HISTORICAL METROLOGY AND A RECONSIDERATION OF THE TOLTEC MODULE

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The Toltec Module of 47.5 m has been proposed as a standardized unit of measurement employed in the layout of the Toltec Mounds site in central Arkansas (Sherrod and Rolingson 1987). Other researchers have hypothesized that this and other standardized measurements were employed in the construction of numerous late prehistoric mound sites throughout the Southeast. Many of these studies have not taken into account the methodological issues of an appropriate margin of error, the expected occurrence of the proposed measurements by chance, possible fractionations of the measurements in question, or the change in shape and size of the mounds through time. These studies have also lacked theoretical justification for inferring a prehistoric cognitive template (the unit of measurement) from distances measured at the sites today. I propose that as it is currently formulated, the Toltec Module is untenable as a prehistoric unit of measurement. Using GIS to measure all distances between features considered key locations in the Sherrod and Rolingson study reveals that the Toltec Module does not rise above the statistical background as significant. I also explore several theoretical issues concerning historical metrology (the study of past units of measurement), particularly as it applies to the prehistoric Southeast.

Prehistoric units of measurement, or *quanta*, have been suggested as existing at many prehistoric archaeological sites throughout the world. Perhaps most famous are those postulated for megalithic sites in Europe (summarized in Heggie 1981), including the Megalithic Yard of 0.829 m (Thom 1971; see Baxter 2003:228–235 for a recent summary of research into the Megalithic Yard). Such quanta have been proposed for sites in North America as well, including a unit of 57 m at numerous Hopewell earthworks (Marshall 1979, 1987), a measurement of 5 m at Cahokia (Smith 1969), the Archaic Standard Unit of 1.666 m and Standard Macro-Unit of 86.63 m (Clark 2004), a measure of 48 m at Kolomoki Mounds (Pluckhahn 2004), and the Toltec Module (TM) of 47.5 m at the Toltec Mounds site in central Arkansas (Sherrod and Rolingson 1987). These studies are examples of *historical metrology*—the study of past units of measurement. Few such reports in North America acknowledge this field, however, or refer to the literature for theory and methodology (see Kula 1986 for an outline and history of historical metrology). Deciphering prehistoric quanta in the Southeast would of course hold important implications for the societies who employed them. It is not at all clear, however, that any such units of measurement exist. I propose that the Toltec Module, as it is currently formulated, is theoretically and methodologically untenable. Many of the arguments presented here apply to other studies of historical metrology throughout the Southeast in general.

Sherrod and Rolingson (1987) proposed the TM of 47.5 m as a unit of measurement employed by the builders of Toltec Mounds and 26 other late prehistoric sites (including Cahokia and Spiro), used in the construction of the sites and still expressed in mound layout and patterning. Toltec Mounds is a Late Woodland civic ceremonial center and the type site for Plum Bayou culture. Archaeomagnetic and calibrated radiocarbon dates show the site to have been occupied from about A.D. 700 to 1050, although this may not reflect the full extent of the occupation (Rolingson 1998:24–25). There are at least 19 mounds known to have been present, within a core site area defined by a backwater pond on the northwest and an embankment and accompanying ditch surrounding the rest (Figure 1). The area surrounded by the embankment measures roughly 900 m northeast to southwest and 450 m northwest to southeast. The mounds surround two open plaza areas, one near the north end of the site and one near the south. The TM quanta was based on the apparent ubiquity of multiples of this distance between what were considered significant “target” points at the sites. Understanding exactly how a distance of 47.5 m was first derived is instructive in understanding how it was determined to be significant:

A module of measurement at the Toltec Mounds site was first recognized as a 95 m value. This was found by discovering that the major axis dimension of the base of Mound A, 95 m, was present in that dimension, or multiples of it, between Mound A and other mounds on the south plaza. Since some mounds were spaced on one-half of this increment, or 47.5 m, it was thought that this smaller unit would be a more useful one, even though the larger was more common (Sherrod and Rolingson 1987:36).

It thus appears that Sherrod and Rolingson tested only for multiples of 47.5 m, not other potential distances. The target points that were used to search for the module included the centers, edges, and “midslopes” of the mounds, the edges and openings in the surrounding embankment, and the ditch accompanying the embankment. Their method consisted of straight-line measurements between target points (some measured on the ground and at other sites apparently
measured from maps), and calculations of how closely these distances approximated multiples of the TM. Figure 1 shows several of Sherrod and Rolingson's (1987) measurements from the center of Mound A. Exactly how many such measurements were made at this and other sites, and how key target points were chosen for inclusion, is not explained in the original study. Sherrod and Rolingson suggest that the TM may be expressed in the heights of some of the mounds as well (as fractions of 47.5 m), but the heart of their argument lies in horizontal distances between certain target points. Those they posit as corresponding to the TM at the Toltec Mounds site are presented in Table 1 (Table 3 from Sherrod and Rolingson 1987:39). These represent “all module data” (1987:36) from a transit survey of the site.

Although 42 occurrences of the TM are presented in the table, it is important to note that 16 of these were derived from a stake set in the location of Mound H, which had previously been leveled. Mound H was proposed as being in line with the equinox, directly east of Mound A. The stake was placed exactly 9 TM (427.5 m) east of the center point of Mound A, on an exact 90-degree azimuth, not necessarily in the geographic center of Mound H. In addition, 16 occurrences presented in the table were based on other mounds no longer present. The locations of most of these mounds were estimated from earlier sketch maps and artifact concentrations on the surface (of a field which had been plowed for several decades). Only 19 of the 42 distances posited as significant were based on existing mounds.

Sherrod and Rolingson's conclusion of the TM as a unit of measurement was based on its common occurrence between the chosen target points. The apparent ubiquity of the TM convinced other researchers as well, and one review of the original study noted, “The 'Toltec Module' fails to hit the mark in enough cases that the authors must posit both local variations of the base unit and also considerable imprecision on the part of the ancient surveyors. Nevertheless, the
occurrences of both alignments and the module are so frequent that there seems little doubt of their reality” (Webb 1989:439). The TM has since been accepted in several summaries of archaeoastronomy and related fields (e.g., Brown 1997:478–479; Haag 1993:105–106), and other researchers have applied the TM directly to other sites. With appropriate caveats, Young and Fowler (2000:277) speculate on possible subdivisions of the TM used in the construction of woodhenges and other features at Cahokia. In a popular summary of the site, Kitt Chappell (2002:53) states 47.5 m as a significant distance in the layout of Cahokia. Most recently, Pluckhahn (2004) proposed the limited use of a 48-m module for the Kolomoki site in Georgia, which he suggests may be related to the TM.

In this paper I outline several problems with interpreting the TM as a unit of measurement employed in the construction of its type site, the Toltec Mounds. Many of these arguments are also directly applicable to any study of historical metrology conducted on mound sites in the Southeast. I argue that the margin of error used by Sherrod and Rolingson is so great that most apparent TM measurements at the site are spurious. In fact, the margin of error inherent in all Southeastern mound sites, due to the nature of the archaeological evidence, makes any attempt to derive a unit of measurement as short as the TM suspect. I then use geographic information systems (GIS) modeling of the Toltec Mounds site to demonstrate that multiples of 47.5 m do not stand out as significant against the statistical background. Multiples of the TM appear to be common not because of the specific layout of the site but because 47.5 m is a short distance compared to the numerous targets that are relatively close together. Any similarly short distance would be nearly ubiquitous, and the shorter the distance, the more common its occurrence. Taking another approach with GIS, I use statistical time-series analysis (applied to spatial instead of temporal data) in an attempt to determine which distances occur most commonly between Sherrod and Rolingson’s target points. While somewhat speculative, this time-series analysis demonstrates that there are many distances at the site which occur more commonly that the proposed TM. Finally, I discuss theoretical issues concerning the search for a prehistoric unit of measurement, particularly in light of what we know about mounds and mound centers in the prehistoric Southeast.

The Quantitative Approach: Methodological Problems with the Toltec Module

Margins of Error and the Propagation of 10 percent

A problem with the original derivation of the Toltec Module becomes apparent when we consider the criterion for deciding whether or not any particular measurement within a site “fits” a multiple of the TM. Sherrod and Rolingson write that the unit “was assigned a value of 47.5 m, although it has a range from 46 to 49 m, with most variation within 1.5 m of the 47.5 m” (1987:36). The standard actually applied to distances, however, is a wider range; the “actual distance of the module varies by up to 10% or ± 4.75 m from a precise 47.5 m” (1987:134). While a margin of error must of course be taken into account in any such study, the size of the margin and exactly how it is applied must be carefully considered. In the case of Sherrod and Rolingson’s study, the margin of error is relatively large to begin with, and the wording and use of “margin of error” is somewhat ambiguous. Strictly speaking, the margin of error employed is 20 percent of a TM, as the margin is applied to both sides of the intended target—in this case, 47.5 m ± 4.75 means anywhere between 42.75 and 52.25. By this standard, one out of every five measurements across the site would appear to fit the TM by chance alone.

The problem in the original study is even deeper, though. The margin of error is not held at a constant ± 4.75 m but is applied as a percentage of the entire measured distance and therefore propagated with each multiple. For example, when considering distances at the Cahokia site, Sherrod and Rolingson conclude that 1,960 m between Monk’s Mound and Mound 1 corresponds to 41.3 TM, which they consider to be an error of only 0.6 percent (1987:101). The nearest TM increments to 1,960 m are 41 TM at 1,947.5 m and 42 TM at 1,995 m. So how can 1,960 m, almost equidistant between two TM increments, be considered to have an error of only 0.6 percent? Figure 2 illustrates how the margin of error is propagated with distance to achieve this result. At one TM any measurement between 42.75 to 52.25 m would be considered within 10 percent of the distance; at five TM the 10 percent includes all distances between 213.75 to 261.25 m—an entire TM distance. In other words, at a distance of five or more TM, it is impossible to find a measurement which does not fall within 10 percent of the stated margin of error. Given this propagation of the margin of error, the larger the distance the smaller the margin of error it can possibly contain, and any measurement over 213.75 m will automatically fall within the 10 percent standard.

Aiming at a Blurry Target: Where Are the Mounds?

Sherrod and Rolingson’s initial study of the Toltec Module focused on distances between key points at the Toltec Mounds site, primarily the edges and centers of the mounds, and the edges and openings in the embankment around the site. In order to conduct this type of study, the edges and center points of the mounds must first be determined with at least as much precision as the analysis employs. If the mound edges or center points
1 Toltec Module = 47.5 m

margin of error:
+/- 10% = 42.75 to 52.27 m

2 Toltec Modules = 95 m
margin of error:
+/- 10% = 85.5 m to 104.5 m

5 Toltec Modules = 237.5 m
margin of error:
+/- 10% = 213.75 to 261.25 m

Figure 2. Diagram of the propagation of error as employed by Sherrod and Rolingson. Because the 10 percent margin of error is applied to the entire distance being measured, it becomes larger with each TM increment. At a distance of 5 TM, the margin of error equals 1 TM, and it becomes impossible to find any measurement which is not within 10 percent of the “error.”

are mapped inaccurately, the measurements between them will be correspondingly inaccurate. It is unclear how precisely the mound locations were determined, but the original study employs increments of 50 cm, so we must assume that the locations of the mound edges and centers were demarcated with at least this precision.

How accurately and precisely, though, can we realistically pinpoint the edges and centers of these large features? The largest mound at the site (Mound A) is about 95 m long. Plotting its general position on a map is an easy task, but what about demarcating the exact locations of the edges with submeter accuracy? Even on a 1:1000 scale map (such as the master site map for the Toltec Mounds site), a typical 0.75- to 1-mm-wide pencil line covers 75 to 100 cm of width on the ground. Drawing distances between these lines on this or any similar map would result in an additional margin of

75 m (approx.)

Figure 3. Mound B at the Toltec Mounds site, facing northeast. The break in slope angle represents the upper limits of slope wash; the mound has likely been altered both above and below this point.
experiencing erosion from rain, gravity, tree falls, and the natural mixing of the soil through biological and other means. For several decades before a formal map of the site was made, the grounds were subjected to repeated plowings, the grazing of animals, foot traffic, and other disturbances. The locations of mounds that have been leveled (the majority of mounds at the Toltec Mounds site) were inferred through earlier sketch maps and photographs, surface artifact concentrations, and soil stains visible on the surface and through excavation.

How confident, then, can we be in any estimation of mound edges? The precision undoubtedly varies from site to site, depending on the preservation of the monuments, and the extent and precision of any excavations or surveys of the mounds. As a hypothetical case, assume we have determined the location of a mound's edge within a margin of error of ± 2 m (the edge may be 2 m either direction from our exact demarcation). Measuring between any two points, we would need to sum this uncertainty for a total margin of error of ± 4 m, which is 16.8 percent of a TM distance. We should therefore expect about 16.8 percent, or about one out of every six measurements, to conform to a TM distance by chance alone (even without propagating the margin of error with each multiple).

This problem is further compounded when we consider what is meant by the "center" of a mound. Disregarding the theoretical question of why the location of the exact midpoint of an earthen monument would be significant to prehistoric populations, how do we interpolate from edge to center? Most prehistoric mounds do not present a perfectly round bull’s-eye target in plan view. They may be rectangular, oblong, or irregularly shaped with adjoining mounds, ramps, and other associated features. Center point determination may be done through simple geographic estimation or with a weighted mean method that takes into account deviations from spherical. It is also possible to determine a three-dimensional center taking into account the total volume of a mound. In addition, many mounds have flat summits that do not perfectly conform to the outline of the base. It is difficult to quantify the additional margin of error introduced in light of these considerations, even for a single mound. Clearly, though, different methods will lead to different center points, possibly with significant distances between them.

Statistical Background I: How Many Occurrences of a Measurement Should We Expect by Chance?

Disregarding problems with delineating the precise location of mounds and the propagation of the margin of error, is there some way we can determine whether TM distances (or any particular distances) occur across a site more commonly than we should expect by chance? This is, after all, the basis for deriving the TM at the Toltec Mounds site, for the 48-m module Pluckhahn (2004) tentatively suggests for Kolomoki, and for the 1.666- and 86.63-m units Clark (2004) proposes for numerous Archaic sites. Multiples of these particular distances seem to come up quite frequently when researchers look for them, and the distances are therefore interpreted as significant. Deriving a statistical background is necessary for any test of significance, but can be quite difficult in the case of spatial entities. Kvamme (1999:169-170) offers several ways GIS can be employed to test for statistical significance in spatial contexts even where populations may be nonparametric and overall statistical parameters are difficult to determine. It is possible to derive the statistical parameters for the TM at the Toltec Mounds site by using GIS to measure all possible occurrences of this distance, to and from the target points deemed significant by Sherrod and Rolingson.

Idrisi software (version 132.2) was used for all GIS operations in this analysis. Mound locations were digitized on screen from a scanned 1:1000 scale paper map provided by Dr. Martha Rolingson, Arkansas Archeological Survey Station Archaeologist at the Toltec Mounds site. The mound edges are defined by the solid polygons in this raster, and center points were determined through a weighted-mean method using the outer edges of each mound (Figure 4).

The first step in the analysis was the creation of distance surfaces from the edge of the embankment and edges and centers of the mounds (no center point was
Figure 5. TM increments (± 2 m) as measured from the edge of Mound A. Of the area within the embankment (shaded area), 8 percent is covered by a TM multiple.

Figure 6. Overlap of all TM increments (within the embankment only) from the edges and centers of all mounds and the edge of the embankment. Overlaps have been reduced to three categories for display.

generated for the linear embankment). The distance surfaces were then reclassified to keep only those values corresponding to the TM and its multiples. For this analysis, a conservative ± 2 m on either side of TM distances was used as a margin of error. Figure 5 illustrates TM distances derived from the edge of Mound A. The area within the embankment is shaded. All points on the ground that are covered by the concentric TM distances in this image would be considered a TM multiple—that is, it is possible to measure from the edge of Mound A to all points covered by these lines, and come within 2 m of a multiple of 47.5 m. The "hits" from the edge of Mound A derived this way cover about 8 percent of the core site area. This is the statistical background of TM distances from the edge of Mound A with a margin of error of ± 2 m; every point on the ground within the enclosure has an 8 percent chance of being considered an occurrence of the TM distance, simply because of the size of the module in question, the margin of error, and the overall size of the site.

Sherrod and Rolingson employ numerous target points in their analysis, primarily the edges of all mounds and the embankment, and the centers of all mounds. In order to derive the statistical background taking into account all of these potential targets, it is necessary to sum the TM occurrences from all of them. Figure 6 is the result of this summation: the overlap of all rasters of TM distances (± 2 m) from the edges and centers of all mounds and from the edge of the embankment. Each cell in this raster is coded with a value corresponding to the number of target points from which it is possible to measure within 2 m of a TM distance. The values in the figure are collapsed into three categories for display. Only 6 percent of the area is not covered by at least one occurrence of a TM; 41 percent is covered by one to two occurrences, and a full 53 percent is covered by three or more. Table 2 shows the percent of area covered by each overlap increment. From this analysis it is clear that every point within the enclosure has a 94 percent chance of being within 2 m of a TM distance from a target point simply by chance. Note that this analysis does not even include the full suite of targets used by Sherrod and Rolingson, particularly the five gaps in the embankment, the surrounding ditch, and mound "midslopes." Note also that this analysis employs a very modest margin of error of ± 2 m. A realistic margin of error at most mound sites may be significantly larger.

Any similarly short measurement would cover a large percentage of the site and occur quite frequently simply by chance as well. The smaller the distance tested in this way, the more commonly it will occur, and the larger the distance the less commonly it will occur. This is an inherent property of any such site, regardless of the
Table 2. TM Distance Overlaps by Percentage of Area Covered, Derived from the Raster Shown in Figure 6.

<table>
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<th>Cumulative Percentage (Excluding 0)</th>
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Figure 7. (Left, a): Distance surface: all points are coded with their distance from the edge of Mound A. (Right, b): Distances corresponding to all other mounds and the embankment have been extracted by masking out all other cells.

actual layout of the mounds. The percentage of area covered is a function of the size of the site, the number of targets from which to measure, the length of the unit being tested, and the margin of error employed.

Statistical Background II: What Measurements Occur Most Frequently?

Given that the TM is a nearly ubiquitous measurement across the site simply by chance, is there a way to determine what distances are most common? In other words, instead of beginning a priori with a set distance and testing its ubiquity, is there a way to measure all possible distances between potential targets and then analyze this data set for regularities? Beginning again with GIS, this is possible with statistical frequency analysis through periodograms. Periodograms are used to determine peak periodicities in serial data, usually applied to time-series variables (see Warner 1998 for periodogram and other time-series analysis methods). A periodogram of electrical discharge from a person’s heartbeat, for example, can show the regularity and timing of the heartbeats’ main cycles and subcycles. Stock market fluctuations are subjected to periodogram analysis in the search for cycles of rising and falling prices. For this analysis, I apply the technique not to a temporal sequence, but to a spatial sequence: distances of all potential targets radiating from the edges and centers of the mounds.

In order to cover all potential distances within mounds, and to give a larger overall picture of distances across the site as a whole, the entire area covered by each mound is included as a potential target. The data sets thus include distances from the centers and edges of each mound, measured to all raster grid cells covered by each of the other mounds. Because the embankment is a very large target area and covers the ground in a qualitatively different way from the mounds (essentially surrounding them all), the analysis is conducted both with and without it as a target. The analysis is also conducted from both the center points and edges of the mounds, resulting in a total of four distance determination methods (from mound edges with and without the embankment, and from mound center points with and without the embankment). Figure 7 illustrates the construction of one of these distance data sets. The distance surface (Figure 7a), in this case created from the edge of Mound A, is used as a base layer masked by all other mounds, including the embankment. The resulting raster (Figure 7b) contains values corresponding to all possible measurements from the edge of Mound A to all cells within all of the other mounds and the embankment. The raw distance values were extracted from this raster and imported into statistical software (S-Plus, version 6.0). This data set contains all of the measurements in the raster, but in a tabular rather than spatial format.

Displaying the distances in this data set as a histogram shows peaks and valleys in distance frequencies. Figure 8 shows the Mound A histogram constructed in this way. The shaded lines correspond to TM multiples. A small mound is conjoined to Mound A, resulting in a few very short distances on the histogram. At a distance of just over 100 m there are no other mounds from the edge of Mound A, and no measurements are therefore represented. The most common distance measurements from the edge of Mound A are around 150 to 200 m, mostly corresponding to the mounds around the southern plaza. Similar histograms were constructed for all mounds, in each of the four variations described above, for a total of 78 distance data sets.

Note that the most common distances expressed in the Mound A data set do not generally correspond to TM multiples (shaded gray lines in Figure 8). In fact, TM distances entirely miss the most prominent peaks. The single co-occurrence of a TM multiple and a local peak in the data is at about 95 m (2 TM). Mounds B, C, and D contribute the greatest number of measurements to this local peak in the data, and as Sherrod and Rolingson noted, some of the mounds ringing the southern plaza...
are close to 95 m from Mound A (1987:36). The histograms from the other 77 iterations of this analysis are similar: there are peaks and valleys in the data, but few corresponding directly to TM multiples. Figure 9 shows combined distance histograms from all mounds, computed with all four distance methods. The shaded lines correspond to TM multiples. Peaks in the measurements correspond fairly closely to TM multiples in some cases, but not at all in others. Even if one of the methods were to generate sharp peaks in distance measurements which corresponded only with TM distances, citing this as evidence for the existence of the TM would be post hoc reasoning without prior theoretical justification for choosing one particular distance determination method over another.

Another way to look at the distance histograms is to consider not the highest peaks they contain (which define the most common measurements from the feature in question), but the distances between the largest peaks, which define the most common measurements in the data set as a whole. In Figure 8, for example, the most common measurement expressed in the data is not the highest peak (at about 175 m). The most commonly expressed distance in the data set is actually represented by the most common distance between prominent peaks, each of which represents a large number of measurements from the target in question.

This is where time series analysis is applied: viewing the data sets as spatial sequences, periodograms derive the most common distances between the peaks. Figure 10 is the periodogram derived from the histogram in Figure 8 (distances to all mounds and the embankment from the edge of Mound A). The horizontal axis is given in meters and represents potential frequencies within the data, from 2 m to infinity (because the histogram is composed of 1 m bins, two is the shortest frequency expressible). The vertical axis represents the spectrum, or relative strength of each frequency. The vertical axis represents the spectrum, or relative strength of each frequency.

Two relatively short frequencies are weakly expressed in this periodogram, at two and four meters. These frequencies are the result of square pixels within the GIS raster—the distances represented in the histogram do not sweep smoothly around the edges of the mounds, but step around them stair-wise at the distance of the edge of a pixel. When such stepping around several mounds lines up in phase (rounded to the nearest meter in the histograms), these frequencies are expressed as significant peaks in the periodograms.

The important frequencies for this analysis are the strongest ones expressed in the data, or the frequencies with the highest spectrum in each periodogram plot. These represent the most common measurements in each data set. In the case of Figure 10, it is 720 m. Figure 11 is a series of line graphs, showing each of the peak frequencies from all mounds, derived from each of the four iterations described above. Not all of the period-

The Qualitative Approach: Theoretical Problems with the Toltec Module

Many of the earliest measurements we know about are anthropomorphic, based on the length of a stride, a foot, a nose, a forearm, and so forth. These "standardized" units are of course variable depending upon the body being used as the model. Even when such measures became standardized they did not remain static for long. Glover (1989:416-417) reports the lengths of no fewer than 12 different cubits (elbow to fingertip distance) from the ancient world, spanning a range from 18.0 to 21.8 inches. Some early measures not based on anthropomorphic principles include the bowshot and stone's throw (both common in many
areas throughout the world) and an uncounted number of idiosyncratic units, including a Latvian measure of the distance from which one can hear a bull bellowing and the Hungarian “hatchet’s throw backwards from a sitting posture” (Kula 1986:7–8). If standardized units of measurement existed in the prehistoric Southeast, and if they followed historic precedence, they would vary through time and according to region, possibly by a significant amount. Considering the length of time between the beginning and ending of the construction of many mound sites, on what grounds could we assume that the same measure was applied throughout the site’s occupation? Or even that the same units were used in both the construction of the individual mounds and the overall layout of the site?

The most common type of historical metrology is literally historical: the study of past units of measurement as described, defined, or employed in written records. Scales and weights recovered archaeologically are sometimes used to calibrate the measurements named in these written records. Less frequently does historical metrology concern itself with attempting to discover units about which there is no written record. I propose that this subdiscipline of the field be more appropriately termed *cryptometrology* (defined as the search for past units of measurement), because it attempts to derive units of measurement about which nothing is known, and which may not even exist. The question immediately comes to mind of how to interpret the results of distance analyses: even if a particular distance stands out against the statistical background at

Figure 9. Histograms of all distances from the edges and centers of all mounds and the edge of the embankment, measured to all raster grid cells within the mounds and embankment. Vertical bars represent TM multiples.
HISTORICAL METROLOGY AND A RECONSIDERATION OF THE TOLTEC MODULE

Figure 10. Periodogram of the spatial-series data presented in Figure 8. Frequencies of 2 and 4 m are weakly expressed. These frequencies are an artifact of the square raster cells; distance measurements are "stepped" around the edges of mounds. The most significant frequency within the data occurs at 720 m.

a mound site, on what basis could we infer that it was actually a measurement of length employed by the people who built the mounds? Patterns, cycles, and regular distances are quite common in purely natural phenomena. The territories of birds, the scales of fish, desiccation cracks in mud, and ripples from a stone thrown into a pond all exhibit a remarkable regularity that can be quantified, but these patterns are easily explained through external, natural factors. Might similar patterns be expressed in human constructions, unrelated to standardized units of measurement?

For a modern example of how standardized measurements are not always directly related to a finished product, consider the overall construction of wood frame homes and many other buildings in North America. The frames of these buildings are usually made with standard 2-x-4 pieces of lumber, 2-x-4 referring to the cross-sectional size of the wood. A 2-x-4 piece of lumber is not actually 2 by 4 inches in cross section, however. These dimensions refer to the nominal cross-section of the lumber as it is rough milled and do not include the kerf (the thickness of wood removed by the blade). The cross-section is further reduced as the wood is smoothed through planes and sanders. A standard 2-x-4 has a cross-section closer to 1 1/2 by 3 1/2 inches—but even this can vary by as much as a quarter inch or more depending on the lumber mill, the type and moisture state of the wood, and many other factors. Attempting to deduce a standardized unit of inches from such cross sections would clearly be problematic.

The lengths of pieces of lumber can be equally capricious. Generally cut to something close to an even foot at the mill, 2-x-4s are sectioned into smaller pieces using not only inches but decimal fractions of feet—7/10 of a foot, for example (equal to 8 2/5 of an inch—not one of the more common inch divisors). Lengths of wood are oftentimes not even cut to any preexisting measure, but fit individually to custom insets and windows, various slopes, bevels, bezels, and other irregularities in a structure, and the inevitable gaps and minor overlaps that occur with any major construction. The spacing of 2-x-4 studs in building frames is generally consistent (usually between 16 and 24 in) but can vary greatly depending on local building codes.

Figure 11. Bar graphs of the most significant frequencies derived through all four iterations of periodogram analysis.
the load an individual wall is intended to carry, the presence of doors, windows, chimneys, or other structures that must be taken into account, and so on. So we begin our construction with raw materials that are conceived, produced, bought, sold, and nailed together under a paradigm of feet and inches, but which may not reflect these dimensions in their final form. The example is extended but the point is a simple one: there is no reason to believe a priori that standardized units of length will be expressed in the features they are used to construct.

Related to this is the question of scale, certainly an important issue in matters of cryptometry, although little has been written about it in the Southeast or elsewhere. What is the proper scale at which to address prehistoric units of length? If a mound site were indeed engineered using multiples of a particular measurement, at what scale should we be addressing the question: centimeter to decimeters, meters to decameters, decimeters to kilometers? The answer depends on the length of the unit that was used to engineer the site to begin with. If the base unit were only a few centimeters long, we should not expect to find it clearly expressed across distances of hundreds of meters or more. If the unit were 50 or so meters in length, and we didn’t know into what fractions it may have been divided, it would do us no good to look for expressions of the unit at the scale of a few meters. And here we are stuck: without knowing the length of the unit to begin with, we don’t know if we are applying the appropriate scale of analysis to find it, and if we don’t know whether our scale of analysis is appropriate, how can we have confidence that our conclusions are? If our mathematical locutions are not to become completely circular, we must begin with some external line of reasoning for choosing a scale of analysis to begin with; some separate bit of information to tell us, independently of the measures we measure, what and where we should measure in the first place.

The question of scale is tied to the question of fractionation. The metric system standardizes fractionations into decimals, but this particular system is no older than the French Revolution that spawned it. Myriads of other systems of metrics are still in use today. Feet are fractioned into tenths and hundredths by engineers but into the duodecimal system of inches by most everyone else. Inches are fractioned by doubling the increments with every iteration from halves to quarters to eighths to sixteenths and so on. At the other end of the scale, measures are also extrapolated inconsistently. Feet are commonly grouped into three to become yards, and it takes a somewhat enigmatic 1,760 yards to make a mile. If such inconsistent fractionations and extrapolations were employed in prehistoric times, it is difficult to imagine that the base units would yield easily to mathematical analysis, even if significant target points could be determined with precision.

Modern counter-examples come to mind where specific units of length are clearly expressed in large-scale features. County section lines, for example, are easily recognizable on many road maps in flattish portions of the North American midcontinent, tessellating the landscape with a fairly regular 1-mile grid. The grid is obvious at this scale because the measure is so much larger than any potential margin of error in the size of the roads: an average road width of 25 ft is 0.5 percent of the measure the roads are demarcating. This is much smaller than the margin of error for proposed prehistoric units of measurement in the Southeast, though, and county section roads only follow section lines in flat areas of the country which were platted using mile sections, which does not cover a great deal of the country. There are also examples of very regular spacing at a large scale that have little to do with any unit of measurement. In aerial photographs of modern housing developments, for example, the structures are commonly spaced at almost exact distances from one another. In this case, the spacing reflects average house and lot size, and the locations of the houses within the lots. Regular distances between houses are fairly uniform within individual developments, and vary from one development to the next. In this case, the “module” of average house-to-house distance would reflect average lot and house size (and possibly convey important information about differences between developments) without having been employed as a specific unit of measurement in the construction of the houses or layout of the development.

At this point I can only offer a direction for theoretical discussion: how would we know whether a regularly expressed distance—even if it were very strongly expressed—represented a unit of measurement used by the builders of any particular feature or set of features?

Target Practice: Why Measure From Here to There?

We may also employ our archaeological understanding of the mounds in studies of cryptometry. We know, for example, that prehistoric mounds were generally not static monuments. Many of them were active, dynamic features whose size and shape changed significantly through time, and numerous reports have shown active mound construction over much of the occupation of a site. Mississippian platform mounds with 10 or more stages are not uncommon (Blitz and Livingood 2004). New stages of mound construction change the heights and shapes of mounds, sometimes over the course of several centuries. The edges and center points of mounds were therefore not just blurry targets whose precise location is difficult to discern, but moving targets as well. At what point in a site’s history should we expect any particular unit of length to be
expressed? The studies by Sherrod and Rolingson (1987) and Clark (2004), treat the mounds as if the final locations of their edges or center points were the intended goal of the societies who constructed them, who sometimes began the construction hundreds of years before they were completed.

Such studies in the Southeast have also failed to explain why certain points on the landscape or within a particular site should express prehistoric units of measurement. Why would the inhabitants want mounds to be located with their edges or centers set at even and arbitrary increments from one another? The centers and edges of mounds seem a popular choice of targets among modern researchers, but there is no explanation as to why they would have been so to the people who built the monuments. Because of the nature of the archaeological record these are the easiest targets for us to measure to and from, even if they are fuzzy and moving targets. It is easy to see how cryptometrological reasoning can become circular and an exercise in simply trying to find a fit between targets, without considering why they may have been important in the first place. A passage from Sherrod and Rolingson reveals this tendency. Reflecting that the TM did not always fit with precision, they write, “The fact that it is not exact may reflect either that the Indians were not concerned with precision or did not have the techniques to make it accurate, or that the modern measurements are not taken at the right places” (1987:44; emphasis added). In other words, if only we could measure to and from the right places, we would find good fits for the measurement we are looking for. But how would we know they were the right places? The reasoning seems to be that we would know because they would be good fits for the measurement we are looking for.

Another example comes from Clark (2004), who posits an Archaic period Standard Unit (SU) of 1.666 m, which was combined in multiples of 52 to create the Standard Macro Unit (SMU) of 86.63 m. Clark uses equilateral triangles drawn onto maps of mound sites to support his conclusions, with the corners and edges of the triangles conforming to features such as “the outer edges of the row of mounds and natural rises along the eastern bluff” (2004:164, at the Caney Mounds complex). Exactly why these features are significant, and exactly how the location of “natural ridges along the eastern bluff” was determined with submeter precision, is not explained. Clark’s equilateral triangle drawn on the Caney Mounds site, for example (2004:164, Figure 10.1), is drawn to the upper edge of the natural bluff line that is supposed to define the triangle’s northern corner, but near the base of the bluff line on the east. What would be the significance to the site’s inhabitants of the top of the bluff in one location but the bottom of the bluff in another? Concluding that these points (or the triangle as a whole) were significant because of an approximate conformity to a Standard Macro-Unit is circular reasoning, without a priori grounds for deciding exactly where to put the triangle to begin with.

Discussion and Conclusions

On Measurement Is Founded the Whole Progress of Man?

Some of the earliest archaeology in North America was intended to answer the “mound builder” question of who was responsible for the earthworks that so impressed early European observers. Popular opinion held that Native Americans could not have possibly descended from a people capable of creating such spectacular monuments. In a way, archaeologists have faced an uphill battle ever since, trying to demonstrate to a wider audience that prehistoric North America contained numerous and diverse societies that were culturally, politically, and even technologically sophisticated. Studies of historical metrology and related ideas are sometimes cited as evidence for the sophistication of prehistoric populations. Concerning prehistoric use of mathematical principals in general, for example, Marshall writes, “As to why one should do this research, an important reason is the very different impression of American history and the prehistoric and historic American Indian that emerges from these facts” (1987:40). Making a similar case seems to be an undercurrent in Sherrod and Rolingson’s study. They conclude, “One fact is quite clear regarding the prehistoric engineers of Cahokia and of the other community centers throughout the Mississippi River Valley—they were innovative, skillful, and resourceful and slight glimpses of their intricate thought can be discerned in the evolving patterns of the mounds they left behind” (1987:141). Clark aims to alter the perceptions not only of the general public but of archaeologists as well, writing, “What I propose here about ancient practices, knowledge, and concerns violates cherished academic notions of the imagined primitive tribes we have slotted into our narratives for the Middle and Late Archaic period” (2004:208).

But how exactly does the employment of a standardized unit of measurement demonstrate cultural or technological sophistication? Enlightenment philosophy certainly held metrics in high regard. Measuring and quantifying with accuracy and precision were the cornerstones of the New Science. One of the most prolific writers of the Enlightenment, Montaigne, wrote of the New World, “As recently as fifty years ago the written word, weights and measures, clothes, corn or wine were unknown there” (from Kula 1986:11). (Montaigne’s “corn,” of course, refers to Old World grains, not maize.) So even if Montaigne was an early advocate of cultural relativism, he considered it worth pointing out that societies in the New World were unclothed, illiterate, and (worst of all?) had no weights or measures.
The importance of standardization and precision to the advancement of society was further crystallized in the industrial revolution, epitomized by Henry Ford's assembly line: an executed plan for conformity of automobile parts intended to reduce the cost of production and increase automobile ownership—A Ford in every garage. This industrial ideal is tightly intertwined with notions of standardization, precision, and above all, progress.

A World War II-era promotional pamphlet from the Sangamo Electric Company embodies this idea in its very title: *On Measurement is Founded the Whole Progress of Man* (Sangamo 1944). A similar pamphlet from the General Motors Company (GM) proclaims in its title: *Precision: A Measure of Progress* (General Motors 1952). This publication outlines the history of measures from Egypt’s cubits to GM’s interferometry. Recall the “Rise of Man” motif showing stages in our evolutionary history flanked by a pre-human ancestor crouching on the left and a Caucasian man standing with good posture on the right: the quintessential tableau of progress from the twentieth century. GM’s pamphlet contains a metrological version of this concept (Figure 12). Certainly highly accurate and precise measurements are necessary in modern factory production, but how does this idea apply to prehistoric sites in the Southeast? Should we really consider the societies who built the mounds less sophisticated if they did so without a standardized unit of measurement? Clark implies that skepticism toward his claims of prehistoric quanta are grounded in such bias, writing, “The larger issue is why, when confronted with detailed evidence and illustrations, many colleagues find a disbelieve-the-messenger response more comfortable than believing Archaic peoples had the superior cultural IQ advocated. If my arguments are correct, all that is at stake academically is a prejudice against ‘primitive’ tribes.” (2004:206). In other words, standardized units of measurement equal sophistication, and positing that a society did not employ them is tantamount to calling that society primitive.

I reject the notion that societies could not conceive, construct, and utilize mound centers in highly sophisticated ways without standardized units of measurement. Perhaps measures were used, and perhaps they were not. I see no reason for either case to be used as a marker of technological sophistication. In fact, might the assumption that prehistoric units of measurement would yield to cryptometrological analysis imply that the societies were not at all sophisticated in their employment of the measures? Why would prehistoric societies have been bound by the procrustean ideal that mounds must be arranged with their edges or centers set at even integers of a single unit of measurement? Recall the 2-x-4 and the spacing of houses within a modern development. Is it likely that prehistoric Southeasterners could imagine no complex fractions and combinations of measurements as we do? And if they employed measures in sophisticated ways, would the measures really be expressed in the final form?

**Summary**

Examining claims of both prehistoric units of length and astronomical alignments at Megalithic sites in Europe, Heggie (1981) called for a statistical approach as the only way to test for significance. Heggie considered his approach successful in ruling out some proposed measurements (they did not stand out against the statistical background), and demonstrated that others did indeed occur more than would be expected by random chance. As a methodological approach
spatial statistics can likewise help us sift through historical metrology claims in the Southeast, but still lack the power to establish any particular measurement as a unit of length actually used by prehistoric people. For this we need more than just numbers; we need theory to bridge the gap between the numbers and our conclusions. Even if a particular distance at a site occurs more commonly than we would expect by chance alone, this would not in itself imply that it was a measure employed by the site's builders.

Methodologically, future studies of cryptometrology in the Southeast should at the very least derive a statistical background for the measurement in question. This is possible by taking into account the accumulated margin of error (from uncertainties about the exact location of the features, and the techniques used to derive these), the length of the unit(s) in question, and the number and clustering of potential targets. The GIS techniques for deriving a statistical background presented above are surely not the only way to do this. GIS is ideally suited to the question, though, and perhaps these techniques will inspire more sophisticated means of employing computer technologies in future studies. Theoretically, any such studies should explicitly state exactly how and why certain points are chosen as targets, and why the chosen scale of analysis is deemed appropriate. If a regular pattern of multiples or fractions of a particular distance are derived, such studies would still need to bridge the theoretical gap: Why would this imply that the distance was a prehistoric unit of measurement and not the result of some other factor of site patterning?

Notes

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