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# A Volumetric Assessment of Ancient Maya Architecture: A GIS Approach to Settlement Patterns

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ABSTRACT

This paper will discuss the general applications of GIS technology to our research in the Yalahau Region of northern Quintana Roo, Mexico. In particular we will address the use of a volumetric analysis as a means of developing an architectural comparative framework at both the intrasite and regional scales. The comparative framework is a powerful tool that allows us to investigate and visualize the distribution of social power both within the site of T'isil and across the region. The direct relationship between social power and architectural volume is predicated on the assumption that actors who utilized the largest dwellings were able to coerce (or force) the greatest number of people to aid in their construction.

## Introduction

The Yalahau region, where the current research is being conducted, is located in the north-eastern corner of Mexico's Yucatán Peninsula and represents a unique physiographic landscape dominated by extensive freshwater wetlands. This water rich environment stands in sharp contrast to the dry karstic plane that characterizes the rest of the northern Yucatán Peninsula and is perhaps the most biotically rich and diverse ecosystem in the northern Maya Lowlands (Lazcano-Barrero 1995).

Limited archaeological reconnaissance had been conducted in the region prior to the 1993 initiation of the Yalahau Regional Human Ecology Project. More pertinent for our discussion here, however, is the project's implementation of Geographic Information System (GIS) technology, which began in 1999. Initially used as a data management tool, the GIS has more recently been applied as an analytical tool to the settlement pattern data from the ancient Maya sites in our study area. This paper investigates the application of GIS for the analysis of volumetric calculations that can be used to address questions concerning the socio-political, cosmological, and economic organization of the sites in the region at both the individual site and regional levels.

## Why Volume?

It is our assumption that the relationships that create social networks within a society are predicated on "power" relations. Therefore, to begin understanding social relationships, the allocation of "power" within those relationships must be determined. "Power" here is defined as "the control of resources and the productive means to exploit and distribute these resources" (Hendon 1989:894). Using this definition, how is power displayed in the archaeological record, recognizing that it is not absolute power that we are after but differences in relative power?

As Eliot Abrahms (1989:53) noted "architecture, by virtue of its capacity to absorb relatively large amounts of energy during production, can hypothetically reflect a significant range of organizational behaviors requisite for such construction, an important index of cultural complexity." Following this statement, our interest in architectural volume stems from its ability to represent the labor force that was organized by administrators at a particular site and thereby a proxy measure of administrative power. The volumetric mass of the largest architecture in the site center will be the main factor in measuring the size (administrative power) of a site.

## Site Level Analysis

Volumetric analysis has different applications at the site level and at the regional scale. At the site level the questions being addressed by the volumetric analysis correspond to a model of Maya community organization first proposed in the archaeological literature by Michael Coe (1965). Coe proposed a concentric zone model for community structure based on ethnohistoric evidence of Yucatec Maya communities. The communities tended to be situated around cenotes (limestone sinkholes). Cenotes are interesting features on the landscape that blur the line between sacred and profane spaces. In the dry northern Maya Lowlands they were important sources for drinking water, yet at the same time cenotes represent portals of communication between the "lived" world and the watery underworld. Because of their conduit properties between the levels of existence, they were conceptualized as the axis mundi of communities.

Using Coe's model, we would expect to find the cenote bounded by the most impressive architecture, marking the residences of the elite and temples of worship. This pattern can be seen as a reflection of the unequal distribution of social power within the community where "(h)ouses…are 'structuring structures' - culturally loaded spaces that socialize by encouraging practices consistent with the meanings they encode" (Johnston and Gonlin 1998:145). Additionally, Hirth notes "residential architecture is perhaps the strongest and most consistent expression of wealth and rank in agrarian societies and is a product of both a household's social functions and energetic capabilities" (Hirth 1993:123), and at the site level will be the object of study. Therefore, the relative grandeur of architecture is a symbolic form of communication stating the importance of those individuals to the rest of the community. In Coe's model, social differentiation within the community is expressed through peoples proximity to the site center, and the access to the supernatural realm, the temples and cenote, which that proximity brought. This implies that the largest and most elaborate architecture will be located closest to the community center.

At the site level, Coe's model has been applied to the 2,000 year old site of T'isil, located about an hour drive west of Cancun. The site appears to be centered around a cenote, and over the past four field seasons, the northern half of the site has been almost completely mapped. Mapping the site of T'isil has been achieved by the use of optical transits, Brunton compasses, metric tapes, range finders and other conventional equipment. The site covers approximately 3.5 square kilometers, and further mapping of T'isil is continuing. In addition to the mapping, extensive surface collections have been made along with preliminary test excavations that have revealed a short major occupational period dating to the late part of the Late Preclassic period to the early part of the Early Classic period (c. 100 B.C - A.D. 350).

### Regional Survey

At the regional scale, however, the questions change due to the intensity of the study being conducted. The major research question being addressed at this scale of analysis concerns the socio-political organization of the region. Specifically, the research will test four models of the spatial distribution of administrative centers within the Yalahau region in order to address the complexity of the socio-political organization. The focus at the regional scale is not on the distribution of domestic architecture but on "monumental" architecture at the site center, which includes domestic and public buildings.

The "size" of each center is to be measured by mapping the largest structures at the site, while the basic elements of the site plan will be recorded by mapping all of the structures within the defined site core. The mapping strategy is different on the regional project than at T'isil. The sites are being geographically positioned using a handheld GPS and mapped with a Topcon total station. As the number of structures mapped at the site core will be judgmentally determined and will certainly vary between sites, a standard of the five largest structures will be used to calculate the architectural volume of each site and create a comparative volumetric database. While the number five is primarily arbitrary, it does have significance in Maya cosmology (center and four cardinal divisions), and may represent a principal of site planning as discussed above (see Ashmore 1991, Coe 1965). The creation of a comparative volumetric database will be the main tool used when creating a hierarchy of sites within the region.

### GIS Methodology

ArcView 3.3 with the 3D Analyst extension was used to calculate the volume for each structure at both the site and regional scales. Points corresponding to each structure were highlighted in the view using the select button. Then using the Surface pull-down menu, we selected the Create Tin from Features option and created a Tin (Triangulated irregular network) surface. At that time, the Tin was highlighted in the ArcView Table of Contents. Using the Surface pull-down menu again, the Area and Volume Statistics option was chosen. This results in planimetric and surface areas, as well as volume calculations for each structure. A table created from the data generated by the Area and Volume Statistics option was then used to generate a polygon theme based on volume calculations at T'isil, allowing us to visually display the distribution of volumes across the site.

### Other Methods

A search of the Environmental Systems Research Institute's (ESRI) webpage produced an ArcScript extension, written by wildlife biologist Jeff Jenness, that allows the user to calculate various surface and topographic characteristics for Point, Line or Polygon themes that overlay a GRID or TIN surface. This script allowed us to automate the volume calculations for each structure quickly and easily and directly placed the volumetric calculations in the structure's table.

It was suggested to the authors at the 2003 CAA meeting that the use of the Cut and Fill tool, part of 3D Analyst, would provide a way to more accurately calculate structure volumes. To use the Cut and Fill tool two TIN surfaces must be created that are bounded by the same polygon. The bottom surface would be created using the points defining the basal platform and the upper surface would be the TIN of the whole structure. This method seems to be the most accurate but we have had little time to fully apply it to our data.

### Pros and Cons

There are pros and cons associated with both of these methods. The Point, Line and Polygon ArcScript extension from the ESRI web page was written to calculate all volumes from a single base elevation and this proved to be problematic because our sites, like the vast majority around the world, do not occur on perfectly level planes. Even though the topographic variation across T'isil is no greater than a meter and a half, volumes generated using Jenness' script proved to have a 3-6 % error rate in comparison to the more manual method described previously. The advantage of Jenness' method is that it allows volume calculations to be automated, saving many hours of labor. This method would be acceptable when working with a relatively flat site, where accuracy is not critical.

Volume calculations obtained by using the 3D Analyst extension also had a slight error associated with the data produced. The Area and Volume Statistics option calculates volume using an elevation of the researcher's choosing, typically the lowest elevation point of the structure, generating a horizontal plane to represent the bottom of the structure. Again, this calculation would only be accurate if each structure was on a perfectly level plane. However, the error from this method was minimal in our calculations because there are no major slope changes associated with the individual structures at the site. The measurements from this method are skewed high, and the Cut and Fill method would alleviate this error. The Area and Volume Statistics method did turn out to be very time consuming at the site level, as there are approximately 600 structures currently mapped at T'isil, and a TIN had to be individually generated for each structure. This problem is compounded with the Cut and Fill method because 2 TINs must be generated for each structure. At the regional scale, however, this was not a problem due to the limited number of structures mapped at each site.

## Results

At this point in time any discussion of results on the proposed power of this tool in the elucidation of a regional hierarchy of administrative nodes across the landscape would be premature due to lack of data. However, two of the larger sites in the region, Site 7 and Kimin Yuk, provide an example of the possible strength of the volumetric tool. The sites are located approximately 7 km from each other and have very different organizational properties in terms of the way in which they were laid-out and the manner of building construction used. Glover's initial impression after spending some time at each site was that they were approximately the same size. After calculating the volume of the structures at both sites, however, his initial impression proved to be very wrong. The 3 platforms mapped to date at Kimin Yuk measure 83,206 cubic meters while the 5 largest structures at Site 7 measure 13,704 cubic meters.

More concrete results came at the site level. Volume calculations at T'isil appear to support the concentric zone model proposed by Michael Coe. Volumetric assessment of structures at T'isil revealed a natural break in the size distribution, with the eleven largest structures at the site measuring more than 450 cubic meters. As would be expected when applying Coe's model, the vast majority of these large structures (9) clustered closely (within 180 m) around the cenote that marks the geographic center of the site. The eleven largest structures at this site all had a volume greater than 450 cubic meters, and as would be expected when applying Coe's model, nine of these structures are situated within 180 meters of the cenote at the site center. The site of T'isil has a maximum radius of approximately 1,100 meters, so it is significant that the majority of the largest structures are located in such close proximity to the cenote, supporting the concept of a site center. Site planning principles, such as those described by Coe's model, have been documented at Maya sites during the Classic, Postclassic and Contact periods, but have not been widely researched at Preclassic sites such as T'isil. This volumetric study is significant because it supports the idea that these same site planning principles have their origins in the Preclassic period and have deep temporal roots.

## Conclusion

In conclusion, this paper presents the results of our initial foray into the realm of GIS driven volumetric calculations for the explicit purpose of developing a proxy measure for social power. It appears that our preliminary attempt has produced interesting and useful results. Further applications of GIS technology to volumetric calculations may become a useful tool for archaeologists in various areas of future research. We are still hoping to create an automated script that will be nuanced enough to incorporate the topographic variation across a site.

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