# The Electronic Atlas of Ancient Maya Sites

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[presented at the Symposium on Current Applications of Remote Sensing and GIS in North America and Mesoamerican Archaeology, 67th Annual Meeting of the Society for American Archaeology, Denver, CO, Friday, March 22, 2002]

## ABSTRACT

We describe the development of a regional GIS for the Maya culture area of southern Mexico and northern Central America. First, we explain the intended purposes of the GIS, which determine its structure. Then we present the data model we developed, as well as the methods we are using. Various challenges, such as acquiring regional-scale data sets that cross national boundaries and the conversion of multiple data sets to a single geographic coordinate system, are described. Finally, we present initial results from archaeological analyses developed using the GIS.

## INTRODUCTION [SLIDE 1]

[SLIDE 2] With support from the Electronic Cultural Atlas Initiative, the Middle American Research Institute, and the Science Museum of Virginia, we have been developing a regional scale GIS system that includes the entire Maya area. Our main goals in this endeavor are: [SLIDE 3]

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.

To these we should add that we also hope to one day be able to provide an application for archaeological data management to the local and national governments of the region (Brown and Witschey 2001, 2002).

[SLIDE 4] Most archaeological GISs are designed either for research or for cultural resources management purposes, but rarely both (Lang 2000). The development and maintenance of state, provincial, and national heritage management GIS systems (Blasco Bosqued et al. 1996; Farley et al. 1990) are beyond the resources of most researchers, even those with substantial institutional support. Researchers sometimes make use of such applications to address theoretical questions, but by and large they are used for public administration and record keeping. GISs that are designed and used for research are usually much smaller in scope, either because their geographical extent is limited (perhaps to a single site [e.g., Potts et al. 1996] or because the total amount of data is limited to specific types, classes, or periods (Ruggles and Church 1996; Van West and Kohler 1996). Thus, creating a GIS for both information management and research is difficult because doing so combines regional geographic breadth with the richness of detail and accuracy need for research. In this paper we discuss some of the obstacles to achieving these goals, which include accuracy, precision, and scale.

The Maya area [SLIDE 5] encompasses the Yucatán Peninsula, including [SLIDE 6] 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. Our area of interest, thus, includes part or all of several countries and, perforce, numbers of states, departments, and provinces within those nation-states. One result of the modern political diversity of the region is that geographical data are not consistently available, and when they are available, they are often come in different and incompatible formats, whether as maps, paper documents, or computer files.

## SCALE [SLIDE 7]

Scale is a subject of recent interest in both archaeology and GIS (Gaffney and van Leusen 1995; Lam and Quattrochi 1992; Stein and Linse, eds. 1993). The scale at which one records data in a GIS obviously affects the cost, labor, and computing power necessary to create and utilize the system. The resolution of the mapping also influences the questions that may be asked, and answered by the data set.

The development of a GIS on a large regional scale is necessary and advantageous to address certain question in archaeology and prehistory, some of which cannot be answered in any other ways, but as we shall see it presents a variety of special challenges. [SLIDE 8] For example, it is extremely difficult to identify, develop, store, retrieve and analyze the kind of detailed data for a whole region that one would normally incorporate into an intra-site GIS. A GIS for a single site might include 50-cm or 1-m contours either as hypsography or as a digital elevation model (DEM) . Such data do not appear to exist for the whole region with which we are concerned. One can certainly include varied patches of data in the GIS, but to the extent that they are not consistent across the region, large-scale analyses are difficult. Similarly, on a regional scale, the cost and labor of including all archaeological features or structures may be prohibitive, however desirable it may to do so. As a result, it may be necessary to use sites rather than artifacts, features or structures as the basic unit of analysis, with the understanding that a "site" is not always an appropriate concept for analysis or description of archaeological spatial distributions of features. In short, the choice of scale for data is critical and will affect the utility of the system. Since our system includes two nation-states and parts of three others, it is convenient and necessary for us to use relatively coarse data for many purposes, at least until we succeed in obtaining more resources.

Our current base map data, that is, the essential cartographic background over which we have laid archaeological site locations, is the Digital Chart of the World (DCW) [SLIDE 9] created for the United States' Department of Defense. The detailed data layers of the DCW are mapped at a scale of 1:1,000,000 with absolute horizontal accuracy from about 2000 to 4200 m. (Defense Mapping Agency 1992). It provides [SLIDE 10] data on land use, oceans, rivers, streams, lakes, roads, railroads, and modern town and cities, among others. The absolute accuracy reflects, at least in part, the quality of the maps – mainly military air navigation charts – from which the DCW was built.

We have also imported [SLIDE 11] the appropriate tile (W100N40) of the GTOPO30 global digital elevation model (DEM) created by the United States Geological Survey Earth Resources Observation Systems (EROS) data center (see http://edcdaac.usgs.gov/gtopo30/readme.html). Elevations in the model are regularly spaced at 30-arc seconds (approximately 1 kilometer, or 0.008333333333333 degrees, per pixel). The horizontal coordinate system is decimal degrees of latitude and longitude referenced to WGS84.

The vertical units represent elevation in meters above mean sea level. The elevation values range from -407 to 8,752 meters. In the DEM, ocean areas have been masked as "no data" and have been assigned a value of -9999. Lowland coastal areas have an elevation of at least 1 meter, so in the event that a user reassigns the ocean value from -9999 to 0 the land boundary portrayal will be maintained.

Scale is not as simple and obvious a concept as it might appear at first glance. It is not merely a matter of deciding how much detail to make visible at different magnifications. Many geographic phenomena, both physical and cultural, exhibit *scaling* or *scale invariance* (DeCola and Lam 1993; Goodchild and Mark 1987) A phenomenon that is scale invariant exhibits the same geometry at all scales of observation. We believe that Maya settlement, for example, is scale invariant (self-similar and fractal) across several orders of magnitude (Brown and Witschey 2002).

The large regional scale of the GIS also creates some natural challenges because of the range of environments that it encompasses. For example, topographic relief in the area varies dramatically: the northern Maya lowlands exhibit very low relief (albeit with complex and critically interesting variation) while the Maya highlands (as the name suggests) have extremes of altitude. This wide variation in altitude and slope requires complex algorithms to achieve meaningful and understandable display of the data. Merely selecting a single contour interval for the whole region (for instance) results in poor data display in either the highlands or the lowlands. These are common cartographic problems, in no way unique to our system, and there are a variety of solutions in GIS. But the greater complexity of those solutions increases the computational speed, power, and storage required to implement them; multiplies the difficulty of learning, using, and maintaining the system; and raises the cost and labor required to create the system.

## ACCURACY [SLIDE 12]

The accuracy of our data is of key importance. It directly affects the ability of the GIS to address the questions asked of it. There are several different issues enveloped in the deceptively simple term "accuracy". First, one first probably imagines the absolute accuracy of the coordinates: are the latitude and longitude recorded correctly and precisely, and if so, how precisely? Second, Maya archaeological sites are often quite large, and since we are still representing them as points rather than polygons or multiple objects, a question arises about which point in the site we chose as a proxy for the whole site. Third, inaccuracies can enter into data from conversions between map projections or during de-projecting data sets to geographic (decimal degrees) format. Fourth, in theory, the numeric coding of number in computer memory can introduce further inaccuracies in data, but such problems are largely a thing of the past.

In fact, most of data sources (archaeological maps and atlases) are not accurate to within less than 100 m. In many cases, the random error (of measurement and transcription – as opposed to gross mistakes of cartography) is certainly in the hundreds of meters. Of course, it is notoriously difficult to orient oneself in the rainforest of the Maya lowlands, and so some very large sites have remained lost for decades. The difficulty of travel and lack of landmarks mean that older maps often include imprecise or highly suspicious site locations. The newer mapping efforts, of course (e.g., Garza and Kurjack 1980), utilized GPS with its inherent advantages and precision. Newer maps from the region also incorporate information from aerial photography, photogrammetry, and airborne or satellite remote sensing data, all of which provide significant supplements and enhancements to traditional cartographic data.

Somewhat to our surprise, [SLIDE 13] we have found that our site locations are often more precise than our base data. The absolute horizontal accuracy of the DCW, as mentioned above, is only approximately 2000 to 4200 m. We find that some sites are horizontally displaced from known landmarks (coastlines, roads, towns) in the base data by as much as a kilometer. After comparison to printed topographic quadrangles maps, we conclude that most of the error is in the base data rather than in the archaeological data set. This conclusion is gratifying to us as archaeologists, but ultimately remains unsatisfying to our cartographic instincts. Fortunately, the DCW data is replaceable with higher resolution files as available, since any fine-grained analysis of the relationships between archaeological site location and natural features (e.g., drainage, elevation) rely on the accuracy of both the archaeological and the base data.

## DATABASE STRUCTURE [SLIDE 14]

Database structure is rarely discussed in current publications on GIS. Discussions of it were more common a decade ago (e.g., Stine and Lanter 1990). The silence on this subject presumably implies that the issue no longer carries any theoretical interest and is intellectually trivial, that it has become a mere technical matter. In fact, the database structure fundamentally determines which data can be represented and how. In larger GISs produced by government and industry, the issues of data structure and architecture are matters of extensive, detailed, and laborious consideration (e.g., Lang 2000). Our database is based around a "site" table that has a single unique record for each site. The site table has a one-to-many relation with a daughter table that represents components or occupations. That table in turn is related to daughter tables with information about ceramics, lithics, and architecture (and many other taxa) from the site.

## GIS AND ARCHAEOLOGICAL THEORY

Archaeological GIS is closely associated with environmental and ecological explanation in archaeology. Specifically, there is a strong tendency for archaeological GISs to implicitly or explicitly "explain" or "predict" archaeological patterns by reference to environmental variables (e.g., Warren 1990a, 1990b; see Kohler and Parker [1986] for overview). Even projects that claim to go beyond cultural ecology usually end up by "explaining" archaeological settlement in terms of a few simple environmental variables (e.g., Maschner 1996).

The current situation has both historical and proximate causes. Historically, the development of GIS, particularly in North American archaeology, has been contemporaneous, if not coeval, with the lengthy supremacy of cultural ecology, environmental determinism, and neo-evolutionism of the New Archaeology. The two trends have numerous and specific points of intersection, often involving the same individuals. On a more immediate and practical level, the collection of base mapping data that forms the substrate of most GISs is a major effort that is usually beyond the resources of archaeological projects. Thus, those data are borrowed from national or international spatial data infrastructure sources, which overwhelming provide environmental data collected for planning, development, or military purposes. Consequently, those are usually the only independent variables available for modeling. In conjunction, then, theory and practice have combined to make environmental determinism dominant in archaeological GIS (Gaffney and van Leusen 1995). In response to these observations, it is asserted that GIS is only a tool, and cannot itself be blamed for its misuse.

We seek to make non-environmental variables more prominent in our archaeological GIS by consideration of four types of data: 1) [SLIDE 15] textual, hieroglyphic data, which provide information about politics and language; 2) [SLIDE 16] cultural landscape data, such as roads, caves, quarries, fortifications, and port facilities; 3) [SLIDES 17, 18] the internal spatial relationships among sites (i.e., the internal structure of regional settlement patterns) and 4) [SLIDE 19] modal-level stylistic data from lithics, ceramics, and architecture. We believe that the inclusion of such data will help us develop more cognitive and ideological models of settlement and polity than other GIS systems.

## CONCLUSION [SLIDE 20]

We hope our project will help justify the construction of regional GISs, which are the only tools available to address some archaeological questions, in spite of the difficulty and expense. We are also developing a more assertively cognitive and social approach to GIS that will both respond to some of the valid criticisms of archaeological GIS and also adopt a theoretical perspective that is congenial to current trends in Maya archaeology.

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