its catchment, a linear configuration would result (Figure 2a). This line would have a slope of k, and would pass through the origin (0, 0) of the axes. A settlement whose catchment had zero productivity would therefore contain no inhabitants.

It is interesting to note that exactly the same relationship holds true no matter how the autonomous villages are organized internally. Even if the sociopolitical structure of each settlement were hierarchical, with a segment of nonproducers being supported by tribute drawn from a segment of producers, equation (1) would still apply. As long as all tribute flows take place within settlements and not between them, the number of inhabitants will continue to be determined solely by the amount of food that can be produced in each settlement's catchment (Figure 2a).

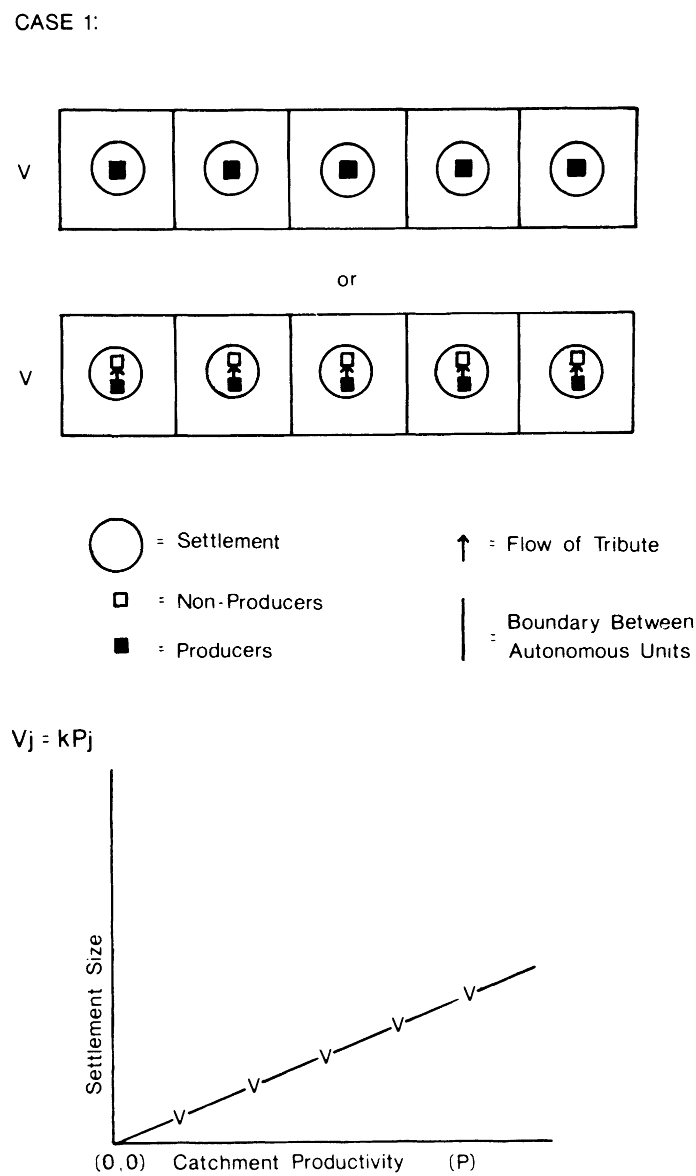


Fig. 2a. Schematic depiction of model for Case 1.

Case 2

Now consider a situation where the political settlement hierarchy is of two levels. The region is divided into autonomous districts, each district containing one local center and several politically subordinate villages. Within each district, all producers allocate a fixed proportion (t_1) of their output as tribute to the political establishment.

If we envision villages as being inhabited solely by producers, then the size of each village is proportional to the amount of food produced in the village's catchment, minus the amount paid out as tribute. This relationship is mathematically expressed as follows:

$$V_{ij} = k(P_{ij} - t_1 P_{ij}) \quad (2)$$

$$= k(1 - t_1) P_{ij} \quad (3)$$

where V_{ij} is the population of the *j*th village in the *i*th district; P_{ij} is the productivity (annual yield) of that village's catchment; and t_1 is the fraction of that productivity given up by the producers as tribute.

Local centers, because they do collect tribute, are inhabited not only by producers but by nonproducers as well. The number of producers (S_p) is once again proportional to the productivity of the catchment, minus what is allocated as tribute. The number of nonproducers (S_n), on the other hand, is proportional to the total intake of tribute, which includes that obtained from the producers in the center itself, as well as that collected from the villages under the center's direct political control. Thus we have:

$$L_i = S_p + S_n \quad (4)$$

$$= k(P_i - t_1 P_i) + k(t_1 P_i + \sum_j t_1 P_{ij}) \quad (5)$$

$$= k P_i + k t_1 \sum_j P_{ij} \quad (6)$$

where L_i is the population of the center in the *i*th district, and P_i is the productivity of that center's catchment.

When the settlements described by equations (3) and (6) are plotted on the scatter diagram, a different pattern than the one described previously will result (Figure 2b). Once again, the villages will be found along a line that passes through the origin. The local centers, however, will be found above the line of villages. If the aggregate amount of tribute collected by each center from the villages in its district is generally the same (that is, $\sum_j t_1 P_{ij}$ remains constant for all *i*) then the centers will fall along a line of slope k, with a y-intercept equal to $k \sum_j t_1 P_{ij}$. The existence of a y-intercept greater than zero reflects the fact that even if a center's catchment has no productive potential, the center could still support a number of people solely on the food it draws in as tribute from the other settlements. Note also that because k is always greater than $k(1 - t_1)$, the line of centers will generally have a slope somewhat steeper than that of the villages.

If the amount of tribute extracted by each center from the villages in its district varies somewhat (that is, $\sum_j t_1 P_{ij}$ is not constant for all *i*), then the points representing the centers will not form a perfect line, but rather will show some dispersion. Yet the amount of dispersion present in most cases should not obscure the overall linear tendency of the relationship.

Case 3

The final case we will consider is one in which yet another level of administrative control has emerged, resulting in a settlement hierarchy of three tiers. As in the previous case, the region is divided into a number of districts, each of which has a political center with a number of villages under its direct control. However, one of the centers is now a regional center, incorporating all the local centers and their districts under its political hegemony. The pattern of tribute flow in such a system would be as follows: all producers allocate a certain fraction (t_1) of their total output to the center within their district; furthermore, each local center passes up a specified fraction (t_2) of all the tribute it collects

Case 2:

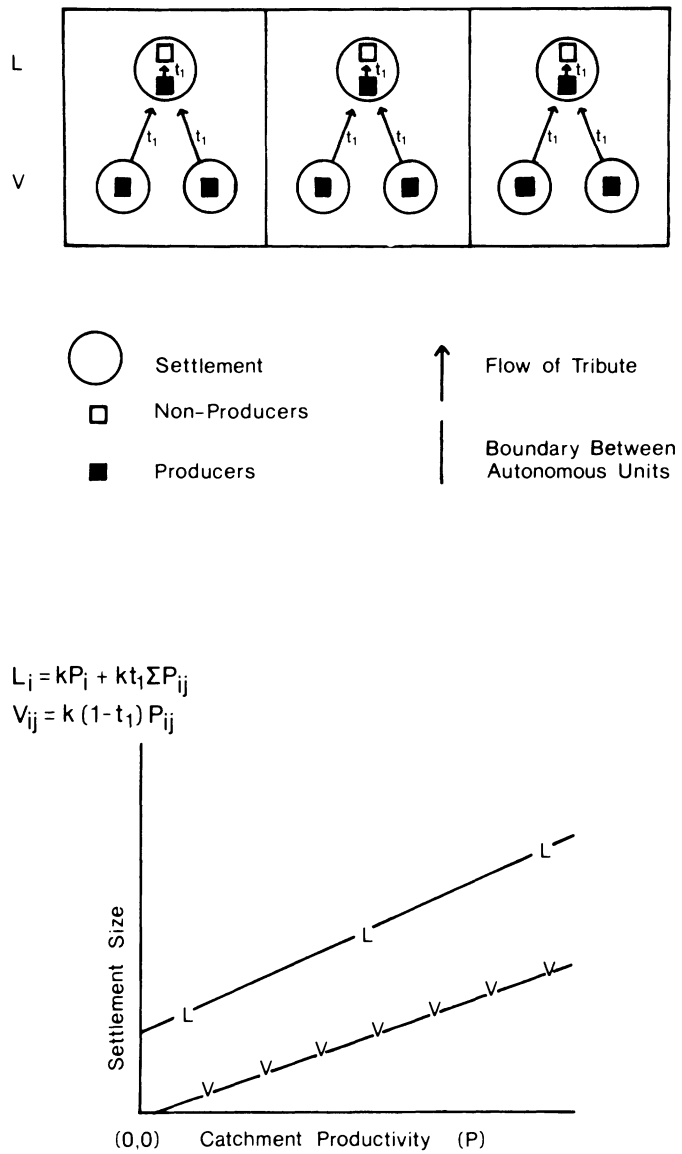


Fig. 2b. Schematic depiction of model for Case 2.

to the regional center (for ethnographic examples, see Steponaitis 1978). This pattern is schematically depicted in Figure 2c.

Under such conditions, the equation describing the sizes of villages is identical to equation (3). The equation for local centers, however, must be altered to reflect the payment of tribute to the regional center:

$$L_i = S_p + S_n \tag{7}$$

$$= k(P_i + t_1 P_i) + k\left((t_1 P_{ij} + \sum_j t_1 P_{ij}) - t_2 (t_1 P_{ij} + \sum_j t_1 P_{ij}) \right) \tag{8}$$

$$= k(1 - t_1 t_2) P_i + k(t_1 - t_1 t_2) \sum_j P_{ij} \tag{9}$$

where t_2 represents the fraction of all the tribute collected by the local center that gets passed up to the regional center.

For the regional center itself, the number of producers (S_p) is determined in the same way as for the local centers: again, it is simply proportional to the productivity of the catchment minus the amount allocated to the nonproducers. The number of non-producers (S_n), however, is augmented because of the regional center's comparatively greater access to tribute. This tribute includes the food extracted (1) from the producers in the regional center itself, (2) from the villages in the regional center's own district, and (3) from the local centers under the regional center's hegemony. We therefore arrive at the following expression:

$$R = S_p + S_n \tag{10}$$

$$= k(P_r + t_1 P_r) + k\left(t_1 P_r + \sum_j t_1 P_{rj} + t_2 \sum_i (t_1 P_i + \sum_j t_1 P_{ij})\right) \tag{11}$$

$$= k\, P_r + k t_1 \sum_j P_{rj} + k t_1 t_2 \sum_i (P_i + \sum_j P_{ij}) \tag{12}$$

where R is the population of the regional center; P_r is the productivity of the regional center's catchment; and P_{rj} is the catchment productivity of the *j*th village in the regional center's district.

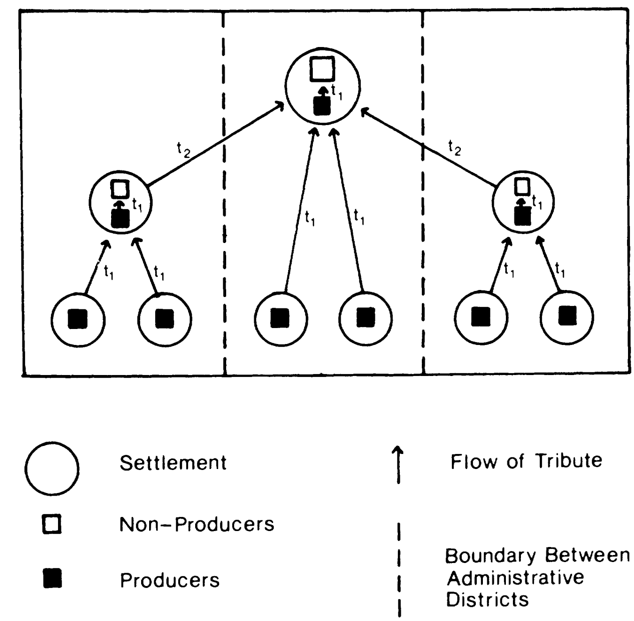
When settlement size is plotted against catchment productivity, equations (3), (9), and (12) define three distinct linear relationships, each corresponding to a level within the settlement hierarchy (Figure 2c). Lowest on the diagram are the villages, whose line again has slope $k(1 - t_1)$ and passes through the origin. Above the villages are the local centers; if the amount of tribute collected by each local center from the villages in its district is roughly the same (i.e., $\sum t_1 P_{ij}$ remains approximately constant for all *i*), then these points will fall along a line of slope $k(1 - t_1 t_2)$, with the y-intercept at $k(t_1 - t_1 t_2) \sum P_{ij}$. Highest on the diagram is the line that defines the position of the regional center. This line has a slope of k and a y-intercept equal to

$$\left(k t_1 \sum_j P_{rj} + k t_1 t_2 \sum_i (P_i + \sum_j P_{ij})\right).$$

Note that since t_1 and t_2 must both be less than 1.0, k is greater than $k(1 - t_1 t_2)$, which in turn is greater than $k(1 - t_1)$. Therefore, each successively higher line has a somewhat steeper slope.

It should also be pointed out that the equations previously developed for cases 1 and 2 can be regarded as specific manifestations of the more general equations derived for case 3. If we set t_2 equal to zero, implying that there is no tribute flow (hence no substantial centralization) above the level of the regional center, then equations (12) and (9) both reduce to equation (6)—characteristic of case 2. Similarly, if we set both t_1 and t_2 equal to zero, implying that there is no tribute flow (hence no significant hierarchical differen-

Case 3:



$$R = kP_r + kt_1\Sigma P_{rj} + kt_1t_2\sum^{I}(P_i + \sum^{J} P_{ij})$$

$$L_i = k(1 - t_1t_2)P_i + k(t_1 - t_1t_2)\sum^{J} P_{ij}$$

$$V_{ij} = k(1 - t_1)P_{ij}$$

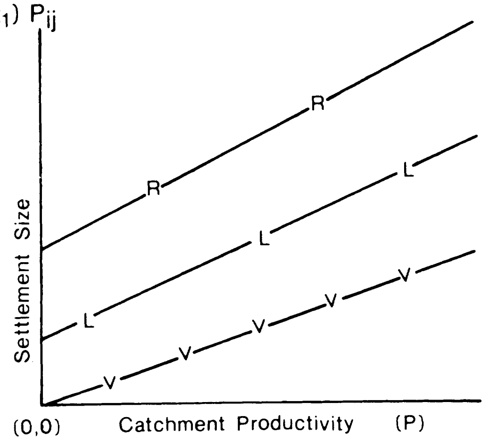


Fig. 2c. Schematic depiction of model for Case 3.

tiation) between settlements at all, then equations (12), (9), (6), and (3) all reduce to equation (1)—characteristic of the autonomous villages in case 1.

The model just described has a number of methodological implications concerning the manner in which political settlement hierarchies, as they occur archaeologically, can be recognized and properly interpreted.

The first implication has to do with how discrete levels within such a hierarchy can be identified. For systems of the kind we have considered, each level within the hierarchy appears as a distinct tier of points on a scatter diagram showing settlement size versus catchment productivity. Because each tier is defined by a line of positive slope, the settlements belonging to different levels do not necessarily sort out into mutually exclusive classes based on size alone (Figures 2b, c). Note, for example, that a village whose catchment is particular productive may well be larger than a center in somewhat less productive zone. This calls into question the applicability to such systems of the technique based on Central Place Theory, where modalities in a histogram of site size frequencies are interpreted as levels in a hierarchy (cf. Earle 1976:206-207; Johnson 1977:494-496). In the political hierarchies characteristic of nonmarket societies, the significant variable differentiating among levels is not a settlement's overall size, but rather is the size of its contingent of nonproducers. A settlement's overall size may include both nonproducers and producers. Thus, in order to isolate the variability in nonproducers, one must control for the number of producers by taking catchment productivity into account.

Since the vertical separation between tiers on the scatter diagram is due to systematic differences in the numbers of nonproducers at settlements of each level, this separation must also reflect systematic differences in the amount of tribute controlled. If the differences in the amount of tribute controlled by settlements at adjacent levels in the hierachy is not large, then the lines representing these levels will appear very close together on the diagram. Indeed, if the difference in the amount of tribute controlled is sufficiently small, then the lines may be virtually indistinguishable. Thus, centers of a given level will appear as a distinct tier on the diagram only when the degree of centralization at that level is pronounced.

Stating the matter more precisely, it can be shown mathematically that the vertical distance of any center above the line or village indicates the number of nonproducers at that center, and hence is directly proportional to the amount of tribute which that center controls. Note that in equations (5), (8), and (11), the term that defines the number of producers (S_p) living at the center is identical to equation (2), the expression that defines the size of a village. Thus, the number of nonproducers is simply the difference between the actual size of a center, and what that size would be were the center a village. The relationship is shown graphically in Figure 3.

This finding is not only of theoretical interest, but has some practical utility as well. It means that if the patterning predicted by the model is found archaeologically, the information gleaned from the scatter diagram may make it possible to calculate both the degree of centralization and the relative amount of food mobilized to support the political establishment.

The degree of centralization, as discussed earlier, can be measured as the ratio of the amount of tribute controlled by a center at the uppermost hierarchical level, to the average amount controlled by a center in the level immediately below. Since the number of nonproducers (S_n) at each center is directly proportional to the amount of tribute controlled, estimating the index from a diagram such as Figure 3 is straightforward. One simply takes the value of S_n for the regional center, and divides it by the mean value of S_n for all the local centers.[1]

Estimating the relative amount of food used to maintain the political establishment is also straightforward, for it should approximately equal the ratio of nonproducers to the population as a whole. Using the information in Figure 3, one first evaluates the following three quantities: the total number of nonproducers living at centers ($u = \Sigma S_n$), the

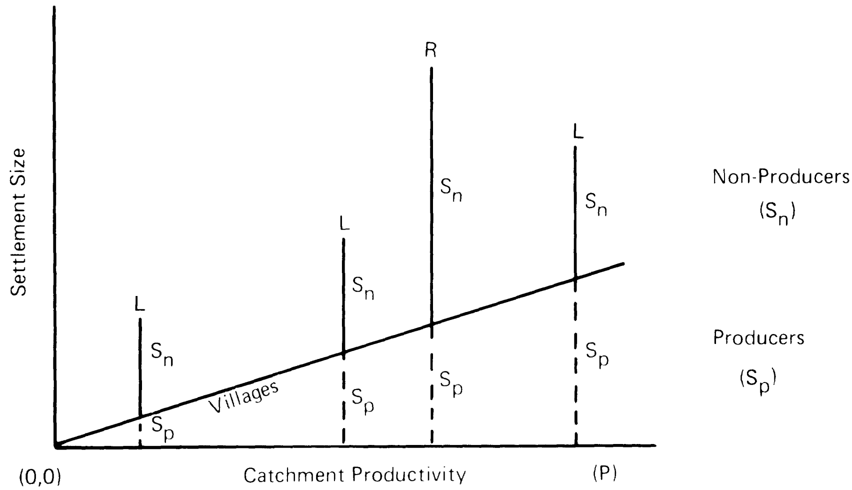


Fig. 3. Diagram showing how the line representing villages graphically partitions the population of each center into segments of producers and nonproducers. (L indicates local center, R indicates regional center.)

total number of producers living at centers ($v = \Sigma S_p$), and the total number of people living in villages ($w = \Sigma V_{ij}$). The proportion of nonproducers, and hence the relative surplus that must be mobilized to feed them, is then arrived at as follows:

$$t_1 = u / (u + v + w) \tag{13}$$

This procedure will yield an exact estimate only if all the people living in villages are producers. To the extent that the latter assumption does not hold perfectly true, the estimate obtained for t_1 will be conservative. This estimate is also conservative in the sense that it measures the fraction of the average producer's output that is mobilized and *retained* by the political establishment. In most societies of the kind we are dealing with here, some (usually small) portion of the tribute extracted gets "redistributed," and finds its way back to the producers from whom it originally came. Thus, t_1 probably underestimates the fraction of the total production that is mobilized in the first place.[2]

APPLYING THE MODEL TO THE FORMATIVE PERIOD IN THE VALLEY OF MEXICO

Now that the model has been presented, it remains to illustrate its utility by applying it to a body of empirical data. These data come from the Valley of Mexico, an area that has been the subject of numerous intensive surface surveys since 1963. Specifically, I will deal with four contiguous regions within the Valley: Texcoco, Ixtapalapa, Chalco, and Xochimilco (Figure 4). Each of these regions has been surveyed in its entirety, assuring that virtually all sites visible on the surface have been recorded. Detailed information on the sites in the first two regions has already been published in monograph form (Parsons 1971; Blanton 1972b), and unpublished data on the sites in Chalco and Xochimilco were graciously provided by Jeffrey Parsons (see also Parsons 1974).

The analysis will be carried out on the sites dating to three sequential periods: Middle Formative (ca. 800-500 B.C.), Late Formative (ca. 500-200 B.C.), and Terminal For-

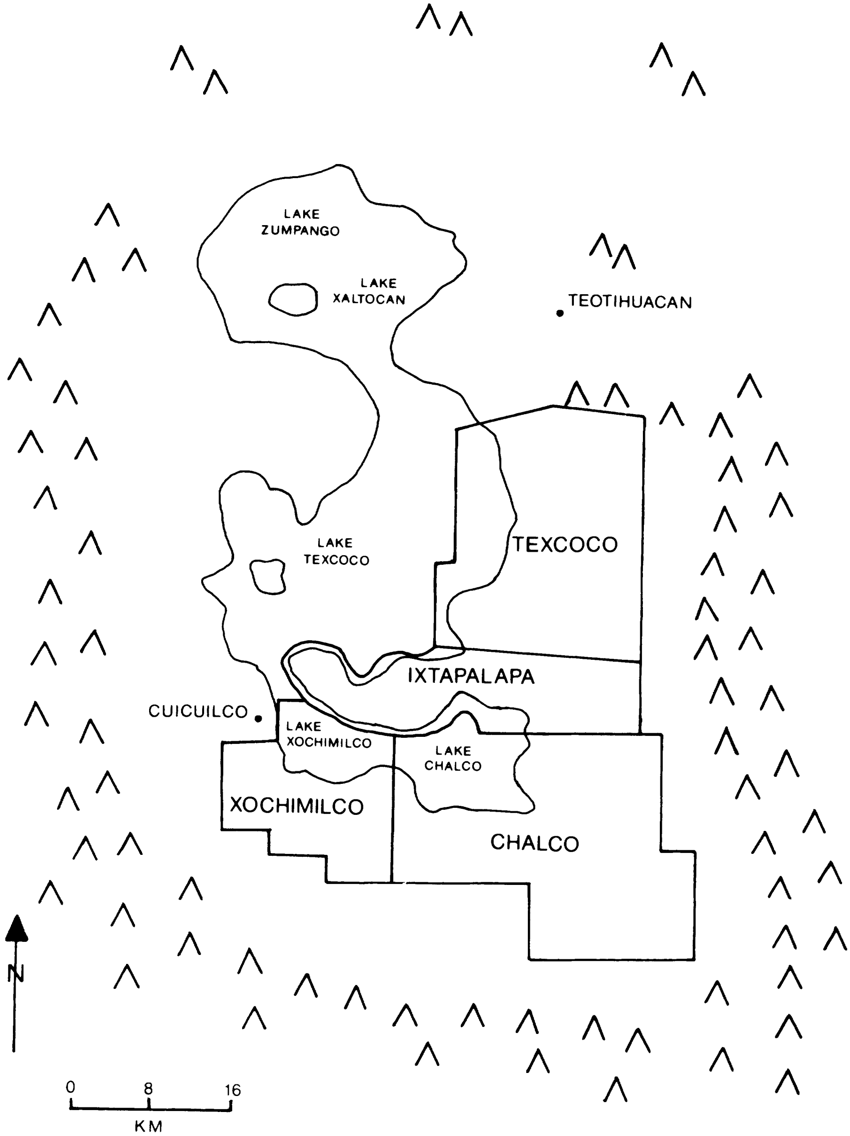


Fig. 4. The Valley of Mexico, showing the surveyed subregions considered in the present analysis. Mountain ranges are depicted schematically.

mative (Patlachique phase, ca. 200 B.C.-A.D. 1).[3] These periods were selected for several reasons. First, there is ample evidence to suggest that the societies during most of this time span had a complex political organization, with regional hierarchies of settlements. Yet there is no reason to believe that any of the settlements in the regions with which we specifically deal were engaged in market activity of any kind.[4] All available evidence is consistent with the assumption that most of the inhabitants of these sites were primary producers, and that any nonproducers were mainly supported, either directly or indirectly, by food extracted as tribute by the political establishment. This assumption is, of course, critical to the legitimate application of the model.

Another important consideration is that during the span of these periods, the societies in the Valley underwent a great deal of evolutionary development. Although the degree to which Middle Formative societies were hierarchically organized is debatable (cf. Blanton 1972a; Parsons 1974:104; Sanders, Parsons, and Logan 1976:164-165; Tolstoy et al. 1977:102-104), clear-cut vertical differentiation in both burials and settlements appears in Late and Terminal Formative times. Thus, these periods present us with a range of political forms to which the quantitative measures derived from the model can be applied. In typological terms, the societies through most of the periods we are considering are generally regarded as chiefdoms; state emergence apparently did not occur until near the end of the Terminal Formative (Sanders and Price 1968; Parsons 1974).

The final reason for choosing these periods is that Brumfiel's (1976) earlier work has empirically established that the size/productivity relationship predicted by the model did, in fact, hold in the Late and Terminal Formative (see Figure 1). One might even wonder why I do not simply reinterpret her results in light of the present framework. The problem is that Brumfiel's analysis included only those sites larger than 30 ha, effectively eliminating most of the villages in the area she studied. Although this exclusion was perfectly consistent with the particular question she was trying to answer, for present purposes it would seem desirable to include a more representative selection of the sites that exist. Not only will my own analysis take into account a much greater number of sites, but also there will be a few other differences in procedure that will become apparent as the discussion proceeds.

Before moving on to the results of the reanalysis, however, it is important to describe the assumptions that were made in estimating population and agricultural catchment productivity from the kinds of archaeological data available. Many of these assumptions are necessitated by weaknesses in the data which can, in principle, be remedied by future work.

Whenever evidence of discrete households is not visible on the surface, one procedure for estimating site population is to multiply the size of the residential area by an estimate of the residential density. For present purposes, and for lack of excavated data to suggest an alternative, I have assumed that the residential density is the same for all sites within a given period.[5] Arriving at an exact value for this density is unnecessary because the model requires only that population be dealt with in relative, and not absolute terms. Thus, population size was taken to be directly proportional to the size of the residential area. For villages, the residential area was regarded as equivalent to the total area of the site itself. Political/administrative centers, on the other hand, are likely to have substantial portions of their area taken up by nonresidential public architecture, and in making relative population estimates it was necessary to correct for this difference in some way. Unfortunately, not one of the centers being considered has been excavated sufficiently to determine what proportion of the total area was nonresidential. The only basis for an estimate comes from a small Middle Formative site in Oaxaca, where excavations revealed that 13% of the settlement's area consisted of what appeared to be public architecture (Marcus 1976:84). Applying such a figure to the large Formative centers in the Valley of Mexico is tenuous at best, but for lack of better data I have assumed that the residential zone of a political/administrative center comprises 85% of its total area.

Catchment productivity was assessed in terms of the number of hectares of arable land that would have been available to the inhabitants of each community. Once again, since only a relative index is called for, the absolute levels of productivity in the Formative need not concern us here. All land was considered arable except that which (1) fell on steep slopes or cinder cones, (2) lay in the former bed of Lakes Texcoco and Chalco-Xochimilco (below an elevation of 2240 m.), or (3) lay above the maximum elevation at which maize cultivation is feasible (2750 m.). Undoubtedly there are differences in the relative productive capacities of soils within the zone of arable land, but without reliable information with which these differences can be quantified (cf. Sanders 1976b), equal fertility has been assumed.[6]

In order to determine the boundaries of each site's catchment, it was assumed that agriculturalists would walk only a certain maximum distance to reach their fields, and that this maximum distance was the same for all sites of a given period. This assumption was also employed by Brumfiel, who, following the suggestion of Vita-Finzi and Higgs (1970), used a catchment radius of 5 km. However, in light of the ethnographic evidence presented by Chisolm (1968) such a distance seems a bit excessive:

> Beyond about 1 kilometre, the costs of movement become sufficiently great to warrant some kind of response; at a distance of 3-4 kilometres the costs of cultivation necessitate a *radical* modification of the system of cultivation or settlement—for example by the establishment of subsidiary settlements—though adjustments are apparent before this point is reached. If the distances involved are actually greater than this, then it is necessary to look for some very powerful constraining reason which prevents the establishment of farmsteads nearer the land. Over much of the world, the present spontaneous tendency is to modify the patterns of rural settlement and land holding in such a manner that the distance separating the farmstead from the lands cultivated is reduced to something in the order of 1 or 2 kilometres. . . . [Chisolm 1968:131]

The appropriateness of a smaller catchment radius was also suggested by the fact that the Late and Terminal Formative sites included in the present analysis were almost always spaced less than 5 km. from their nearest neighbor. Thus, three different radii were selected: 1 km., 1.5 km., and 2 km.

Ideally, the catchment boundaries at any given radius should be determined by measuring that distance directly from the periphery of the site. However, in view of the large number of sites included in the analysis, and the relatively small scale of the topographic maps on which the measurements were made (1:20,000), a slightly modified procedure was used. The procedure involved calculating the average distance (d) in kilometers between the center and periphery of the site; this average distance is purely a function of the site's size in hectares (S):

$$d = \sqrt{S/314.16} \tag{14}$$

The average distance was then added to the catchment radius (r), and a circle of radius $r + d$ was drawn with a compass around the center of the site. Whenever the catchment circles of adjacent sites overlapped, the area of overlap was partitioned by drawing a line between the points where the circles intersected. Once the boundaries were established in this way, the number of hectares of arable land within each catchment was measured (excluding the land covered by the site itself). To the degree that any site's shape departs from being perfectly circular, using the approximation based on d tends to underestimate the actual amount of land within a particular distance of the site's edge. But the efficiency gained by using this method more than offsets the slight amount of error involved.

We must also consider what effect varying the catchment radius itself has on the index of productivity. Clearly, using a larger radius will tend to increase the absolute number of arable hectares available to each site. By increasing the radius from 1 km. to 1.5 km. to 2 km. the mean value of the index changes from 375.6 ha. to 674.5 ha. to 982.4 ha. respectively (Table I). However, the *relative* values of the index remain about the same no matter which radius is used. This fact is illustrated in Table II, which shows that the values derived using the three different radii are highly intercorrelated. From a practical standpoint, such a finding implies two things. First, it indicates that using any one of these catchment radii will produce broadly similar results in light of the model. Second, it removes us from the predicament of ever having exactly to determine the actual radius of

TABLE I. THE MEAN, MINIMUM AND MAXIMUM VALUES OF THE INDEX OF PRODUCTIVITY, MEASURED USING THREE DIFFERENT CATCHMENT RADII (SITES FROM ALL THREE PERIODS INCLUDED).

Radius	N	Mean	Minimum	Maximum
1 km.	84	375.6	83	640
1.5 km.	84	674.5	101	1183
2 km.	85	982.4	105	1778

agricultural land-use in the Formative. As long as the actual radius was somewhere in the vicinity of 1 or 2 km., and was approximately constant for all communities, then any of our indices should provide a fairly good relative estimate of the amount of agricultural land exploited.

Another set of potential measurement difficulties stems from the lack of very fine chronological control. Each of the periods being considered represents a span of about 300 years, and the sites assigned to each must be regarded as contemporary. However, it is certainly possible that some sites may have been occupied for only parts of one period, or else intermittently, such that the assumption of total contemporaneity may not be perfectly accurate. Departures from total contemporaneity may in some ways adversely affect our estimates of both relative population and relative productivity. Although it is not likely that the problem in this case has been serious enough to distort severely the general outcome of the analysis, it is still important to be cognizant of the errors that may potentially exist.

One potential difficulty arises when estimates of total population are made by summing the estimates for individual sites. If the sites being summed were not all occupied at one time, then the estimated total will be inflated to some extent. Tolstoy, for example, has suggested on the basis of his finer-grained chronology that such inflation for the Middle Formative in the Valley of Mexico may be as high as 18 to 25% (Tolstoy 1975:337).[7] Since our relative comparisons of total population will be framed not between periods, but rather between different levels of the settlement hierarchy within periods, inaccuracies will arise only to the extent that the inflation factor is not the same for each level.

Site noncontemporaneity can also have an impact on our estimates of relative productivity. It was pointed out earlier that the extent of a site's catchment is reduced by the presence of a closely adjacent neighbor. If the two sites are in fact contemporary, then such a procedure is defensible on the grounds that the agricultural land falling within reach of both sites would have to be shared. On the other hand, if the sites were not actually occupied at the same time, then the overlap in their catchments is merely apparent and not real. In such a case, partitioning the area of overlap between the two would cause us to underestimate the relative amount of land that was actually available to each.

In the preceding paragraphs I have stressed the various difficulties that can arise in applying the model to archaeological data. Yet it should also be pointed out that these difficulties would have been much greater, were the survey data from the Valley of Mexico

TABLE II. CORRELATION COEFFICIENTS COMPUTED BETWEEN INDICES OF PRODUCTIVITY MEASURED USING THREE DIFFERENT CATCHMENT RADII (SITES FROM ALL THREE PERIODS INCLUDED).

	1 km.	1.5 km.	2 km.
1 km.	1.000	.932	.823
1.5 km.	.932	1.000	.951
2 km.	.823	.951	1.000

not of such extraordinary quality. Rarely does one find a survey that not only provides complete coverage over a large region, but also provides accurate information on site size with reasonable chronological control. Considering all the possible sources of measurement error, the patterns that emerge in these data are surprisingly clear, and as we shall see, fit the predictions of the model remarkably well.

The Sample of Sites

The analysis is framed in terms of a simplified version of the site typology developed for the Valley of Mexico by Parsons (1971:22) and Blanton (1972b:20). The formal criteria on which the simplified typology is based are presented below:

1. *Center:* a relatively large site with moderate or heavy sherd scatter, and usually with surface evidence of substantial public architecture.
2. *Segregated elite district:* a distinctive site type occurring only in the Terminal Formative, characterized by a topographically prominent location and abundant public architecture.
3. *Nucleated village:* a site with generally moderate or heavy sherd scatter, but with no substantial public architecture. (This category includes Blanton's "village.")
4. *Dispersed village:* a site with very light and/or discontinuous sherd scatter and no substantial public architecture. (I have also lumped into this category the very small sites the Parsons and Blanton call "hamlets.")

In measuring catchment productivity, all centers and nucleated villages were considered;[8] also considered were those dispersed villages and segregated elite districts with areas larger than 10 hectares. Ignoring sites of the latter two categories smaller than 10 ha. is justifiable on the grounds that they clearly do not represent the kind of nucleated settlements to which the assumptions of the model apply. Most of the sites excluded cover less than 2 ha. and probably were inhabited by no more than a few households each. Thus, it hardly seems realistic to think of them as exploiting an agricultural catchment of 1 to 2 km. radius. The subsistence requirements of such tiny settlements would not have been great, and their presence would not have substantially reduced the amount of agricultural land available to the larger settlements nearby.[9]

Methods of Analysis and Mode of Presentation

The analysis was carried out on a series of scatter diagrams showing site size (an indicator of population) versus catchment productivity. The model predicted that each diagram should exhibit one or more linear scatters of points. Such scatters were in fact found, but of course they were never perfectly linear. There was always some degree of "blurring" caused by measurement error and by real-world deviations from the idealized assumptions on which the model was based. Nevertheless, the underlying form of any linear relationship could still be described by calculating the line that best fit the scatter of points. This calculation was accomplished by using the technique of least-squares regression (Blalock 1960:279-283; Dixon and Massey 1969:193 ff). Furthermore, the degree to which the underlying scatter of points approximated a perfect linear configuration could be measured by means of the r^2 statistic (Blalock 1960:298). This statistic represents the proportion of the total variance in site size that is accounted for by a linear relationship with catchment productivity. Thus, it can take on values ranging from 0 to 1.0. When r^2 equals zero, a linear relationship is absent; when r^2 equals 1.0, the linear relationship is perfect. Viewed in another way, r^2 numerically expressed the degree to which the observed scatter of points is "spread" above and below the best-fit line. The

TABLE III. DATA USED IN CONSTRUCTING SCATTER DIAGRAMS.

Site	Period	Type	Size (ha.)	P (1 km.)	P (1.5 km.)	P (2 km.)
CH-15	M.F.	N.V.	17.4	146.6	308.6	541.6
CH-4	M.F.	D.V.	16.9	428.1	761.1	1160.1
CH-5	M.F.	N.V.	52.8	557.2	977.2	1489.2
CH-8	M.F.	D.V.	14.0	438.0	894.0	1507.0
CH-9	M.F.	N.V.	42.1	573.9	1091.9	1755.9
IX-1	M.F.	N.V.	9.0	141.0	334.0	589.0
IX-4	M.F.	N.V.	12.5	184.5	421.5	703.0
TX-13	M.F.	N.V.	45.0	425.0	815.0	1253.0
XO-2	M.F.	D.V.	20.3	294.7	562.7	939.7
CH-1	L.F.	N.V.	59.7	556.3	1020.3	1519.3
CH-12	L.F.	N.V.	43.2	553.8	1059.8	1578.8
CH-15	L.F.	N.V.	14.0	349.0	613.0	916.0
CH-16	L.F.	D.V.	19.7	455.3	786.3	1107.3
CH-2	L.F.	N.V.	67.0	583.0	978.0	1295.0
CH-20	L.F.	N.V.	73.6	633.4	1183.4	1688.4
CH-35	L.F.	D.V.	10.0	442.0	898.0	1415.0
CH-4	L.F.	N.V.	34.8	440.2	753.2	1155.2
CH-48	L.F.	N.V.	11.8	403.2	859.2	1238.2
CH-5	L.F.	C.	130.0	508.0	830.0	1095.0
CH-50	L.F.	N.V.	17.8	367.2	695.2	1159.2
CH-53	L.F.	N.V.	20.5	144.5	339.5	550.5
CH-6	L.F.	C.	86.0	616.0	1027.0	1336.0
CH-9	L.F.	D.V.	17.8	325.2	515.2	757.2
IX-12	L.F.	N.V.	15.0	315.0	488.0	707.0
IX-2	L.F.	C.	37.0	236.0	466.0	765.0
IX-3	L.F.	N.V.	20.0	308.0	638.0	1010.0
IX-6	L.F.	C.	65.0	275.0	562.0	824.0
IX-7	L.F.	N.V.	30.0	283.0	455.0	890.0
IX-8	L.F.	N.V.	7.0	171.0	261.0	393.0
TX-12	L.F.	C.	86.0	534.0	1070.0	1778.0
TX-14	L.F.	N.V.	4.5	.	.	115.0
TX-22	L.F.	N.V.	40.0	576.0	1083.0	1730.0
TX-29	L.F.	D.V.	12.0	304.0	647.0	1092.0
TX-8	L.F.	D.V.	20.0	511.0	969.0	1487.0
TX-9	L.F.	N.V.	33.0	425.0	963.0	1336.0
CH-11	T.F.	D.V.	10.6	427.4	684.4	966.4
CH-14	T.F.	C.	129.0	496.0	701.0	581.0
CH-15	T.F.	D.V.	23.6	394.4	579.4	763.4
CH-16	T.F.	C.	74.6	609.4	879.4	1090.4
CH-19	T.F.	D.V.	35.2	400.8	572.8	711.8
CH-23	T.F.	D.V.	12.3	373.7	730.7	1115.7
CH-24	T.F.	D.V.	12.7	418.3	778.3	1237.3
CH-46	T.F.	D.V.	11.2	440.8	896.8	1504.8
CH-54	T.F.	D.V.	10.4	374.6	813.6	1413.6
CH-55	T.F.	D.V.	14.0	438.0	894.0	1383.0
CH-59	T.F.	N.V.	43.4	464.6	839.6	1252.6
CH-6	T.F.	D.V.	20.9	489.1	807.1	1154.1
CH-61	T.F.	D.V.	33.8	497.2	974.2	1496.2
CH-63	T.F.	D.V.	74.0	308.0	498.0	693.0
CH-7	T.F.	D.V.	11.1	258.9	372.9	523.9
CH-9	T.F.	C.	75.0	443.0	689.0	918.0
IX-10	T.F.	N.V.	32.0	296.0	508.0	1039.0
IX-13	T.F.	N.V.	41.0	577.0	934.0	1036.0

Site	Period	Type	Size (ha.)	P (1 km.)	P (1.5 km.)	P (2 km.)
IX-2	T.F.	N.V.	16.0	109.0	162.0	254.0
IX-3	T.F.	N.V.	20.0	230.0	399.0	621.0
IX-4	T.F.	C.	37.0	83.0	172.0	248.0
IX-5	T.F.	C.	32.0	476.0	866.0	1258.0
TX-1	T.F.	C.	74.0	398.0	926.0	1423.0
TX-11	T.F.	N.V.	25.0	506.0	972.0	1425.0
TX-13	T.F.	N.V.	10.0	383.0	816.0	1383.0
TX-14	T.F.	S.E.D.	18.0	315.0	529.0	820.0
TX-17	T.F.	C.	118.0	640.0	938.0	1120.0
TX-19	T.F.	D.V.	11.0	434.0	700.0	1004.0
TX-20	T.F.	D.V.	24.0	258.0	592.0	604.0
TX-21	T.F.	D.V.	40.0	410.0	524.0	559.0
TX-25	T.F.	D.V.	50.0	366.0	500.0	635.0
TX-30	T.F.	C.	50.0	294.0	451.0	654.0
TX-31	T.F.	D.V.	19.0	101.0	101.0	105.0
TX-32	T.F.	D.V.	12.0	149.0	267.0	385.0
TX-33	T.F.	N.V.	15.0	132.0	185.0	258.0
TX-34	T.F.	N.V.	9.0	121.0	181.0	223.0
TX-35	T.F.	D.V.	16.0	199.0	250.0	318.0
TX-36	T.F.	S.E.D.	35.0	478.0	840.0	1184.0
TX-37	T.F.	D.V.	10.0	422.0	836.0	1213.0
TX-39	T.F.	D.V.	10.0	425.0	781.0	1177.0
TX-4	T.F.	S.E.D.	15.0	437.0	850.0	1247.0
TX-44	T.F.	N.V.	11.0	185.0	403.0	721.0
TX-50	T.F.	C.	52.0	362.0	690.0	963.0
TX-51	T.F.	S.E.D.	40.0	540.0	944.0	1353.0
XO-1	T.F.	D.V.	11.9	353.1	572.1	688.1
XO-2	T.F.	D.V.	14.7	360.3	643.3	895.3
XO-4	T.F.	D.V.	22.0	328.0	606.0	957.0

closer the value of r^2 is to 1.0, the smaller is the amount of spread, and the more perfect is the linear relationship among the points.

For each period, three different scatter diagrams were constructed: site size was plotted against the amount of arable land in catchments of radius 1, 1.5, and 2 km., respectively. (The data on which these diagrams were based are presented in Table III.) It turned out (not unexpectedly) that the configuration of points on these diagrams remained practically the same no matter which of the three catchment radii was used. Although the exact numerical values calculated for the several indices and statistics did vary slightly from one radius to the next, the nature of the general interpretations they supported remained unaltered. Thus, to avoid needless repetition, the results of the analysis will be presented below with specific reference only to the scatter diagrams based on the 1.5 km. radius.

The reader should also be aware that, although the scatter diagrams presented in the figures show site size on the vertical axis, the variable we are really interested in measuring is site population. For village sites, the correspondence is straightforward, because population is assumed to be directly proportional to size. For centers, on the other hand, population is assumed to be directly proportional to size minus the 15% that is taken up by public architecture. Applying the constant 15% correction factor to centers does not change the degree of linear patterning they exhibit (i.e., the value of r^2 remains the same), but it does make the points representing the centers (and the regression line that best fits these points) appear somewhat lower on the scatter diagram relative to the villages. I have chosen to present the sizes of centers in uncorrected form on these diagrams for two reasons: first, because the value of the correction factor is merely an educated guess and not a confirmed fact; and second, because in uncorrected form the points on the scatter diagram are less crowded, and the relationships among them are easier to discern visually. Where necessary, the best-fit regression calculated for the corrected sizes will be added to the diagram as a dotted line; also, values for the y-intercept of both the uncorrected and the corrected regression lines will be presented in the course of discussion.

Middle Formative

The view currently held by most archaeologists working in the Valley of Mexico is that the degree of hierarchical organization in the Middle Formative was minimal (e.g., Par-

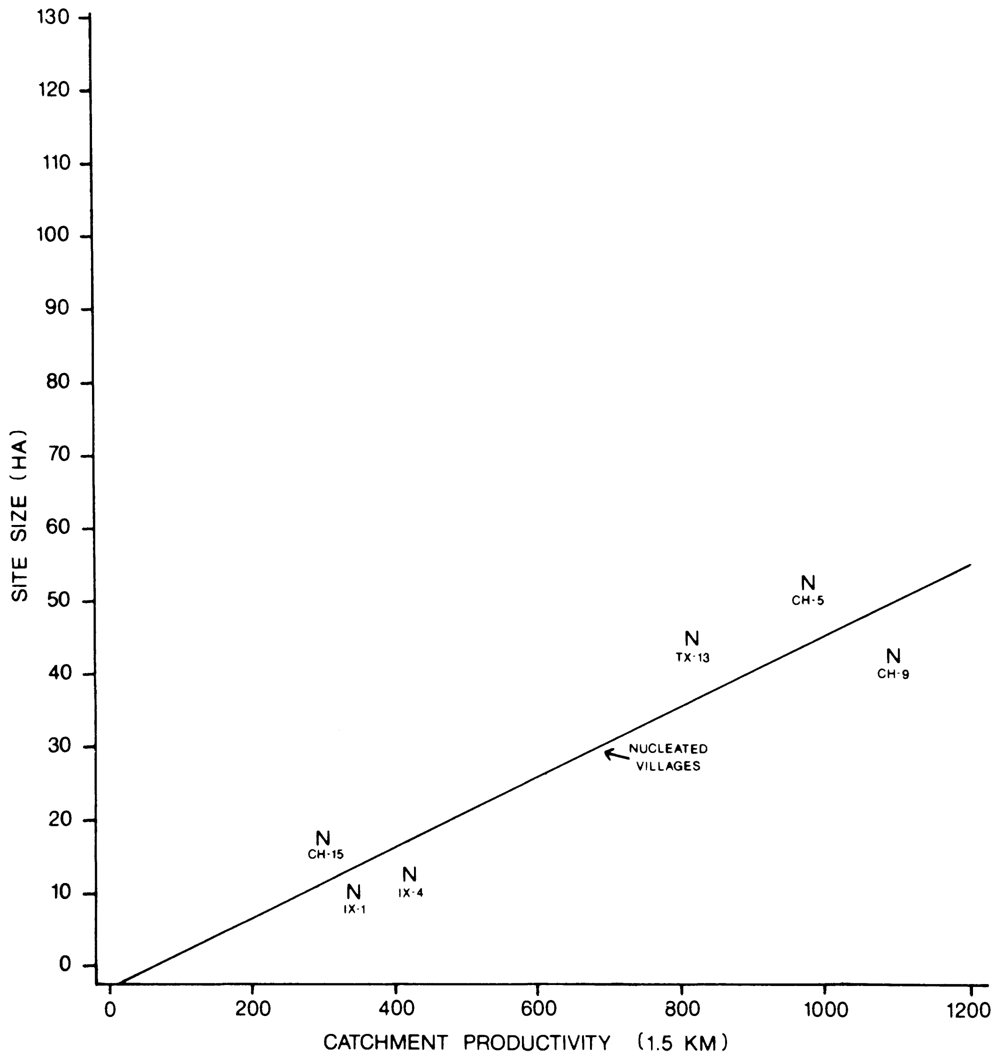


Fig. 5. Site size versus catchment productivity (1.5-km. radius), Middle Formative nucleated villages.

TABLE IV. PARAMETERS OF REGRESSION LINE, MIDDLE FORMATIVE SITES.[a]

Site Type	Slope (m)	Y-Intercept (b)	r^2
Nucleated Villages	.0506	−3.5	.85

[a] This regression line is of the type $S = mP + b$, where S represents site size in hectares, and P represents the number of hectares of arable land in an 1.5-km. catchment.

sons 1974:104; Sanders, Parsons, and Logan 1976:164; Tolstoy et al. 1977:102-105). This impression rests largely on the fact that there seems to be little clear-cut hierarchical differentiation among sites, and little evidence of substantial public architecture. Hence, Parsons and Blanton placed all the sites they recorded into the categories nucleated village, dispersed village, and hamlet; not one site was classified as a center.

If in fact there was no political centralization at the regional level, there would not have been any large amounts of tribute flowing between settlements. This expectation is fully confirmed, in light of the model, by the scatter diagram in Figure 5.

Nucleated villages exhibit a very close linear relationship between size (i.e., population) and catchment productivity ($r^2 = .85$); the line that best fits the scatter of points has a y-intercept of −3.5, a value very close to zero as the model would predict (Table IV). In other words, the population of villages was directly proportional to the amount of arable land in their immediate vicinity; a settlement with no arable land could support no population. These results imply that each nucleated village was self-sufficient in terms of production, and did not have access to substantial amounts of food extracted as tribute from other settlements.

Dispersed villages exhibit a somewhat different pattern, one not directly interpretable in light of the model (Figure 6). No positive association between size and productivity is evident. Rather, two of these dispersed villages (CH-4, CH-8) have sizes that are relatively small, even though their catchment productivity is relatively high. In attempting to explain this phenomenon, we must keep in mind that dispersed villages are differentiated from nucleated villages on the basis of one criterion: a lighter density of sherd scatter. This lighter density of sherd scatter could be related to many different factors, among them: (1) a lower density of households, (2) a shorter span of occupation, and (3) depth of postdepositional overburden. In this particular case, I suspect that the second of these factors may have been operating. Once a village had reached the maximum size its catchment could reasonably support, any excess population would have to split off and form daughter communities. CH-4 and CH-8 may represent such daughter communities that were founded relatively late in the period and so were not occupied long enough to reach their maximum size; the fact that they may be daughter communities is further suggested by their close proximity to the largest of the nucleated villages, CH-5 (Figure 7).

Thus, the present analysis suggests that the Middle Formative was characterized by a pattern of village autonomy in political affairs. This, of course, does not preclude the possibility that some degree of political centralization and tribute flow existed *within* villages. Nor does it deny that there may have been some social and/or political ties between the large nucleated villages, and the smaller dispersed villages/hamlets in their vicinity. The point is that even if such ties existed, they do not appear to have been strong enough to allow one settlement to mobilize large amounts of surplus from another.

Late Formative

The Late Formative settlements in the Valley of Mexico show much clearer evidence of hierarchical differentiation than those of the preceding Middle Formative. In addition to

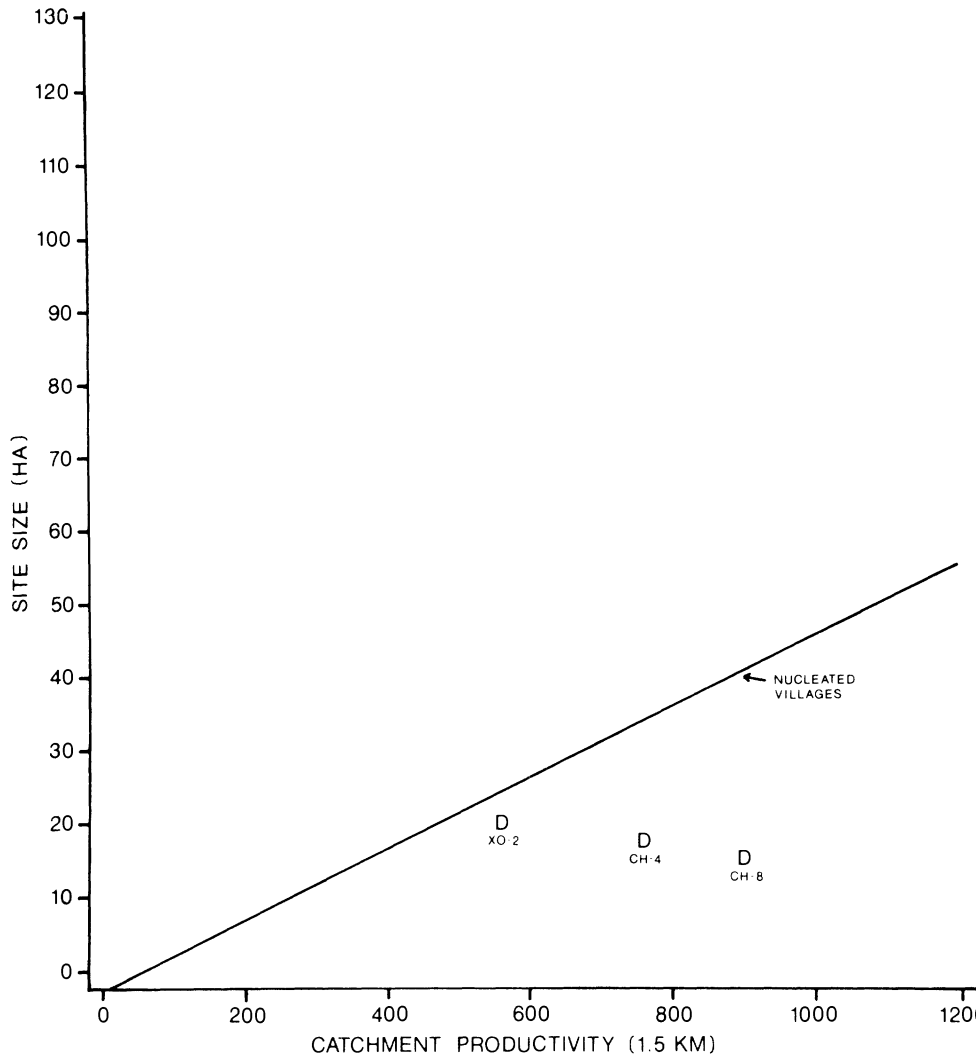


Fig. 6. Site size versus catchment productivity (1.5-km. radius), Middle Formative dispersed villages. (Best-fit line for nucleated villages is depicted for comparison.)

the numerous nucleated villages, dispersed villages and hamlets, five sites in the study area were classified by Parsons and Blanton as centers. These centers range in size from 37 to 130 ha., and all show evidence of public architecture. The site of Cuicuilco, located just outside the study area to the west of Lake Xochimilco (Figure 4), appears to have been a center at this time period as well. Unfortunately, this site remains poorly understood, for the entire area in which it is situated was covered by lava in pre-Hispanic times. There is, however, some evidence of public architecture at Cuicuilco dating to the Late Formative (Heizer and Bennyhoff 1958, 1972), and Parsons (1974:93) estimates that the site's occupation in this period may have covered up to 150 ha.

It is thus evident that a political hierarchy among settlements existed in the Late Formative, but how many levels this hierarchy contained has been somewhat more difficult

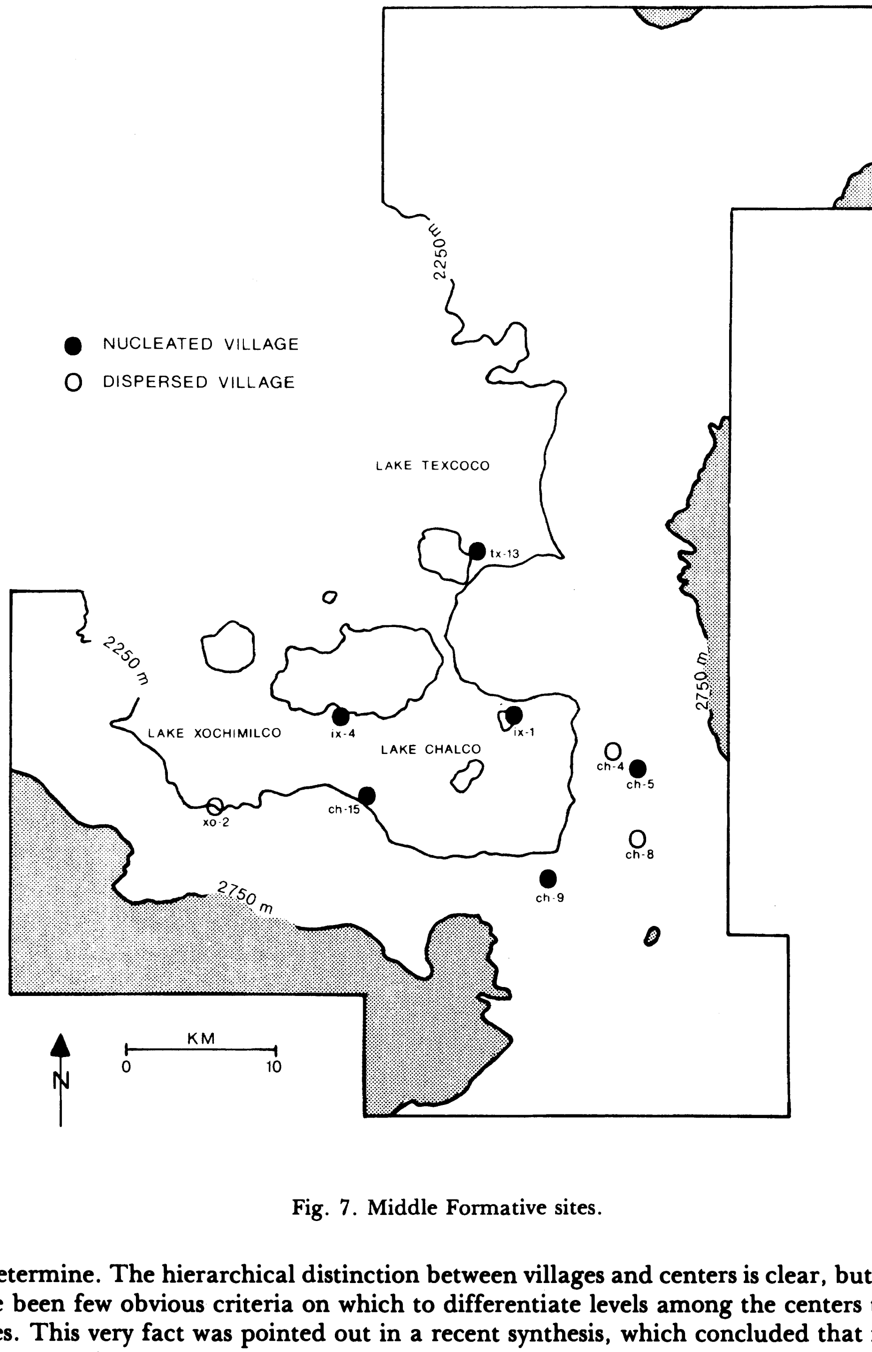


Fig. 7. Middle Formative sites.

to determine. The hierarchical distinction between villages and centers is clear, but there have been few obvious criteria on which to differentiate levels among the centers themselves. This very fact was pointed out in a recent synthesis, which concluded that in the Late Formative, "no single center . . . can be designated as regionally dominant on the basis of what we now know, with the possible exception of Cuicuilco" (Sanders, Parsons, and Logan 1976:165). Such a view, of course, has implications which can now be tested in light of the model. If all the centers in our study area (which excludes Cuicuilco) were of approximately coordinate political status, then we would expect them to line up on the

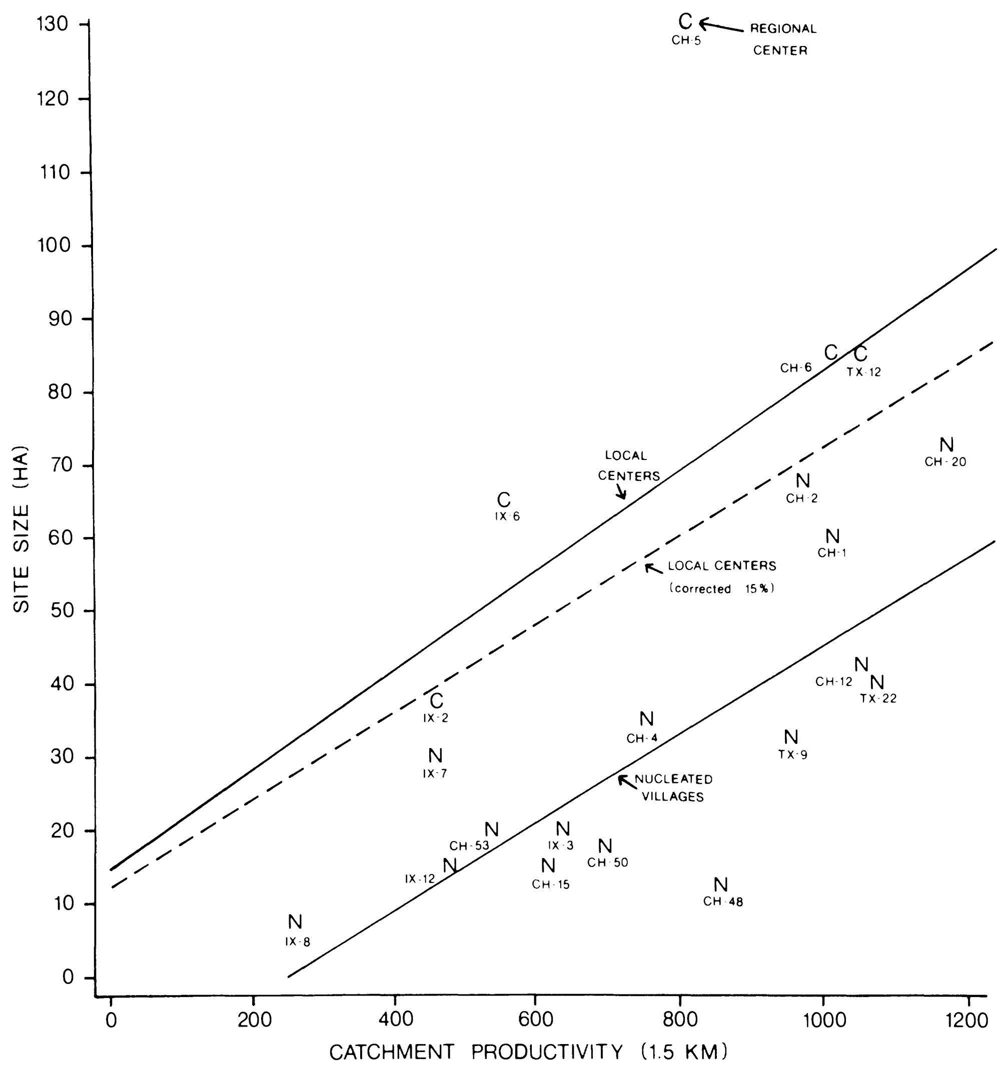


Fig. 8. Site size versus catchment productivity (1.5-km. radius), Late Formative centers and nucleated villages.

scatter diagram in a single tier above the tier of villages. In fact, the pattern that emerges on the scatter diagrams is somewhat more complex (Figures 8, 9).

Centers are indeed higher on the diagram than the village sites, but they seem to form two tiers instead of one. The lower of these two tiers consists of a linear scatter of four points (r^2 = .85), corresponding to the sites IX-2, IX-6, CH-6, and TX-12. These sites appear to have been *local* centers. Note that the y-intercept of the regression line that describes them falls at 14.7 ha. (corrected value = 12.5 ha.), substantially above zero as the model would predict (Table V). The uppermost tier consists of only one site, CH-5. This site thus appears to have been a *regional* center, which probably had at least some of the local centers under its hegemony and collected tribute from them.

Nucleated villages again exhibit a clear-cut linear relationship between size and pro-

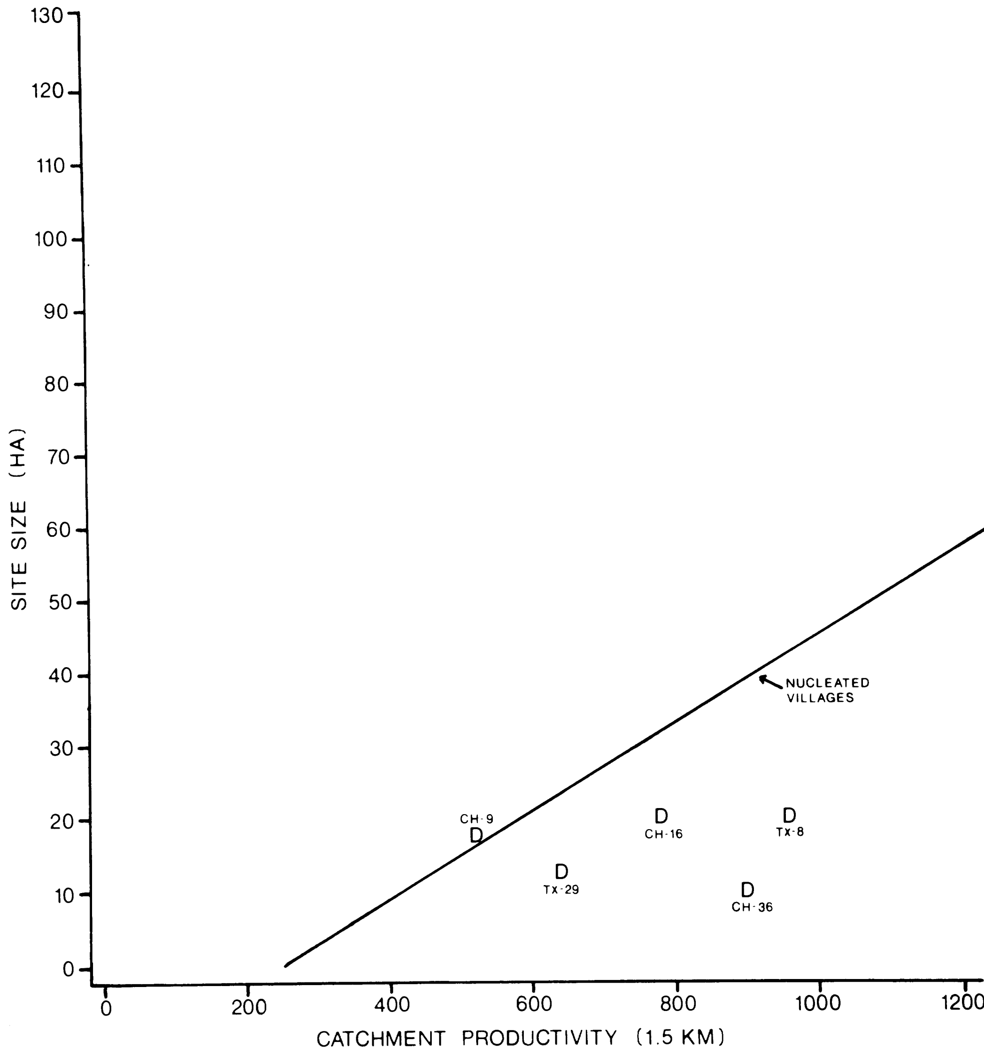


Fig. 9. Site size versus catchment productivity (1.5-km. radius), Late Formative dispersed villages. (Best-fit line for nucleated villages is depicted for comparison.)

ductivity (r^2 = .61), although their degree of scatter around the best-fit line is much greater than that for the Middle Formative. The y-intercept of the best-fit line is − 13.3 ha., somewhat lower than the zero value we would expect, but not inconsistent with the amount of measurement error that seems to inhere in the data (Table V).

Dispersed villages, just as in the Middle Formative, show no positive association between size and productivity (Figure 9). Again, the lack of relationship stems from the fact that several of these villages (particularly CH-36 and TX-8) are considerably smaller than what the productivity of their catchments would seem to allow. It is possible that processes similar to those I have described for the Middle Formative may be at least partially responsible for the pattern observed here. However, this explanation is purely speculative, and there seems to be little point in dwelling on the matter further until some relevant excavated data become available.

TABLE V. PARAMETERS OF REGRESSION LINES, LATE FORMATIVE SITES.[a]

Site Type	Slope (m)	Y-Intercept (b)	r^2
Local Centers	.0689	14.7	.85
Local Centers (Corrected 15%)	.0586	12.5	.85
Nucleated Villages	.0592	−13.3	.61
Nucleated Villages (Calculated to Pass through the Origin)	.0438	0	.56

[a] The regression lines are of the general type $S = mP + b$, where S represents site size in hectares, and P represents the number of hectares of arable land in a 1.5-km. catchment.

In sum, the evidence from the scatter diagrams suggests that there were three levels of settlement hierarchy in the study area during the Late Formative. Precisely where Cuicuilco fits into this hierarchy we cannot be absolutely certain, but most likely the site was a regional center approximately coordinate with CH-5 (Figure 10). It must be kept in mind, of course, that archaeologically we observe the political settlement hierarchy at its point of maximal development within the period. We should probably regard the Late Formative as a time during which several transformations took place, first with one, then with a second level of administrative control emerging above the level of the nucleated village. From this viewpoint it seems most likely that CH-5 and (possibly) Cuicuilco did not attain the status of regional centers until near the end of the period. Even so, this represents a remarkable amount of political development in a span of only 300 years.

We can now use the information contained within the scatter diagram to estimate the degree of political centralization at the level of the regional center. As explained previously, the index of centralization can be calculated as the mean number of nonproducers per regional center, divided by the mean number of nonproducers per local center. Since our indicator of population in this case is site area, it is therefore necessary to estimate how much area at each center was occupied by nonproducers. As in Figure 3, the regression line calculated for nucleated villages can be used to partition the corrected area of each center (S_c) into two segments, representing producers (S_p) and nonproducers (S_n) respectively. In so doing, the regression line for nucleated villages has been recalculated to pass through the origin. This step has been taken because the theoretically expected y-intercept for the village line is zero, and it is reasonable to assume that any slight empirical deviation from this value is merely the result of measurement error. The recalculated line differs little from the original one, and probably gives us a slightly better approximation for the purposes at hand. Following out the above method, the index of centralization is computed to have a value of 3.09 (Table VI). In other words, the regional center CH-5 appears to have controlled roughly three times more tribute in food than the average local center.

The same figures can also be used to estimate the relative food surplus extracted as tribute (t_1), which estimate is equivalent to the ratio between nonproducers and the population as a whole. Based on the calculations presented in Table VII, it appears that about 16% of the population in the study area may have consisted of nonproducers supported by tribute ($t_1 = .159$).[10]

Of course, the estimates derived above can only be regarded as very crude approximations. Because the potential for error is rather large, it may be wise for the time being not to accept these figures too literally, but rather to regard them as comparative indices

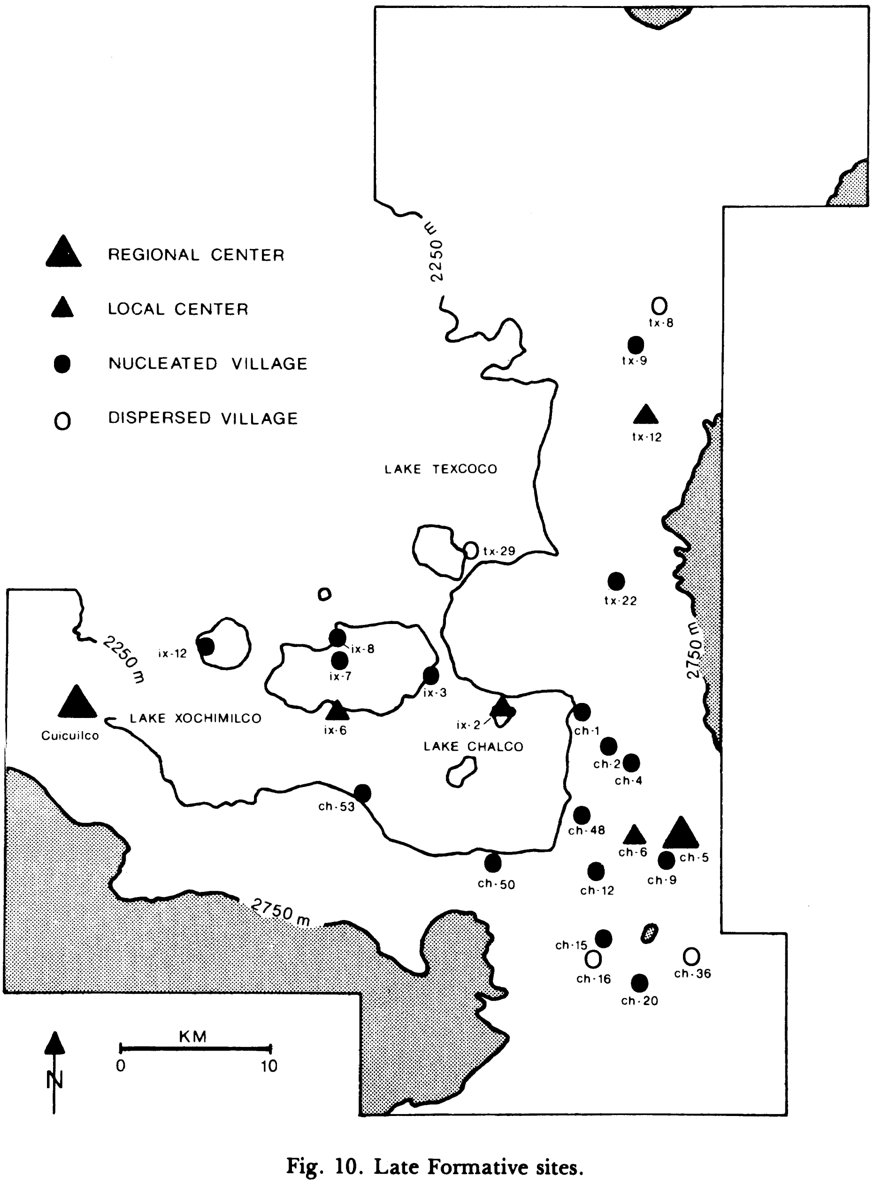


Fig. 10. Late Formative sites.

capable of monitoring trends through time. Yet despite all the potential for inaccuracy, it is significant to note that the estimates arrived at here do fall within a range that is ethnographically plausible.[11]

Terminal Formative (Patlachique Phase)

The process of increasing hierarchical differentiation among settlements appears to have continued in the Terminal Formative. This period was characterized by the emergence of two very large centers within the Valley of Mexico—Teotihuacan and Cuicuilco. Both centers were located just outside of the present study area, but they un-

TABLE VI. CALCULATING THE INDEX OF CENTRALIZATION FOR THE LATE FORMATIVE CENTERS.

Site Designation	Site[a] Size (S)	Corrected[b] Site Size (S_c)	Catchment[c] Productivity (P)	Area Occupied[d] by Producers (S_p)	Area Occupied[e] by Nonproducers (S_n)	
Ch-5	130	110.5	830	36.4	74.1	
					74.1	Total
					74.1	Mean
IX-2	37	31.5	466	20.4	11.1	
IX-6	65	55.2	562	24.6	30.6	
TX-12	86	73.1	1070	46.9	26.2	
CH-6	86	73.1	1027	45.0	28.1	
					96.0	Total
					24.0	Mean

$$\text{Index of Centralization} = \frac{\text{Mean Area Occupied by Nonproducers at Regional Center}}{\text{Mean Area Occupied by Nonproducers at Local Centers}} = \frac{74.1}{24.0} = 3.09$$

[a] Expressed in hectares.
[b] $S_c = .85\,S$
[c] Number of hectares of arable land within a 1.5-km. radius.
[d] $S_p = .04385\,P$ (This is the regression line for nucleated villages calculated to pass through the origin.)
[e] $S_n = S_c - S_p$

TABLE VII. CALCULATING THE RELATIVE FOOD SURPLUS (t_1) MOBILIZED AS TRIBUTE, LATE FORMATIVE PERIOD.

Centers—Total Area Occupied by Nonproducers:[a]	$u = 170.1$
Centers—Total Area Occupied by Producers:[b]	$v = 173.3$
Noncenters—Total Area Occupied:[c]	$w = 740.8$

Relative Food Surplus Mobilized as Tribute:

$$t_1 = \frac{u}{u+v+w} = \frac{170.1}{1084.2} = .157$$

[a] Calculated from data in Table VI, $u = \Sigma\,(S_n)$.

[b] Calculated from data in Table VI, $v = \Sigma\,(S_p)$.

[c] This figure represents the total area covered by all nucleated villages, dispersed villages and hamlets in the study area. Data taken from Parsons (1971; personal communication) and Blanton (1972b).

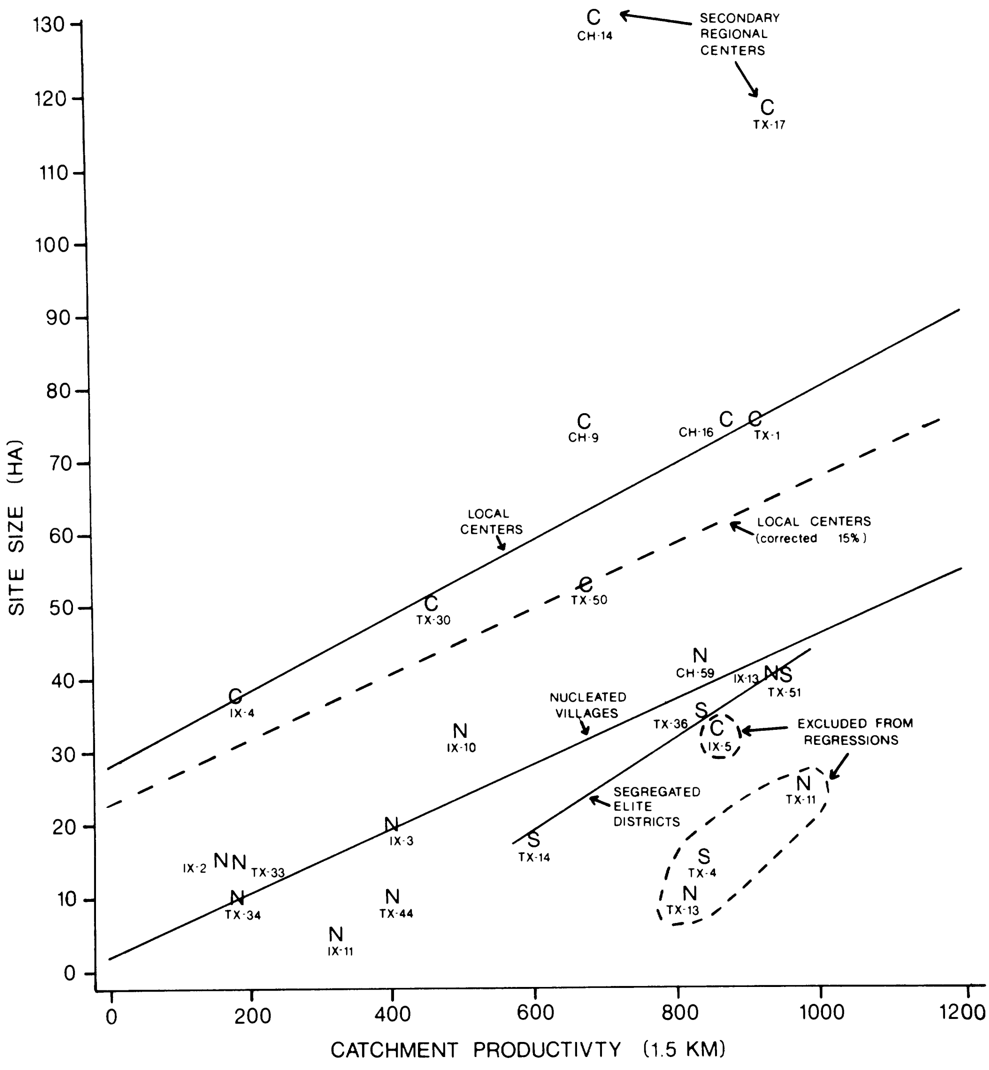


Fig. 11. Site size versus catchment productivity (1.5-km. radius), Terminal Formative centers, segregated elite districts, and nucleated villages.

doubtedly formed an integral part of the overall settlement system with which we are concerned (Figures 4, 13). It is therefore necessary to describe briefly these sites before moving on to the study area proper.

Teotihuacan, situated just north of the Texcoco region, had been a site of relatively modest proportions in the Late Formative; in the beginning of the Terminal Formative, however, it underwent tremendous growth. The Patlachique phase settlement at Teotihuacan covered some 825 ha., and probably had a considerable amount of public architecture (Cowgill 1974:381–383; Millon 1973:53). Cuicuilco, situated to the west of the study area, grew in importance during this phase as well. Although the actual extent of occupation is now difficult to determine with certainty, Parsons (1974:93) estimates that the site may have reached a size of some 400 ha. Further evidence of Cuicuilco's

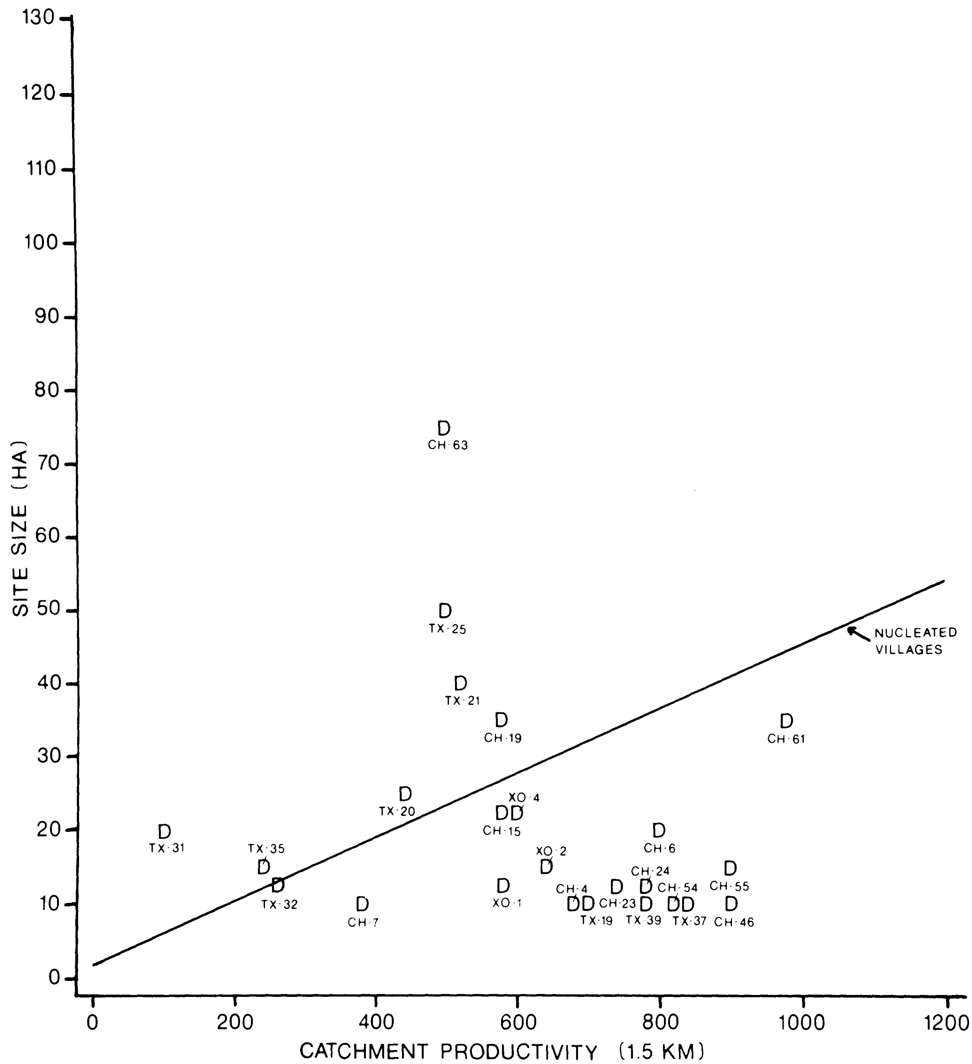


Fig. 12. Site size versus catchment productivity (1.5-km. radius), Terminal Formative dispersed villages. (Best-fit line for nucleated villages is depicted for comparison.)

political importance is found in the size of its public architecture: a number of pyramidal platforms are visible above the lava, the largest of these is some 20 m. high, and 70-80 m. in diameter (Parsons 1974:93).

The settlements found within the study area proper were all considerably smaller and architecturally less complex than the "primary regional centers" just described. Nine sites within the area were classified by Parsons and Blanton as centers, but not one of these was larger than 129 ha. Seven other sites, none larger than 40 ha., were placed in the category of segregated elite districts. The function of these latter sites, as well as their dating, is still to some extent problematical; one suggestion is that they may have been places "where certain high-ranking lineages and their retainers resided on a full-time or periodic basis" (Parsons 1971:191).[12] The remaining sites in the area, and by far the great majority, comprised the basal stratum of nucleated villages, dispersed villages and hamlets.

It therefore appears probable that Teotihuacan and Cuicuilco were political centers of roughly equivalent order and together formed the apical level of the settlement hierarchy within the Valley of Mexico. However, the question of how many levels of centers there were below this uppermost tier still remains to be resolved. This matter will now be examined in light of the model, with reference to the scatter diagrams in Figures 11 and 12.

Centers form two principal tiers on the diagram, occurring well above the nucleated villages. The upper tier consists of two sites, CH-14 and TX-17, which appear to have been regional centers. The lower tier consists of a highly linear scatter (r^2 = .80) of six sites, which seem to represent a subordinate stratum of local centers. These local centers are IX-14, TX-33, TX-50, CH-9, CH-16, and TX-1. Their best-fit line has a y-intercept of 27.8 ha. (corrected value = 23.6 ha.); this value, in conformance with the theoretical expectation, is considerably greater than zero (Table VIII).

Note that one site classified as a center, IX-5, does not fall into either of the two tiers just described. Rather, it is positioned low on the scatter diagram, very close to the line of segregated elite districts. This finding strongly suggests that IX-5 is actually a misidentified segregated elite district. The site's topographically prominent location high on a mountain slope seems perfectly consistent with such a conclusion (cf. Blanton 1972b:59).

Segregated elite districts, with the exception of TX-4 (which will be discussed later), show a very close linear relationship between size and productivity (r^2 = .99) (Table VIII). In view of these sites' postulated function, their pattern on the scatter diagram suggests two things. First, the fact that their size tends to be positively correlated with the amount of arable land available indicates that a large fraction of their population was probably engaged in production. Second, because their distribution on the diagram is so close to that of the nucleated villages, it would seem that the resident faction of nonproducing elites, if present at all, was probably not very large.

Nucleated villages, but for two anomalous sites, also fall into the expected linear configuration (r^2 = .78) with a y-intercept very close to the origin (b = 2.3) (Table VIII).

The two anomalous villages, TX-11 and TX-13, together with the anomalous segregated elite district TX-4, all occur in a single cluster in the lower-right-hand portion

TABLE VIII. PARAMETERS OF REGRESSION LINES, TERMINAL FORMATIVE SITES.[a]

Site Type	Slope (m)	Y-Intercept (b)	r^2
Local Centers[b]	.0514	27.8	.80
Local Centers (Corrected 15%)	.0437	23.6	.80
Segregated Elite Districts[c]	.0634	−19.2	.99
Nucleated Villages[d]	.0438	2.3	.78
Nucleated Villages[d] (Calculated to pass through the origin)	.0477	0.0	.78

[a] These regression lines are of the general type S = mP + b, where S represents site size in hectares, and P represents the number of hectares of arable land in a 1.5-km. catchment.

[b] Excluding IX-5, which is probably a segregated elite district.

[c] Excluding TX-4.

[d] Excluding TX-11 and TX-13.

of the scatter diagram. Their position on the diagram implies that each site has a population considerably smaller than its catchment productivity would warrant. It is therefore interesting to observe that the same three sites also occur in a single geographical cluster, located at the northernmost fringe of the study area (Figure 13). The fact that they are so close together geographically suggests that their divergence from the prevailing pattern might well have been due to the same underlying cause. One possible explanation is that the productivity per hectare of cultivated land is drastically lower in the vicinity of these sites than it is elsewhere in the study area. This, however, does not seem very likely for the following reasons. Although it is true in a general sense that the Texcoco subregion is somewhat less suited for maize agriculture than Chalco and Xochimilco farther south, there is no obvious aspect of rainfall or topography that would make the vicinity of these particular sites agriculturally worse off than any other part of the Texcoco piedmont (Sanders 1976a:61-65). To the contrary, two of the sites (TX-4 and TX-11) have large parcels of prime alluvial soil within their catchments. Perhaps a more important factor underlying the reduced populations at these sites was their close proximity to the rapidly developing center of Teotihuacan. Whether this underpopulation was the result of conflict with the center, or the selective attraction of people *to* the center, it is difficult at this stage to say.

Dispersed villages as in the previous two periods show no positive relationship between size and productivity (Figure 12). Most of these settlements remained small even when their catchment productivity was fairly high. Note, however, that unlike in previous periods there are also a few dispersed villages whose sizes appear unusually large relative to their productivity (CH-63 and TX-25 in particular). My suspicion is that each of these large "villages" may actually consist of several smaller, noncontemporaneous occupations which partially overlap in space and thereby appear as one site. This proposition is, of course, speculative and remains to be tested by future archaeological work.

Thus, with relatively few exceptions, the patterning of sites in the Terminal Formative corresponds fairly well to the configuration predicted by the model. The evidence suggests a three-level settlement hierarchy within the study area proper, with two levels of political centers above the basal tier of nucleated and dispersed villages. If the two regional centers within the study area came under the political hegemony of Teotihuacan and Cuicuilco, then the overall settlement hierarchy in the Valley of Mexico would have been of four levels.

Each of the two regional centers in the study areas appears to have formed the nucleus of a geographically discrete cluster of local centers and villages (Figure 13). One cluster was located in the vicinity of Lake Chalco, and included the regional center CH-14, along with the local centers CH-16, CH-9 and possibly IX-14. The second cluster, located in the Texcoco subregion, included the regional center TX-17, as well as local centers TX-1, TX-30, and possibly TX-50. One therefore gets the impression of two separate, internally centralized political units, set off by a fairly wide expanse of unoccupied territory (cf. Parsons 1971:191-192; Parsons 1974:93, 96, 105; Sanders, Parsons, and Logan 1976:166-168; Earle 1976:206-212). Near the beginning of the Terminal Formative, these two units may well have been politically autonomous. That is, CH-14, TX-17, Cuicuilco, and Teotihuacan may initially have been competing regional centers of roughly equivalent status, each controlling the subordinate settlements in its own immediate vicinity. The distant and relatively even spacing among these four centers is certainly consistent with such an idea. Later in the phase, however, the power of Teotihuacan and Cuicuilco increased to the point where they came to dominate the entire study area. When this happened, TX-17 most likely came under the hegemony of (and paid tribute to) Teotihuacan, whereas CH-14 probably found itself in a similar subordinate position to Cuicuilco.

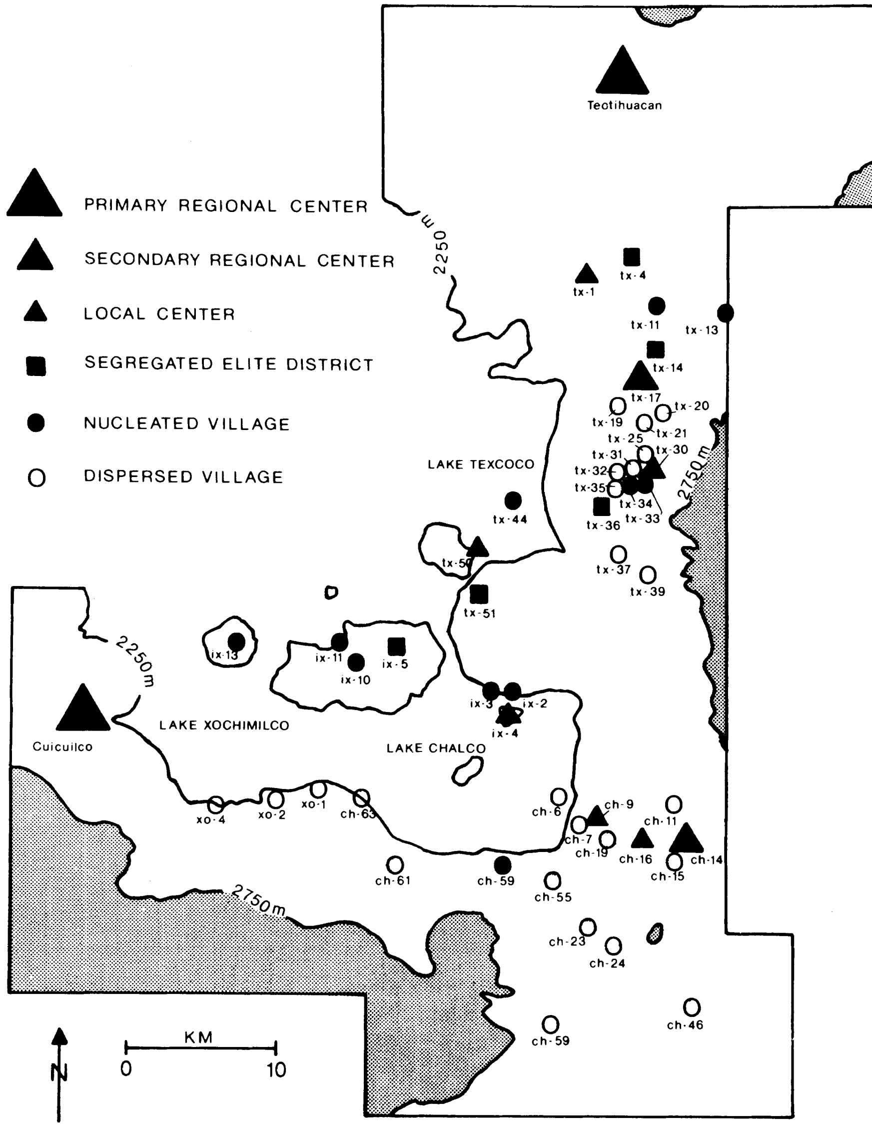


Fig 13. Terminal Formative (Patlachique phase) sites.

Since Teotihuacan and Cuicuilco were not included in the sample of sites analyzed, we cannot now proceed to estimate the degree of centralization at the uppermost level of hierarchy. It is, nevertheless, possible to carry out the calculations for the secondary regional centers CH-14 and TX-17, keeping in mind that we are thereby measuring the degree of centralization at the next-to-apical level. Using the procedures outlined in the preceding section, the index of centralization for the study area as a whole is calculated to have a value of 3.12 (Table IX). This value is virtually identical to that which characterized the Late Formative; again, it implies that the average (secondary) regional center controlled about three times more tribute in food than the average local center. This estimate should reflect the point at which the regional centers' power was at a maximum

TABLE IX. CALCULATING THE INDEX OF CENTRALIZATION FOR TERMINAL FORMATIVE CENTERS.

Site Designation	Site[a] Size (S)	Corrected[b] Site Size (S_c)	Catchment[c] Productivity (P)	Area Occupied[d] by Producers (S_p)	Area Occupied[e] by Nonproducers (S_n)	
TX-17	118	100.3	938	44.7	55.6	
CH-14	129	109.7	701	33.4	76.3	
					131.9	Total
					65.95	Mean
IX-4	37	31.5	172	8.2	23.3	
TX-1	74	62.9	926	44.2	18.7	
TX-30	50	42.5	451	21.5	21.0	
TX-50	52	44.2	690	32.9	11.3	
CH-9	75	63.8	689	32.9	30.9	
CH-16	74.6	63.4	879.4	41.9	21.5	
					126.7	Total
					21.12	Mean

$$\text{Index of Centralization} = \frac{\text{Mean Area Occupied by Nonproducers at Regional Centers}}{\text{Mean Area Occupied by Nonproducers at Local Centers}} = \frac{65.95}{21.12} = 3.12$$

[a] Expressed in hectares.
[b] $S_c = .85\ S$
[c] Number of hectares of arable land within a 1.5-km. radius.
[d] $S_p = .04770\ P$ (This is the regression line for nucleated villages calculated to pass through the origin.)
[e] $S_n = S_c - S_p$

relative to the local centers they controlled. Thus, we can reasonably conclude that the degree of centralization *at this level* did not substantially increase beyond what had been attained in the Late Formative. We cannot, however, be certain that the degree of centralization at this level did not decrease at some time during the Terminal Formative, because the consequent decrease in center size would not be detectable given the present data. Indeed, it is quite conceivable that as Teotihuacan and Cuicuilco gained ascendancy over the entire Valley, the power of the secondary regional centers relative to their local centers may have declined (cf. Earle 1976:208-212).

For the study area as a whole, we can also estimate the relative surplus extracted from the producers, by computing the ratio of nonproducers to the total population. It appears from the calculations in Table X that about 16% of the average producer's output was passed up the hierarchy as tribute ($t_1 = .162$). This figure is virtually identical to that calculated for the study area as a whole in the Late Formative. Thus, there is no clear evidence that the effective tribute rate or the proportional size of the chiefly establishment increased during the Patlachique phase, even though the political hierarchy in the Valley continued to differentiate vertically. This estimate, of course, applies only to the study area itself; it is not possible to determine how this figure would be affected if Teotihuacan, Cuicuilco, and their hinterlands in other parts of the Valley of Mexico were taken into account.

As noted earlier, the centers within the study area seem to fall into two clusters, each of

TABLE X. CALCULATING THE RELATIVE FOOD SURPLUS (t_1) MOBILIZED AS TRIBUTE, TERMINAL FORMATIVE PERIOD (PATLACHIQUE PHASE).

Centers—Total Area Occupied by Nonproducers:[a]	u = 258.6
—Total Area Occupied by Producers:[b]	v = 259.7
Noncenters—Total Area Occupied:[c]	w = 1082.8
Relative Food Surplus Mobilized as Tribute:	

$$t_1 = \frac{u}{u+v+w} = \frac{258.6}{1601.1} = .162$$

[a] Calculated from the data in Table IX, u = Σ (S_n).

[b] Calculated from the data in Table IX, v = Σ (S_p).

[c] This figure represents the total area covered by all segregated elite districts, nucleated villages, dispersed villages, and hamlets in the study area (except the three sites which date to the Tzacualli phase: TX-7, TX-16, and TX-42). Data taken from Parsons (1971; personal communication) and Blanton (1972b).

which may well have been a distinct political unit. It should therefore be interesting to compute the various indices for each cluster separately. For present purposes the boundaries of these units can be defined by drawing Thiessen polygons around the four major centers in the Valley (Haggett 1965:247-248). In effect, each regional center is assigned all the sites that are closer to it than to any other regional center (Figure 14). Although the boundaries suggested by this procedure are obviously hypothetical, the fact that they do tend to correspond to actual discontinuities in the geographical distribution of sites makes them at least plausible. It is also worthwhile to note that the two clusters thus defined are identical in terms of their estimated total population (compare u + v + w for each cluster in Table XI).

The measures calculated for each cluster are summarized in Table XII. In regard to the degree of centralization, the index takes on a value of 3.02 for the Chalco centers, and 3.27 for the Texcoco centers. Although the value for Texcoco is slightly greater, the difference between the two values is proportionally rather small, and probably has little practical significance given the amount of measurement error we can reasonably expect. Thus, the two units seem to have attained roughly the same degree of regional centralization.[13] A rather more pronounced difference between the two units does appear, however, in the relative amounts of surplus mobilized. The estimate of t_1 is about 22% for Chalco, as compared to only 16% for Texcoco.

These results, though tentative, do suggest that the political establishment in the Chalco region was able to amass more food as tribute than its counterpart in Texcoco. Evidently, the food surplus politically extracted in Chalco was greater not only *per capita,* but also in absolute terms, as indicated by the larger number of hectares occupied by nonproducers (compare values of u in Table XI). This phenomenon may well have been related to dissimilarities between the two regions in the natural conditions for agricultural production. Because of its greater annual rainfall, the Chalco region was probably less dependent upon irrigation to insure sufficient crop yields. Therefore, its overall agricultural regime was probably less labor-intensive (cf. Sanders, Parsons, and

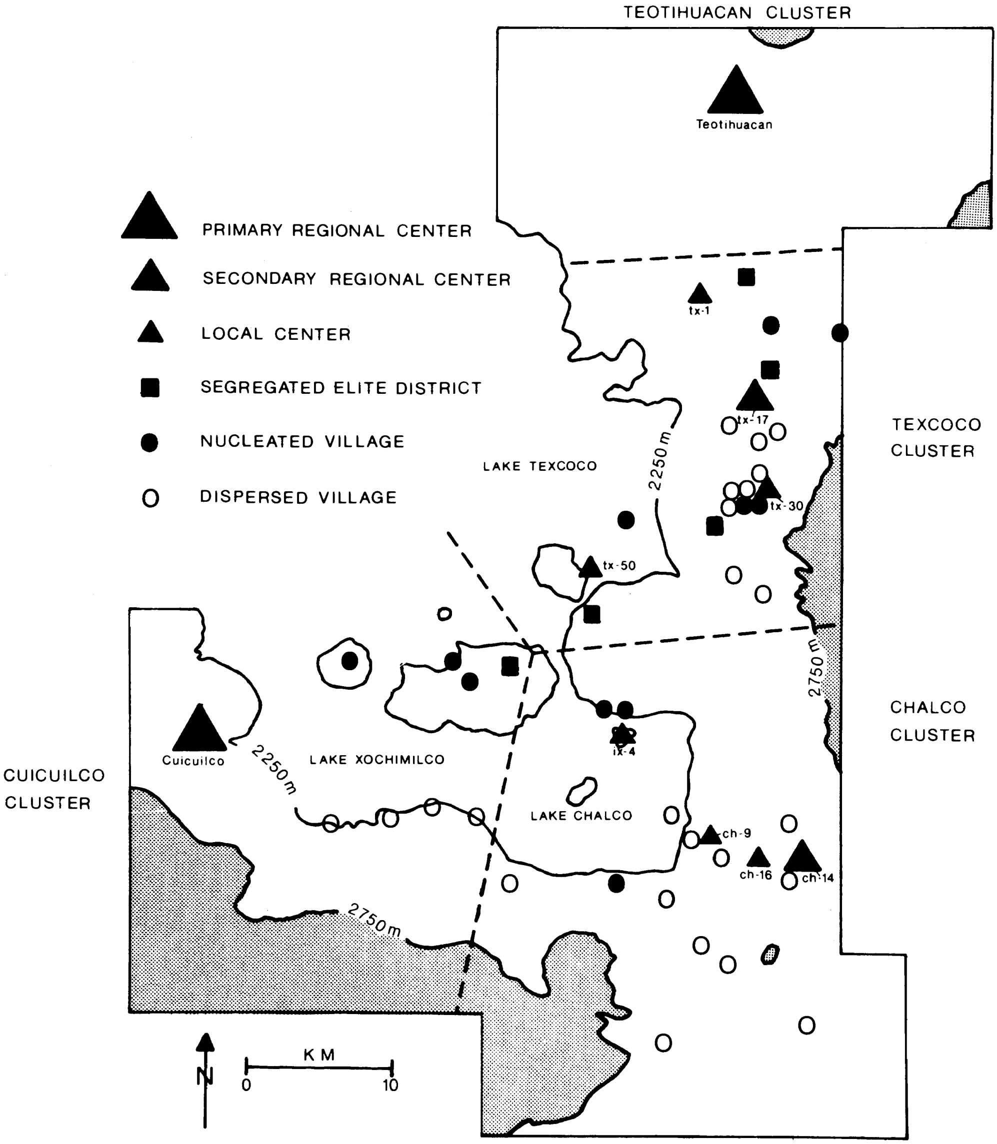


Fig. 14. Hypothetical boundaries of political units, Terminal Formative period (Patlachique phase).

Logan 1976:167); per unit labor input, more food could be produced in the relatively humid south than in the relatively dry north. How this would affect the political economy of the two regions is clear. Even if the amount of labor mobilized for the purposes of the political establishment in each region were the same, the amount of surplus food that would result from that labor would be greater in the Chalco region than in Texcoco.

Summary

Having applied the model to the settlement data from the Valley of Mexico, we can now briefly review the major findings which have emerged.

TABLE XI. CALCULATING THE RELATIVE FOOD SURPLUS (t_1) MOBILIZED AS TRIBUTE FOR THE TWO REGIONAL CLUSTERS SEPARATELY, TERMINAL FORMATIVE PERIOD (PATLACHIQUE PHASE).

Texcoco Cluster[a]

Centers—Total Area Occupied by Nonproducers:[b]	u = 106.6
Centers—Total Area Occupied by Producers:[b]	v = 143.3
Noncenters—Total Area Occupied:[c]	w = 427.0

Relative Food Surplus Mobilized as Tribute:

$$t_1 = \frac{u}{u+v+w} = \frac{106.6}{676.9} = .157$$

Chalco Cluster[d]

Centers—Total Area Occupied by Nonproducers:[b]	u = 152.0
Centers—Total Area Occupied by Producers:[b]	v = 166.4
Noncenters—Total Area Occupied:[c]	w = 408.2

Relative Food Surplus Mobilized as Tribute:

$$t_1 = \frac{u}{u+v+w} = \frac{152}{676.6} = .225$$

[a] Includes all sets in Texcoco subregion, plus IX-6.

[b] Calculated from data in Table IX.

[c] Calculated from data obtained from Parsons (1971; personal communication) and Blanton (1972b).

[d] Includes all sites in Chalco subregion, except CH-63; also includes IX-1, IX-3, and IX-4.

TABLE XII. SUMMARY OF INDICES CALCULATED FOR THE CHALCO AND TEXCOCO CLUSTERS SEPARATELY, TERMINAL FORMATIVE PERIOD.

	Chalco	Texcoco
Index of Centralization[a]	3.02	3.27
Relative Food Surplus Mobilized[b] (t_1)	.225	.157

[a] Calculated by partitioning the data in Table X.

[b] Calculated in Table XI.

During the Middle Formative, nucleated villages appear to have been politically autonomous. Although it is possible that these nucleated villages may have exercised some political control over the dispersed villages and hamlets in their immediate vicinity, there is no evidence that this control was strong enough to allow one settlement to mobilize substantial amounts of surplus from another.

In Late Formative times, the pattern of village autonomy disappeared. A three-level hierarchy emerged during this period, with two levels of administrative centers dominating (and drawing tribute from) a subordinate tier of villages. The degree of centralization at the apex of this hierarchy was pronounced: one regional center appears to have controlled roughly three times more tribute in food than the average local center. Additionally, the evidence suggests that approximately 16% of the total population in the study area consisted of nonproducers supported by tribute.

During the Terminal Formative Patlachique phase, a fourth level emerged in the Valley of Mexico settlement hierarchy. However, the two sites making up the uppermost level were situated just outside the study area, and so they were not included in the scatter diagrams on which many of the interpretations were based. Three levels of sites were again distinguished within the study area proper. The estimated degree of centralization at the highest-order centers *within the study area* was no greater than it had been in the previous period: at most, each (secondary) regional center had access to about three times more tribute in food than the average local center. The overall relative surplus mobilized as tribute also appeared to remain stable at about 16%, although some regional differences in this variable were noted between Chalco on one hand and Texcoco on the other. It was suggested that the various estimates may best reflect the political structure early in the phase, before the study area came under the hegemony of Teotihuacan and Cuicuilco.

CONCLUSION

In this paper, I have examined some relationships between political complexity and the relative sizes of settlements. A model expressing these relationships was formalized, and the model was applied in interpreting the settlement data from the Formative period in the Valley of Mexico. Although some of the specific interpretations may change as more data and finer chronological controls become available, the utility of the model itself as an analytical framework has, I think, been adequately shown.

More generally, this paper has attempted to illustrate the utility of monitoring political complexity along multiple dimensions, and also the feasibility of measuring some of these dimensions along a continuous scale. The intent has not been to argue that evolutionary classifications are inherently useless, but rather that a classificatory strategy is in itself not enough. Dealing adequately with questions of political evolution often requires that we come to grips with differences of degree rather than kind, and it is precisely these differences of degree that classifications have a tendency to mask.

One should not, of course, expect the present model to be equally applicable in all nonmarket situations. There are many factors, both cultural and environmental, which may intervene and cause the observed pattern to differ significantly from one that the model would predict (see Forge 1972; Peebles 1978). When such a divergence occurs, it may not be possible to calculate the measures of political complexity using exactly the methods described here. In such cases, it is hoped that the investigator will be led to formulate other models and better methods, with which to reveal the fine-grained variation in political systems that is of interest.

NOTES

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[1] In the real world, of course, the distinction between producers and nonproducers is never as absolute as we for simplicity have assumed. This fact alone, however, does not vitiate the utility of the model in making relative estimates of tribute flow. The "producers" and "nonproducers" to which we refer in calculating our estimates should not be viewed as individuals per se, but rather as units of consumption *equivalent* to individuals. Thus, for example, a single "nonproducer" may be one person drawing all his support from tribute, two people drawing half their support from tribute, or any other equivalent combination; the implications of the model in any such case remain the same.

[2] If we make the additional assumption that the number of producers in the district of the regional center is the same as the average number of producers in the district of a local center (i.e., $P_r + \sum_j P_{rj}$ is equal to the mean value of $P_i + \sum_j P_{ij}$), then the information in the scatter diagram can be used to estimate t_2 as well. Let A represent the vertical distance of the regional center above the line of local centers; let B represent the vertical distance (S_n) of each local center above the line of villages; further, let p stand for the number of local centers, and q stand for the number of regional centers. Given the conditions specified for Case 3, the desired estimate can be arrived at as follows:

$$t_2 = CA/(CA + \sum B)$$

$$\text{where } C = p/(pq + q).$$

[3] The Terminal Formative period is generally considered to subsume the Tzacualli phase as well (ca. A.D. 1-100). However, components of this phase are very rare in the study area. Only three small sites in the Texcoco region seem to date predominantly to this phase, and these were excluded from all aspects of the analysis. Specifically, the three sites are TX-7, TX-16, and TX-42 (Parsons 1971:189).

[4] The earliest good evidence for full-time craft specialists in the Valley of Mexico dates to the latter part of the Terminal Formative, and is found at the emerging urban center of Teotihuacan—outside the survey regions with which we are specifically dealing. The evidence consists of scatters of debris that are suggestive of specialized obsidian workshops (Millon 1973:53). Although these specialists may have been engaged in some form of incipient market activity, it is equally plausible that their activities were subsidized by the political establishment. In this light it is interesting to note that the area of the Great Compound at Teotihuacan, thought to be a central marketplace, does not appear to have been intensively utilized until *after* the end of the Terminal Formative (Cowgill 1974:387-388).

[5] Previous workers in the Valley have made population estimates for these sites based on site size and surface sherd density (Parsons 1971; Blanton 1972b). This approach has been based on the assumption that differences in surface sherd density in some way reflect differences in residential density. Although such an assumption is not entirely unreasonable, Tolstoy and Fish (1975) have rightly pointed out that at least two extraneous variables can affect sherd density as well: the depth of overburden, and the length of time the site was occupied. In view of these difficulties, I decided not to consider surface sherd density in making my estimates of population.

[6] Brumfiel (1976:240-241) used data from a recent agricultural census to estimate differences in the relative fertility of certain portions of the Valley. Although her approach was reasonable, I decided not to follow her lead for two reasons. First, the available agricultural data pertained to only one-half of the present study area, and there was no reliable way to deduce comparable estimates of fertility for the other half. Second, even in the area for which data were available, the differences in fertility were generally not very large; therefore, it seemed likely that the number of arable hectares alone would provide an adequate measure for the purposes of this analysis.

[7] However serious this problem may be when dealing with all Middle Formative sites, the problem is not nearly as severe with respect to the sites included in the present analysis. Based on Tolstoy's chronological chart (1975: Figure 2), it is evident that eight of the nine Middle Formative villages used in my analysis were occupied contemporaneously throughout the entire period. The one exception appears to be CH-8 (Tolstoy's site 37), which was definitely occupied only in the last phase of the Middle Formative. Since the catchment of this site does not overlap with that of any of the others, its lack of complete contemporaneity has no effect on the results of the analysis.

[8] There are three nucleated villages whose catchments at some radii included no arable land whatever. They are located on slight rises well within the borders of the preconquest lakes. Apparently, the inhabitants of these sites lived primarily by exploiting lacustrine resources. Since I have no way of estimating catchment productivity in nonagricultural terms, these sites had to be excluded from the scatter diagrams on which the analysis was based. Two are Late Formative sites XO-2 (8.6 ha.) and TX-14 (4.6 ha.); the other is Terminal Formative site TX-46 (19 ha.). TX-14 was excluded when considering radii of 1 km and 1.5 km; XO-2 and TX-46 were excluded at all three radii.

[9] Also excluded from the analysis were those sites that appeared to be nonresidential in function. Among these are the sites Parsons classified as "hilltop ceremonial precincts" (1971; personal communication). Terminal Formative site TX-47 was excluded because it appears to have been primarily a locus of basalt quarrying activity.

[10] Using the equation given in note 2, we can make some tentative estimates of t_2 for the Late Formative system. If all four local centers were simultaneously under the hegemony of CH-5, then roughly 30% of all the tribute they obtained would have been allocated to the regional center (t_2 = .29). If, on the other hand, only the two closest local centers (IX-2 and CH-6) paid tribute to CH-5, then about 50% of the surplus food extracted from their districts would have been passed up to the regional center (t_2 = .46).

[11] Ethnographic data on tribute rates in complex chiefdoms and simple states have rarely been recorded. However, some relevant information does exist for the Tswana, a Bantu group in southern Africa whose traditional organization was comparable to that of a complex chiefdom (Taylor 1975). In 1932, the chief of the Kgatla segment was receiving annually "about 1200 bags of Kafir corn from his tribute fields, 30 head of cattle in stray stock, and from 20 to 40 head of cattle in court fines" (Schapera 1956:101-102). It is also reported that in 1938-39 a total of 32,000 acres were cultivated, of which 77% were planted in Kafir corn (Schapera 1943:118, 139). Since the average yield appears to have been about .48 bags of Kafir corn per acre (Schapera 1943:125), we can estimate a total yield for that year of some 11,830 bags. Assuming that there were no drastic changes in total yield between 1932 and 1939, it appears that the Kgatla chief's tribute consisted in approximately 10% of all the corn that was produced (i.e., t_1 was approximately equal to 0.1). Of course, it must be realized that these observations were made at a time when the native government had already been somewhat altered by the European presence; a portion of each household's surplus, which might otherwise have gone directly to the chief, was being siphoned off into a tribal treasury set up by the colonial administration. Thus, a chief's direct access to tribute may well have been greater before the Europeans arrived.

[12] Segregated elite districts are characteristically associated with the Tezoyuca ceramic complex. This complex is known to date somewhere close to the Late Formative-Terminal Formative transition. However, there is some question as to whether it overlaps primarily with the latter end of the Late Formative Ticoman phase, or the beginning of the Terminal Formative Patlachique phase (Parsons 1976:81).

[13] Estimating t_2 by means of the formula in note 2, we arrive at values of .44 for the Texcoco cluster and .43 for the Chalco cluster. Thus, the tribute rate that each regional center imposed on its local centers appears to have been about the same.

REFERENCES CITED

Adams, Richard Newbold
1975 Energy and Structure: a Theory of Social Power. Austin: University of Texas Press.

Blalock, Hubert M.
1960 Social Statistics. 1st ed. New York: McGraw-Hill.
Blanton, Richard E.
1972a Prehispanic Adaptation in the Ixtapalapa Region, Mexico. Science 1975:1317-1326.
1972b Prehispanic Settlement Patterns of the Ixtapalapa Peninsula Region, Mexico. Pennsylvania State University Occasional Papers in Anthropology, No. 6. University Park: Pennsylvania State University.
Brumfiel, Elizabeth
1976 Regional Growth in the Eastern Valley of Mexico: A Test of the "Population Pressure" Hypothesis. *In* The Early Mesoamerican Village. Kent V. Flannery, ed. pp. 234-249. New York: Academic Press.
Chisolm, Michael
1968 Rural Settlement and Land Use: An Essay in Location. 2nd ed. Chicago: Aldine.
Cowgill, George L.
1974 Quantitative Studies of Urbanization at Teotihuacan. *In* Mesoamerican Archaeology: New Approaches. Norman Hammond, ed. pp. 363-396. Austin: University of Texas Press.
Dixon, J. W., and J. F. Massey
1969 Introduction to Statistical Analysis. 3rd ed. New York: McGraw-Hill.
Earle, Timothy K.
1973 Control Hierarchies in the Traditional Irrigation Economy of Halelea District, Kauai, Hawaii. Unpublished Ph.D. dissertation, Department of Anthropology, University of Michigan, Ann Arbor.
1976 A Nearest-Neighbor Analysis of Two Formative Settlement Systems. *In* The Early Mesoamerican Village. Kent V. Flannery, ed. pp. 196-223. New York: Academic Press.
1977 A Reappraisal of Redistribution: Complex Hawaiian Chiefdoms. *In* Exchange Systems in Prehistory. Timothy K. Earle and Jonathan E. Ericson, eds. pp. 213-229. New York: Academic Press.
Erasmus, Charles J.
1965 Monument Building: Some Field Experiments. Southwestern Journal of Anthropology 21:277-301.
Flannery, Kent V.
1972 The Cultural Evolution of Civilizations. Annual Review of Ecology and Systematics 3: 399-426.
Forge, Anthony
1972 Normative Factors in the Settlement Size of Neolithic Cultivators (New Guinea). *In* Man, Settlement, and Urbanism: Proceedings of a Meeting of the Research Seminar in Archaeology and Related Subjects. Peter J. Ucko, Ruth Tringham, and G. W. Dimbleby, eds. pp. 363-376. London: Duckworth.
Fried, Morton H.
1967 The Evolution of Political Society: an Essay in Political Anthropology. New York: Random House.
Haggett, Peter
1965 Locational Analysis in Human Geography. London: Edward Arnold.
Hatch, James Willis
1976 Status in Death: Principles of Ranking in Dallas Culture Mortuary Remains. Ph.D. dissertation, Department of Anthropology, Pennsylvania State University.
Heizer, Robert F., and James A. Bennyhoff
1958 Archeological Investigation of Cuicuilco, Valley of Mexico, 1957. Science 127(1): 232-233.
1972 Archeological Excavations at Cuicuilco, Mexico. National Geographic Society Research Reports, 1955-1960 Projects. pp. 93-104.
Johnson, Gregory A.
1973 Local Exchange and Early State Development in Southwestern Iran. Museum of Anthropology, University of Michigan, Anthropological Papers No. 51.
1977 Aspects of Regional Analysis in Archaeology. Annual Review of Anthropology 6:479-508.

Kaberry, Phyllis
1957 Primitive States. British Journal of Sociology 8:224-234.
Kaplan, David
1963 Men, Monuments, and Political Systems. Southwestern Journal of Anthropology 19: 397-410.
Kopytoff, Igor
1964 Family and Lineage among the Suku of the Congo. *In* The Family Estate in Africa. Studies in the role of property in family structure and lineage continuity. Robert F. Gray and H. P. Gulliver, eds. pp. 83-116. London: Routledge and Kegan Paul.
Kottak, Conrad P.
1977 The Process of State Formation in Madagascar. American Ethnologist 4(1):136-155.
Lewis, I. M.
1959 The Classification of African Political Systems. Rhodes-Livingstone Journal 25:59-69.
Lloyd, P. C.
1965 The Political Structure of African Kingdoms: An Exploratory Model. *In* Political Systems and the Distribution of Power. A.S.A. Monographs 2:63-112. New York: Praeger.
Marcus, Joyce
1976 The Size of the Early Mesoamerican Village. *In* The Early Mesoamerican Village. Kent V. Flannery, ed. pp. 79-90. New York: Academic Press.
Millon, René
1973 The Teotihuacán Map. Urbanization at Teotihuacán, Mexico. Vol. 1. Austin: University of Texas Press.
Muller, Jon
1978 The Kincaid System: Mississippian Settlement in the Environs of a Large Site. *In* Mississippian Settlement Patterns. Bruce D. Smith, ed. pp. 269-292. New York: Academic Press.
Nicholas, Ralph
1966 Segmentary Factional Political Systems. *In* Political Anthropology, Marc J. Swartz, Victor W. Turner, and Arthur Tuden, eds. pp. 49-59. Chicago: Aldine.
Orans, Martin
1966 Surplus. Human Organization 25:24-32.
Parsons, Jeffrey R.
1971 Prehistoric Settlement Patterns in the Texcoco Region, Mexico. Memoirs of the Museum of Anthropology, University of Michigan, No. 3.
1974 The Development of a Prehistoric Complex Society: A Regional Perspective from the Valley of Mexico. Journal of Field Archaeology 1:81-108.
1976 Settlement and Population History of the Basin of Mexico. *In* The Valley of Mexico. Studies in Pre-Hispanic Ecology and Society. Eric R. Wolf, ed. pp. 69-100. Albuquerque: University of New Mexico Press.
Peebles, Christopher S.
1978 Determinants of Settlement Size and Location in the Moundville Phase. *In* Mississippian Settlement Patterns. Bruce D. Smith, ed. pp. 369-416. New York: Academic Press.
Peebles, Christopher S., and Susan M. Kus
1977 Some Archaeological Correlates of Ranked Societies. American Antiquity 42(3):421-448.
Sahlins, Marshall D.
1963 Poor Man, Rich Man, Big-Man, Chief: Political Types in Melanesia and Polynesia. Comparative Studies in Society and History 5:285-303.
1972 Stone Age Economics. Chicago: Aldine.
Sanders, William T.
1976a The Natural Environment of the Basin of Mexico. *In* The Valley of Mexico. Studies in Pre-Hispanic Ecology and Society. Eric R. Wolf, ed. pp. 59-67. Albuquerque: University of New Mexico Press.
1976b The Agricultural History of the Basin of Mexico. In The Valley of Mexico. Studies in Pre-Hispanic Ecology and Society. Eric R. Wolf, ed. pp. 101-159. Albuquerque: University of New Mexico Press.
Sanders, William T., Jeffrey R. Parsons, and Michael H. Logan
1976 Summary and Conclusions. *In* The Valley of Mexico. Studies in Pre-Hispanic Ecology

and Society. Eric R. Wolf, ed. pp. 161-178. Albuquerque: University of New Mexico Press.
Sanders, William T., and Barbara J. Price
1968 Mesoamerica: The Evolution of a Civilization. New York: Random House.
Schapera, Isaac
1940 The Political Organization of the Ngwato of Bechuanaland Protectorate. *In* African Political Systems. M. Fortes and E. E. Evans-Pritchard eds. pp. 56-82. International African Inst. London: Oxford University Press.
1943 Native Land Tenure in the Bechuanaland Protectorate. Lovedale, South Africa: The Lovedale Press.
1956 Government and Politics in Tribal Societies. London: Watts.
Service, Elman R.
1962 Primitive Social Organization: an Evolutionary Perspective. New York: Random House.
Steponaitis, Vincas P.
1978 Location Theory and Complex Chiefdoms: A Mississippian Example. *In* Mississippian Settlement Patterns. Bruce D. Smith, ed. pp. 417-453. New York: Academic Press.
Taylor, Donna
1975 Some Locational Aspects of Middle-Range Hierarchical Societies. Ph.D. dissertation, Department of Anthropology, City University of New York. Ann Arbor: University Microfilms.
Tolstoy, Paul
1975 Settlement and Population Trends in the Basin of Mexico (Ixtapaluca and Zacatenco Phases). Journal of Field Archaeology 2:331-349.
Tolstoy, Paul, and Suzanne K. Fish
1975 Surface and Subsurface Evidence for Community Size at Coapexco, Mexico. Journal of Field Archaeology 2:97-104.
Tolstoy, Paul, Suzanne K. Fish, Martin W. Boksenbaum, Kathryn Blair Vaughn, and C. Earle Smith
1977 Early Sedentary Communities of the Basin of Mexico. Journal of Field Archaeology 4: 91-106.
Vansina, J.
1962 A Comparison of African Kingdoms. Africa (London) 32:324-335.
Vita-Finzi, C., and E. S. Higgs
1970 Prehistoric Economy in the Mount Carmel Area of Palestine: Site Catchment Analysis. Proceedings of the Prehistoric Society 36:1-37.
Winters, Howard D.
1968 Value Systems and Trade Cycles of the Late Archaic in the Midwest. *In* New Perspectives in Archeology. Sally R. Binford and Lewis R. Binford, eds. pp. 175-221. Chicago: Aldine.
Wright, Henry T.
1977 Recent Research on the Origin of the State. Annual Review of Anthropology 6:379-397.
Wright, Henry T., and Gregory A. Johnson
1975 Population, Exchange, and Early State Formation in Southwestern Iran. American Anthropologist 77:267-289.

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