The Geographic Analysis of Ancient Maya Settlement and Polity

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Introducation

Many elements of ancient Maya culture — language, art, ecology, economics, politics — have a geographic aspect and can be profitably investigated through geographic analysis. We are developing a geographic information system (GIS) for the purpose of studying prehistoric Maya settlement and society. The GIS is composed of archaeological, epigraphic, and locational data. It includes the whole Maya area and is designed for the study of regional issues, such as political organization, dialectology, and material culture.

Although the GIS has many possible uses, we have two overriding goals that have determined it structure and design. Those goals are:

1. To identify social, economic, and political systems, including polities, using settlement data and epigraphic data; and

2. To test theoretical models of settlement patterns by identifying and predicting settlement patterns in unsurveyed areas.

In the next section, we will present some basic information about Maya history and culture that is necessary to understand the remainder of this article. Then we will explain the theoretical background of our research, which provides the intellectual context and justification for the questions we have posed. In the remainder of the paper we explain our methods, data, and results.

THE ANCIENT MAYA

With the exception of the Huastecs of northern Veracruz, the ancient Maya lived in a contiguous region encompassing the Yucatán Peninsula (including the Mexican states of Yucatán, Campeche, and Quintana Roo, and the country of Belize), the eastern parts of the Mexican states of Tabasco and Chiapas, all of Guatemala, and the western portions of Honduras and El Salvador (Figures 1-2). The Maya lowlands constitute most of this area. Lowland Maya culture was distinctive, especially during the Classic period (A.D. 250-950). The Maya highlands of southern Chiapas and Guatemala were somewhat peripheral to the Classic Maya florescence. Most of the problems and analyses that we discuss below concern lowland Maya culture, although the GIS includes data from the Maya highlands, too.

The origins of Maya culture remain elusive. At present, there is no evidence for an in situ evolution from Archaic hunters and foragers in the Maya lowlands. In the early Maya archaeological components, there appear to be some links to the earlier Olmec culture, but the connections tend to be general and stylistic. The actual Olmec occupation of the Maya area is quite limited. There are also influences from the Maya highlands in the south. The earliest direct evidence of ancestral lowland Maya culture dates from the Middle Formative period (ca. 1000 to 300 BC) in northern Belize (Andrews V and Hammond 1990; Hammond et al. 1991:55-60). The early Swasey phase there, and other Middle Formative lowland Maya phases, do not closely resemble any of the various Early Formative village cultures of Mesoamerica or Central America.

During the Late Formative period (300 BC to AD 250), Maya culture flowered. Many of the great Maya sites have massive Late Formative occupations. At this time, most of the distinctive elements of Maya culture coalesced, including the art style, the architectural style, and the famous hieroglyphic script.

During the Classic period, the Maya built large cities dominated by massive public and ceremonial architecture. Major building types include multi-story palaces with scores of rooms arranged around quadrangular courtyards and towering pyramids topped by small temples. The pyramids often contain royal or noble tombs, and the temples were often dedicated to ancestor worship. The cities encompassed substantial residential populations, although they were not as densely populated as an orthogonally-organized, planned urban district. The settlement patterns, although always distinctly Mayan, vary regionally along with geomorphology and house forms. The public and ceremonial areas of the cities are the locations of most of the monumental, carved inscriptions, which mostly discuss dynastic, historical, and sometimes religious topics.

There is currently an active debate about the language(s) of the inscriptions (Houston, Robertson, and Stuart 2000). Some believe the language to be proto-Chollan, while others think it is proto-Yucatecan, and there is a distinct possibility that the language varied regionally. It has also been suggested that the inscriptions were written in a kind of lowland Maya lingua franca. This is an issue that really has to be studied through geographical (i.e., dialectological) analysis.

As it turns out, the Maya script proved intractable for many decades because it was a remarkably complicated writing system — a complex mix of logographs with a phonetic syllabary. Epigraphers can now transcribe and translate the majority of hieroglyphic phrases and expressions. The syntax has been largely disentangled, too, thanks to intensive study of the modern Maya languages.

The recent success in reading the inscriptions has revealed that most of the textual content (of the monumental inscriptions, not the codices) was historical, rather than religious or astronomical. The extraordinary Maya calendar was the first part of the inscriptions to yield to decipherment, beginning in the nineteenth century. The correlation between the Mayan and Christian calendars is now well established. One of the first indications of the historical content of the inscriptions was Heinrich Berlin's (1958) discovery of "emblem" glyphs, which seem to be the names of sites, or possibly of their ruling lineages. Berlin's analysis revealed a geographic pattern of glyphic occurrence: emblem glyphs tend to appear at their reference sites, and rarely at other sites. The subsequent recognition of dynastic records yielded glyphs for birth, accession to the throne, and various political titles (Proskouriakoff 1960). The reading of the monumental inscriptions, thus, has produced precisely dated registers of kingly (and queenly) succession, references to wars, royal marriage alliances, conquests and defeats. Thus, in the Maya area, we have a historical record from the only fully literate ancient civilization in the Americas. But even these remarkable texts leave us with only an outline of history. Much research and interpretation remains for us to be able to fill in the outline with substance and detail. Much of this analysis, particularly of political geography, requires a systematic geographical approach, such as that offered by GIS.

The hieroglyphic texts, however, can only offer a partial picture. In some places, they have eroded, been looted, never existed, or cannot be read. Therefore, we must turn to other sources of information in our study of cultural and political geography. Maya architecture is complex, ornate, and symbolically rich. Architecture varied in style from one region to another. Well known regional styles include the Peten, Puuc, Chenes, Río Bec, Southeastern, Usumacinta, and Western styles. Other Maya arts also exhibit complex geographical patterns of stylistic and technological variation whose study can contribute to our understanding of the ancient economy, trade, and even political relations.

The Classic period ended with a significant depopulation of the southern Maya lowlands accompanied by a cessation in the erection of monuments with Long Count dates. The so-called Maya collapse did not take place instantaneously, but over a century or more. Some cities, particularly in northern Yucatán and eastern Belize, seem to have sustained a Maya culture for centuries after the first major cities were abandoned (Pendergast 1981). The collapse was associated with — coincidentally, if not causally — waves of Mexican influence. The Postclassic period, which lasted until the Spanish conquest, produced a vibrant and interesting mix of Mexican and Maya cultures that flourished both in northern Yucatán and in the southern Maya highlands. Although separated by the still-abandoned central Maya lowlands, these distinctive cultures shared many characteristics.

THEORETICAL BACKGROUND

One of the most persistent and impassioned debates in Maya archaeology is about the scale and character of Maya political organization. The argument about whether the Maya had states is a point of theoretical importance, the debate may be traced back to the early nineteenth century. John Lloyd Stephens thought the Maya had big cities and dynasties (e.g., Stephens 1841:II: 355-356), but Louis Henry Morgan argued that they were village people living in long-houses like the Iroquois (Morgan 1908:11, 186). E. H. Thompson (1892) refuted Morgan quite effectively by presenting archaeological data on house mounds. In the first half of the twentieth century, Eric Thompson and Sylvanus Morley thought that the Maya had small states, like the classical Greek or medieval Italian city-states (Marcus 1993: 111, 113). In the theoretical ferment of the 1960s, the argument raged about whether the Maya were chiefdoms or states. The idea that Classic Maya polities were chiefdoms has largely been abandoned. The debate continues about whether the Maya were segmentary states, pulsating galactic polities, or unitary bureaucratic states. The main points in this dispute include a) the size of Maya states (i.e., small city-states or regional polities), b) their internal organization and complexity, c) the role of kinship in politics (Demarest 1984, 1996; Fox et al. 1996).

These debates have relied upon the interpretation of several bodies of data: epigraphic, ethnohistoric, and archaeological. Some of the key arguments that have been made, and that we wish to address with our GIS, relate to the size of polities and settlement pattern theory.

Size of Polities

The size (i.e., territorial extent) of ancient Maya polities, which seems likely to be related to their internal structure and complexity, has been a matter of significant disagreement among scholars. On one hand, Marcus (1976, 1993:139-140) has argued that the Classic Maya (in Cycle [or baktun] 9 [A.D. 435-830]) had large, regional states. This argument was built on the following evidence:

A four-tier hierarchy of sites, as opposed to a three-tier hierarchy in Cycle 8;
Presence of palaces, as indicia of the increasing ritual isolation and growing economic and political power of kings;
Secondary centers form hexagonal lattices around major centers, like those predicted by Central Place Theory for a hierarchy that maximizes administration; the average distance between the major and secondary centers is 27.8 km (Figure 3);
Distribution of Emblem Glyphs: subordinate centers refer to major centers, but rarely the reverse (Marcus 1993: 144-145) (Figure 4);
Use of different accession glyphs in primary and secondary centers (Marcus 1993: 141; see also Bricker 1986);
Dynastic marriage alliances indicating relations between sites;
Economic specialization of smaller settlements (Marcus 1993)

Evidence that may also support this hypothesis comes from Harrison's discovery (Harrison 1981) that centers were distributed with some uniformity in southern Quintana Roo, adjacent to the area where Marcus identified a hexagonal-lattice settlement structure. Harrison found in his study area that large centers were spaced about 26 km apart and the medium-sized center occurred at 13-km intervals (Figure 5).

Mathews, in contrast, has argued for much smaller polities in the Maya lowlands. He believes that one can identify the size of polities by drawing Thiessen polygons around sites that have their own emblem glyphs (Mathews 1991; Mathews and Willey 1991). This method results in the awkward result that the largest sites sometimes have the smallest polities because large sites with emblem glyphs tend to cluster in spatially autocorrelated groups. In fact, in this model, there is a tendency toward an inverse relationship between the volume of civic-ceremonial architecture and geographic extent of the polity. This pattern develops because population centers tend to cluster, with numerous second and third rank sites – some with their own emblem glyphs – surrounding the largest sites. Thus, emblem glyphs seem to have proliferated in some of the most highly developed and heavily populated areas.

We also believe that the geographic distribution of superordinate/subordinate titles, like *ahau* vs. *cahal* (or *sahal*) (Schele and Mathews 1991:251-252; Sharer 1994:246-250) may reflect dominant - subordinate relations between different sites and, therefore, may provide clues to the size and structure of polities.

It has been suggested (e.g., Adams 1981:251-252) that the use of the rank-size relationship in the study of regional settlement patterns can help determine the composition of political and economic units -- polities. The rank-size rule is an empirical observation that expresses the relationship between settlement size (population) and rank (its numerical position in the series created by ordering all the settlements in the system from large to small). The idea that settlement size and rank have a systematic relationship was popularized by Zipf (1949), who expressed it as:

(1) $P_r = \frac{P_1}{r^k}, r = 1,2,\ldots$

where P_r is the size of the settlement of r-th rank in the system and k is a constant, which is typically of the magnitude of 1, in the ideal case described by Zipf. The exponent k is calculated empirically by plotting the logarithm of rank against the logarithm of size: k is the slope of the best-fit line. The rank-size rule has been applied to archaeological data in various contexts (e.g., Cavanagh and Laxton 1994; Hodder 1979; Laxton and Cavanagh 1995). It is noteworthy that this is an empirical rule and does not depend on any sociological theory, like Zipf's "Law of the Least Effort." Rank-size has been used to analyze ancient settlement data from the Maya area and other parts of Mesoamerica (Adams 1981; Hammond 1974; Kowalewski 1990; Kowalewski et al. 1983). The deviation of settlement systems from the expectations of the rank-size rule has been studied as well (Hodder 1979; Zipf 1949:416-444), for example, primate settlement systems that may be related to colonialism. Consequently, use of the rule is not merely a mechanistic exercise, but an informative model of settlement. We believe that the application of the rank-size rule to the local settlement hierarchy in different regions of the Maya area may help establish the sizes of different polities by delineating those sites that participate in different settlement systems. The study of this phenomenon will also help us distinguish the presence of primate settlement patterns, which would indicate that certain sociopolitical processes were operating (like colonization) (Adams 1981).

Finally, Kurjack and Andrews V (1976) have analyzed another body of evidence that is clearly related to the issue of polity size and distribution: the presence of roads (*sacbeo'ob*) and fortifications. Roads link elements of the same polity, while fortified sites mark boundaries between polities.

Thus, in order to study the issue of polity size, structure, and location, we argue that, at a minimum, the following data should be compiled in the GIS: site ranks in a three or four tier system; site sizes; presence of palaces; location and spacing of centers; distribution of emblem glyphs; different accession glyphs and clauses; dynastic marriage alliances described in inscriptions; locations of roads; and presence of site fortifications. In sum, we are collecting and mapping all the data we can that are relevant to the question of polity sizes and their internal organization. Most of these classes of data will be discussed further below.

Settlement Pattern Theories

As we have discussed above, there is evidence for a highly patterned distribution of Mayan sites in the lowlands. We will call this, for convenience, the Central Place Model of Maya settlement. The evidence for this model takes the form of Marcus's (1976) discovery of the hexagonal lattice pattern of a four-tier hierarchy of centers, and Harrison's (1981) discovery of equidistant spacing of sites in southern Quintana Roo. These theories permit predictions of site locations in areas that have not been fully surveyed.

We also believe that Maya settlement is fractal in a variety of ways. Geographers have shown that many modern and ethnographic settlement patterns are fractal (Batty and Longley 1994; Batty and Xie 1996; Eglash 1999). Fractals are self-similar sets of fractional dimension. The theory of fractal settlement patterns is not incompatible with the Central Place Model. For example, Arlinghaus (1985, 1993) has shown that Central Place lattices, particularly the hexagonal ones, are ideal fractals. Settlement hierarchies that obey the rank-size rule are fractal because the rank-size rule is a fractal relation (Cavanagh and Laxton 1994; Laxton and Cavanagh 1995) (Figures 6-7). The size-frequency relation for sites in many settlement patterns, including some Lowland Maya data, is a fractal (power-law) relation (Brown 1999; De Cola and Lam 1993:17-19) (Figure 8). In addition, Brown has shown that lowland Maya intrasite settlement patterns are strictly and mathematically fractal, and that the fractality is structurally related to the ancient Maya kinship system (Brown 1999:169-177), which is conceptually self-similar (Figures 9-10). One use of the GIS will be to examine the fractality of Maya settlement on the regional scale. We have used the so-called box-counting method (Mandelbrot 1983; Peitgen et al. 1992:212-219) to perform the actual calculations (Leibovitch and Toth 1989; Sarraille and Myers 1994).

We will use these models of settlement to predict site locations in areas that have been surveyed poorly or not at all. We hope to test such predictions through actual, archaeological fieldwork. In conjunction with the predictions of site location, we will use the GIS to identify gaps in our existing knowledge of site distributions and to address basic problems of cultural-historical integration. There are large areas in which not only are sites not known, but also in these same areas (obviously), there are major gaps in our knowledge of architectural styles, ceramic spheres, lithic spheres, and so forth. In some of these areas, it appears that multiple ceramic spheres and architectural styles overlap. It will be important to use the GIS to plot the distribution of modes and attributes, not just major types (be they building types or ceramic types), in order to understand the nature of ethnic interactions in these areas. For example, both the sharpness and the character of the stylistic boundaries may tell us something about relations among political and cultural entities (Hitchcock and Bartram 1998:47-48; Hodder 1979). Similarly, the types of modes and attributes that area shared among sites or that differentiate them may help us understand the relationships among the communities. We also hope to examine stratigraphic relationships among the architectural and ceramic styles in the areas of overlap.

METHODS

Software

We have chosen the ArcView version 3.2 geographic information system by ESRI for mapping and spatial analysis. Its features include entry of data by several mechanisms (keyboard entry; import of previously constructed databases; digitizer entry; and direct visual entry onto the map). It further permits the reconciliation of a variety of coordinate systems into a single standard (decimal degrees) that can then be re-projected in a variety of formats. It also permits direct output to a size E plotter for printing.

Data selection features permit the inclusion or exclusion of individual sites based on their characteristics in the database (all shell middens; all sites with Polvero Black pottery; all sites above 500 feet elevation above rank 3, and so forth). Scripts for drawing Thiessen polygons and calculating the nearest neighbor statistic are readily available.

Spatial analysis to test theoretical models is made possible in ArcView by the powerful scripting language "Avenue". Using this language, for example, it is possible to readily construct analytical polygons and distance computations as a part of their graphic display.

We are storing much of our data in an MS Access relational database. It was chosen for its wide availability, ease of use, and ability to import data in a variety of formats, as well the ease with which one can exchange data with ArcView GIS. Obviously, it is undesirable to burden the ArcView system with large quantities of data that may not be required for an individual graphic analysis. MS Access provides the basic data holding-data extracting mechanism for our system.

In addition to the major software components above, we use Microsoft Excel to perform the transformation of UTM coordinates (in which many site locations are recorded) into latitude and longitude, and for the import of some digitally scanned, tabular data.

We are using ESRI's "Digital Chart of the World" (DMA 1992; ESRI 1993) shape files and coverages as data for our base map. This provides accurate information for modern settlements, roads, shorelines, water features, railroads, elevations and landform data. It provides the base layer data on which our archaeological data and analyses are overlaid.

We find that this combination of software and data provides accuracy, precision, and reasonable performance on the microcomputers at our disposal.

Data recorded

In this section, we describe in greater detail the data we are compiling in the GIS. We explain some of the problems we are encountering and our solutions to them.

Site Locations

We are recording site locations in decimal degrees of latitude and longitude, and, as described above, converting them from other coordinate systems as necessary. Accuracy of site location is a traditional problem in the Maya lowlands because of dense vegetation, lack of permanent landmarks, and other difficulties of travel, survey, and orienteering. Some major sites, of which Río Bec is the most famous, have been "lost" for long periods of time. Accuracy refers to the absolute correctness of the site locational data, that is, whether it represents the true position of the site on the ground. The accuracy of the data is variable. For data collected by GPS receiver, we expect an accuracy of perhaps 100 m, or sometimes much less. For data digitized from older atlas maps, the accuracy may be as poor as 500 to 1000 m.

Most Maya sites – or at least those that have been recorded – are rather large. Few sites smaller than 1 ha have been recorded individually; individual mounds or *plazuela* housemound groups are rarely registered separately, and often where there is more than one group of housemounds, the site exceeds 1 ha in size, often by a great deal. In short, we hope and expect that, in almost every case, the accuracy of the data will suffice to relocate sites on the ground. We are making every effort to include the most current information available. We are evaluating contradictory and inconsistent site location data both on a case-by-case basis and by considering the quality of the source. Generally, we refer to original, detailed sources to determine which of several locations is the most accurate. We are concerned about the security of the site location data, and we are taking steps to ensure that they do not become publicly available.

Site Rank

We are recording site rank in a four-tier hierarchy, with Rank 1 the largest and Rank 4 the smallest (Figures 11-14). The choice of four tiers is related both to the theoretical questions asked of the data (see discussion above of Marcus 1976) and to the use of the same system by Garza and Kurjack in the *Atlas Arqueológico del Estado de Yucatán* (1980) and other authors. These data are not "rank" data in the sense contemplated by the rank-size rule. Actual site size, or population, which is appropriate to the rank-size rule, is usually not available for Maya sites. Only a small number of scattered sites have been completely mapped. Proxies for site size include courtyard counts (Adams 1981), volumetric assessments of architecture (Turner et al. 1981), and number of monuments (Mathews and Willey 1991). Although none of the proxies are entirely satisfactory, we will enter them in the near future in order to calculate the rank-size relation and the associated fractal dimension.

Site Function

Site function is an indispensable element in the study of settlement patterns and their use to infer the complexity of society. Site functions include shell middens (a form of resource procurement); caves (water sources, major ritual locations in the sacred landscape); *sacbe'oob* (roads; transport); quarries (for building, for marl, for monuments, for lithic material for chipped stone tools); and fortifications (defense) (Figure 15). Most Maya sites, especially the larger ones, were obviously multi-functional, and those functions included residence, ritual, and administration.

Chronology

We are recording chronological information about sites in several ways. We are recording Long Count dates in the Maya calendar. The Long Count dates are discussed below under the rubric "epigraphy".

We are entering absolute dates such as radiocarbon and obsidian hydration dates. These are associated with specific components and sometimes structures. We are also collecting chronological information in terms of archaeological periods (e.g., Late Formative, Early Classic, Late Postclassic) so as to be able to filter site data into contemporaneous groups. We also are collecting chronological data in the form of ceramic complexes, which are somewhat more precise than periods. In fact, we create individual records for each component or occupation of a site. Obviously, most of the theoretical questions asked in the earlier portion of the paper require either synchronic (contemporaneous) data sets or the ability to deal with the temporal dimension of dynamic models.

Ceramics

We are including ceramic data for both chronological and regional analysis. When available, we will include the ceramic sphere and complex. We expect to add ceramic types, varieties, and modes in order to examine these data geographically. Concepts such as "ceramic spheres" and even "types" are subject to empirical geographical analysis, refinement, or even falsification. For example, the intersection, interpenetration, and stratigraphy of the Cehpech/Sotuta ceramic complexes with the southern Campeche complexes, like Bejuco (Ball 1977), are still somewhat mysterious and would benefit from a detailed geographical analysis. In many cases, the ceramic data should be entered (or calculated) as percentages or Brainerd-Robinson coefficients rather than as raw frequencies for intersite or inter-component comparisons. The ceramic data should include, as time and resources permit, elemental data from Instrumental Neutron Activation Analysis of selected types of archaeological ceramics.

Lithics

Our plan to include lithic data is similar to that for ceramic data, and its underlying logic and motivations are the same. The appropriate data are lithic tool types, reduction sequences, complexes, spheres, and raw materials. Lithic materials in the region include a variety of cherts, for some of which the sources are known (Figure 16); obsidian, all imported from outside the Maya lowlands, mainly from known and elementally-characterized sources; jadeite; and ground stone, much local, some imported. These data, like some of the ceramic data, are very useful for mapping trade patterns. The same is true of other types of artifacts, like bone and shell. The presence of workshops devoted to the production of finished commodities from these kinds of raw materials sometimes indicates the presence of economic specialization in different settlements.

Architecture

The elaborate architectural styles of the Maya have been intensively studied and categorized into regional expressions of geographical and chronological interest, such as Río Bec, Chenes, Puuc, Petén, "Petén Corridor," Western Area, and Belize, some of which are sometimes combined into larger units (i.e., Central Yucatán style) (Pollock 1965; Potter 1977). The evolutionary, chronological, and ethnic relationships among the regional styles are of great interest, but are poorly understood. Some of the major gaps in our knowledge revolve around areas that lack data. We believe that some important problems will be susceptible to geographical analysis using GIS. For example, Paul Gendrop, one of the greatest students of Maya architecture, attempted geographical analysis of Maya architectural attributes using essentially pencil and paper. Notwithstanding his very interesting results (Gendrop 1983; 1985), we think the same problems can be better addressed using GIS. We envision including detailed data on architectural attributes related to the regional styles, like types of moldings, types of columns/pilasters, types of capitals, types of masonry (Puuc veneer stones), vault shapes and styles, types of mortar, iconography of stucco-work, style/iconography of mosaic architectural sculpture, types of chultunes, etc, etc (the list is endless).

Epigraphy

To solve the theoretical questions proposed earlier in this paper, we must make use of a variety of epigraphic data (Figure 17). The relevant data consist of the corpus of inscriptions. The codices are generally irrelevant because their proveniences are not known. We originally intended to incorporate a limited number of graphemes or clauses (such as emblem glyphs, long count dates, and titles), their transcriptions (into the system of "Thompson numbers" [Thompson 1962]), and their semantic values or translations. Now, however, the Maya Hieroglyphic Database project, under the direction of Martha Macri at the University of California at Davis, has developed a database of the complete corpus of inscriptions.

Her database contains of images each glyph block, transcriptions, and translations. We are discussing with Dr. Macri and her collaborators the possibility of linking to her database rather than trying to duplicate a subset of it. This would provide her with the ability to perform geographical analyses of the distribution of graphemes, orthography, and ultimately, of the language and dialects of the inscriptions. The Macintosh format of the hieroglyphic database will make importing it into MS Access a bit of a challenge, but not an insurmountable one. The hieroglyphic database is in the form of a single data matrix; it does not have multiple tables or internal relations or joins. This simple structure means that it would be relatively easy to link it to our master archaeological site data table. We expect to be able to link the hieroglyphic to our database through a site name or site number field. We look forward to being able to study the inscriptions geographically: it would be a great advantage in the study of the linguistic affiliation of the inscriptions.

Bibliography

We tag our data with the bibliographic reference from which they derive. As a consequence, we sometimes have several references associated with a single site, especially large and important sites.

ANALYSES

We propose to perform several analyses with these data using the software we have described to address the questions we have posed. These analyses include:

1. examining the uniformity of Maya settlement and, in particular, how well it conforms to the hexagonal lattice structure predicted by Central Place Theory for the maximization of administration;

2. drawing Thiessen polygons among sites that have Emblem Glyphs and calculating the areas of the resulting polities;

3. measuring the fractal dimension of regional settlement, using the box counting method, for different portions of the Maya area where good survey coverage exists;

4. measuring the fractal dimension of the rank-size relations for areas where appropriate data are available;

5. predicting site locations in unsurveyed areas using the results of the first four analyses.

We will also use the GIS to examine geographic distributions of ceramics, lithics, architectural elements, and other artifact types and varieties to see how they relate to polity boundaries. Similarly, we will examine trade patterns using data such as that available on raw material sources (i.e., obsidian, shell, chert, etc.). We will also study the geographic distribution of graphemes and glyphic collocations.

CONCLUSIONS

Results

Since we are still entering and editing site location data, it is too early to present most of the results of our analyses. Nevertheless, we can describe two analyses that we have begun. First, we have identified a number of major gaps in archaeological survey. One is in the approximate middle of the Yucatán Peninsula (Figure s 18-19). It begins a little north of the point where the three states of Yucatán, Campeche, and Quintana Roo meet, also known as the "Punto Put" after the name a little village. The *terra incognita* continues south along the border between Campeche and Quintana Roo to a point some distance north of the Chetumal-Escárcega highway, where it approaches the Río Bec region around Becan and Xpuhil, which has been surveyed. There are smaller gaps in the data in Quintana Roo and in parts of the Department of Petén, Guatemala. The existence of gaps like these is not news, but the GIS will help us predict the location of settlement within them. The archaeological fieldwork will then serve to evaluate the hypotheses about the location of settlement.

Second, we have begun using the GIS to identify and study fractal patterns of Maya settlement. To evaluate fully the fractality of Maya settlement, we would like to map every structure in some large region and then test to see if the pattern is self-similar and scale invariant across all scales of observation. Because this is a practical impossibility, we must resort to the examination of a variety of data sets that contain data at more restricted ranges of observation. We have begun with one set of regional data: the point locations of archaeological sites in the state of Yucatán. We have examined the spatial distribution of these sites to see if they form a pattern that is geometrically fractal.

A geographical distribution of points or objects can be fractal. A set like this is fractal when the pattern is self-similar and of fractional dimension. In the case of a pattern that is embedded in two (Euclidean) dimensions, self-similarity is commonly expressed as hierarchical, nested clusters, that is, clusters of clusters of clusters, *ad infinitum*. The fractality can be ideal or statistical. With empirical data sets such as ours, the fractality is usually statistical. This is the kind of fractal pattern that a distribution of sites across a landscape may exhibit.

The method used to evaluate the fractality of this kind of phenomenon, and to calculate the fractal dimension, is called the box-counting method. It is logically and methodologically linked to the Hausdorff-Besicovitch and capacity dimensions and normally provides an accurate estimate of them. The idea is this: one overlays a grid of squares on the points or curve to be measured, and one counts the number of boxes crossed by the curve. The number of squares, N, required to cover the curve will depend on their size, s, so N is a function of s, or we can write $N(s)$. Now one reduces the size of the grid repeatedly, recording the two variables, N, and s. One plots the log of $N(s)$ against the log of s. Let the slope of the least-squares regression line be d. Then the fractal dimension is $D = - d$.

This procedure is difficult to perform by hand, but it is easily automated. A number of programs exist that perform some or all of the process, including scripts for some GIS applications. We have not written a script for this yet in ArcView. Instead, we used a program written by DiFalco and Sarraille called FD3 (Sarraille and Myers 1994) that was "inspired by" an algorithm devised by Leibovitch and Toth (1989). This program takes as input a series of coordinates for points, with one set of coordinates for one point on each line. The number of columns depends on the embedding dimension of the figure; our embedding dimension was 2, just x, y coordinates describing the locations of archaeological sites.

To estimate the fractal dimension of Maya settlement on a regional scale, we chose the part of the Maya area that has been most completely surveyed: the state of Yucatán, México. We combined the data in the *Atlas Arqueológico del Estado de Yucatán* (Garza T. and Kurjack 1980) with the supplementary data in Dunning (1992:Table 5-1) to create a single list of 1197 sites in the state of Yucatán. So far as one can tell, all appear to have been occupied contemporaneously, during the Late and Terminal Classic period. Even major Late Postclassic sites such as Mayapán, or Formative period sites such as Kom Chen, also contain Late Classic components. Of course, further research may reveal that some sites do not possess components of this period, but it seems likely that such sites will be few in number and would not alter the results of this analysis.

We converted the UTM codes from both works to a decimal degrees latitude and longitude format and used them as Cartesian *x,y* coordinates for input to the FD3 program. The program calculated a fractal (capacity) dimension of $D = 1.11$. Since this value is clearly a fraction, not an integer, the pattern is fractal. Maya regional settlement may be fractal because of the economic and political forces that made it conform to the patterns predicted by Central Place Theory for a hierarchy that maximizes administration (Marcus 1976). As mentioned before, Arlinghaus (1985, 1993) has shown that such Central Place lattices are ideal fractals.

Problems

The definition of sites is problematic in most of the Maya lowlands. The region could be a laboratory for the study of "non-site" archaeology. Most prehistoric Maya settlements exhibit a relatively low density of settlement for an urban area in their residential zones; these then blend imperceptibly into the rural hinterlands, which are relatively densely occupied for agricultural areas (see Culbert and Rice, eds. 1990). One consequence of this pattern is that site boundaries are difficult to define. A second difficulty is how to represent large sites, especially when their area is non-trivial in relation to the distance between sites. We have been representing sites as points, but we shall have to shift eventually to appropriate polygons, much as the modern settlement data is shown on our base maps. The final solution to these problems will be to map individual structures, but doing so will represent an immense investment of time and resources. Furthermore, as noted earlier, only a few sites have been "completely", or even substantially, mapped. Consequently, the size, shape, and other geographic characteristics of these sites are poorly known.

Geographic analysis of Maya civilization has for a long time been a secondary consideration or afterthought, although, ironically, for many years geographical issues like trade and settlement patterns have dominated Maya archaeology. Is it our goal to address questions like polity, settlement, and exchange from an explicitly geographic perspective. We will thereby bring a fresh (or at least refreshed) perspective to these fundamental problems.

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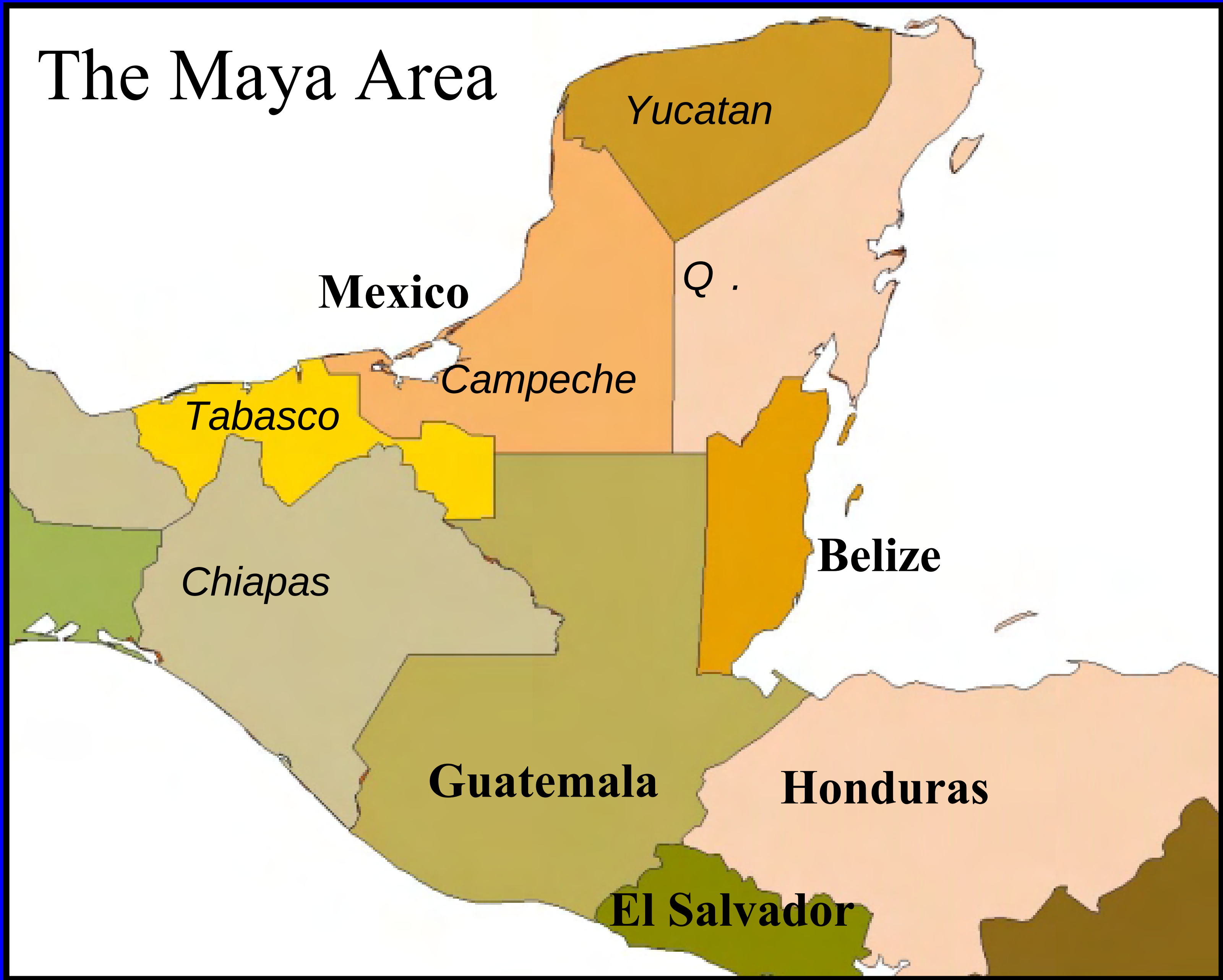
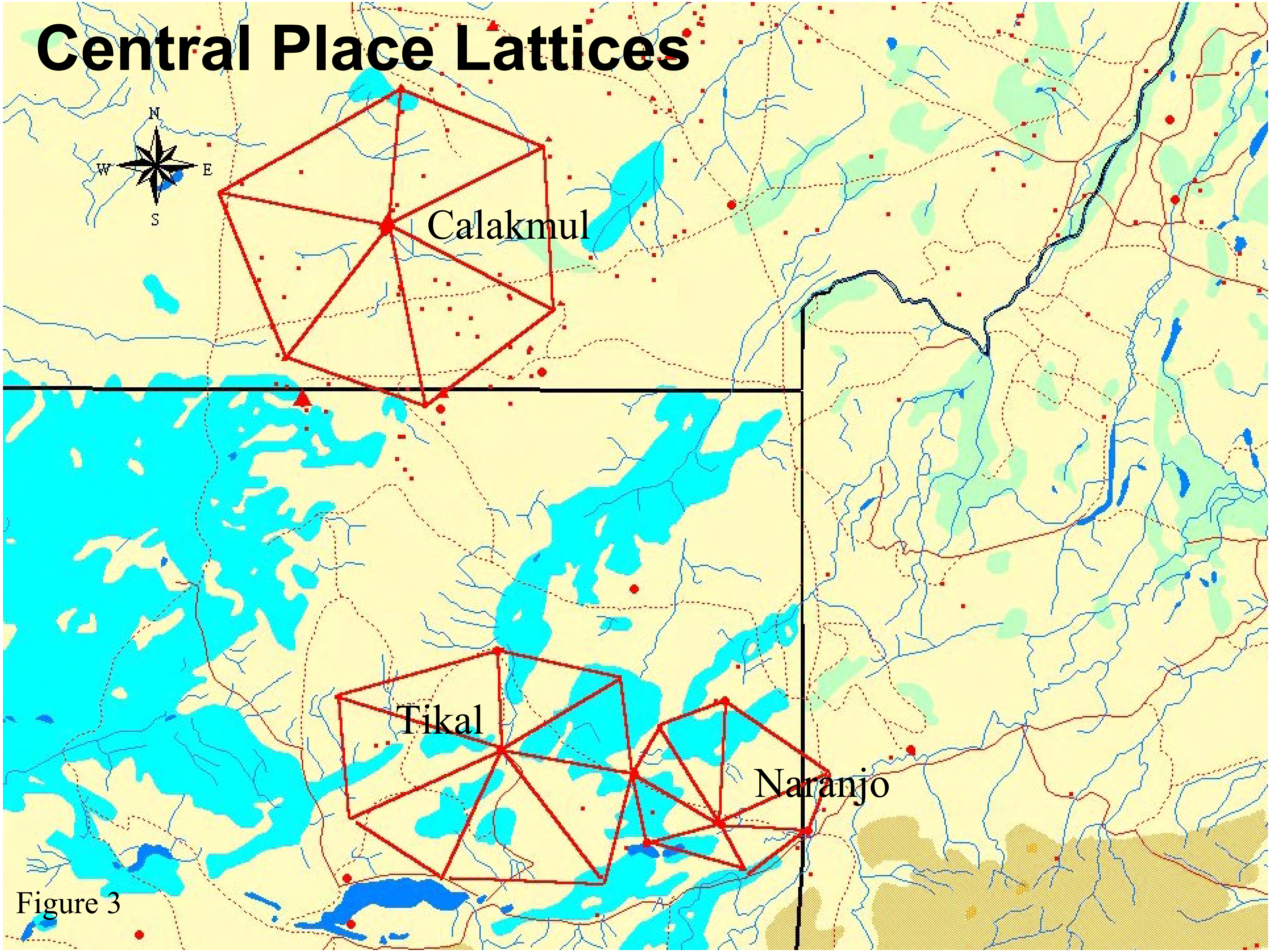
Figure 1

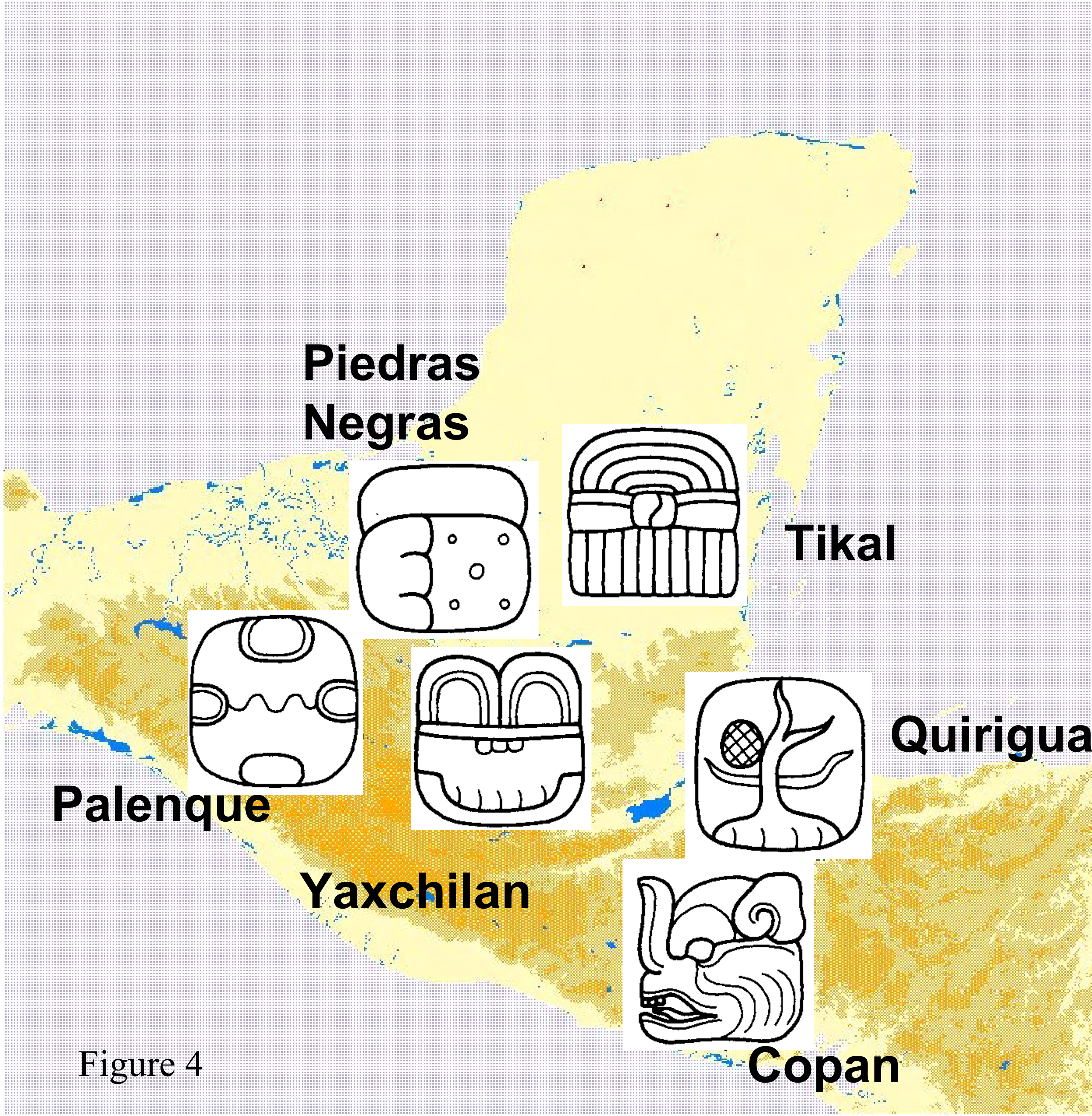


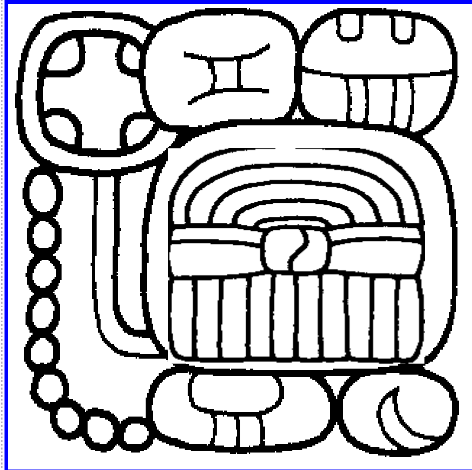
The Maya Area
Yucatan
Mexico
Q .
Campeche
Tabasco
Chiapas
Belize
Guatemala
Honduras
El Salvador

Figure 2


Central Place Lattices
N
W
E
S
Calakmul
Tikal
Naranjo
Figure 3

Structure of Emblem Glyphs





After Coe 1992

Figure 4

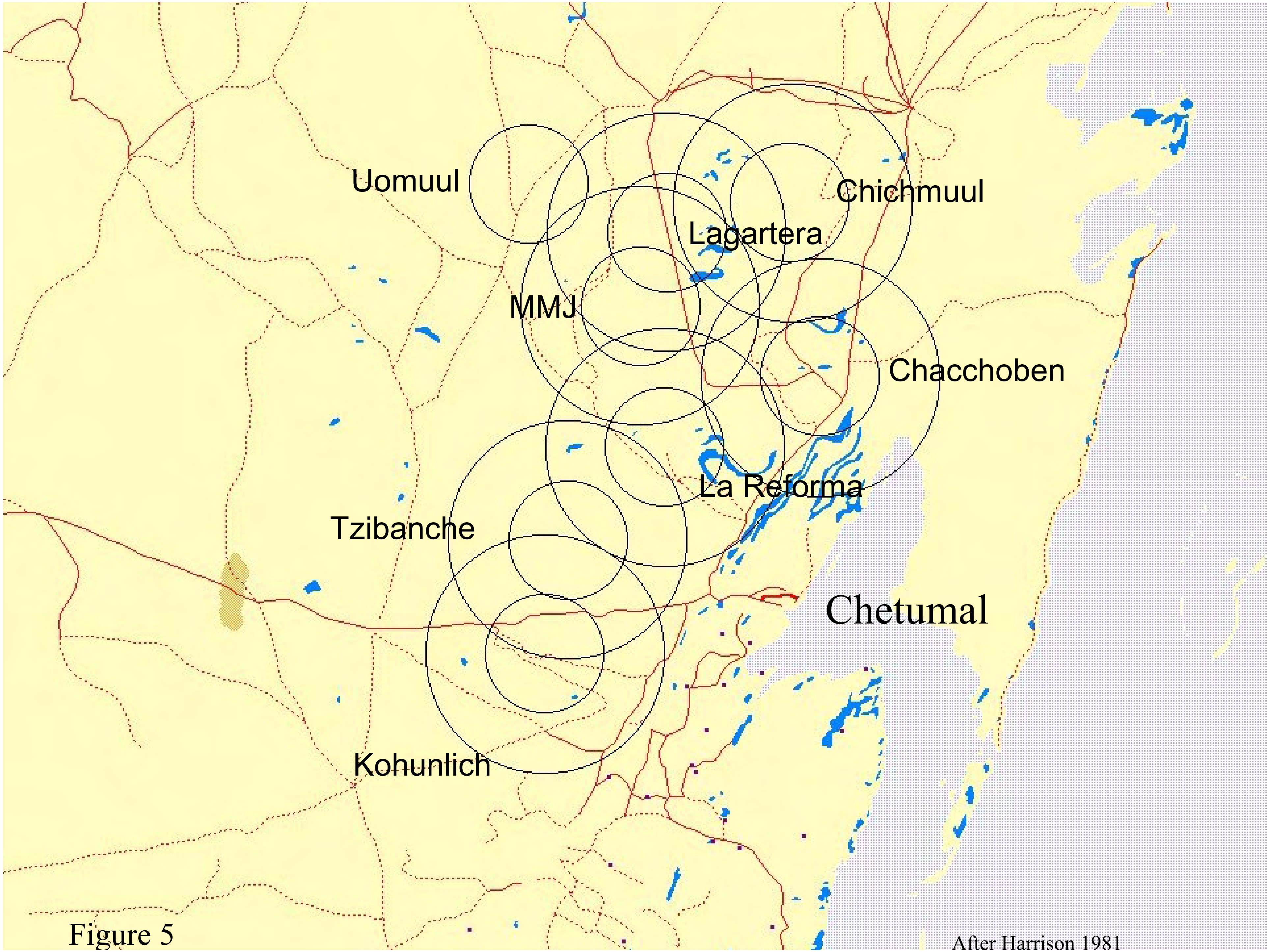


Figure 5

After Harrison 1981

Rank-Size Dimension, Central Peten Sites (without smallest sites) (Adams 1981)

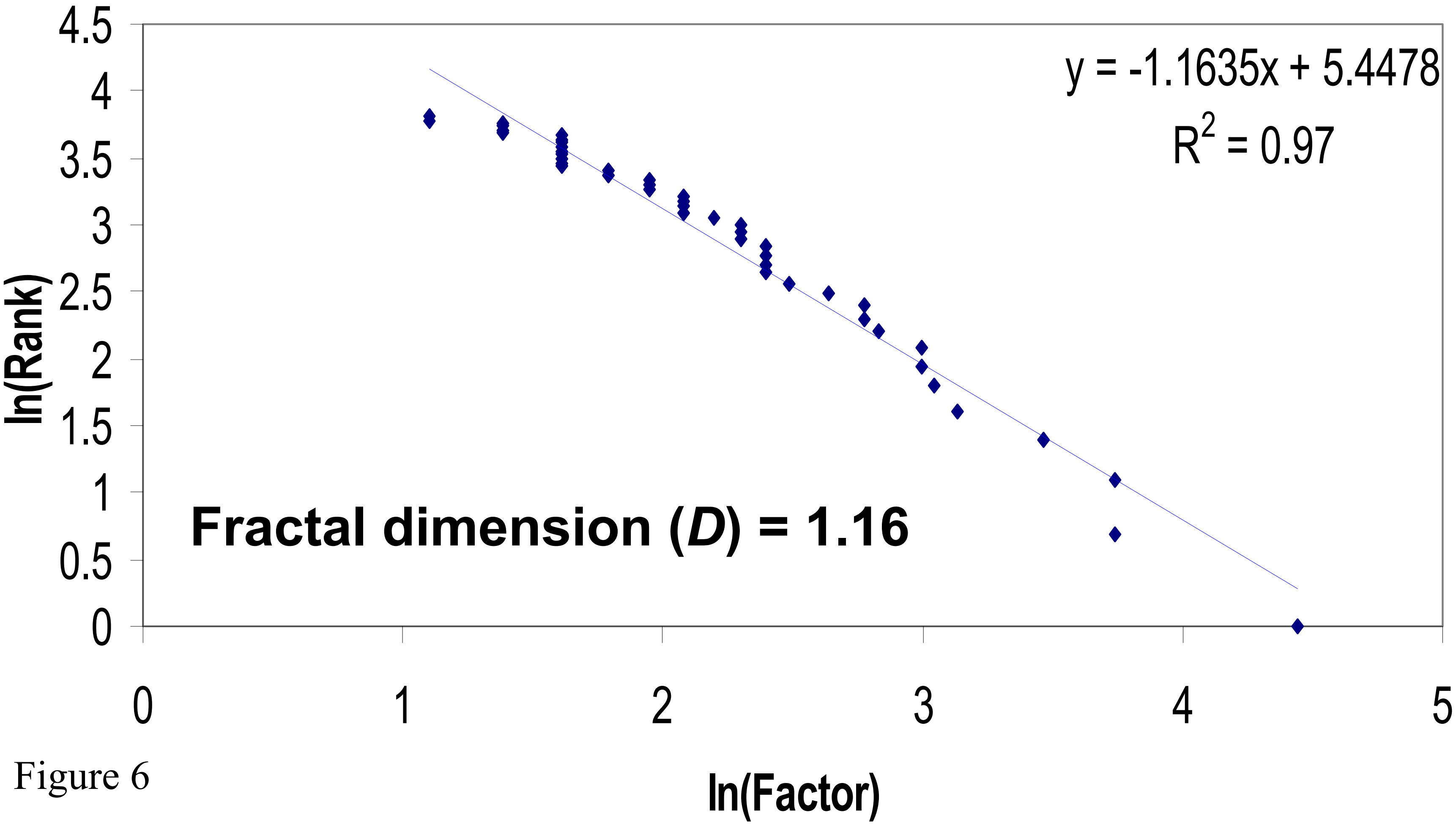


Figure 6

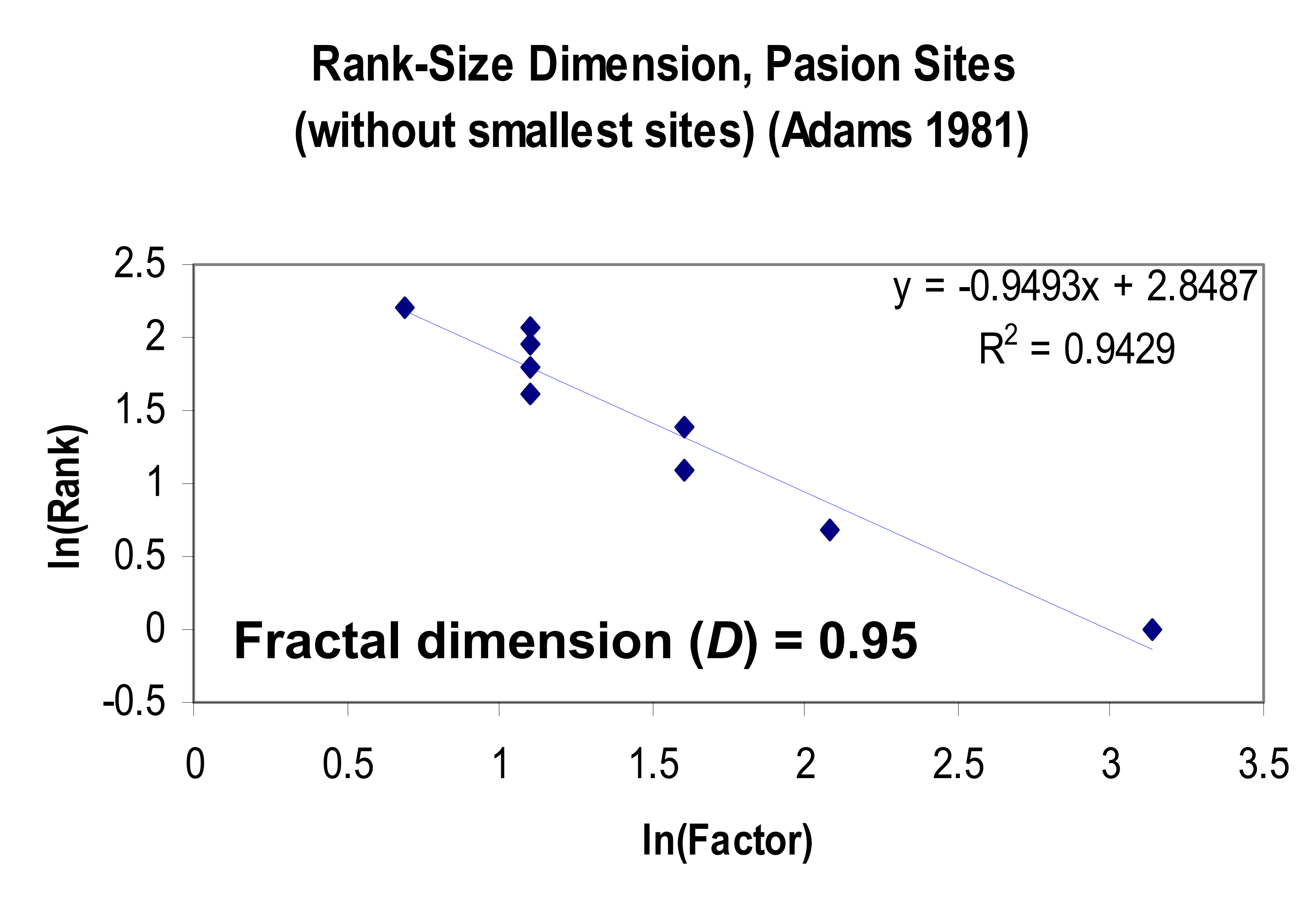

Rank-Size Dimension, Pasion Sites
(without smallest sites) (Adams 1981)
y = -0.9493x + 2.8487
R2 = 0.9429
Fractal dimension (D) = 0.95
ln(Rank)
ln(Factor)
2.5
2
1.5
1
0.5
0
-0.5
0
0.5
1
1.5
2
2.5
3
3.5

Figure 7

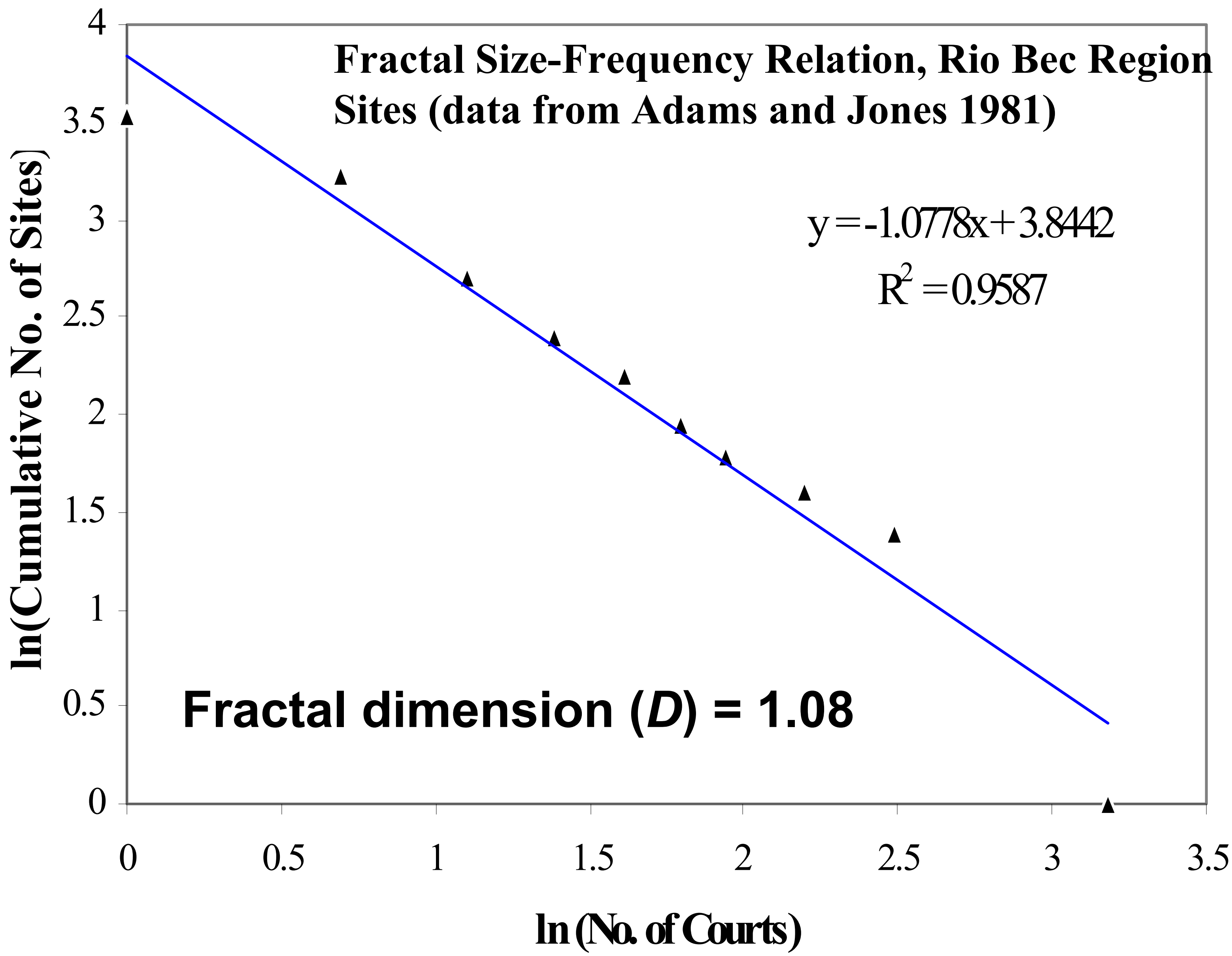
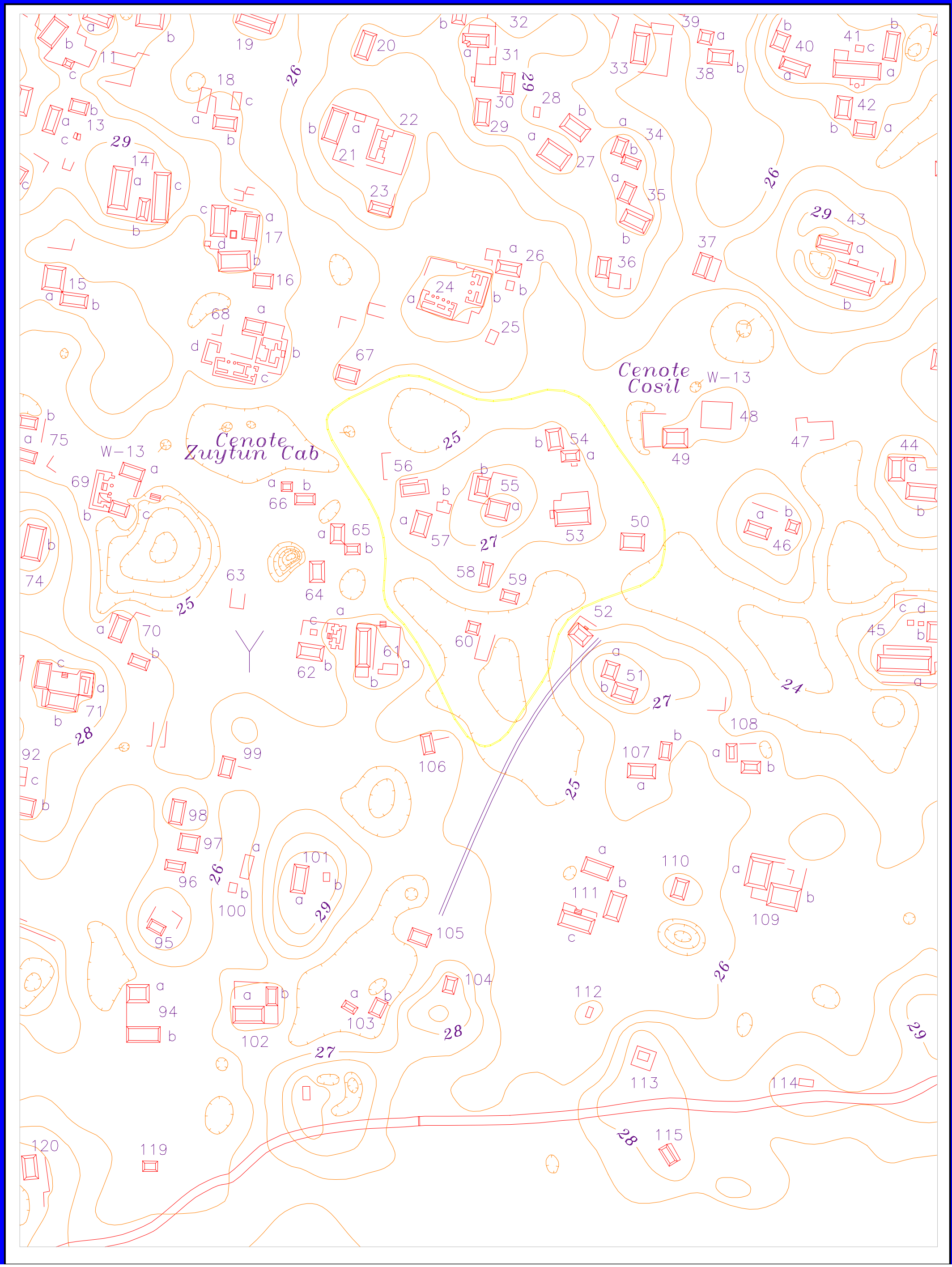

Fractal Size-Frequency Relation, Rio Bec Region Sites (data from Adams and Jones 1981)
y = -1.0778x + 3.8442
R2 = 0.9587
Fractal dimension (D) = 1.08
ln(Cumulative No. of Sites)
ln (No. of Courts)
0
0.5
1
1.5
2
2.5
3
3.5
4

Figure 8



Excerpt from the map of Mayapan (Jones, Morris (1952, Map of the Ruins of Mayapan, Yucatan, Mexico. *Current Reports* No. 1. Washington, D.C.: Carnegie Institution of Washington, Department of Archaeology.)

Edited by A. L. Smith and Karl Ruppert and re-issued in 1957 by H. E. D. Pollock as an editor's note to the *Current Reports*.

Illustration digitized by Lynn A. Berg for Brown, Clifford T., 1999, Mayapan Society and Ancient Maya Social Organization. Ph.D. dissertation, Department of Anthropology, Tulane University.

Square Y in the south central part of the site is shown. A segment of the great wall and part of a small sacbe can be seen.

The clusters of structures are part of a self-similar (fractal) pattern of clusters at many scales.

Figure 9

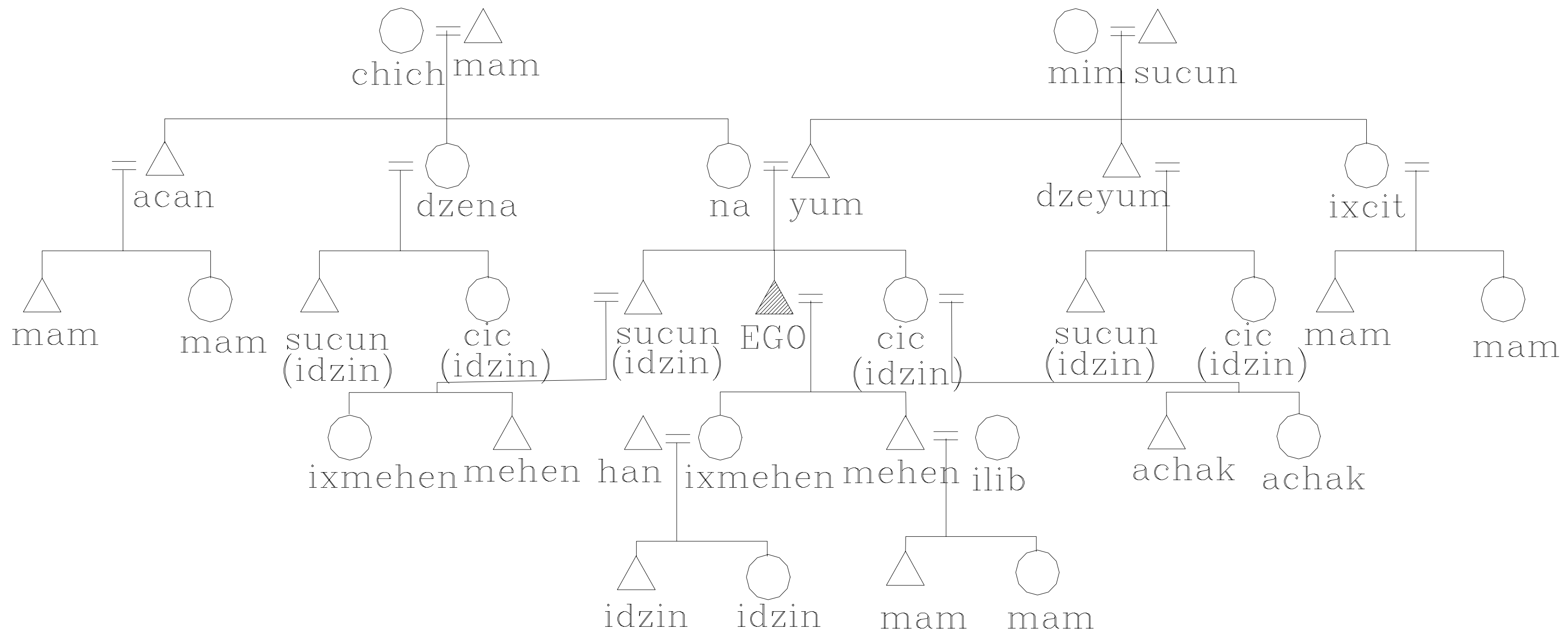
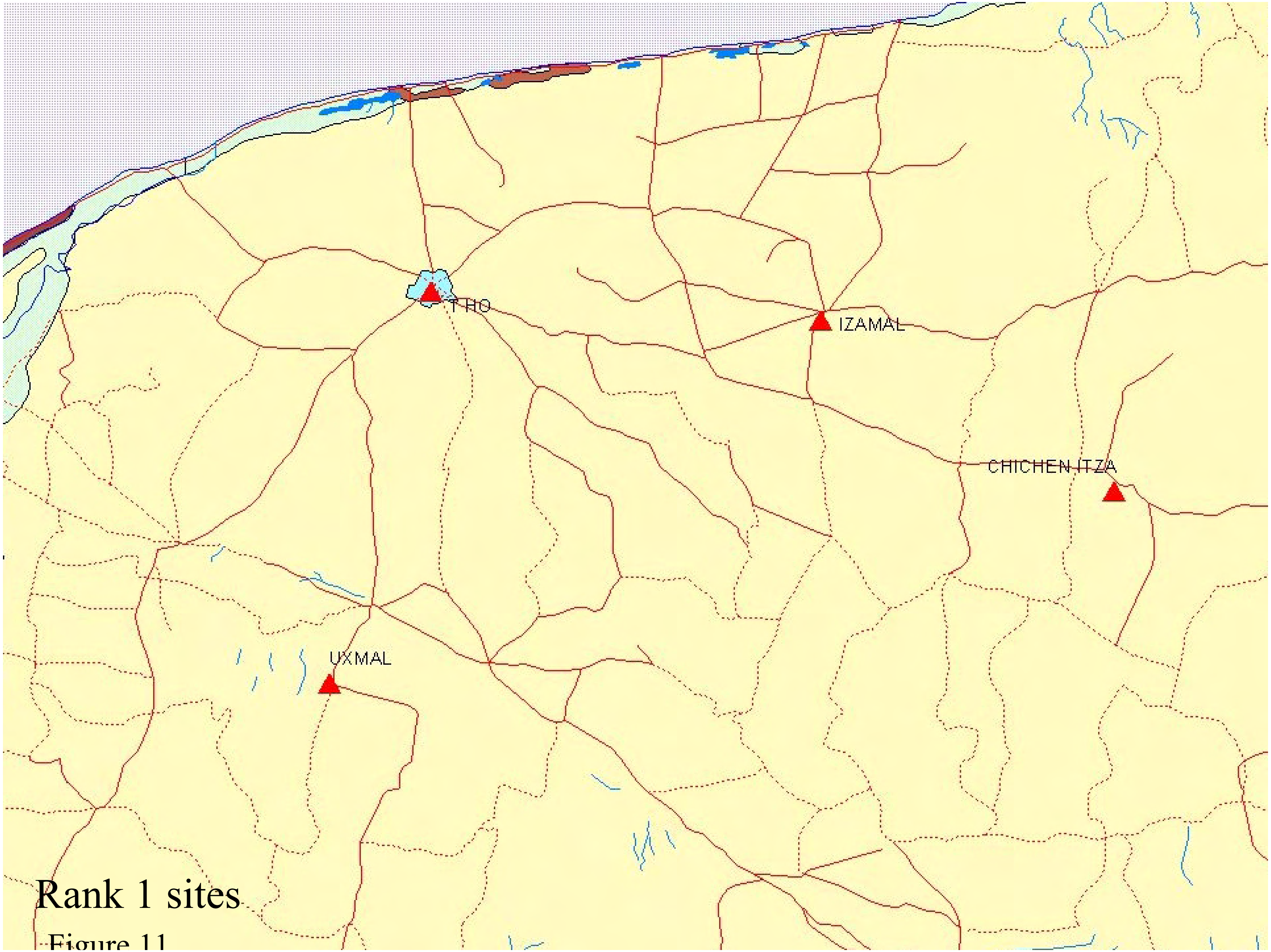
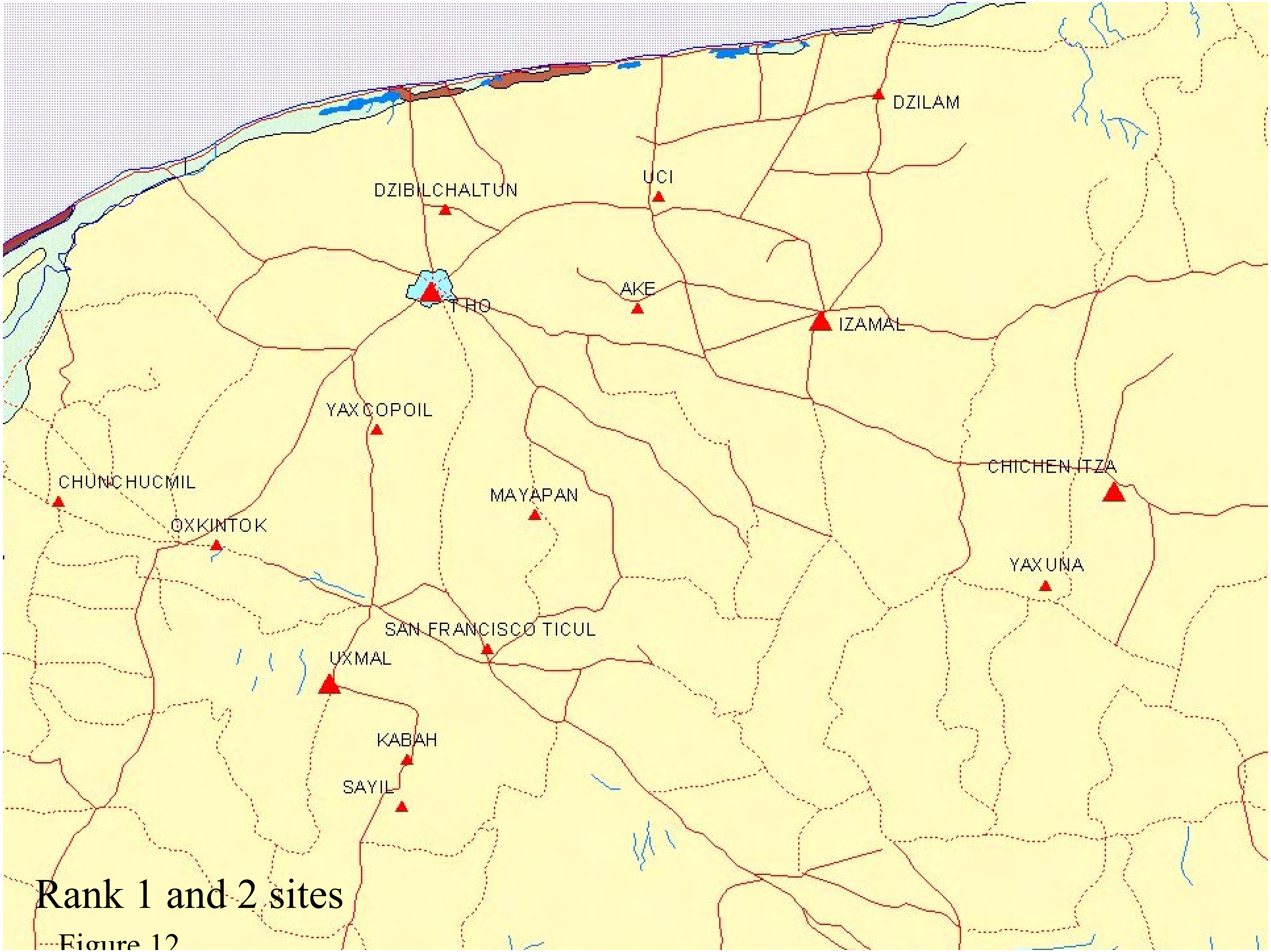


Figure 10. Yucatec Maya kinship terms, males-speaking (After Thompson 1978)



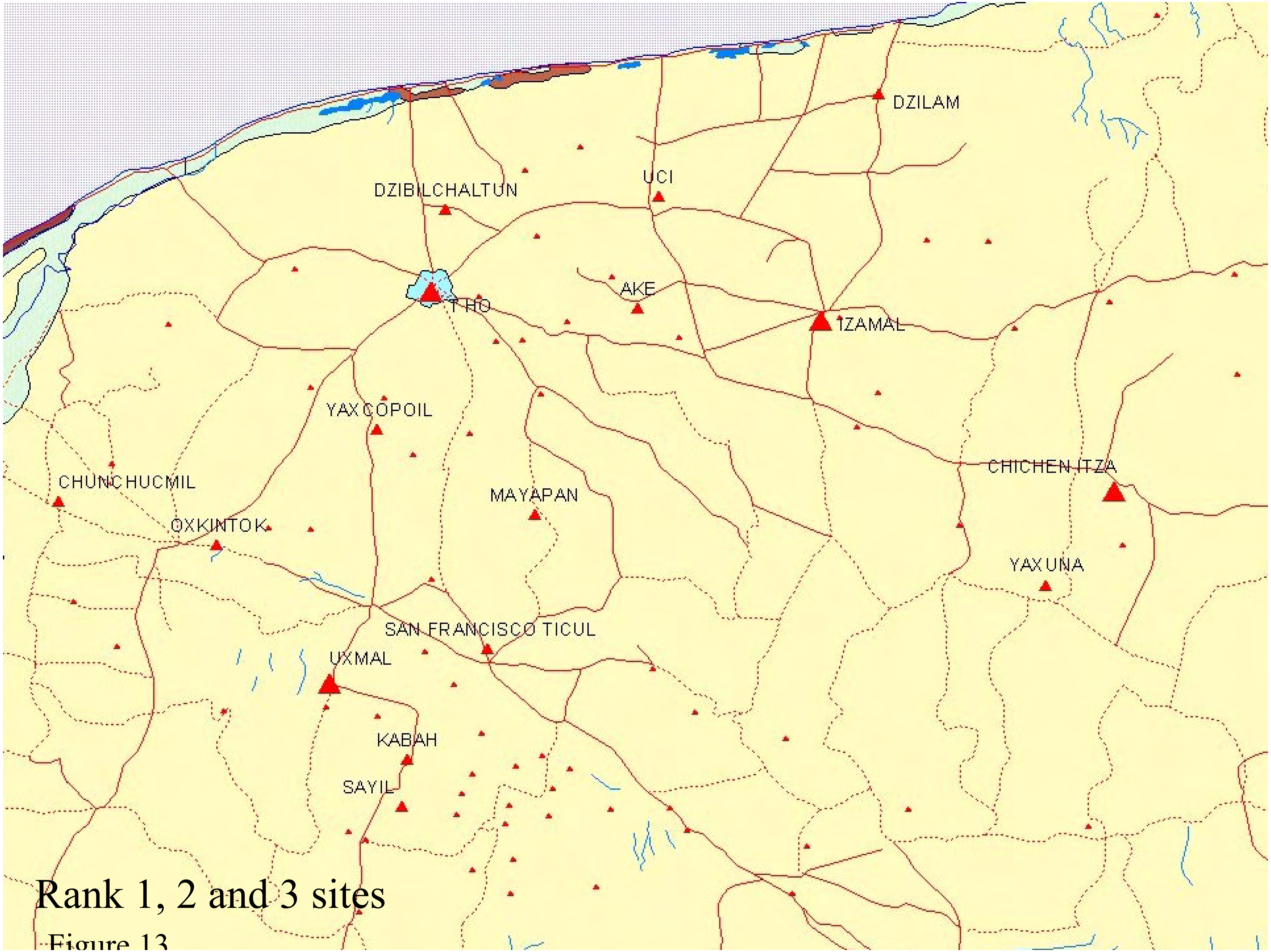
Rank 1 sites

Figure 11



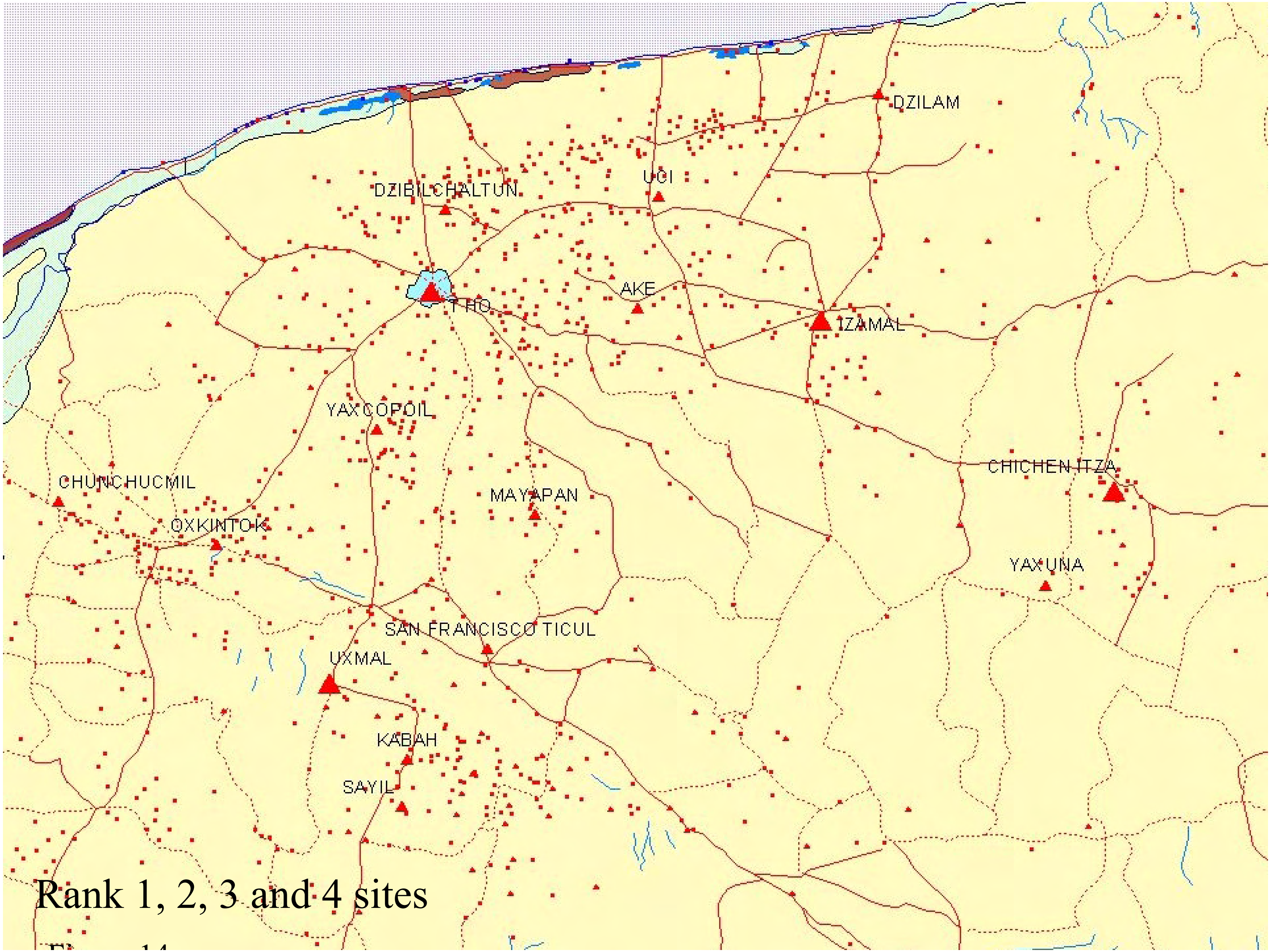
Rank 1 and 2 sites

Figure 12



Rank 1, 2 and 3 sites

Figure 13



Rank 1, 2, 3 and 4 sites

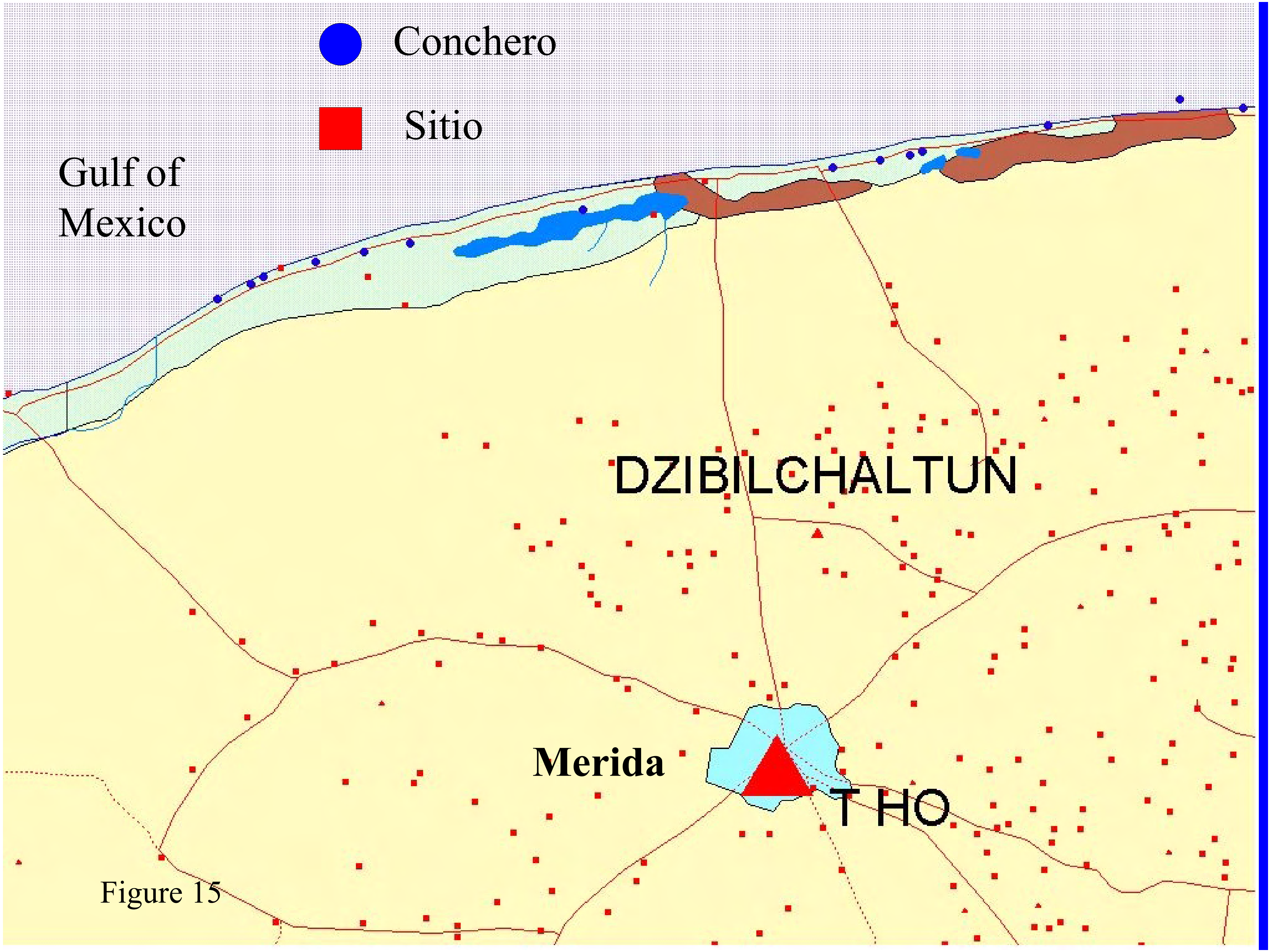


Figure 15

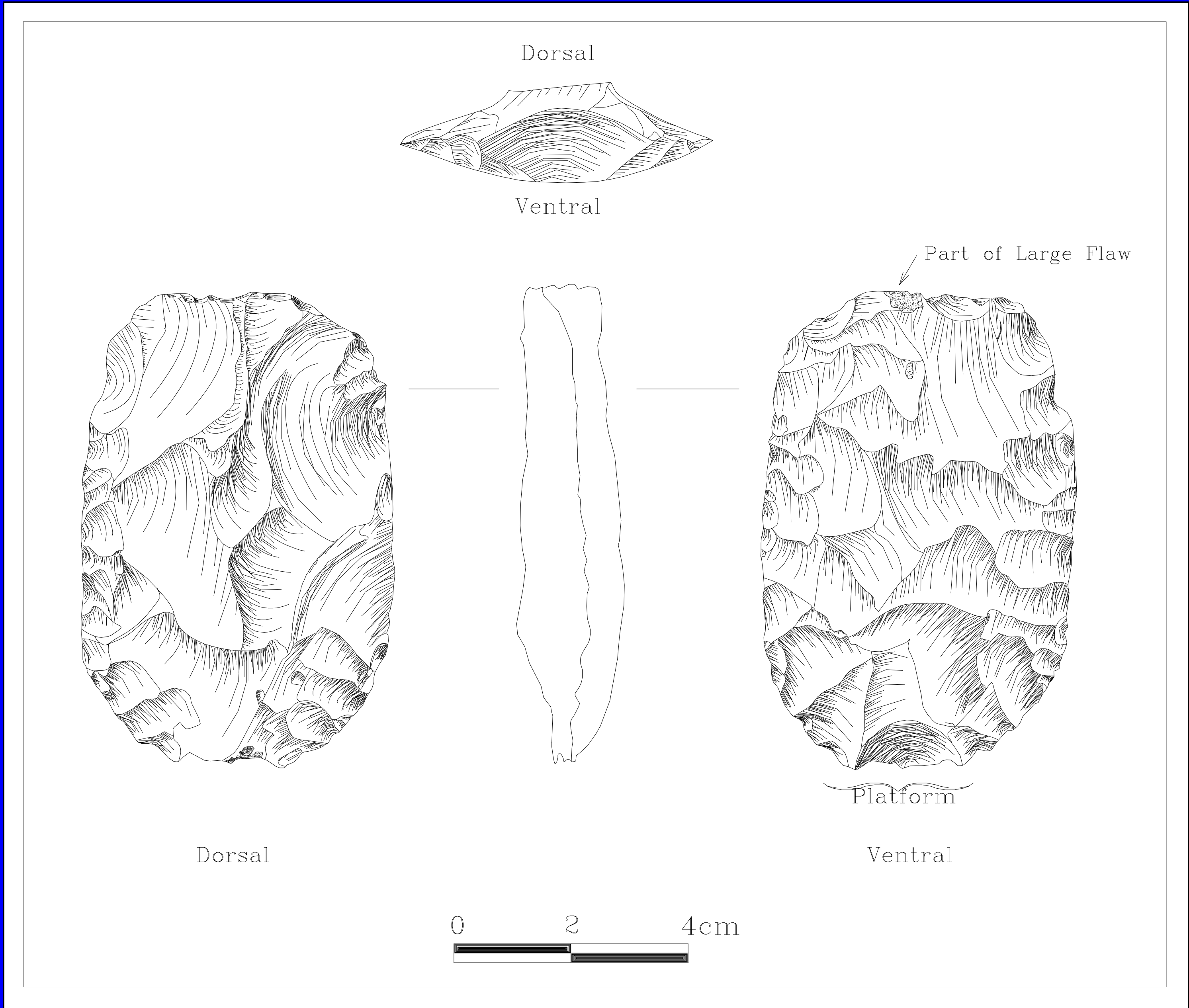
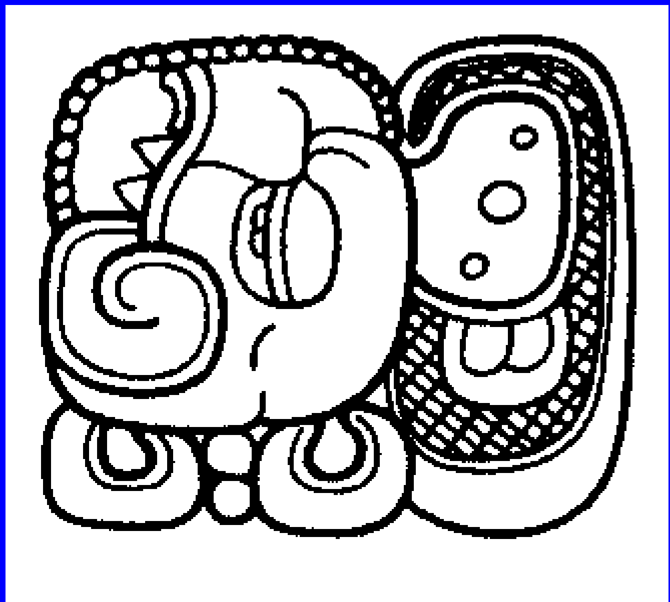


Figure 16: Chert Biface Excavated at Mayapan, Yucatan, Mexico

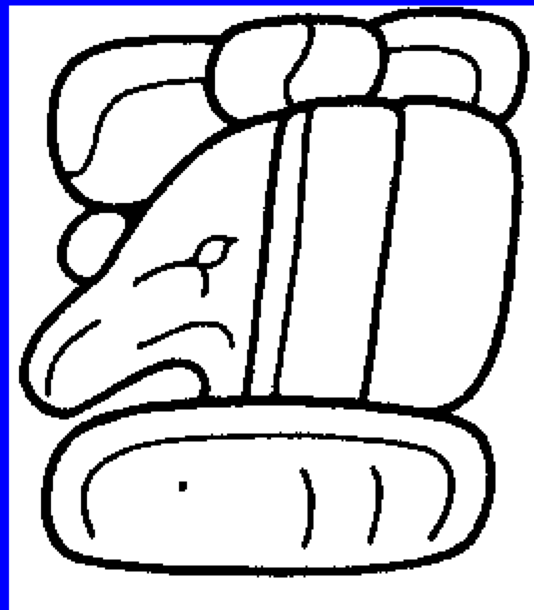
Dynastic Events

Birth



(Upended Frog)

Accession



(Toothache)

Figure 17

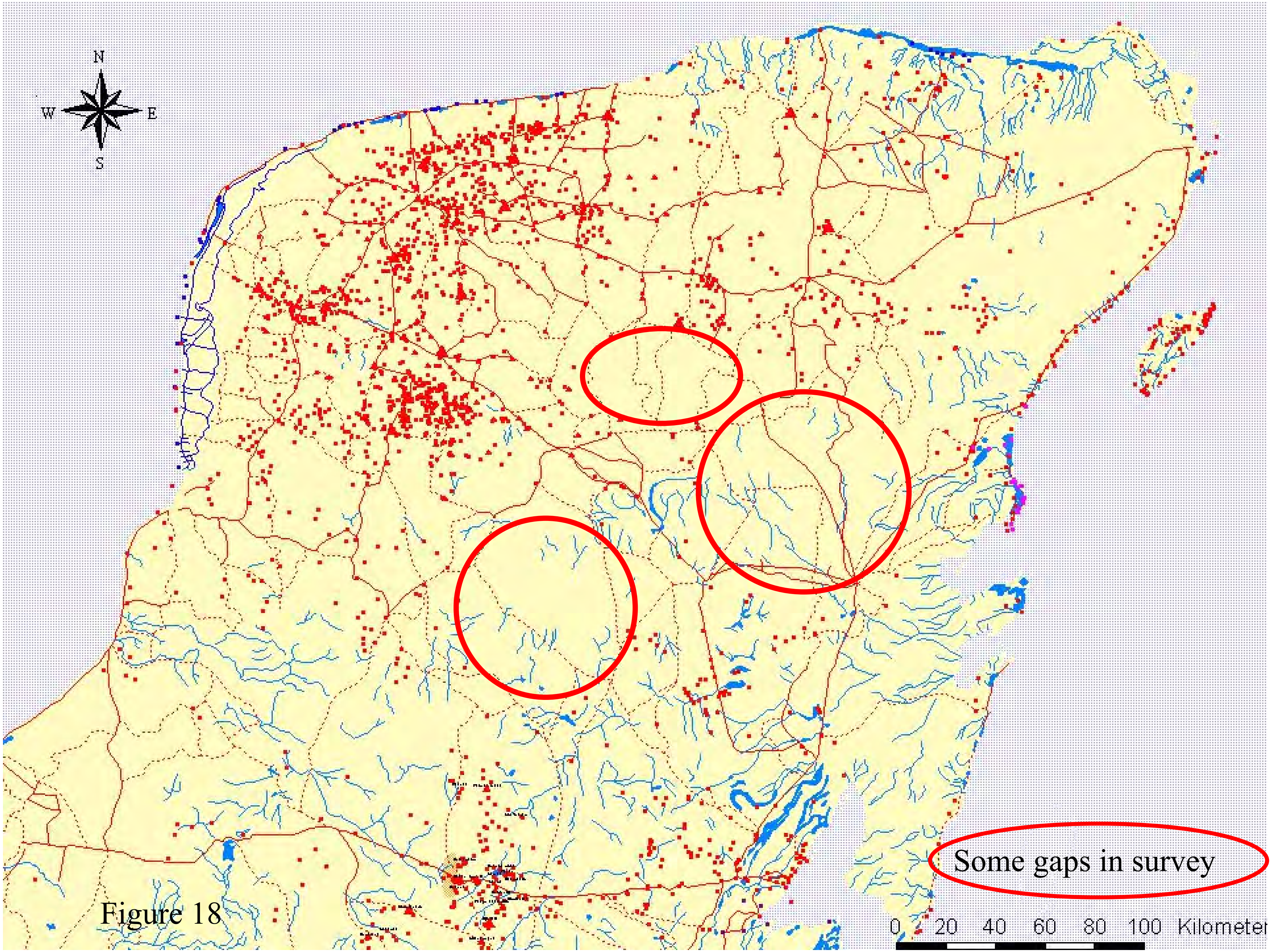


Figure 18


The Land of the Ancient Maya
N
W
E
S
Gulf of Mexico
Caribbean Sea
Pacific Ocean
0 25 50 100 150 200
Kilometers