SPATIAL PATTERNS AND REGIONAL GROWTH AMONG CLASSIC MAYA CITIES

R. E. W. Adams and Richard C. Jones

An objective methodology, based upon the rank-ordering and spatial patterning of Maya centers of the central Peten and central Yucatan zones, is used to infer developmental sequencing in the Maya Lowlands. If courtyard counts are employed as the basic measure of center importance, the Tikal and Calakmul regions each exhibit a size continuum of centers, consistent with the rank-size rule. The Rio Bec and Chenes regions exhibit a size distribution characterized by the existence of several large centers of nearly the same size, i.e., a situation of pluralism. These findings suggest that at the end of the Classic period, Tikal and Calakmul were dominant centers in economically mature regions, with a balance between external and internal growth forces. On the other hand, the later Rio Bec and Chenes centers appear to be in a state of growth redistribution or decline, their external ties truncated by the collapse to the south. Spatial patterning is less conclusive and suggests a relatively dispersed pattern of centers in all regions. The overall conclusion, especially from the frequency distributions of centers by size, is that the "periphery" (exemplified by Rio Bec-Chenes) developed first, reached a period of stasis, and developed further only on the collapse of the "core" centers (Tikal-Calakmul).

A LONG-STANDING PROBLEM IN MAYA ARCHAEOLOGY has been the definition of the nature of Maya Lowland sites. No current assessment of Maya Lowland urbanism is based on direct and objective methodology. As a result of this situation an important theoretical impasse has developed in mesoamerican archaeology. Leading exponents of cultural ecology, especially William T. Sanders and Barbara J. Price (1968), have forcefully argued that the Maya lacked true cities and permanent urban populations and were therefore without true bureaucratic state organization. The constraint of ecology in tropical forest zones is cited as the major limiting factor. The force of this argument is somewhat vitiated when one makes a logical distinction between urban and state organizations (Tolstoy 1969), and when one considers the mass of data indicating a high order of urban-level activities in Maya centers. A great deal of this information derives from deciphered Maya texts which treat of dynastic histories, social and marriage alliances, conquests, and probably tributary relationships. Nevertheless, the interpretation of Late Classic period Maya political structure as being, at best, a sort of "high chiefdom" still has attractions for many scholars.

An ecological explanation for the rise of Maya civilization explains process in terms of interaction between a less naturally favored "core" zone and a more favored "buffer" zone (Rathje 1971). It is argued that resource deprivation in the "core" zone led to compensatory developments in social and political organization which gave that area the processual edge in developing Maya civilization. While the earliest sophisticated remains in the Maya Lowlands were still to be found in the "core" zone sites, this was a viable, if somewhat negative, explanation. Recent work has indicated that the earliest and some of the most complex developments in the Maya Lowlands are to be found on the peripheries of the Lowlands, in the "buffer" zone (Hammond 1977; Freidel 1977, 1979; Hester 1979). In addition, there are indications that while the geographical distinction be-

R. E. W. Adams and Richard C. Jones, Division of Social Sciences, The University of Texas at San Antonio, San Antonio, TX 78285

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tween "buffer" and "core" may be accurate, almost certainly Rathje's formulations of evolutionary sequence and causal factors are not. The well-known phenomenon of secondary industrial state development can be applied here. Briefly, the phenomenon consists of the observed sequence of the primary, initially innovative industrial states (Britain and France) being overtaken and surpassed by the secondary industrial states (the United States and Japan). A major factor in this reversal of roles is that the really successful secondary industrial developments are based on immensely greater natural (ecological) resources than those that were available to the primary states. We believe that the analogy can be applied to the general evolutionary sequence as now available in the Maya Lowlands. Rathje's concept implies primary and retained innovation and sophistication in the "core" area due to the causal factor of resource deprivation. We argue that the earliest and most sophisticated developments in the Maya Lowlands are in the so-called "buffer" zones, specifically Belize. It should be noted that the initial cultural complexity seems to be based on the early development of trade and market systems (Freidel 1979; Hester 1979). Therefore the Rathje model may have to be adjusted to account for the different sequence of events which now are implied, as well as for the advantaged rather than deprived status of the greater Peten zone. The greater demographic potential of better and more extensive soils in the central Peten zone constituted a major and advantageous resource. In other words, the Tikal region did not suffer a resource deprivation, but possessed a resource advantage (Sanders 1977). This advantage was one which was realized only after the initial development of social and organizational complexity on the peripheries. When this sophistication was transferred to the interior, the greater numbers of people which could be marshalled into state organizations literally swamped the heretofore important trade centers on the coasts.

An equally pressing and related problem is that of assessing relationships among Maya centers. Political relationships have been suggested on the basis of central place theory, nearest neighbor boundary definition, and the use of Thiessen polygons drawn on maps of the Lowlands (Flannery 1972; Hammond 1974). However, as these authors recognize, the results suffer, in the absence of differential weighting, from the basic assumption that each center was as important as every other center. This leads to the patently absurd result of the very large site of Tikal (16 km^2 in extent) being given only as large a territory as the very small center of El Encanto (less than 1 ha in extent). Therefore, the question of hierarchical relationships among the ancient centers becomes crucial.

Hammond has defined nine levels of site hierarchy for the centers of northern Belize (1975). This ranking is somewhat inferential, however, and depends heavily on excavated evidence, which is unavailable for most sites in the Maya Lowlands.

Joyce Marcus (1973, 1976) has suggested a model for the Maya political universe based on both a Maya cosmological model and patterns of emblem glyph distributions and hierarchy in Maya texts. The cosmological model dictates four world quarters, with four equivalent regional states. Marcus attempts to validate the model by examining hieroglyphic text patterning of smaller sites only mentioning the larger ones and those only mentioning the capitals, which finally only mention each other. There are certain problems with this approach which show up in the incongruities of the results, such as when Calakmul, the northern capital (over 5 km^2 in extent), is replaced by Motul de San Jose (about .5 km^2 in extent) in Marcus's reconstruction (1976: Table 13). Again, the lack of an objective means of assessment of Maya ceremonial center size interrelationships seems to be causing at least some of the difficulty here.

Finally, the question of change and development of Maya centers cannot be adequately understood or even attacked until the structure of the end product is somehow systematically described and defined. Such developmental questions also relate back to the effect of ecological constraints and possibilities which loom so large in Sanders and Price's and in Rathje's schemata.

In this paper, a means of systematic description and assessment of Maya cities is outlined. The data resulting from numerical assessment are used to rank-order Maya cities. The rank-size rule is applied to the data in order to test for the extent of lognormality of center size distributions among different regions. Boundaries are suggested for possible regional states, and implications for Maya social, political, and economic structures are drawn from the patterns elicited.

In our quantitative analyses, we were not able to verify the evolutionary linkages between the central Peten (Tikal-Calakmul regions) and coastal Belize, both for current lack of representative mapping in the latter and because in Belize individual city-states (as opposed to functional urban hierarchies) appear to have been the norm. Adequate map coverage of the central Yucatan zone (Rio Bec and Chenes regions) to the north does allow us to make a comparison between the central Peten zone and part of its periphery, however. We are thus able to compare possible evolutionary sequences between (and within) the two areas, although we do not hypothesize a functional link between the two.

MAYA URBANISM

The ambivalence with which scholars have traditionally viewed the large aggregates of monumental architecture of the Maya Lowlands is reflected in the labels which they have attached to those aggregates. Ceremonial centers, civic centers, and just plain "centers" have all been used and advocated. Some have argued that because Maya centers functioned as urban centers in all ways except, possibly, as locations of large-scale populations, they should be called functional or dispersed cities (Adams and Culbert 1977:5). Lately, even this caveat has disappeared with the development of data indicating that Maya centers had populations comparable to those of pre-industrial cities in other parts of the world (Haviland 1970; Kurjack 1974). Without arguing here the residual point as to the permanency of residence of Maya urban populations, it is hereinafter assumed that the weight of present evidence demonstrates the validity of the interpretation that the Maya had a large number of cities at least by the Late Classic period (A.D. 600–850).

Maya centers can be defined by a limited number of functional classes of major architecture. Palace structures are multiple-use buildings which contain from 4 to over 50 rooms. These structures functioned as elite-class residences, administrative offices, places of religious retreat, storage areas for valuables and commodities, and as locales of aristocratic court protocol (viz. Potter 1977:41). Temples are buildings which are often erected on tall platforms, have three rooms or less, and are frequently the locations of sumptuous burials of distinguished members of Classic Maya society, who were also often rulers. These two classes of architecture are highly variable in style from region to region. The two together probably make up 90% or more of the total public architectural mass of any given city. The rest of large-scale Maya construction is made up of a multitude of functional classes including ballgame courts, reservoirs, fortifications, and internal road nets (*sacbes*). These classes all exclude the vast acreages of paved surfaces which served as bases for the superstructures.

While the excavated sample of Maya cities is presently less than 1% of the total, it is probable that 60% of the total number of Maya cities are known and at least partially mapped (Adams 1969: Table 1). It is the existence of these maps that allows for a method of assessment of relative importance. While these maps are highly variable in quality and extent, several regions have benefited from systematic surveys and good mapping over long periods of time and thus provide reliable data. Regions herein selected for analysis are the north-central Peten, southeastern Campeche, the Rio Bec, and the Chenes (Figure 1). Fortunately, Tikal, Mirador, Calakmul, and Naranjo, the largest and most complex known centers of Maya civilization, fall within these regions.

METHODOLOGY

It has long been recognized that Maya cities were organized in a highly distinctive pattern. Major and minor buildings alike (as well as rural domestic architecture) are nearly always oriented inward upon a courtyard or plaza (Pollock 1965). Thus, the various classes of Maya buildings come together in a physical and functional association which can be termed the "*courtyard group.*" If Maya cities are defined as aggregates of courtyard groups, it is possible to count courtyards of major architecture at a given site or to make more precise quantitative assessment of paved areas and associated architectural masses. These approaches can lead to numerical

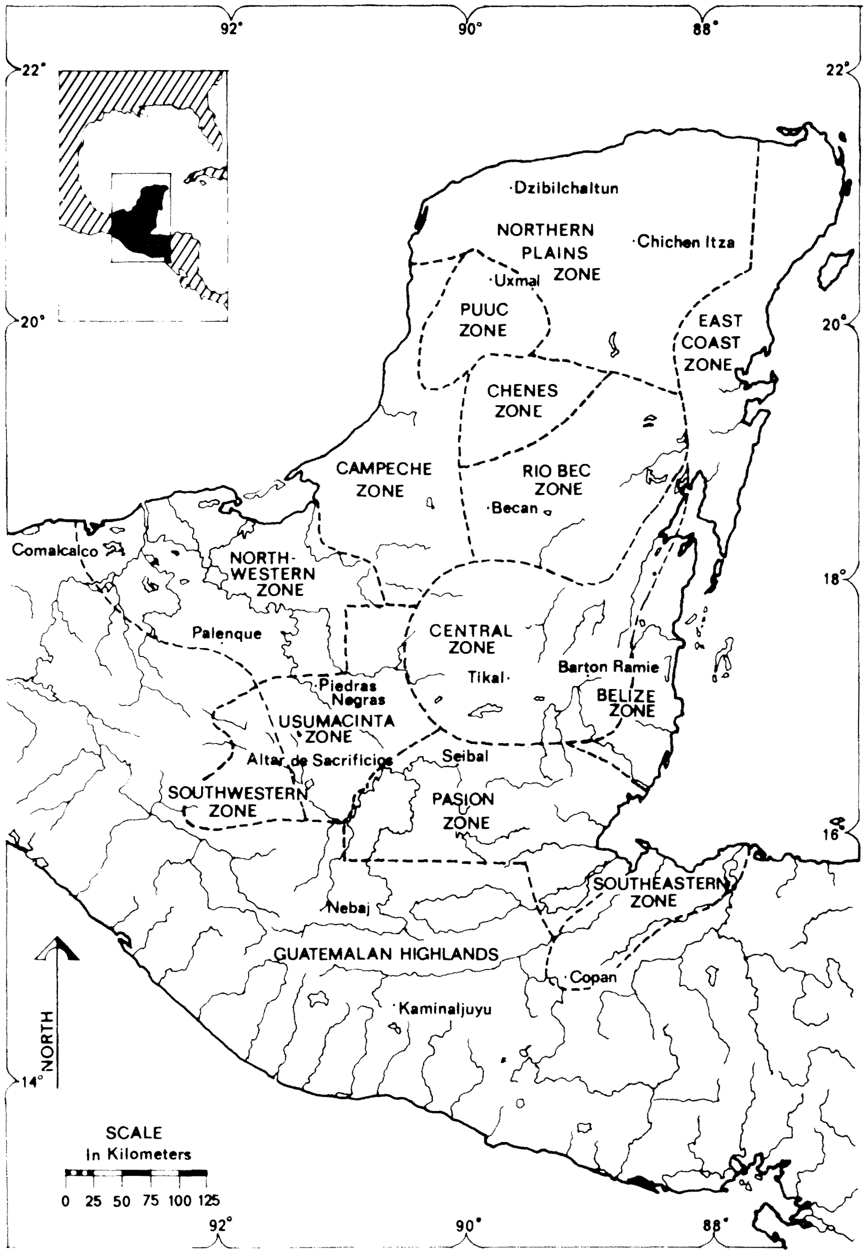

Figure 1. Maya Lowland archaeological zones (after Adams and Culbert 1977).

assessments and hierarchical ranking of Maya cities. Such systems have been developed and applied to the cities of the regions mentioned above, and the results have been used as a means of rank-ordering them (Table 1). The rather complex methodology and lengthy examination of alternative results are being published elsewhere (Adams 1981; Turner et al. 1981). Briefly, the major methodological problems are those of sample quality and size. That is, we know from experience that even carefully done preliminary surveys often do not completely map all major architecture. Especially in the Peten, new maps of sites will show a number of newly found courtyards of ar-

Table 1. Maya Ceremonial Centers Shown on Figure 2.

Index Number	Name	Number of Courtyards	Hierarchical Level
Tikal Region			
1	Tikal	85	
2	Naranjo	42	
3	Uaxactun	23	I
4	Kinal	20	
5	Yaxha	20	
6	Caracol	17	
7	La Honradez	16	
8	Nakum	16	II
9	Ucanal	11	
10	Tayasal	10	
11	Chochkitam	8	
12	Ixkun	8	
13	Xultun	7	
14	Benque Viejo	5	
15	Chunhuitz	5	III
16	San Clemente	5	
17	Hatzcab Ceel	5	
18	Holmul	5	
19	Ixlu	5	
20	Cahal Pichik	4	
21	Itsimte	4	
22	Rio Azul	4	
23	Motul de San Jose	3	IV
24	El Encanto	1	
25	Uolantun	1	
26	Xmakabatun	1	
27	Yaltitud	1	
Calakmul Region			
28	Calakmul	42	
29	Mirador	32	I
30	Naachtun	21	
31	Nakbe	14	
32	La Muñeca	11	II
33	Oxpemul	11	
34	Uxul	9	
35	Alta Mira	8	III
36	Balakbal	5	
37	La Muralla	1	
38	Pared de los Reyes	1	IV
Rio Bec Region			
39	Rio Bec Center	24	I
40	Becan	12	
41	Pechal	12	II
42	Peor es Nada	12	
43	Hormiguero	9	
44	Km. 132	7	
45	Chicanna	6	III
46	Nochebuena	5	
47	Okolhuitz	5	

(Table continues on the following page.)

Table 1. Maya Ceremonial Centers Shown on Figure 2.

Index Number	Name	Number of Courtyards	Hierarchical Level
48	Xpuhil 2-4	4	
49	Xpuhil 1-4	4	
50	Km. 122	3	
51	Carmelita	3	
52	Laguna de Zoh	3	
53	Ramonal	3	
54	Porvenir	2	
55	Puerto Rico	2	
56	Buenos Aires	2	
57	Channa	2	
58	Corriental	2	
59	Culucbalom	2	
60	Payan	2	IV
61	Pueblo Viejo	2	
62	Ceibarico	2	
63	Pasión del Cristo	2	
64	Desprecio	1	
65	Halatun	1	
66	Km. 183	1	
67	Namac	1	
68	Noh-Sayab	1	
69	San Lorenzo	1	
70	Tortuga	1	
71	Xaxbil	1	
72	Xuts	1	
Chenes Region			
73	Sta. Rosa X.	20	I
74	Dzibilnocac	19	
75	Itzimte	15	II
76	Suum	11	
77	Dzehkabtun	7	
78	Pixoy	6	III
79	Hochob	3	
80	Dzibiltun	2	
81	Nocuchich	2	
82	Chanchen	1	IV
83	Chunlimon	1	
84	Huntichmul	1	
85	Tabasqueño	1	
86	Nohcacab	1	
Other Centers on Map			
Pasion Zone			
87	Seibal	23	
88	Altar de Sacrificios	8	
89	Dos Pilas	5	
90	Aguateca	5	
91	Cancuen	3	
92	Tamarindito	3	
93	La Amelia	3	
94	El Caribe	3	
95	Ixcoche	2	
96	Aguas Calientes	1	
97	El Pabellon	1	

Usumacinta Zone		
98	Yaxchilan	15
99	Piedras Negras	11
100	Bonampak	3
Other Central Zone		
101	Nohmul	12
102	Lubaantun	11
103	Machaquila	10
104	Polol	10
105	Ixtutz	8
106	San Esteván	7
107	El Palmar	7
108	La Florida	6
109	San Jose	6
110	Altun Ha	5
111	Chowacol	5
112	Baking Pot	4
113	Pusilha	3
114	Sta. Rita	1
Other Central Yucatan (Rio Bec, Chenes)		
115	Uaacbal	1
116	Uxmal	14

Source: Adams (1981).

chitecture (e.g., Seibal; Willey et al. 1975). Further, it is known that the sample is defective in the absolute numbers of sites known (Graham 1967). That is, there are still major and minor aggregations of Maya construction both beyond and within the zones of major exploration. New sites are being discovered all the time. In regard to quality, however, we argue, again based on field experience, that the sample quality from site to site is likely to be similar. Put another way, the sample is not likely to be of worse quality at one site than at another, especially if they were mapped by the same person(s). There are exceptions in which the initial map was wildly inadequate, but these tend to be the largest centers, such as Tikal, where the sheer size of the center defeated initial survey efforts (Tozzer 1911; Carr and Hazard 1961). There is likely to be only one Tikal, however, or at least very few of them. It is possible that the second-rank sites such as Calakmul and Mirador will be found to be as large as Tikal when they are completely mapped. In regard to the matter of sample size, we argue that most of the larger sites have already been found (Adams 1969). The sample is inherently likely to be poorest at the lowest levels of any hierarchy.

In view of the above, we feel that although it is clearly hazardous to rank-order data of such dubious quality and size, the hazard mainly lies in the acceptance of these assessments as conclusive. We think that rank-ordering and rank-sizing are interesting and useful in eliciting patterns from the data *as they now stand*. As the data improve, the analysis can be repeated and adjustments made to patterns and hierarchies. On a final cautionary note, we are also aware of the speculative nature of numerical extrapolation from such a data base. We feel, however, that demonstration of the validity of the analytical methods for generating patterns and hypotheses makes the exercise worthwhile, even if the explanations we advance ultimately prove to be defective. The general agreement of the two systems of courtyard counting and of volumetric assessment have elicited patterns which seem to reflect political, economic, and demographic hierarchies. These patterns may be developed further by using concepts and techniques developed by geographers for dealing with modern urban centers.

The rank-size rule is herein applied to Maya cities both overall and regionally in order to determine the existence of primate, lognormal, or "plural" hierarchies of cities within regions. We find that we are not the first to apply the rule to ancient mesoamerican cities. Richard E. Blanton (1976) has used the rule to test for primacy among the cities of the Valley of Mexico during the period of dominance of Teotihuacan culture. He and his colleagues are also applying the rule in dealing with the sites of the Oaxaca valley (Blanton 1978). Blanton's hierarchies are indirect, however, and based on estimated population sizes from surface surveys, whereas we are here dealing with hierarchies based upon directly measured architectonic complexes. It would seem likely that the methods are complementary and that one can be used to check the other.

Boundaries based on geographical contiguity are defined in order to provide tentative definition of economic and political boundaries. Combining the latter with the quantitative hierarchical measures and with population estimates from more standard settlement pattern studies, we now have the possibility of testing the above mentioned hypotheses and theories about ancient Maya social and political structures and their evolution.

Our expectations are that ceremonial-center patterns of some zones are more "developed" than others. "Developed" patterns are deduced below from geographic theory. Suffice it to say at this point that *a developed size-distribution of ceremonial centers is one in which there is a uniform continuum of centers, from largest to smallest, with few "breaks" in between. A developed spatial pattern of ceremonial centers is one in which centers are neither aggregated nor dispersed on the landscape.*

Regional Definition

We have selected four regions as having the most reliable and complete information for our purposes. One is the Tikal region in the northeastern Guatemalan Peten; second, the Calakmul region, astraddle the north Peten's boundary with Campeche, Mexico; third, the Rio Bec region, in Campeche and Quintana Roo, Mexico; and fourth, the Chenes region, in Campeche and Yucatan, Mexico. These regions are found in Figure 2; their boundaries are defined more explicitly below. The Tikal and Calakmul regions are set apart from the Rio Bec and Chenes regions by their architectural and ceramic styles, which geographical separation seems to confirm. The reason, then, for four divisions instead of two lies in the concept of geographical isolation as it reflects the autonomy of internal functions. The Calakmul and Tikal regions, if defined in terms of the location of their larger ceremonial centers, were separated by some 50 km and so were likely to have been autonomous. This conclusion seems even more valid for the Rio Bec and Chenes regions, which are separated by some 90 km of brushy tropical savanna.

We have (further) employed the criterion of geographical contiguity to exclude from given regions individual ceremonial centers which are so peripheral that they were probably isolated subregions themselves. In order not to be arbitrary on this criterion, we have redefined our regional boundaries such that centers which are more than 35 km from a large center in the contiguous portion of each region are excluded from that region. The figure of 35 km is an estimate of the maximum distance traversable on foot in a day's time in the central Lowlands in Classic Maya times (Adams 1978); centers more than 35 km apart would be expected to have far less commerce with each other because of the necessity of an overnight stop. This procedure excludes a number of ceremonial centers—notably Nohmul, Lubaantun, Machaquila, and Polol from the Tikal region; and Uxmal from the Chenes region (Figure 2 and Table 1). Notice that the resultant Tikal region is much larger than the others, which are nearly equal. In terms of square kilometers, the relative regional sizes are: Tikal 21,095, Calakmul 8,907, Rio Bec 7,932, and Chenes 8,632. Note also the greater number of large centers in the Tikal and Calakmul regions. These two observations already suggest the greater spatial influence and importance of the ceremonial centers of the Peten.

The reasons for excluding the Pasion and Usumacinta regions from our consideration are straightforward. Neither region has been sufficiently well mapped to provide a large enough sample of centers, specifically larger ones, to validate our methodology. Moreover, they are too spatially separated to be considered as a single region. Otherwise, it would be desirable to include these areas, because they played a seminal role in the peopling of, and trade with, the central zone.

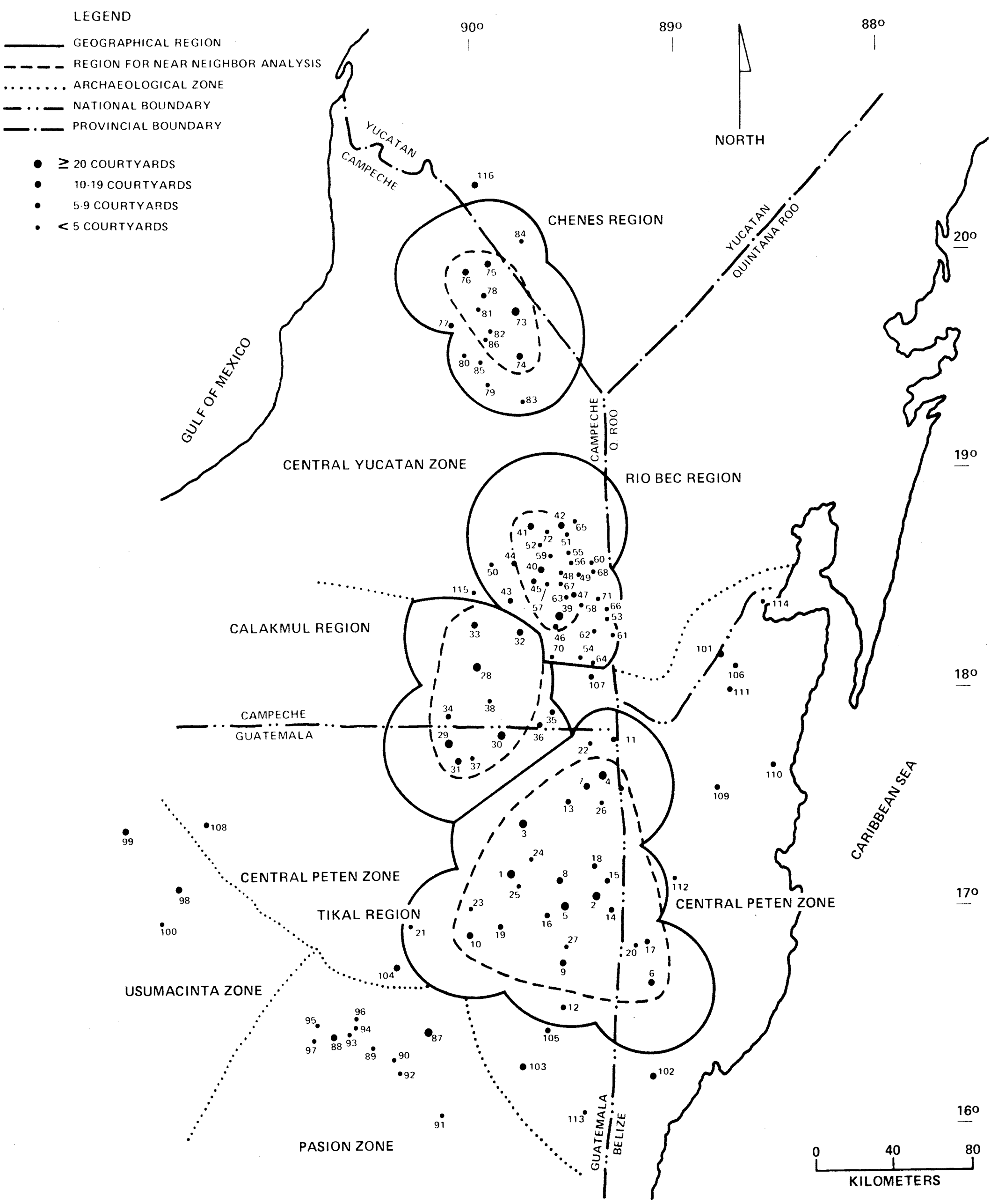

Figure 2. Lowland Maya ceremonial centers and geographical/archaeological areas.

Sizes of Ceremonial Centers

The index of center size which we use is the number of courtyards plus two times the number of acropolises (large composite structures) present in the contiguous built-up area of a given site. The 2:1 ratio of acropolises to courtyards is based on volumetric assessments of the average architectural masses of each (Turner et al. 1981). In general, because of the infrequency of acropolises the index is a function of the number of courtyards; we will drop reference to its acropolis component from here on. The number of courtyards has been found to correlate closely with more sophisticated volumetric assessments of center size. Moreover, as an index it has value in its simplicity, since it can easily be calculated for centers which have not yet been excavated.

A basic and crucial assumption is that rank-ordering by architectural mass is valuable because the patterns it elicits from the data are somehow reflective of economic, political, and social rankings. Among modern cities, it is apparent that most architectural mass supports the socioeconomic needs of the resident population—i.e., it serves residentiary rather than export-base (nonresidentiary) activities—and therefore is not reflective of a city's importance, in the sense of its linkages with the outside world. Maya cities, on the other hand, were centers of ceremonial functions for a dispersed tributary population on which they directly depended for their labor force, food supply, and institutional support. Thus, architectural mass in such cities reflected their ties with the outside quite well; not only ties with the immediate tributary area but also ties to smaller ceremonial centers at a distance. Furthermore, the importance of architectural monuments to a leadership which is known to have been essentially aristocratic and of a moral nature is that such monuments reinforce the prestige of that leadership (Adams 1977). There is a direct linkage between the prestige of an aristocratic group and the monument that they are able to build. Because political leadership among the Maya has been demonstrated to have been based upon social status and geneelogy (see, for example, Jones 1977; Haviland 1967, 1968, 1972), then these prestigious monuments should also reflect political status. The linkage, we believe, is self-evident and demonstrable (see also Culbert 1974:68–74).

The rank-ordering of ceremonial centers by region (Table 1) reveals a relatively clear-cut hierarchy:

First-order centers: ≥ 20 courtyards
Second-order centers: 10–19 courtyards
Third-order centers: 5–9 courtyards
Fourth-order centers: < 5 courtyards

We will not try to justify the cutoff points for these levels, except to say that they appear corroborated by visual inspection of the breaks in the data.

CENTER-SIZE DISTRIBUTIONS BY REGION

The distribution of central places, or cities, by size classes reveals a great deal about the internal organization and external ties of a region or a country. The phenomenon may be examined by double-logarithmic scaled graphs, the ordinate of which is a place's *size*—usually measured by population—and the abscissa of which is its *rank* among all places being considered. All the places are plotted on the graph, and a straight line or a curve is the result.

A downward-sloping straight line with a slope of -1 means that there is a continuous progression of center sizes—specifically, $P_r = P_1/r$, where P_r is the population of the r^{th} rank place and P_1 is the population of the largest place. This is the famous rank-size rule; *it generates a rank size, or lognormal, distribution.* The rule allows us to estimate a place's population knowing simply its place in the hierarchy. For example, in the United States in 1970, New York City had 7,896,000 people; under the rank-size rule, Los Angeles's population should be 7,896/3 or 2,632,000, Cleveland's 7,896/10 or 790,000. The actual populations in 1970 were 2,810,000 for Los Angeles and 751,000 for Cleveland, suggesting (for the largest cities at least) that U.S. cities approximate the rank-size rule. There are two other graphical possibilities:

1. A concave curve, suggesting a distribution in which there is a single place of great size and a number of small places. This is a *primate distribution.*

2. A convex curve, suggesting a distribution with several large places of nearly equal size, and a paucity of smaller places. This is what we will call a *plural distribution.*

What do these curves have to do with regional development? A *rank-size* urban distribution is thought to represent a system in which many complex and often random forces have operated. It is typical of large regions or of those which have had long periods to evolve. A *primate* distribution represents the converse—a system in which a few simple forces have operated, and it is typical of smaller or younger regions (Berry 1961). A *plural* distribution appears, on the surface, to be a rank-size distribution with an even longer period of evolution. It is best distinguished, however, by the concept of "closure" (Vapnarsky 1969). Closure is the extent to which social transactions take place within a system as opposed to between systems. It thus indexes degree of contact with the "outside world." For our purposes, we recognize three levels of system: intraurban, interurban (regional), and interregional. In the Maya system, *interurban transactions* took place within a large ceremonial center and its tributary area; *interurban transactions* were between ceremonial centers of a given region; and *interregional transactions* were between whole regions (such as the four defined above). To get back to plural distributions: they imply low contact (i.e., high closure) with other regions, but high contact (i.e., low closure) with other urban areas in their region (Table 2). They are inward-focused, possibly without the stimulus of outside forces, and thus probably in a condition of growth redistribution or decline. Primate distributions are just the reverse: tied to strong forces outside the region, while exhibiting little integration within the region, they are probably in a condition of growth polarization and dynamism. In the rank-size case, outside forces *and* redistributive forces are operating simultaneously—a sign (generally) of economic and social maturity. Finally, we have inserted an "isomorphic" distribution in the table to represent either a "terminal" or an "initial" phase in which there are no differences in urban sizes. Such a case would find urban ministates, isolated from each other, each having adapted in its own way to its resource base (here assumed to be uniform for all places in a region).

The evidence from the central Maya Lowlands is that toward the end of the Classic period (ca. A.D. 900), when building ceased, the Tikal and Calakmul regions exhibited a *rank-size* distribution of ceremonial centers, while farther north in the Rio Bec/Chenes regions, more *plural* distributions were exhibited (Figure 3 verifies this). The ceremonial centers with ≥10 courtyards are labeled, and the others are numbered in correspondence with Table 1. The greater proportion of such large centers for the Tikal and Calakmul regions is readily noted. Most striking, however, is the increasing size-equality of the larger centers as we progress northward from the Tikal to the Chenes regions. Departure of the Rio Bec and Chenes from lognormality is pronounced.

Further verification of our distributional categories comes from two indices—the primacy ratio and the ratio of actual to expected numbers of centers by size class. The primacy ratio reduces a size distribution to a single statistic. Mehta's widely used ratio (Mehta 1964) expresses the relationship between the size of the largest place (numerator) and the sizes of the four largest places combined (denominator). It is easily verifiable that in a perfect rank-size distribution, the ratio would be 0.48 (i.e., $1.00 \div (1.00 + .50 + .33 + .25) = .48$). The greater this ratio is than 0.48, the more primate the distribution; as the ratio decreases below 0.48, the distribution will grow more plural—down to 0.25, which represents either perfect pluralism or isomorphism. The statistic ignores small places, but at any rate it is generally the larger places which set the form of the distribution. The primacy ratio for our four regions (Table 3) suggests a nearly lognormal Tikal region, and increasingly plural subregions toward the north. Additional verification is obtained by solving the rank-size rule for r (i.e., $r^* = P_1/P^*_r$), where P^*_r is the lower or upper size-limit for a given size-class, and r^* is the expected rank assuming a lognormal distribution. The results (Table 4) verify again the approximate lognormality of the Tikal distribution. They also show that

Table 2. Urban-size Distributions Classified by Degree of Closure at Two Scales.

Interurban Closure	Interregional Closure: Low	Interregional Closure: High
Low	Rank-size	Pluralism
High	Primacy	Isomorphism

Source: Authors.

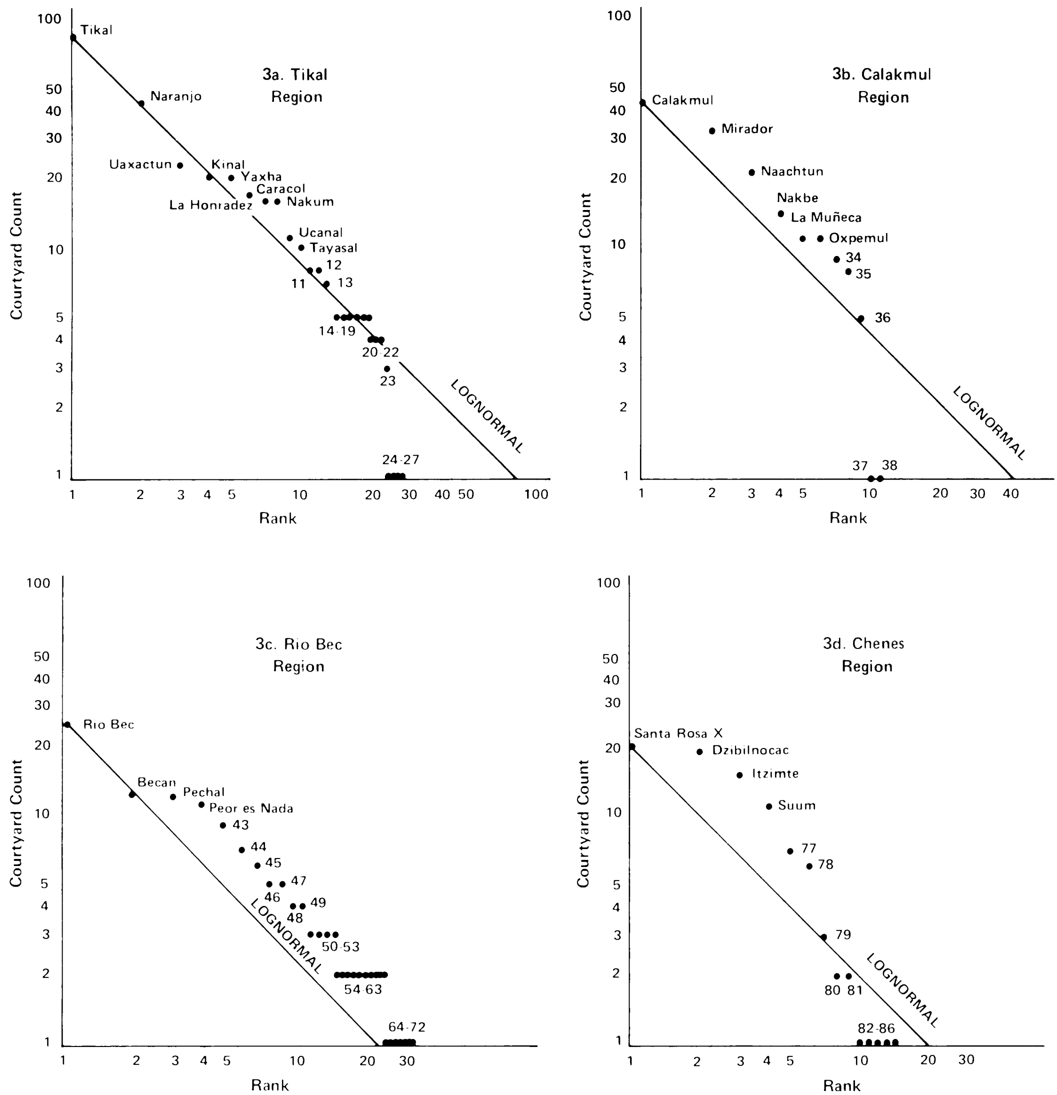

Figure 3. Rank-size distributions of ceremonial centers for four Maya regions.

the 10–19 courtyard class becomes overemphasized in the two northern regions, indicating the generation of plural distributions. The fewer-than-expected numbers of smallest centers, for all regions, cannot be taken too seriously; they reflect the tendency by archaeologists to concentrate on the larger sites.

These results, in which we observe Mayan urban structure "frozen" at the end of the Classic, enable us to infer comparative distributional growth paths for the core and buffer zones. The basic assumption which we must make is that regional Mayan center-size distributions follow a basically similar path, with the peripheral zone growing more rapidly in the Preclassic and the central Peten zone overtaking them in the early Classic. If this can be accepted, and there is evidence to warrant it (Rathje et al. 1978; Willey 1977; Webster 1977), then the evolutionary sequence would be as graphed in Figure 4.

The central zone's initial urban distribution was an isomorphic one, based on fertile soils

Table 3. Primacy Ratios for Four Maya Regions.

Region	Largest Center	Number of Courtyards in Largest	Number of Courtyards in 4 Largest	Ratio
Tikal	Tikal	85	170	0.50
Calakmul	Calakmul	42	106	0.40
Rio Bec	Rio Bec	24	60	0.40
Chenes	Santa Rosa X.	20	65	0.31

Source: Number of courtyards: Adams (1981); calculations by authors.

(Sanders 1977). Population densities then rose to the demand and intensification thresholds discussed previously, and a previously closed region was opened to trade. Tikal then became the dominant economic and cultural force of the Lowlands. Tikal's unique success is perhaps explainable only in special historical terms, although it is describable in systemic terms (Rathje 1977). At some point in the Late Classic, Tikal's growth stabilized, making way for the emergence of intermediate-sized ceremonial centers within its region. This apparently occurred neither because Tikal lost its external ties (Lowland-wide and to central Mexico) nor because of any policy on Tikal's part, but because of functional specialization and demand augmentation in the intermediate-sized core centers. The Late Classic florescence of such centers as Naranjo, La Honradez, Nakum, and Tayasal bears this out (Morley and Brainerd 1956:64).

The suggested evolutionary sequence in the central Yucatan (Rio Bec-Chenes) zone is similar to that in the central Peten (Tikal-Calakmul) zone. Two major cultural historical factors modified the trajectory of urban evolution, however. One is that the trajectory seems to have been interrupted at the start of the Early Classic, possibly by a forcible takeover of the region from the south (Ball 1977; Adams 1977a). The second factor is an effect of the first, and that is a delayed florescence which shortened the length of time available for development before the same disastrous syndrome of factors causing the Maya collapse took a delayed but no less deadly effect. The weak-

Table 4. Actual Numbers of Maya Ceremonial Centers, and Expected Numbers of Centers Assuming Lognormal Distribution, by Size, Class, and Region.

Region and Statistic	Size, Class (Number of Courtyards) ≥20	10–19	5–9	<5	Totals
Tikal					
Actual Number of Centers	5	5	9	8	27
Expected Number of Centers	4	4	9	10	27
Ratio, Actual/Expected	1.25	1.25	1.00	0.80	—
Calakmul					
Actual Number of Centers	3	3	3	2	11
Expected Number of Centers	2	2	4	3	11
Ratio, Actual/Expected	1.50	1.50	0.75	0.67	—
Rio Bec					
Actual Number of Centers	1	3	5	25	34
Expected Number of Centers	1	1	2	30	34
Ratio, Actual/Expected	1.00	3.00	2.50	0.83	—
Chenes					
Actual Number of Centers	1	3	2	8	14
Expected Number of Centers	1	1	3	9	14
Ratio, Actual/Expected	1.00	3.00	0.67	0.89	—

Source: Number of courtyards: Adams (1981); calculations by authors.

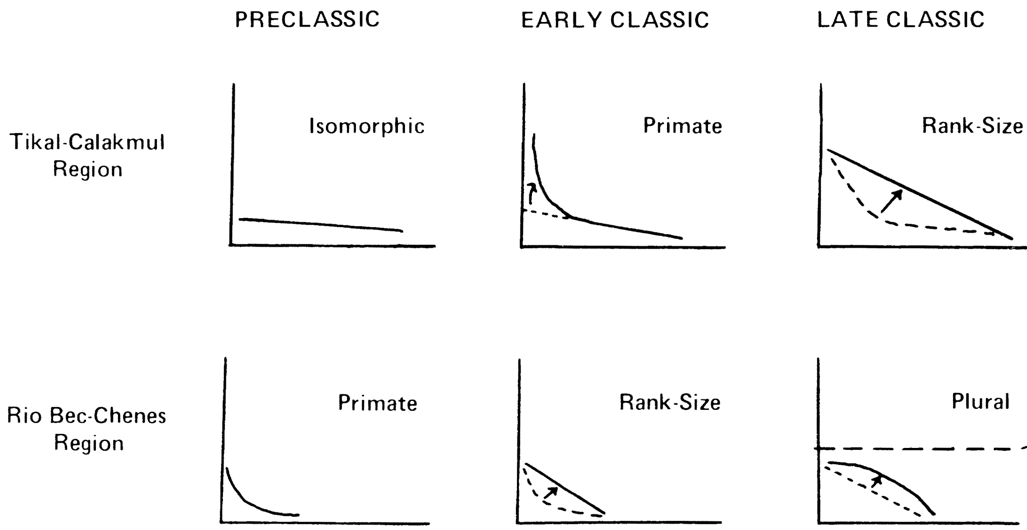

Figure 4. Hypothesized developmental sequence of center-size distributions for two Maya subregions.

ened status of the Tikal-Calakmul zone after A.D. 850 may have been the condition that permitted delayed florescence in central Yucatan. It was also a condition which spread into the north, however, to bring matters to an end. For a discussion of the Maya collapse in detail, the reader is referred to Culbert (1973). In the Late Classic of central Yucatan, therefore, the cities may have become increasingly isolated and autonomous of centralized political control. Closure may be inferred from the asymptotic nature of the pluralistic curve (Figure 4: Rio Bec-Chenes, Late Classic), which apparently approaches some sort of limit, ℓ.

SPATIAL PATTERNING BY REGION

The reduction of complex patterns and shapes to simpler indices has been one important concern of modern geography. From a pattern of urban places, one may infer such underlying influences as the existence of localized resources, topography, land settlement policy, commerce with the outside (in the present context), and stage of growth. A commonly used measure of spatial pattern for a punctiform map is the nearest-neighbor statistic, R, defined as

$$R = r_A / r_E$$

in which r_A is the average distance between a point and the point closest to it; and r_E is the average for such distance that would be *expected* if the points on the map had been distributed by a completely random process (such as extracting coordinates from a random numbers table). Mercifully, the formula of r_E has been worked out by mathematicians, from the Poisson distribution:

$$r_E = 1 \div 2\,(\sqrt{N/A})$$

where N is the number of points and A is the area of the map (or sector, region, etc. on the map). "A" must be in the same unit of measure (except that the units are squared, of course) as r_A. An illustration of the calculation of near-neighbor distances is given in Figure 5. Reciprocal near-neighbors (where each of two points is the other's closest) are shown by the double arrow; such distances are counted twice. For this map sector, r_A is thus $(8 + 3 + 3 + 6 + 5 + 10) \div 6 =$ 5.83 km. Assuming the units of kilometers, if the area of the sector were 400 km^2, then r_E would equal $1 + 2(\sqrt{6/400}) = 4.08$, and R would equal 5.83/4.08, or 1.43. The value of 1.43 indicates a pattern somewhat more *dispersed* than random, because the statistic is considerably above 1.0 (the maximum dispersion possible is $R = 2.15$), indicating interpoint distances that are greater than in a random distribution. An illustration of a continuum of such patterns and their associated R's is given as Figure 6. An R of close to 1.0 signifies a *random* pattern, while fractional values considerably below 1.0 signify *aggregated* patterns.

When examining urban places in a region, an *aggregated* pattern reflects either a strongly localized resource base (see King 1962) or extraregional influence which has focused upon a particular location because of its strategic, trade, or market position in a much wider matrix (see Taylor 1977:161–162). A dispersed pattern reflects either a spatially uniform resource base (King 1962) or internal competition among central places, all of which perform essentially the same functions (Christaller 1966:58–80), or (in a few cases) the external planning of location of such central places so as to minimize distance traveled by a dispersed population to urban service centers. A *random* pattern is a pattern intermediate between the other two—not random in a process sense, but only in that the distances between places are neither quite small nor quite large. Such a pattern is simply transitional between the other two. In terms of the urban-size developmental sequence we posed earlier, it is apparent that an aggregated pattern should be associated with primacy, a random pattern with lognormality, and a dispersed pattern with pluralism.

For analysis of the Mayan spatial patterns, we have redefined each of our regions as the area which is within 10 km of a large (≥ 10 courtyards) ceremonial center, adjusting for convexity of the regions (Figure 2). Since the outer 35 km of the larger boundary used earlier contains no large centers by definition, it creates large regions that give a severe misimpression of spatial clustering—especially in the three northern regions. The larger limit was only intended to exclude truly peripheral places. The alternate, 10-km figure is one-half the average near-neighbor distance between large centers over the whole Lowlands. This is a reasonable figure assuming there are (as yet) undiscovered larger centers "lurking" adjacent to some of our mapped centers. The convexity adjustment, by which amoebalike attenuations are avoided, serves to match the region's form to the pattern of all the known centers, small as well as large.

Furthermore, in our analysis we employ only the ceremonial centers of ≥ 10 courtyards. We would be introducing severe bias into our analysis if we employed the smaller centers, only a small proportion of which have been studied and mapped. The centers studied represent probable growth points in their respective regions.

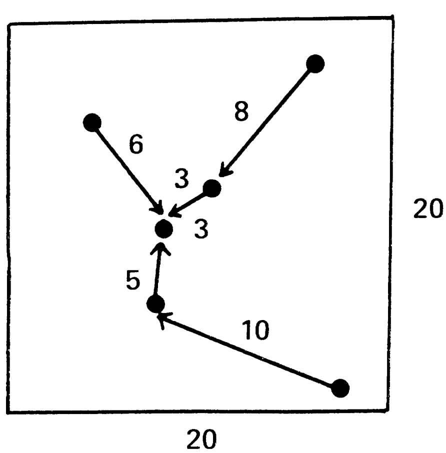

Figure 5. Illustration of the calculation of near-neighbor distances.

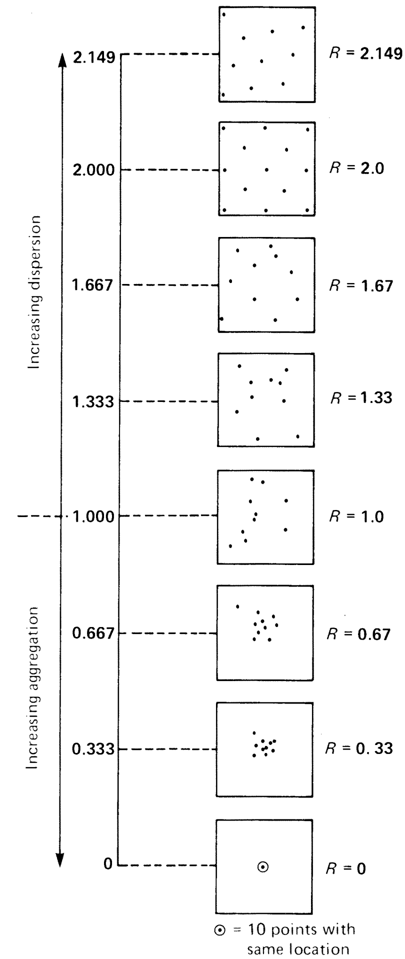

Figure 6. The R-scale in near-neighbor analysis, with exemplary patterns.

Interpretations from our results are limited, obviously, by the small numbers of points. Nevertheless, a discernible trend does appear (Table 5). The Tikal and Calakmul regions, with approximately rank-size urban distributions, tend toward spatial randomness, while Rio Bec, with a pluralistic distribution, tends toward a dispersed spatial pattern. Because of its clearly plural center-size distribution, Chenes is an anomaly; we would have expected a strongly dispersed pattern, whereas its statistic indicates greater randomness than Tikal or Calakmul. This anomaly disappears if the Chenes near-neighbor region is drawn so as to include Uxmal—just outside the 35 km boundary to the north. If this were done, the R statistic would rise to 1.42, indicating a relatively dispersed pattern. We do not, however, feel that Uxmal's inclusion is justified. One additional fact to note is the tendency toward dispersion found in *all* the regions of Table 5. This probably reflects the uniform resource base making its influence felt throughout the Lowlands, despite the aggregative forces of a higher order which are discussed below. In addition, the pattern is compatible with a feudal model of Maya society for this region (Adams and Smith 1981). The feudal dispersion of authority, both real and spatial, seems to be reflected within the regions. (Such patterns compare closely, in fact, with the dispersed urban spatial patterns found by King [1962] in sample quadrants of the U.S. Plains and Midwest—e.g., for Minnesota, $R = 1.38$; for Kansas, $R = 1.33$; for Iowa, $R = 1.35$.)

Table 5. Near-Neighbor Analysis: The Regional Spatial Patterns of Large Maya Ceremonial Centers.

Subregion	Number of Points, N	Area in km^2, A	Mean Expected Near-Neighbor Distance, in km, r_E	Mean Actual Near-Neighbor Distance, in km, r_A	R_A/R_E, the Near-Neighbor Statistic R
Tikal	10	12,390	17.54	22.4	1.28
Calakmul	6	5,230	14.77	19.0	1.29
Rio Bec	4	2,253	11.87	18.5	1.56
Chenes	4	2,728	13.06	16.1	1.23

Source: Calculations by authors.

We can thus hypothesize an evolutionary sequence for spatial patterning (Figure 7) that corresponds to the sequence of urban-size distributions (Figure 4). Regarding Figure 7, consider that we are only inferring spatial pattern from the larger dots (particularly, the two largest spatial pattern size-classes of dots on any given map). Therefore, the following explanation refers only to the location of the larger points at a given period. In the Tikal-Calakmul zone, a better than average soil cover (Sanders 1977) promoted the growth of agricultural hamlets in the Preclassic. Thus, a dispersed pattern of places was coterminous with an isomorphic size-distribution of places. At a relatively early time, the Belize centers had developed more complex societies based on coastal trade networks. Just prior to the Early Classic, and in an unspecified form (acculturation, elite takeover, migration, political alliance), came the transfer of sophistication of which we have spoken, enabling Tikal to rise above the regional central place that the local resource base had supported. Satellite centers—notably Uaxactun—also prospered in this period, and the overall result was an aggregated pattern (growth cluster) with Tikal as its focus. This was the period of primacy in the size-distribution of centers. In the Late Classic, the process of growth redistribution began in the core. Not only did the satellite centers continue to grow, but now centers at the regional periphery—such as the centers of Tayasal and Ucanal, to the south (see Figure 2 and Table 1)—began their growth spurt. As a result, the core's spatial pattern began to

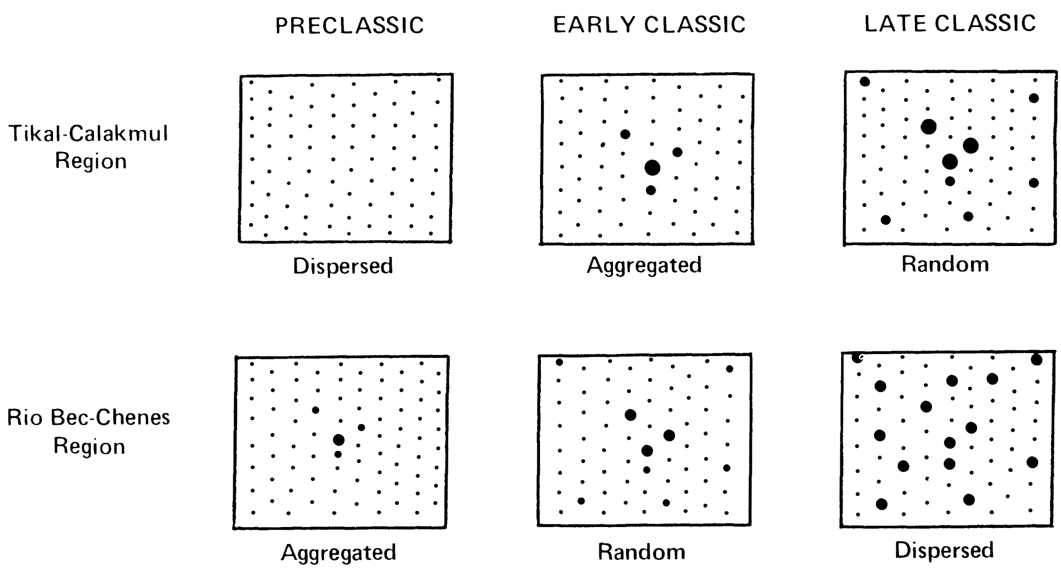

Figure 7. Hypothesized developmental sequence of spatial patterning.

Table 6. Suggested Territorial Sizes of 16–23 Courtyard Centers.

Center	Courtyard Count	Estimated Territory (km^2)
Uaxactun	23	5,053
Kinal	20	4,395
Yaxha	20	4,395
Caracol	17	3,736
La Honradez	16	(3,516)*
Nakum	16	3,516
		21,095

*Replaced by Kinal during the Classic, and thus excluded from the sum.
Source: Calculations by authors.

take on some aspects of both dispersion (the peripheral centers) and aggregation (the satellite centers), which averaged out as spatial randomness. Inspection of our map of the Tikal region (Figure 2), for example, shows both dispersed peripheral centers (particularly to the south) and clustered places at the center of the region. In the central Yucatan zone, we can say (as before) that the evolutionary sequence was basically the same, only it occurred one period ahead of the same sequence in the central Peten. By the Early Classic, a spatially random pattern had developed, and by the Late Classic, the pattern was tending toward dispersion (completing what was, perhaps, a 1,500-year cycle of dispersion to dispersion). The Late Classic pattern was coterminous with a size distribution tending toward pluralism; in short, growth had dispersed spatially to intermediate-sized centers at the expense of the major ceremonial center. Several hypotheses may be offered for this dispersion. One is that the major ceremonial center, along with its satellites, stagnated, leaving growth to the peripheral centers. Another closely associated interpretation is that toward the end of the Classic, interurban isolation followed social disintegration, leaving each center to grow by itself (thus limiting each, as in the beginning, to its own resource base). This last stage of the central Yucatan zone model—the only stage for which data are actually available—remains something of a puzzle nonetheless. One wonders whether the process of metamorphosis, which we have posed, is more valid than a process of chrysalis, in which the system grew over time but maintained the same form. There appears to be more evidence for metamorphism in the Tikal-Calakmul zone than in the Rio Bec-Chenes zone. Finally, there is also the possibility of different paths producing the same final forms. Here, however, we are only suggesting those evolutionary sequences which seem to be implied by our particular analytical approach and results.

DERIVATION OF HIERARCHICAL TRIBUTARY REGIONS

Using the best-controlled sample region, the Tikal region, we can now proceed to derive a hypothetical set of political-economic tributary regions as interpreted from the hierarchical urban patterns elicited by our procedures. As in the previous section, the chronological control is such that we are dealing with the Late Classic (A.D. 600–900). The results of our analysis indicate a possible modification of our original hierarchical classes. Because these classes were originally created for convenience in analysis for all regions, we have specified more precise points of division for the Tikal region.

Tikal is clearly the only candidate for the regional capital. It was probably more than that, considering its size, which is twice that of any other known site. We suggest that at one period in the Classic, it may have also dominated the Calakmul and Rio Bec regions to the north, the Belize area to the east, and the Pasion zone to the south. This would be a total area of more than 100,000 km^2. Naranjo, within a day's journey of Tikal and located on the western edge of the Belize zone, would be a logical administrative center through which Tikal could have exercised control over the eastern territories (Belize). Thus, it would share part of the 100,000 km^2 allocated to Tikal.

Below Naranjo, there appear six centers with approximately the same number of courtyards (16–23); with one exception they are distributed in such a way as to suggest that they were administrative centers at a hierarchical level subordinate to Tikal-Naranjo, dividing the total Tikal region among them. Two of the centers are unusually close in location, La Honradez (16 courtyards) and Kinal (20 courtyards). We suggest that this represents a case of replacement of one administrative center by another during the Classic, and that the total area of the Tikal region was thus subdivided into five districts at this subordinate level. This subdivision would yield an average territory of 4,219 km^2 each. Undoubtedly, idiosyncratic factors intervened and administrative districts were uneven in size. An approach to this question is suggested below.

Rands and Bishop (personal communication) have done studies in the Palenque zone which indicate a maximum area of political control for that center somewhat larger in magnitude than that of the secondary centers of the Tikal region. Marcus's studies of the distribution of Palenque emblem glyphs also define an area larger than the average for the Tikal centers (1976:106–121). It should be remembered, however, that Palenque (15? courtyards), although it may be comparable in size to the Tikal secondary centers, was the most important city of the region: a capital. The Tikal secondary centers were subordinate to Tikal.

We suggest that the uneven distribution of land among the Tikal secondary centers can be estimated using a ratio of courtyards to sustaining area derived from an independent analysis. The total number of courtyards in Tikal secondary centers is 96. Dividing this into the total territory of 21,095 results in an *average* ratio of about 1:220 km^2 (1:219.73). Table 6 presents the suggested uneven distribution of territory among the Tikal secondary centers.

Lacking direct and independent information from these sites, we can only urge that further work be done to produce such information.

SUMMARY AND DISCUSSION

In this paper we have used a rank-ordered set of Maya cities as a basis for the application of certain other analytical techniques, chiefly derived from geography. Four regional areas defined by architectural styles and by spatial contiguity have been set up for testing. These regions represent subdivisions of two major zones, the central Peten and the central Yucatan zones. The Tikal and Calakmul regions constitute the first, and the Rio Bec and Chenes regions, the second. These regions were chosen on the basis of size of sample (number of cities) and reliability of data (maps). The rank-size rule was applied to each of the regions, and in no case did a primate pattern result. The Tikal and Calakmul regions both exhibit more or less standard lognormal distributions. The Chenes and Rio Bec regions show strongly plural distributions which, in turn, usually reflect collapse of strongly hierarchical patterns. We have suggested that cultural evolutionary differences are being manifested in the different end products. Two distinct urban development sequences have been outlined, which account for the two patterns.

The overfilled category of the second-level cities in the pluralistic distributions presents an explanatory problem. We suggest closure of the local systems headed by these cities as one explanation of the phenomenon. Sequential political dominance is an alternative explanation. Local closure after the fall of a city from dominance may be a composite explanation.

Regions defined by spatial contiguity criteria may approximate ancient economic and political systems. It is here posited that Tikal and Calakmul represent the capital regions of competing states, whose stable areas were as drawn herein. These states are further defined by the hierarchical relationships among the cities of the region. The states' boundaries are somewhat obscured by the lack of temporal control on periods earlier than the terminal Classic from which most of the data derive. We hypothesize, however, that Calakmul and Tikal dominated areas far beyond their immediate areas, even though that domination may have been ephemeral and shifting in nature. The domination of the Rio Bec region by Peten-style ceramics during the fifth and sixth centuries A.D. (Ball 1977:170–171) possibly represents the extension of the Calakmul state into this region. The frequent mentions of Tikal in hieroglyphic notations at Dos Pilas in the Pasion region may well indicate the southern extent of the Tikal state. The eastern site of Naranjo, especially in the seventh century A.D., mentions Tikal frequently (Graham and Von Euw 1975; Graham 1978), indicating close political ties. Both Dos Pilas and Naranjo are large sites (the former unassessed in size) and, judging by their secondary or better status, could have acted as administrative subcenters for Tikal in their respective regions.

As far as our data seem to bear on the Marcus cosmological model, there certainly seem to have been two regional states at Calakmul and Tikal during the Late Classic. There is every evidence, however, of two or more contemporary regional states north of the central Peten zone and at least three more centered on Copan, Palenque, and Yaxchilan to the south.

The northern regions herein considered, Rio Bec and Chenes, are geographically separated by an apparent gap in urban distribution, even though they are closely tied together in architectural style. It is not certain whether this gap is a function of lack of reconnaissance or is real. In any case, the plural distribution of the cities of these zones indicates a lack of centralization of control and a replication of local city forms and probably political forms. We suggest that a feudal model for Maya society is especially compatible with the spatial patterning of these two zones (Adams and Smith 1981).

The Rathje "core-buffer" hypothesis is bolstered by the relatively greater complexity of urban development in the "core" Tikal-Calakmul region compared with the "buffer" central Yucatan region. As pointed out, however, the greater development of urbanism and state political apparatus in the Tikal-Calakmul region could be the result of a situation analogous to the development of secondary industrial states. This is not necessarily incompatible with the hypothesis. Should Belize turn out to have been precocious in Preclassic development, Tikal could fill the secondary development role nicely.

The ecological theories espoused by Sanders and Price (1968) and others (viz. Adams 1973), which hold that the Maya were underdeveloped in urban centers and in political forms, seem untenable on grounds other than those we have used here. High density and permanent and completely organized populations have been indicated by much of the recent work on Maya centers (Haviland 1970; Kurjack 1974; Adams 1977). Our analysis of Maya centers in this paper has treated them as cities, and the patterns elicited by the exercise have been congruent with this interpretation, as might be expected if they were, indeed, functional cities.

We have presented a series of techniques of analysis with which to deal with the urban patterns of the Maya and with which to approach various assessment and evolutionary problems. The results, we believe, are striking and provocative enough to warrant further use. As is usually the case, there is a need for more and better data; in this case more and better mapping. The rapid acquisition techniques of side-looking radar and infrared photography will help, but they can never replace the important drudgery of on-the-ground mapping.

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