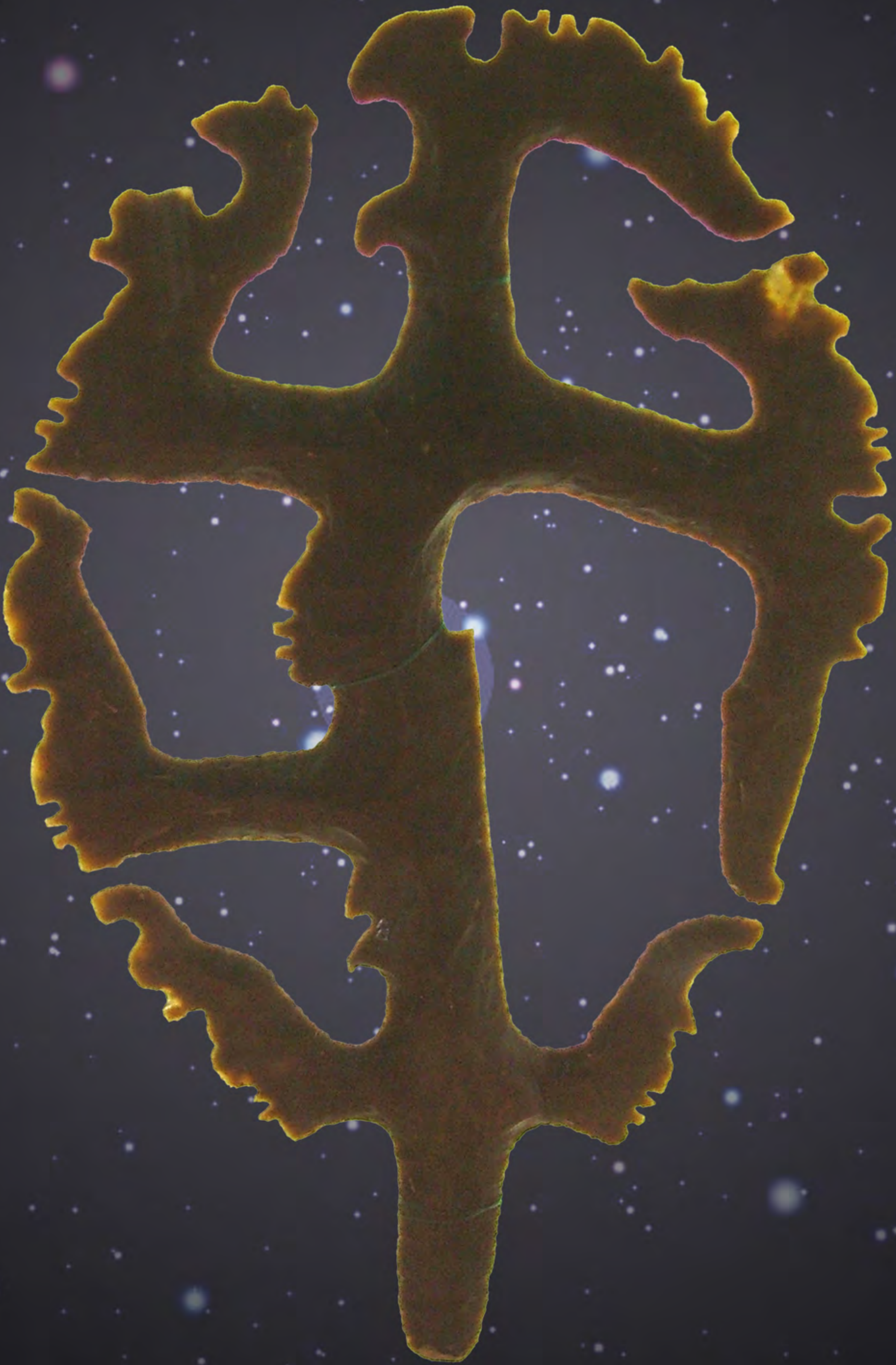
Decrypting The Sacred

RECKONING TIME IN ANCIENT AMERICA



Robert J. Patten

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Reckoning Time in Ancient America

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Foreward

I knew that in the years before his passing in early 2017, Bob was working on a study involving the great ancient complex cultures of Meso- and North America. But I'm a Stone Age archaeologist (studying the period 10 thousand to 3 million years ago). So, when we talked our conversations focused on how knappers made stone spear points during the Ice Age, whether Paleolithic foragers migrated across oceans, and when small hunter-gatherer bands arrived into new areas as they peopled the world after leaving Africa.

Although I cannot speak about Meso- and North America's magnificent complex societies in the way Bob can, I *can* speak to Bob's brilliant, inquisitive, and innovative mind; his attention to detail; his courage in asking difficult questions and pursuing disregarded subjects; and his amazing ability to approach any topic, idea, or hypothesis without bias or preconceived notions getting in the way. I can also speak to Bob's myriad publications in the peer-reviewed, scientific literature; his comprehensive description and analysis of artifacts from many well-known archaeological sites; and his accolades awarded from several archaeological bodies, including the world's largest: the Society for American Archaeology (SAA). Finally, I can speak to the importance of *time* in the past, the subject of this book. Production *time* likely influenced the appearance of artifacts (e.g., Schillinger et al. 2014). Seasonal *time* plausibly dictated the schedule of past humans' resource procurement, migration, harvesting, trade, and rituals (e.g., Mlekuž 2015). And ancient people eventually recorded *time* in scripts and iconography (Budge 1920; Coe and Stone 2005). All ancient peoples thought about time in some way or another, and so it is worth archaeologists' time to think about how ancient people may have thought about time.

I am grateful to Bob's wife Laurey and thankful for her commitment to making the present work publicly available. I am amazed that eight years after his passing, my dear friend and colleague continues to contribute to and challenge our understanding of the archaeological record (Eren and Patten 2019; Eren et al. 2021). And I know that Bob would not be overly concerned if readers of this work agreed with him, or if his ideas are ultimately shown to be supported or falsified. What he would care about is that his ideas are approached with an open mind and considered carefully and with respect. That is how Bob approached his life in research and in general, and there is no reason why the rest of us cannot follow his example.

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March 2025

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TABLE OF CONTENTS

Prologue

In February of 2003, I was invited by Dr. John Clark, of BYU, to accompany him to Guatemala City to study Maya chert eccentrics. John and I had previously worked to resolve how Folsom spear points were crafted from stone 12,000 years ago, and hoped that the experience would be useful for understanding Maya stone technology. When we arrived, we were hosted by Antonio Prado Cobos, a local architect interested in Maya use of precise geometry and measurement. At his studio, Antonio showed us some fabulous chert artifacts that we had not anticipated. In a moment, the question turned from "how?" to "why?" It was certainly not because the technique of manufacture was trivial. It most definitely was *not*. The level of workmanship and refinement was many levels beyond what either of us had experienced before. But even more interesting was the sense of purpose behind such magnificent industry. These artifacts were not merely art, they manifested unparalleled symmetry, compelling iconography, and economy of line more in the spirit of a technical instrument than a stone tool. After a week of viewing hundreds of eccentric chert items, thirty-four artifacts in particular demanded a far more complex explanation than aesthetic craftsmanship. I, for one, will never forget the feeling that we had been privileged to see some of the grandest examples of lithic technology the world had ever known and that the techniques of manufacture were far less important than the tantalizing hint that they might harbor an embedded message—a message we did not yet know how to read. The remainder of this book will explain how it has been possible to understand progressively more and more of the deliberately encoded information.

In stark contrast to most collections of stone tools from the United States, almost none of the chipped stone artifacts we saw appeared to be functional. Edges were trimmed to perfection and showed no signs of damage from cutting or other use. Stylistic designs appeared repeatedly, and generally exhibited an uncanny degree of symmetry. The quality of stone varied considerably, but some of the most astounding results had been accomplished with the least tractable rock. When we thought about the technical challenges of flaking chert in that part of the world, other mysteries loomed. How were intricate forms produced with highly acute edges and nearly devoid of beveling that normally accompanies detailed shaping? What tools were capable of breaking such tough rock with such precision? The few antlered animals in Central America are too small to provide hammers or punches sufficient to explain the size of work we observed, and no substitute materials were immediately obvious. Hardwood punches and hammers might have been used, but would that suffice for the smallest detail? I felt more like a total neophyte than an expert lithic technologist with decades of experience.

One of my tasks was to attempt replication of the simplest form of chert artifact, a leaf shape defined by intersecting compass arcs, very similar to projectiles typical of the Great Plains of North America. Alas, my efforts failed to meet the precision inherent in Maya work. Other artifacts revealed that ovals were not simply aesthetic, but mathematically-perfect ellipses representing conic sections. Even highly intricate designs were found to be ellipses, with strategic bits subtracted to nearly completely obscure the original form. Despite an initial impression of spontaneous art, the artifacts suggested rigid rules of structured geometric construction that implied some hidden meaning. We left Guatemala highly motivated to decipher whatever we could.

During the next two years, I sorted through detailed and accurate scans of the critical artifacts, trying to gain some glimmer of inspiration, with little success. Then, a cache of thirty-three chert eccentrics finally revealed itself as having thematically related sets that could be organized in multiple ways. By using computerized drafting tools, it became more and more evident that each artifact was highly symmetrical, so I oriented each of them by major and minor axis. The relationship of my guide lines convinced me that an undrawn bounding quadrilateral had guided the original craftsmen. When I used the computer to check how well I could match the elliptical shapes, I was astonished to discover often-perfect fits. From that start, the work turned into an exhaustive search to identify whatever rules of geometric alignment the Maya might have used.

Two of the thirty-four artifacts indicated an especially organized sequence of design, and I chose to concentrate on the most elaborate of them, an effigy with seven faces notched into stone edges, very similar in design to several found at Copan. The economy of line on this new artifact somehow appeared to be more engineered than it was artistic. My expertise as a lithic technologist and training as a civil engineer told me that the craftsmanship was off the scale in comparison to anything vaguely similar that I had seen before. What could possibly merit such effort? Astronomy? Cosmology? Or something else?

Archaeologists recognize chert eccentrics of this general appearance as *K'awiil* scepters. During the classic Maya period such scepters were presented as symbols of divine authority when a new ruler took office. *K'awiil* was the Maya God of lightning, whose bolts were thought to leave flint effigies. *K'awiil* was typically depicted with a smoking stone axe in his forehead and with a serpent leg. The *bacob* gods supporting the corners of the world were apparently versions of *K'awiil* as well. It occurred to me that seven faces cut into the artifact corresponded with the fact that seven orbits, including the earth about the Sun, were observable by the naked eye. However, an obvious strategy of depicting intervals of visibility of planets by standard units of measure was not readily compatible, since a 30-day lunar cycle would not fit easily on the same record with the 780-day cycle of Mars.

Over months of study, the artifact revealed secret after secret, suggesting that the Maya used a standard unit of measure barely larger than a millimeter to record numeric information. The system of measure represented earthly distances as physical tallies of heavenly cycles. What began for me as fumbling curiosity ultimately transitioned into the unraveling of an unanticipated and complex cypher. Artistic elaborations often disguise durable records of priceless data containing clues ranging from arcane mathematical manipulation, to complex rules of design, to sophisticated patterns of thought. As records captured in architecture and art are revealed, it becomes evident that they express a profound preoccupation with the reckoning of time. Remarkably, conventions of coding have been found to span six thousand years of time and 55 degrees of latitude between the Great Lakes and southern Honduras. Because the conventions developed and matured over such a long time, their development will be addressed in chronological order.

1

Introduction

The first stirring of human self-awareness was surely accompanied by a questioning of how and why people came to be. Creation stories were necessarily some of the earliest and most enduring myths. There must be an order to the world, and given that an individual was not in control of his own environs, it would be natural to seek comfort from a higher power. Most comforting would be a creator who could be communicated with and was open to negotiation. Since one cannot approach the unseen and unfelt, observable natural phenomena, such as wind, rain, and lights in the sky, must surely represent such a deity. While unpredictable in detail, such phenomena suggested an underlying dependability that just might be put to use if only enough attention were devoted to them. Of all the possible guises of a deity, the heavens would have been recognized as the most constant and reliable, hence the most amenable for communion.

There is a symbiotic relationship between archaeological evidence and myths. Presuming that myths are reasonably accurate depictions of a world view from the distant past, they are necessary elements in the interpretation of evidence from that time. When data appears to provide connections to mythic stories, it will be noted. So many commonalties exist between creation stories from distant parts of the globe, we should at least entertain the idea that diverse myths may share a common basis.

Today, we see a different night sky than people saw thousands of years ago—not because the sky is so different, but because we now live much of our lives sheltered from constant view of the heavens. In earlier times, men would have been as familiar with celestial objects as we are with the patterns in our bedroom ceiling—more so perhaps, because the sky displays so much distinct detail to focus on. Our relatively recent scientific perspective on planetary movement provides a perspective of what we are viewing that our ancestors could not share. Indeed, their own explanation of the universe is what we want to discern. The human brain is "wired" to key in on patterns and anomalies that can be used to reveal an underlying order—it is a basic survival trait. Orbital cycles draw attention because they are repetitive and easy to quantify by counting days. Tally marks on bone show that people were beginning to document their emerging understanding of cycles as early as 30,000 years ago (Marschach 1972).

Observations made over an extended time from the same locale show that certain astronomic phenomena recur periodically at specific points on the horizon, providing standard references for counting cycles. Solstice extremes provide reliable schedules from which to plan seasonal activities, and the appropriate points on the horizon can be easily correlated to landscape features or simple monuments. Constellations, likewise, serve as convenient markers to help associate star positions with the seasons. While we all live under the same sky, our view of it differs according to our latitude, so cultures residing in different regions necessarily had different correlations to observe.

Without clocks or calendars, keeping track of day counts would have required an intimate familiarity with numbers. Mathematics, in fact, would have arisen naturally from a desire to reconcile cycle counts with seasons. For example, knowing it takes 365 days to complete Earth's seasons and that Venus takes

584 days to complete its cycle is not nearly so informative or useful as recognizing that eight cycles of an Earth year counts out the same number of days as five cycles of Venus.

The sky we see is constantly changing, day by day and season by season. Simple conventions available to anyone of any time are sufficient to share observations with one another. A good place to start is with the North Star as a reference bearing. When compared to a cardinal direction, an observed bearing to the setting sun becomes an *azimuth*. Drawing that bearing on a portable surface creates a *vector*. Using a standard base unit of measure then gives a vector a value that can be compared to another vector. This is heady stuff, for it allows observations to be documented and transferred through time and space. With an appropriate reference bearing, one can go to another locale and predict where on the horizon the Moon should appear when it reaches its maximum northern or southern position, called standstill. Putting the pieces together builds an increasingly complex structure of the observable universe.

While searching for meaning in their universe, early people encountered certain phenomena that must have appeared to be guided by an unseen hand, like the solstice, the northern or southernmost position of the Sun on the horizon, that happened in tune with the seasonal year. Just what kind of thoughts would have followed such "Aha" moments in human development? Historian of religion, Mircea Eliade (1959:11) defined *hierophany* as a revelation of the sacred in an object or event of the otherwise profane world. If we take the "Aha" moment to be a hierophany, it also represents an opportunity to interpret Divine guidelines. Whoever could be the first to demonstrate foreknowledge of the workings of the universe would be accorded great respect. For one thing, the insight could be used to invoke a deity's blessing.

Initially, hierophany was only something to be acknowledged or wondered about. Through time, people supplemented natural alignments and coincidences with strategically placed landmarks and monuments. Later designs were created to be entirely independent of the surrounding world in all but a symbolic sense.

My path of discovery actually began with such artificial hierophanies, constructed to codify insights about the nature of astronomy. Eventually, I came to recognize their origin in an interaction between early people and their surroundings. Tracing the step-by-step development through time allows us to appreciate a unique perspective that shaped entire cultures.

Mound building started along the Mississippi River basin at least 5,700 years ago (Saunders 2010). Roughly fourteen clusters of mounds dating to the Middle Archaic are dotted about the lower Mississippi River, each containing a distinct inventory of artifacts, indicating a lack of social cohesiveness between those sites (Gibson 2010). After nineteen hundred years of mound building, there was a hiatus of about 1,300 years during which no mounds were built, even though trading was prolific. The next episode of mound building started about 3,400 years ago and reached a pinnacle at Poverty Point, Louisiana, a prominent center of influence and trading. While mound building continued through the Mississippian period, its importance seems to have lessened with time. Basic concepts are shared among all the mound clusters.

Although there are numerous possible reasons for arranging mounds in distinct patterns, at least one purpose appears to have been simple documentation. Not only are the mounds often positioned relative to each other along solar or lunar alignments, they adhere to repeated geometric relationships with common trigonometric ratios at convenient scales—implying that the builders utilized standards of measure. Counting the number of standard units effectively describes numbers that were recorded and mathematically manipulated, even though no notation has been discovered from such an early time. The numbers found in Louisiana mound sites coincide with numbers and mathematical relationships recorded in Mesoamerica by Maya glyphs, including calendric numbers and planetary cycles.

Once the cycles for the various planets have been counted out, the necessary components are present to construct a calendar, of sorts. Nearly every chronological reckoning that has ever been conceived encounters a series of problems as days accumulate. The actual length of a year is slightly longer than 365 days, which leads to a gradual mis-registration with the seasons when the days are counted as whole numbers. Nowadays, we solve that problem by making a periodic correction of a day every four years (our leap year). The Maya sidestepped the issue by treating their calendar as a linear record against which events could be recorded and tracked. As a consequence of that convention, seasonal activity has to be orchestrated by events, like solstice, that stay in registration with the seasons. Maya counting of time by sets of 365 and 260-day intervals allowed the calendar to regain a perfect seasonal correspondence only once each 1,508 years. However, the combination of 365 and 260 was deliberately and explicitly represented by trigonometric ratios at mound sites in Louisiana.

Following how myths diverge regionally as well as how principles of geometry were incorporated into community organization shows that people chose unique paths of development. The better we can establish linkages between myths and practise of astronomy, the more thoroughly we can follow the dispersion of cultural traits. The earliest astronomical insights seemed to assign special privilege to certain places by their latitudes. Since the privilege was presumably extended to everyone at that location, leadership may have been a local decision. In later times, while various location-specific phenomena seemed to confer special acknowledgement by the deities, the privilege of leadership apparently was divorced from the place it was to be exercised. Whether people saw themselves as special by place or by knowledge led them to impose very distinct cultural patterns. The strong relationship between administrative power and astronomic prowess is undeniable in later Mesoamerica, where cities are designed to align with astronomic events and the ruler occupies a central position. However, it would be inappropriate to impose the same pattern onto Archaic hunter-gatherer-foragers because there is no evidence of permanent habitation or even large gatherings beyond the labor necessary to account for large mounds. Still, we are able to find common values for astronomical cycles and calendar counts documented by similar means in both areas, showing that while rituals and beliefs may have transformed, there is still a solid core of shared cultural heritage.

Many of the discovered records appear to be deceptive, but we cannot be certain whether it is because we are unfamiliar with the format or if it is because we are unfamiliar with ancient thinking patterns or if the data was intended to remain restricted to a particular group. By definition, coding entails deliberate deception by substituting letters or words in order to keep a message secret. Cyphering, on the other hand, transforms a message from one language to another by means of a special key or restricted critical knowledge and may be inadvertently deceptive. Fortunately, artifacts left by ancient astronomers contain messages that reveal much about which astronomical objects were of primary concern, how they were watched, and how they were quantified. Since the same data is conveyed repeatedly, it seems possible that the message was meant to show the creator that his design was understood.

Multiple levels of message are repeatedly encountered, from leaving important design points remaining as un-marked or un-monumented virtual locations, to emphasizing relatively minor elements as a subtle misdirection. When meaning is apparent, it very often has a dual interpretation. The Maya are known to have attributed multiple aspects to each of their deities and apparently saw the same potential in everything about them. It is not unreasonable to expect that numbers and symbols would be given multiple meanings as well.

Measurements are central to decoding the information, but they too have a duality that confounds investigation. Most researchers have previously concluded that body measurements were used exclusively and that no standard of measure was ever present. The resolution may be that the fully precise system was reserved exclusively for the elite while body-based equivalencies were practiced by the remaining populace.

To decipher ancient records requires escaping long-held paradigms and considering the “impossible.” Only by testing new assumptions can unfamiliar patterns become evident. Even traditionally accepted barriers of time for early intellectual development should be challenged. Levels of precision commensurate with modern instrumentation must be applied in order to test some of those assertions. One valuable way to escape unrecognized limitations is to adopt a fresh point of view. We will first try to see things from an egocentric view, but then apply a geo-centric view, and finally employ a cosmo-centric viewpoint. It should become clear that each is required.

When I consider Maya monumental structures, laid out in precise alignment with astronomical positions, my background in engineering and mapping assures me that a well-developed science of measurement was instrumental. That conviction only increases when I see symmetry, regularity, and rhythm expressed in craft after craft. A sophisticated system of endlessly interlocking cycles clearly recorded in abundant glyphs demonstrates that community plans could have been made and kept in the best of administrative traditions.

Trouble is, no suitable evidence has come forth to validate such an optimistic view. Granted, early Spanish accounts tell of native surveyors with rods of standard length, but neglect to explain how long or how accurate the intervals were. Vague comparisons to inconsistent Spanish standards of measure only compound the confusion. Fortunately, there are other means to answer the questions.

Following tangible evidence brings order to the largely frustrated previous attempts to recover lost units of measure and sweeps much uncertaintly aside. In the process, the reasons why resolution has been so difficult become clear. Ancient people placed importance on different distances than we would normally select and direct point-to-point distances were often subordinate to composite distances, like perimeters. Such unfamiliar conventions have effectively concealed native standard measures. Most of us are so comfortably familiar with measuring by multiples and divisions of standard units that we may find it difficult to conceive of another approach, however such an alternative will be shown to be likely.

Maya astrology was so pervasive that space and time cannot be readily separated. Therefore, the intervals marking off linear distance are couched in the same set of numbers found in calendars and planetary cycles. A consequence of this odd (to us) integration is a tendency toward numerology and deliberate skewing of data to force convenient patterns. Another interesting behavior is a strong preference for aesthetically pleasing arithmetic, like multiples of consecutive *integers* (whole numbers), or powers of favorite numbers. Perhaps intriguing patterns were thought of as having mystical properties.

We must guard against unrecognized assumptions. For example, the fact that Maya glyphs record only integer values may not provide sufficient grounds for assuming that there was no other way of sharing decimal-level information. Simply acknowledging the context of information can help us recognize potential assumptions. Later, we will see how adopting different geometric frames of reference can impact decisions about what to measure.

If units of measure were body based, as many believe, parts of a craftsman's body are sufficient instruments. However, Maya art depicts measuring by means of cords which would be unsuitable for very fine divisions because they stretch. Obviously, one's assumption of precision level strongly affects the search for measuring tools. There is reason to expect that levels of precision will vary according to the task at hand. After all, in our own culture, the expediency of pacing is a practical partner to the formality of a yardstick.

Because of the inevitable range of scale and variance of accuracy, known physical phenomena, like the cycles of planets, provide data independent of culture or opinion. Precise geometry and pure numbers are even better for reducing ambiguity of intent. Integer notation is so well understood among the Maya that decimal precision is usually considered unthinkable, however, even the most basic assumptions will be revisited and challenged where appropriate.

Even when we think we understand the system of measure, there are many difficult issues with standards. Not only were ancient practices subject to variation, we have the same problem. How precise do we have to be in order to characterize ancient standards? Are traditional conventions for collecting archaeological data sufficient for resolving the question? Despite these concerns, there are good prospects for resolution.

Your receptivity is preordained by your attitude. That is not a value judgment, just fact. There is no alternative to predisposition because we each carry a unique background of training, experience, and a touch of prejudice. Thinking of people as living in a stone age implies certain technical limitations that cannot be easily overcome without metal. Sure they practiced astonishing astronomy, but just how much were they hampered by the lack of a telescope? Maya buildings tend not to be squared and neatly oriented as those of other advanced civilizations, or so we may be told. Succumbing to the conceit that modern conventions are superior to those of the past threatens to blind us to alternative means for orienting structures consistent with a world view. Assumptions are easy to make but they can turn on us readily as well. It is appropriate that claims made here be scrutinized rigorously rather than accepted without question. An attempt has been made to anticipate and address legitimate challenges as early as possible. While intellectual and social traits of ancient people are difficult to pin down, it is inappropriate to refuse consideration of achievements because we are uncomfortable with the implications.

Some evidence is fixed in place, like a site layout or monument. Others clues are in portable format, like chert eccentrics. Either way, a number of considerations aid in arriving at credible interpretations. Priority should be given to determining what the site or tool *does*. It may be a tool for marking time or predicting events, but it might also be a means of documenting what has been learned from observations. A site may be a place to live or to observe sacred rituals—sometimes both. Then there is the issue of what people *did* at a site or with a tool. Often, what remains for us to see is symbolic. Massive mounds are usually considered an exercise in social power, but a special staff head made of chert might be equally powerful. Constructions can serve dedicated or multiple purposes and be both practical and decorative at the same time. The choice of media probably has as much to do with scale as anything else, but it certainly relates to the likelihood of lasting to our time. Projects that required organized labor and great skill testify to a widespread commitment and dedication to a cause, and the state of preservation strongly impacts one's attitude about the significance that should be attributed to an artifact.

Most relevant to archaeological interpretation is what might be termed the "primitive" paradigm. Modern achievements may seem to be the product of a steady accumulation of intelligence. More accurately, we benefit from an accumulation of *archived* knowledge. There is little to suggest that our intellectual capacity is fundamentally different from our distant forefathers. We are simply supplemented by powerful tools that often lead us to discount technical abilities of past people. Eyeball observations are difficult, but there are techniques and simple aids to increase precision. It is easier to assume ancient standards and limits of variation than to quantify them. Nonetheless, they can be detailed with precision. It is important to avoid projecting one's personal unfamiliarity with the structure of the universe onto someone in the far past who may have been a keen and perceptive observer. Similarly, sophisticated mathematical operations and concepts were in place much earlier than we have been prepared to imagine. Considerable attention will be devoted to how ancient frames of reference may differ from our own.

Once the evidence is digested and formed into a hypothesis, it must be given credibility and satisfy skeptics before it can be widely accepted. Preferably, the principles of astronomic observation should be demonstrated under original conditions. Degradation of much of the evidence and repositioning of celestial objects sometimes makes observation problematic, so virtual reconstruction may be required. Here again, we encounter the challenge of adopting a point of view that may conflict with our modern background. Is it more reasonable to accept a central observation station or to postulate moving from station to station? Were ancient astronomers guided by concepts even remotely similar to our own or did they have a completely different framework for explaining what they saw? The answers cannot be arrived at solely by modern logic because we actually want to understand a past way of thinking. Such reconstruction will require repeated speculation and demonstration before being completely accepted.

I encourage readers to acknowledge their basis for personal opinions and follow the evidence. Even the evidence may be questioned since much of it has been looted, or otherwise removed from its primary context. Although regrettable, "tainted" evidence may be enough to push our attention in productive directions. After all, the Rosetta stone was looted as well but it provided the intellectual leverage that allowed scientists to move far beyond depending on it for deciphering Egyptian text.

Among the many paradigms to be challenged is the notion that special astronomic and mathematical knowledge was restricted to distinct cultures. In actuality, the key knowledge base transcended every cultural barrier. While archaeological distinctions derived from artifact inventories seem to indicate great diversity through time and space, the astronomic and mathematical traits persist virtually unchecked.

2

Early Observations

Interest in the sky did not begin with a calendar, but it would have been impossible *not* to correlate seasonal appearances of heavenly bodies with the passage of time. Stars not only wheel from dusk to dawn, they appear to take up new positions each night. People accustomed to keeping track of their surroundings as they foraged and hunted by day would have had no trouble navigating by the night sky. The Moon's transition through its phases, and the individual schedules of planetary movement would have been part of a familiar routine. Observers would have inevitably realized that many phenomena repeated over regular cycles and that some of those cycles could be linked. As seasons were just another set of cycles to be reconciled, noting how days counted in a planetary cycle relate to timing of the seasons would have been indispensable.

Because we have grown up knowing how to express numbers as notation, or scaled in a drawing, we find nothing awkward about lists of observed cycles or algebraic equations relating various cycles. But how might those concepts have been expressed or explored without some sort of symbolization to represent the idea? The act of counting obviously correlates each number to a physical item. Fingers and toes can be counted but, after twenty, humans run out of digits. Pebbles are sufficiently numerous to allow counting to any number desired, but since they can be easily disturbed, the record is not permanent. Large numbers impose another difficulty—that of keeping track of the relative quantity. Grouping pebbles in piles of five, ten, or twenty creates a base by which one count can be visually captured and compared to another. In our modern society we typically use base ten, with a decimal place to keep track of larger and smaller groupings, but Mesoamerican mathematicians regularly used bases of thirteen or twenty. Combining base numbers into groups leads to the concept of scaling, where the value becomes the base number multiplied by a scaling factor, as in 13 times 20 equals 260. So scaling is both a process of multiplication and a means of standardizing the representation of large numbers. Keeping track of planetary cycles could simply be a matter of tallying pebbles or marks on a wall. But without notation, comparing the cycles would be challenging.

One possibility for comparing numeric quantities is to use a physical analog. If a count of *one* is arbitrarily taken to be the width of a finger, then we could cut lengths of sticks to represent any base we wanted and simply tally up the sticks as scaling factors. Yet arbitrary units have a disturbing flaw. What if the person with whom we want to coordinate our observations adopts a different base for representing a unit? What if he uses a different scaling factor? Even if everyone agreed that a finger width was fine for a unit count of *one*, after measuring out as few as twenty units, one person might say the distance represented a value of nineteen while another could say it was twenty-one—all because fingers come in different sizes. If we want to compare values in the hundreds or thousands, it would be necessary to make the standard interval either very small or very precise. While body parts make good analogs for relatively small dimensional values, they are clearly unsuitable for representing large numbers.

Lengths of cord provide a portable means of comparing dimensional values of almost any quantity. Straight lengths make it easy to compare and estimate any discrepancy. If a cycle is represented as a closed loop, then multiple cycles are simply repeated loops of the same size. Addition, subtraction, multiplication and division are readily visualized and simply executed analog operations. Loops of cord allow a clock arithmetic approach for solving cycle math by comparing day counts marked along the cord.

Early astronomers had two options for developing cycle counts. The most commonly used method was to keep track of *synodic* cycles—the number of days before a planet being tracked returns to a specific spot on the horizon. The 365.2422-day *tropical year* represents the synodic cycle of the Sun. In order to keep track of repeating patterns in synodic cycles, people would have had to take note of how positions of planets and stars varied in relationship to specific landmarks. The Sun and Moon rise and set in daily progressions from north to south and back again. In particular, while the Moon appears to vary the same amount each month, over many years its north-south limits of appearance are relatively extreme. Another approach would have been to track *sidereal* cycles, seeing a planet reappear against a specified backdrop of stars. Sidereal cycles are generally longer than synodic cycles and are seldom noted in an archaeological context. Since sidereal cycles lead directly to modeling planetary movements as orbits about the Sun, Earth-centric synodic cycles are not readily modeled by conventional geometric diagrams. Therefore, the decision to use synodic cycles greatly complicated the problem of explaining how planets move in relation to one another.

At the heart of any calendric system lies the understanding of planetary movements, gleaned from generations of observations. Many of the discovered relationships are shared worldwide, even without means of contact. After all, the same phenomena are being studied and accounted for. The difference is in how data is organized and processed. In this regard, the Maya were especially well armed with mathematical techniques and dedicated attention, and they specialized in finding common ground between cycles.

We can hypothesize a line of inquiry that might have occurred to early astronomers who were well aware that the longest cycle they tracked was the gradual north and south transit of the Moon during approximately 18.6 years. Although there are many orbital perturbations that can lengthen or shorten the basic cycle, individual cycles would have been easy to count and additional observations could have refined the understanding. By noting the position of the Moon in the sky when eclipses occurred, the ancients were able to map the path that we know as the *ecliptic.* The ecliptic represents the plane of Earth's orbit about the Sun. The plane of the Moon's orbit around Earth is inclined 5.14 degrees to the ecliptic, causing the Moon to cross the ecliptic about twice a month. As the Moon's orbit progresses north or south in relation to the ecliptic, the Moon's apparent travel is limited by *standstill*, when the *lunar nodes* (where the Moon crosses the apparent path of the Sun in the sky) are in the plane of the equator. Since eclipses occur when the Moon and Sun are in the plane of the ecliptic, eclipse positions are also nodes where the lunar orbit intersects the ecliptic. Solar eclipses can only occur during a new Moon, while lunar eclipses can occur only during a full Moon phase. Passages of the Moon through an eclipse node often occur when a viewer is not in the right location to observe the eclipse, making the physical model of rotating celestial bodies less easy to visualize and hampering definition of the time between nodal passages. Considering the value of predicting eclipses, the long-term cycle of the Moon would be particularly important if other cycles could be measured by integer multiples of it.

Using an average value of 6,800 days for a lunar standstill cycle, we can now factor the cycle by various values we have noticed from other observations. Length of a tropical year, lunar month, and lunar nodal cycle are each readily counted with sufficient accuracy. The eclipse year can be calculated by dividing the standstill cycle by the number of tropical years plus one.

6,800 days $= 365.2422 \times 18.613$ *tropical year times the lunar standstill cycle*

Dividing the lunar standstill cycle of 6,800 days by a tropical year of 365.2422 days equals 18.613 years but, during the cycle, the Earth completes 6,700 orbits about the Sun. Therefore, it is possible to correlate the 360-day count of *tuns* to a tropical year equivalent by applying an integer ratio of 67:68. The 360-degree convention for dividing a circle is thought by many to have originated from Babylonian base-60 math, but was shared in Egypt, India, and China (Katz 2007. Other cultures may have actually depended on the same correlation with the lunar node cycle to simplify their record keeping.

Counting passages of lunar nodal cycles provides another useful relationship.

6,760 days $= 260 \times 26 = 520 \times 13$ *three lunar node intervals times thirteen*

In terms of clock arithmetic, the dial pointer for the 6,760-day cycle finishes a rotation in synchronization with that of the tropical year and the 360-day *tun* calendar. A cycle of 6,760 days is auspicious since multiplying by 365:260 yields half the calendar round of 18,980 days and accounts fully for the structure of the Maya *tun* calendar. Counting cycles of 260 days, designated as a *tzolk'in,* by repetitions of 13 and 20 days may have made it possible to anticipate eclipses. The synodic cycle of Venus multiplied by that of Mercury approximates ten times the 6,760-day cycle, providing yet another means of commensurating cycles.

Daily counts for divisions of the Maya *tun* (long count) calendar		
Subdivisions of long count	Multiply units by 13 to get subdivision endings	
(*k'in,* day) 1	(trecena) 13	
(*winal*) 20	(*tzolk'in*) 260	
(*tun*) 360	18 *tzolk'in* 4,680	
(*k'atun*) 7200	260 *tuns* 93,600	
(*b'ak'tun*) 144,000	260 *k'atuns* Maya Epoch 1,872,000	5,200 *tuns* 5,128.767 *haab'* cycles 5,125.366 tropical years
5 *b'ak'tuns* 720,000	65 *b'ak'tuns* precession cycle 9,360,000	

Continuously counting by intervals of 260, 360, and 365 days avoids having to choose one optimum integer factoring scheme over another. That the numbers link comfortably with the lunar node, eclipse intervals, and Venus cycle is particularly convenient for linking cycles.

The tilt of the Earth relative to true north moves through a complete revolution once in every 25,765 years, known as the precession of the Earth's axis. This phenomenon reveals itself by first appearance of stars along the horizon regressing over protracted periods of time. Each *tun* ends with a daily count 5.2422 days short of the tropical year, resulting in an ever-widening discrepancy between the calendar and the seasons. Dividing the tropical year by the shortfall of counting *tuns* by 360 days predicts that an arc-degree displacement along the horizon will take 70.688 years and take 25,818 tropical years for a full cycle. Precession can be realized within a single generation by associating star appearances with fixed landmarks, successive generations could quantify the drift with increasing accuracy. Aveni (2001:100; 2002a:118) remarks that there is no evidence that the Maya recognized the precession of the Earth's axis, but what evidence might we look for? When the mathematical structure of the entire system is considered, it seems unlikely that precession was not considered.

The *tzolk'in* divination cycle of 260 days happens to provide an optimum interlock period for cycles of the Sun, Moon, Jupiter, Mars, and Venus (Peden 2004). Venus and solar cycles are exactly locked together at 52-year intervals, but 104 years provides the ideal opportunity for correcting an integer five days of accumulated discrepancies. According to Aveni (2002a:181,187), the long count in base-20 notation was introduced some 800 years after the earliest notation acknowledging the *tzolk'in* cycle of 260 days at about 600 BC. The long count functions much like a Julian calendar yearly count of days, but over a 5,125 tropical year cycle (Aveni 2002a:184).

Ancient Americans were at least as lucky as they were astute in their calendric design. Not generally appreciated is the effort required to keep any calendar accurate. Synodic cycles are not as regular or predictable as one might believe. Earth-centered observations lead to erratic planetary behavior, such as retrograde movements, where planets sometimes appear to reverse course. These complications are caused by helio-centric orbits of varying rates overtaking each other while being observed from a spinning Earth in its own elliptical orbit around the Sun. Most of the surviving Maya codices are tables designed to cope with ever-emerging complexities that only deepened with attempts to make the tables more precise while using integer numbers. However, convenient near-integer relationships between observable synodic cycles and the lunar nodal cycle allow them to be commensurated without undue effort.

Because the lunar node progresses 3.876 days each month, relative to the orbital position of the Moon, intervals between eclipses may take either five or six lunar months. The Maya tables found in the Dresden Codex anticipate those intervals quite accurately (Aveni 2001:169-196). In simple terms, the nearly four day monthly drift between a lunar node and the actual position of the Moon was distributed equally on either side of the lunar standstill cycle. After accumulating a month of drift, the interval was shifted from 177 to 148 days. That the table's structure centers about the standstill lunar node further solidifies the importance of the lunar nodal cycle in regard to timekeeping.

Larger intervals of time reveal additional problematic differences between the tropical year, *haab',* and *tun* intervals. The *haab'* integer year of 365 days is close enough to the tropical year of 365.2422 days that the *haab'* count lags the tropical year count by one in 1,508 tropical years. At that point the two intervals regain their seasonal correspondence, while also matching 18,652 lunations.

$$1{,}508\times365 = 550{,}420 \text{ days}$$

$$1{,}507\times365.2422 = 550{,}420 \text{ days}$$

A *b'ak'tun* contains 1,872,000 days and five *b'ak'tuns* contain 9,360,000 days in 25,644 *haab'* years—also near enough to the Earth's precession cycle. Seventeen intervals of 1,507 tropical years and

1,508 *haab'* years reconcile as follows:

17×1508 *haab'* years = 25,636 *haab'* years = 9,357,140 days

17×1507 tropical years = 25,619 tropical years = 9,357,140 days

As Aveni (2002a:176) commented "...time reckoning is a build-up rather than a break-down process: the idea is to anticipate the future: and as we become more organized, we tend to look further and further ahead, building cycle upon cycle as we go." Ancient Americans required only the synodic cycles of Earth and Venus, along with the lunar nodal cycle, to install their cosmology, mathematics, and system of measure. Through time, additional useful factors emerged.

Typically, the calendar round of Maya time is described as how long it takes to interlace the 365-day *haab'* with the 260-day *tzolk'in.* Imposing modern concepts that use mechanical cogs to give each of 18,980 days a unique number is accurate, but not very helpful for understanding how the Maya perceived time because it fails to address the seemingly "magic" aspects of cycle reconciliation. From the Maya point of view, the calendar round interlaces the 365-day *haab'* cycle with the 260-day *tzolk'in* and allows two important cycles of time to end on the same day after exactly 52 *haab'* years.

The 260-day almanac interval consists of 20 day-names prefixed by numerals 1 to 13 in an endless succession. Day names from the divination cycle were thought to portend a person's destiny from birth. Eighteen 20-day long intervals, called *winals,* were followed by a nineteenth *winal* of five unlucky days, known as *wayeb,* to delineate a 365-day *haab'* year.

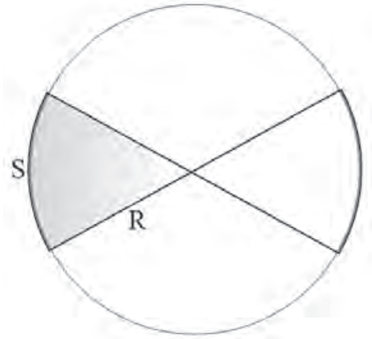
Ultimately though, there are limits to how well cycles can be reconciled by integer counts (without using fractions). Every calendar conceived eventually has to deal with how to correct for the inevitable discrepancies between cycles measured by integer counts, usually by an adjustment called *intercalation.* A simple example of intercalation is the practice of adding a "leap" day every four years to keep the Gregorian calendar in alignment with the seasonal year. While the Maya acknowledged that a discrepancy of five days accumulated every 104 years, they did not apply the correction to the *long count,* the number of days since the zero date of the *tun* calendar. Instead, they anticipated the discrepancies and tracked all cycles from the same starting date, depending on their understanding of the interrelationships to reconcile apparent discrepancies. The *tun* calendar was intended to provide a stable time-line for recording and describing events.

Very few clues remain to show how early people thought about what they saw in the sky, so when astronomical correlation became evident at various mound sites in Northern Louisiana, it was worth exploring at some depth. Dates range from about 7,000 years ago, and the evidence has been subjected to all sorts of disturbance. There are at least thirteen clusters of dirt mounds and low earthworks distributed over a few hundred square kilometers. Some mounds have been swept into rivers and the rest are in various states of preservation. The inhabitants apparently fished, hunted and foraged, in contrast to the stable farming community usually associated with structures of such scope. Despite the ritual appearance of overall site plans, there are indications that houses were built, and normal day-to-day activities are represented in the artifact assemblage.

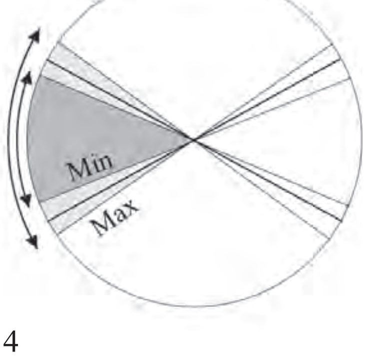
While searching for the basis of Maya measurements, a latitude-specific phenomena became apparent in relation to the earliest mound clusters in Northern Louisiana. Not only did it explain the placement of mounds in relation to one another, it proved to be the source of Maya astronomic practice, the basis for the Mesoamerican calendar, and provided a standard of measure common to most of North America. Before getting into the archaeological evidence, we need to explore the geometric principles that define a particularly sacred place on the surface of the Earth. A series of reasonable insights can be postulated that not only lead naturally to the creation of the Mesoamerican calendric system, but also anticipate archaeological evidence that demonstrates the application. As a geometry emerges from our exploration, we will show how it was used to situate mounds at the Caney Mounds site in Louisiana, dated to 5,600 years ago (Saunders et al 2000).

Let us start by drawing a circle with a compass and divide it with two diameters inclined 57.2960 degrees to each other to represent the solstice viewing conditions at Caney Mounds. The angle between summer and winter solstice is usually called to attention because, at *solstice,* the Sun seems to stand still in its march along the horizon before reversing direction. The northern bearings represent summer solstice rise and set, while the southern bearings follow winter solstice rise and set. If you cut a string equal to the radius, it will match the circumference arc between east and west solstice bearings. The diagram should look like a sideways hour-glass with bowed ends. Since the Sun transits the arc segment twice in a year, the average daily movement on the horizon is 0.31374 degrees. Presuming that you prefer integer numbers, the angle whose tangent is 2÷365 describes 0.31395 degrees per day. If you want to keep track of time, hardly a better reference can be imagined. The fact that the angle approximates one tenth of *pi* will be shown later to have very useful consequences. While the builders of the mounds didn't express figures in precise decimals, they were certainly aware of ratios. Furthermore, the naked eye can sight an azimuth within one or two seconds of arc (Brown 1975:187), or roughly two hundredths of a degree, so decimals are appropriate to reflect such fine visual discrimination. By comparison, a Total Field Station surveying instrument typically records angles to 0.5 arc-second.

We can imagine people observing monthly correlations of the Moon with mounds **A** and **C** at standstill, when the moon appears to stand still before reversing its daily motion along the horizon, and setting stakes along a north-south line at the western edge of the site to establish a bearing at lunar standstill. Those bearings could then have been quantified by measuring the relative displacement north-

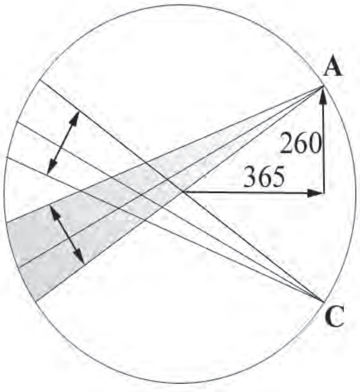


R = S when the angle equals 57.296 degrees. Solstice angles can only meet this condition in the northern hemisphere at latitudes above 31.7 degrees, as in Northern Louisiana.



Because the Moon's orbit is inclined 5.1 degrees from the plane of the Earth's orbit about the Sun, its rising and setting locations on the horizon widen and narrow over a period of 18.6 years. Mounds **A** and **C** at Caney Mounds are comparable to the intersections of lunar maxima with the right side of the circle. Similar north-south pairings of mounds on the east side of multiple sites appear to serve the same purpose and provide a basis for registration between site plans.

south and east-west. At Caney Mounds, as well as other sites, the bearing at lunar maximum is very close to 260 units north-south by 365 units east-west.



I used James Jacobs' 2015 archaeogeodesy.xls program to estimate the theoretical bearings from each station to lunar extrema at the ideal latitude for the optimum lunar maximum spread as seen 5,600 years ago. At the latitude of 32.3 degrees north, the half-angle between lunar maximum bearings can be defined by a tangent of 260 over 365. Since 365 is close to a seasonal year, it provides a counting interval that is obviously useful for keeping track of time in relation to the seasons. The number 260 has been recognized as a useful figure for reconciling planetary cycles with each other (Peden 2004), so there is good reason to count time by intervals of 260 as well.

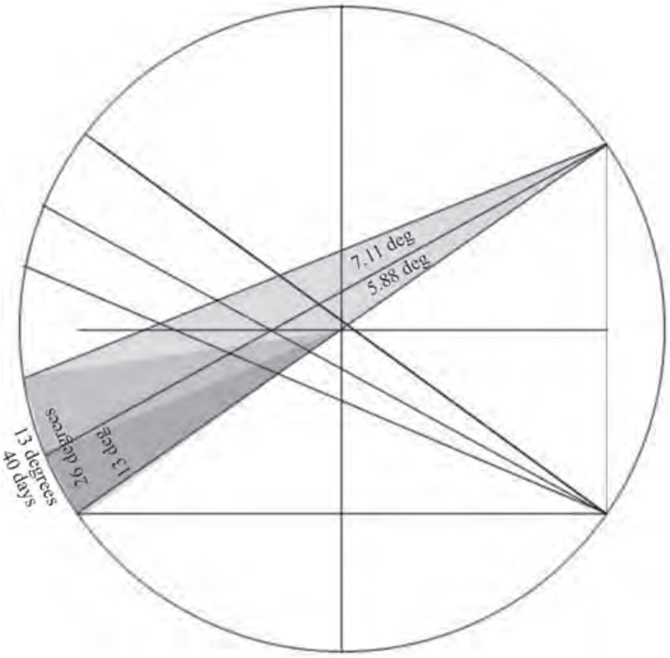
Plugging different latitudes into an archaeogeodesy program allows replication of generations of experience in recognizing that the ideal location for satisfying our lunar magic geometry is about 8 miles north of where the solar relationship would have been perfect at the time of mound construction. Splitting the difference would force a mismatch of just 4 miles and would change the observed solstice angle by only 0.155 degrees. However, these "ideal" locations are constantly on the move by as much as 150 feet in a year or a mile every 35.2 years. The movement is due to the Earth's equator being tilted from the plane of Earth's orbit around the Sun *(ecliptic)* by various cycles spanning between 40,000 and 100,000 years. If one wants to locate themselves at a precise latitude, their observation must be correspondingly exact. Since changing latitude by one-tenth of a degree causes about a 0.05 degree shift of observed angles, assuming a precision of one-tenth degree in the observed angle places an observer only within 14 miles of his target. Archaeologists have the additional challenge of interpreting intent because observed astronomical bearings change by about a tenth of a degree per thousand years due to the change in obliquity of axial tilt.

There are three primary contributions to the precession of the Earth's axis. *Eccentricity* of Earth's orbit shortens and lengthens over a 100,000-year cycle that may be responsible for a similar cycle of ice ages. The last glacial maximum occurred when the ecliptic reached a minimum obliquity of 21.089 degrees. *Axial tilt* relative to the ecliptic is responsible for season and changes from 21.5 to 24.5 degrees through a 41,000-year cycle. The zone favorable for observing the special geometry moved south until about 9,000 years ago, when the obliquity reached its maximum of 24.036 degrees, and has moved northward due to the present axial tilt of 23.5 degrees. *Precession* can be likened to the wobble of a spinning top, and moves apparent north in a direction opposite rotation. This 26,000-year wobble changes the seasonal placement of solstice, or equinox, by 91 days in about 5,750 years. We refer to the cumulative effect of orbital influence as *precession of the Earth's axis.*

An easily overlooked effect of precession is that true north constantly occupies a different position in the star field, making determination of true north without modern surveying equipment somewhat problematic. That, in turn complicates our ability to assess the precision to which ancient observers could measure cardinal directions. Another caution regarding measuring angles arises from the tilt of the Earth's axis. Only at the equator will the cardinal angle measured at winter solstice equal the angle measured at winter solstice. As the latitude of observation increases, the northern trigonometric component increases and the southern component decreases. We will need to find a way to assess ancient capabilities of precision in order to estimate the potential impact on early decisions about how to conduct measurements. Given the inherent difficulties of describing true cardinal bearings, it may be prudent to assume that an observer would have been inclined to simply measure the full swing angle from northern to southern solstice position rather than deal with unequal portions. Considering the limitations of integer math, it is most likely that idealized integer north-south and east-west trigonometric components were used for representing sacred geometries.

Second to N-S mound pairs, the most consistently encountered feature of mound alignments relates to the winter solstice sunset azimuth. When the winter solstice azimuth, viewed from the middle of a sighting mound, passes tangent to the southeast edge of another mound, the second mound has a diameter that fits within twenty days of successive sunsets after the solstice. From a vantage atop the northeastern mound and looking to the southwest, we see that the lunar maximum extends 7.11 degrees beyond the solstice limits while the lunar minimum falls short of the solstice angle by 5.877 degrees; a total of 13 degrees. Returning to the center of the circle, we also find that 13 degrees is the difference between where the lunar maximum and solstice meet the circumference. The *trecena* is a 13-day continuous naming convention for the 260-day tzolk'in, but here it may be linked to 13 degrees. Assuming that each day (or *k'in*) equals a degree creates a 360-day *tun* year that retains registration forever. The *winal* is the 20-day continuous naming convention for the *tun*, but 13 degrees, as viewed from the northeast point, is nearly the same as 40 times 0.31395 degree—the previously defined angle of a solar transit day. Forty days has been noted as an important division of time among some Maya; being referred to as the "footprint of the year." In the Book of Chilam Balam of Chumayel, Roys (1967:116-117) notes that the *winal* was used to pace off the world. It appears that context is needed to reconcile when the same terms are used to quantify time or distance. By a useful coincidence, the twenty-day angle approaches the difference between solstice bearing and the lunar maximum or minimum. That knowledge could have been useful to ancient people in anticipating the correct lunar bearings within a fraction of a degree rather than waiting for nearly nineteen years of observations.

The relationship between 40-day transits of the Sun and 13 degrees



1 year = 365 days = (18×20) +5
(28×13) +1

Setting aside one day at equinox would leave 364 days to be distributed equally between summer and winter seasons as four quarters of 91 days. Those 91 days could be logically divided into seven *trecenas* of thirteen days each.

52 years = 18,980 days = 365×52
(364×52) +52
(360×52) +260
20×949
260×73
13×40×365

Using 18 *winals* to define the 360-day *tun* treats time as degrees of Earth's orbit about the Sun, in contrast to the long count of days elapsed from the beginning of the calendar. Linking an interval of time to degrees indicates that planetary cycles were compared and commensurated by clock arithmetic. Not only are angular measures represented as 1, 13, and 20-degree groupings, they may be described as multiples of the 0.31395-deg daily movement of the Sun on the horizon.

Looking beyond the physical evidence

Thus far, we have considered evidence for tracking celestial phenomena by using bearings that can be marked by structures on the surface of the Earth. Yet it is irrational to think that people would have restricted their attention to the horizon, so what further relationships might they have noticed overhead that might have influenced their thinking?

The zenith observation diagram illustrates solar and lunar events recorded at the ideal latitude for seeing the 260/365 ratio in the lunar maximum, where angles are indicated relative to a vertical gnomon post that acts as a sundial. Shadows would be thrown to the north of the gnomen, with the longest shadows in the winter. Remarkably, the inclination of the Sun at winter solstice would have thrown a shadow 365 units from a 260-unit tall post at this special latitude. These angular relationships correspond so tightly to the horizon-based relationships described earlier that it is too obvious to have gone unnoticed. Even though we have no direct evidence of elevated sightings, we have clearly documented a capability to do so and have seen a proclivity for celebrating hierophanies.

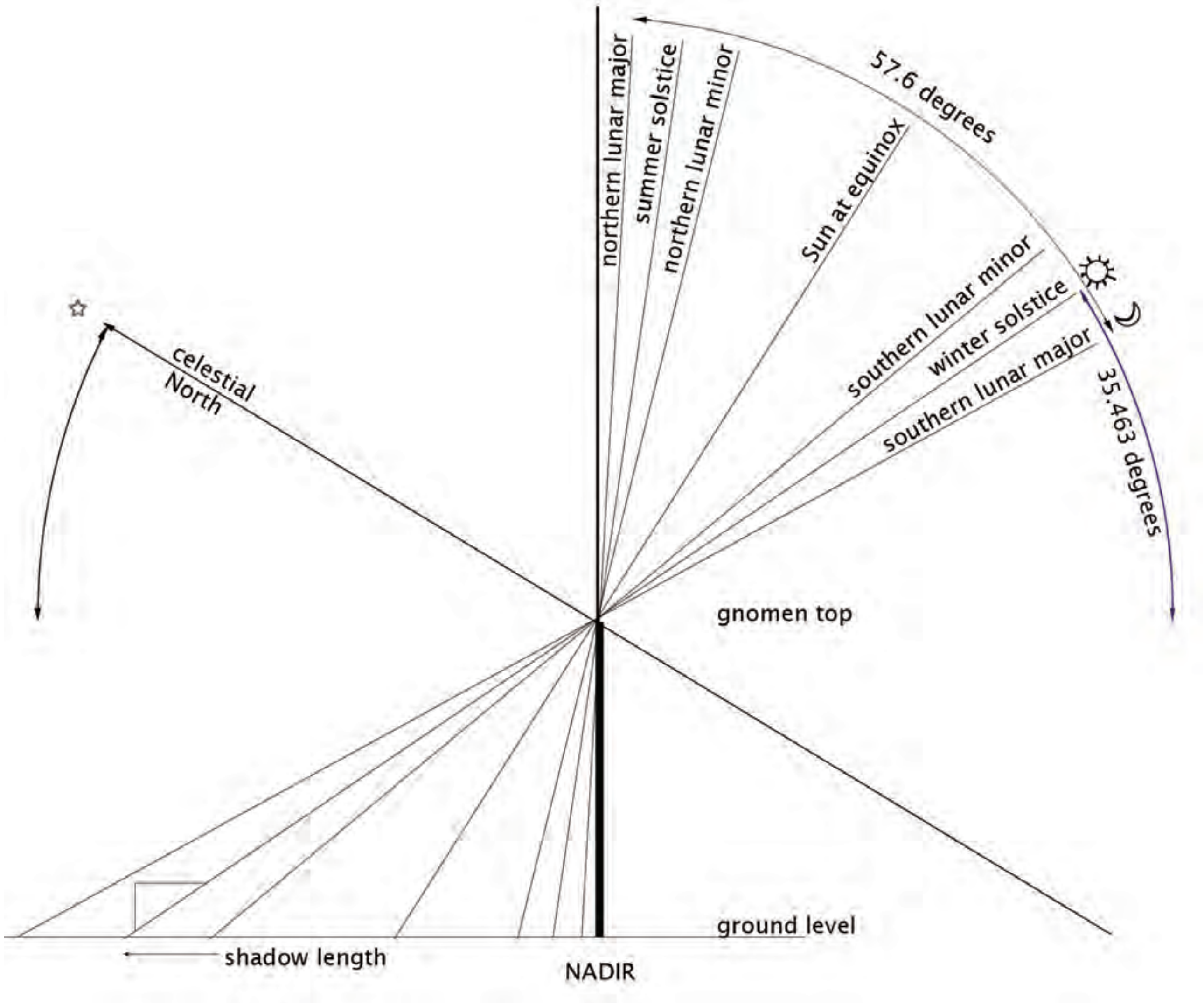
While the earliest evidence celebrates latitude-specific phenomena, when we consider the full spread of zenith angles from northern to southern lunar maximum, we see that it nearly matches the critical angle between solstices in northern Louisiana.

Zenith passages of the Sun, where no shadow is cast at noon, were of great interest to the Maya. At the latitude of Copan and Izapa, the zenith passage divides the year into parts that are 260 and 105 days long (Aveni 2001:144). Such observations cannot be seen north of the Tropic of Cancer, but that should not lull us into thinking that the elevation of the Sun at special times of the year was not important.

Not only can the development of the proto-Maya system be tied to horizontal and vertical observations, the origins may be logically extended another thousand years back in time. The Monte Sano mounds were built about 5,700 years ago along the Mississippi River near the Gulf Coast (Saunders 2010).

The discrepancy between a computer generated angle or geographic position may be attributed to a number of possible factors. Since the Sun and Moon are seen to cross the horizon at an angle, it makes a difference whether the horizon is level or if topography changes the time of appearance. Computer predictions can assume an idealized "zero altitude" horizon with no rises or dips in the surrounding terrain. Similarly, an observation noted at first glimpse differs from one at full visibility. Defining the target as center or edge can change angles as much as 0.25 degree. To compound the difficulty, it is very difficult to date the phases of location, construction, occupation and abandonment of a mound with confidence. Comparison of modern observations with theoretical alignments may partially resolve the questions, and statistical analysis of mismatches may further indicate a range of variability. In general, if mound building in the Middle Archaic were completely controlled by precise integer trigonometry, sites should occur within 87 kilometers north to south. Presuming a ± 0.1 degree error expands that range to about 110 kilometers. The N-S range of mounds considered by this study is about 260 kilometers.

Zenith observations at the "ideal" latitude



As mentioned earlier, the bearing of true north seldom corresponds with a star location, making precise measures difficult. Although it is necessary for investigators to make observations with modern instrumentation and resort to computer reconstructions of ancient alignments, we must remember that earliest astronomy did not require any technical aids. Much work remains to quantify accuracies achieved by the simplest of tools, but preliminary indications suggest remarkable precision.

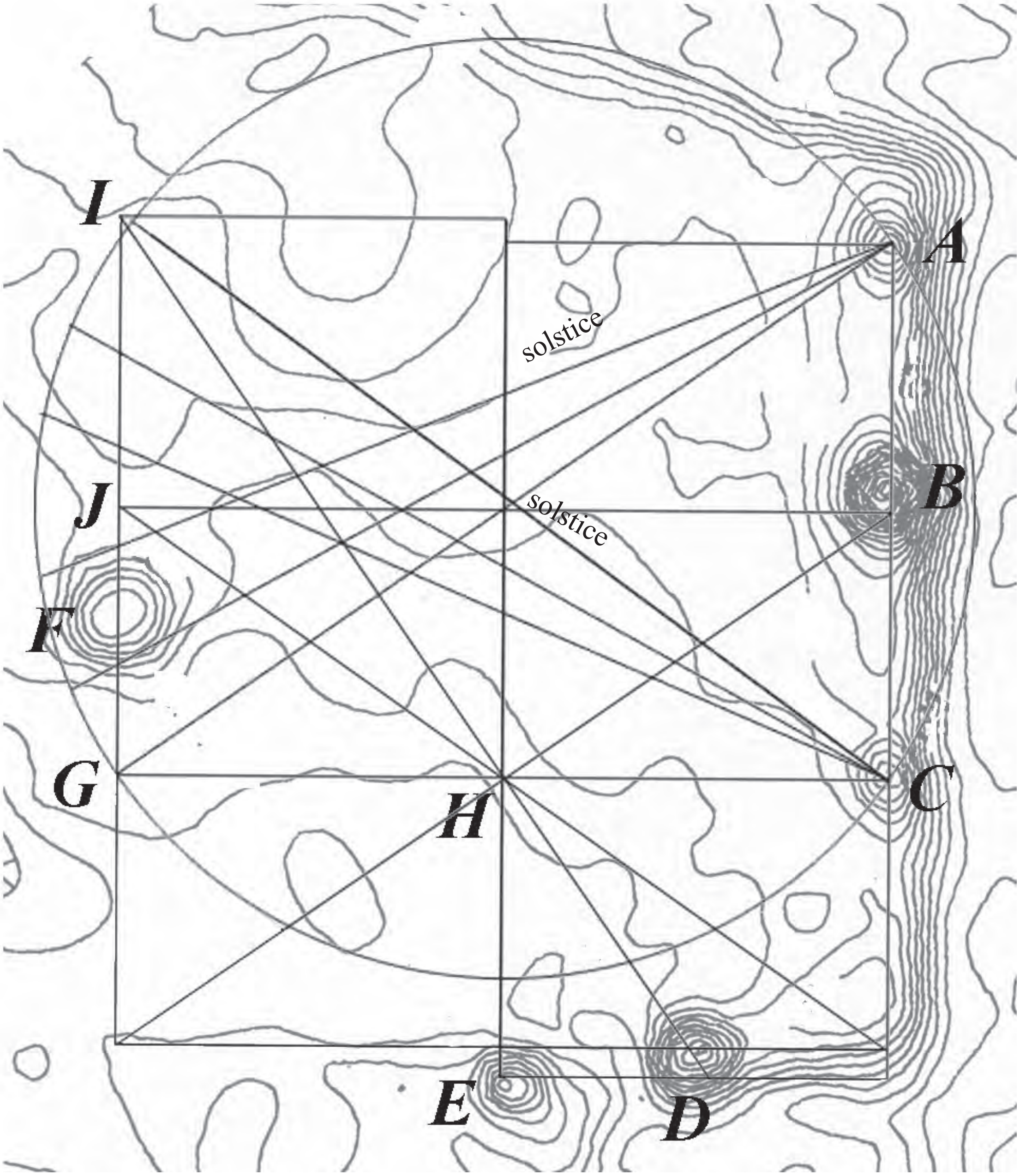
Starting from the geometry described earlier, it is possible to draw logical connections on the diagram by following cardinal directions and connecting existing nodes to create the entire structure found at Caney Mounds without resorting to standard measures. Although a circle is used to clarify the geometric relationships, the construction can be accomplished without physically tracing the circle. The jog between east and west half of the template occurs because the latitude of Louisiana is offset from the plane of the ecliptic.

Rules for constructing a hypothetical template at the latitude of Caney Mounds

1. Draw a circle with cardinal direction axis passing through the origin.
2. Project a northern lunar maximum through the point of origin to define the upper right crossing of the circle as mound ***A*** and the lower left crossing as point ***G***. Project the remaining winter solstice and lunar extrema bearings southwest from mound ***A***.
3. Draw a cardinal line east from point ***G*** to intersect the circle at mound ***C***. Project the winter solar and lunar extrema to the northwest from mound ***C***.
4. The template perimeter is delimited with cardinal lines to make the template radially symmetrical about the radial center, with a bottom jog projecting at the southeast.
5. A diagonal line from point ***I*** through point ***H*** locates mound ***D*** on the southern template while mound ***E*** is located at the southern end of the major axis
6. Mound ***B*** is located such that drawing lines to the upper and lower jogs on the major axis creates a right triangle with the lower angle equal to the latitude and the upper equal to 90 degrees minus the latitude. It is not known whether the angles are deliberate.
7. Mound ***F*** is situated on the west template edge midway between the northern lunar minimum and summer solstice bearings.

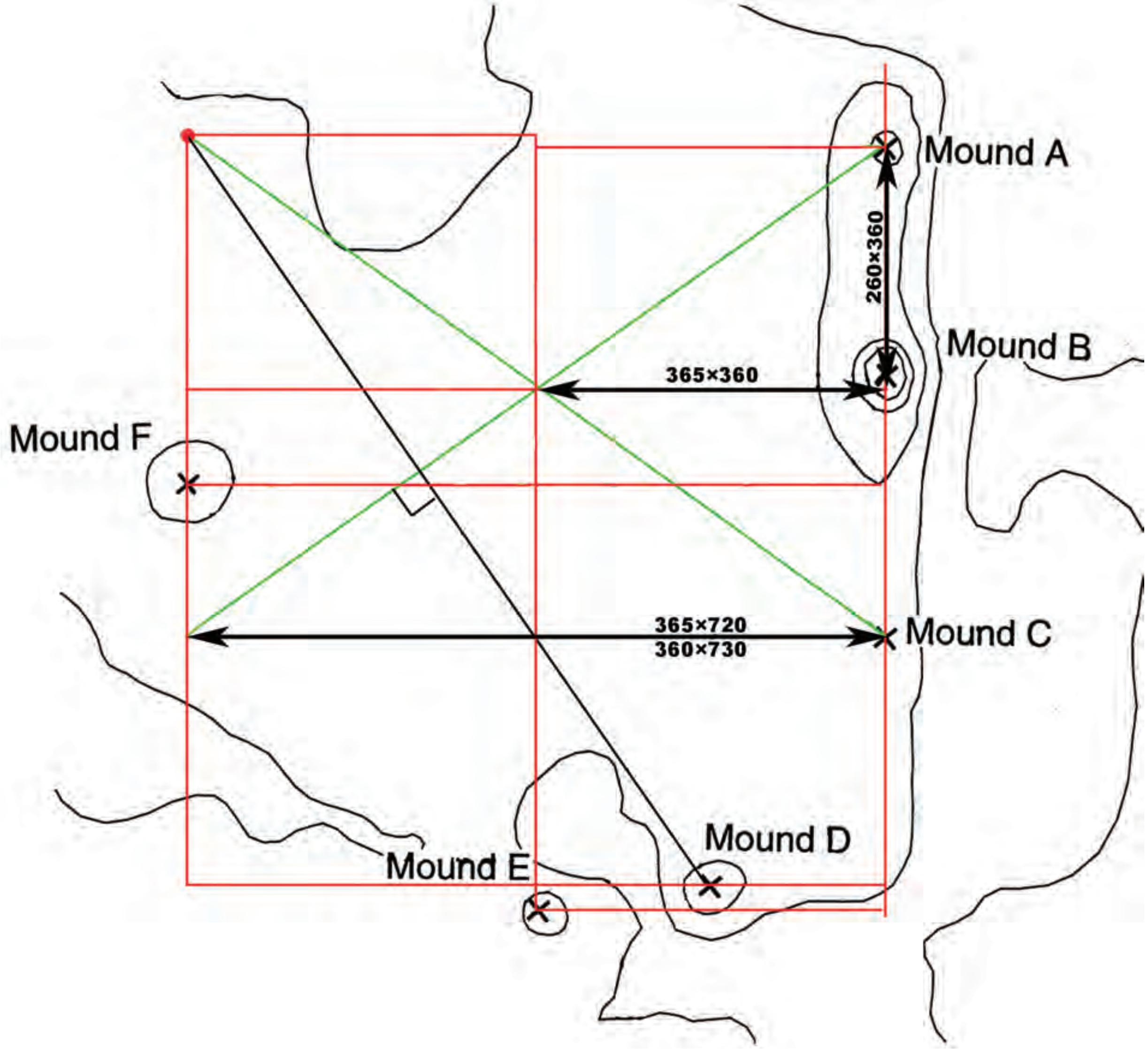
All bearings are as would have been observed at the latitude of Caney Mounds 5,600 years ago, no arbitrary points or alignments are used, and every mound location is accurately accounted for. While a circle was drawn to aid in visualization, the template can be easily created without a compass. Furthermore, a template appropriate for the latitude of any other site can be created by following the same rules. At the equator, the template would be square while higher latitudes would make the template progressively more slender and skewed.

Replicating the layout of Caney mounds (16CT5)



Cardinal direction layout lines pass through the center of six mounds and give the template radial symmetry.

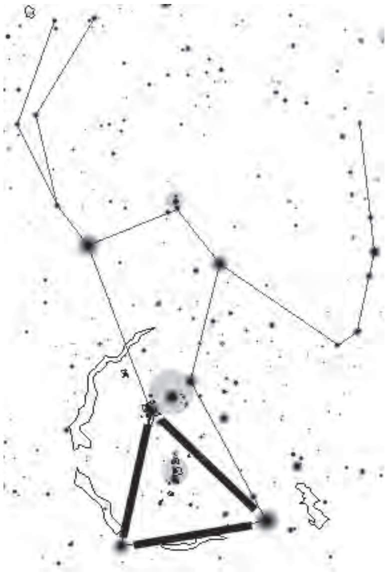
Layout proportions of Caney Mounds (16CT5)



The master template is proportionally correct, but lacks scale unless we can provide a standard unit of measure. Numeric proportions from the lunar extrema allow us to associate specific values with parts of the diagram. Despite the lack of written records, Archaic mounds retain a tangible imprint supporting the development of numeric values. This graphic shows how mounds were organized and proportional dimensions were represented at Caney Mounds in Louisiana, dating between 5600 and 5300 Cal BP. In this case, the E-W dimension linked the 365 day year with one of 360 days by equating 365×720 with 360×730. Mound **F** was built with a diameter of 8×400 units subtended by an angle of 6.32 degrees as viewed from the center of mound **A** at a radius of 400×730 units.

Artists are known to estimate relative proportions by holding a stick at arms length in front of them and marking the apparent distance for transfer to another location. Ancient people must have done the same, but an arm reach does not seem like a very versatile unit of measure, especially when you consider how humans come in many sizes. The same approach would have been useful for drawing accurate maps of the starry nightscape, however, the more detail we need to resolve pushes us harder to refine a highly accurate unit capable of addressing fine detail.

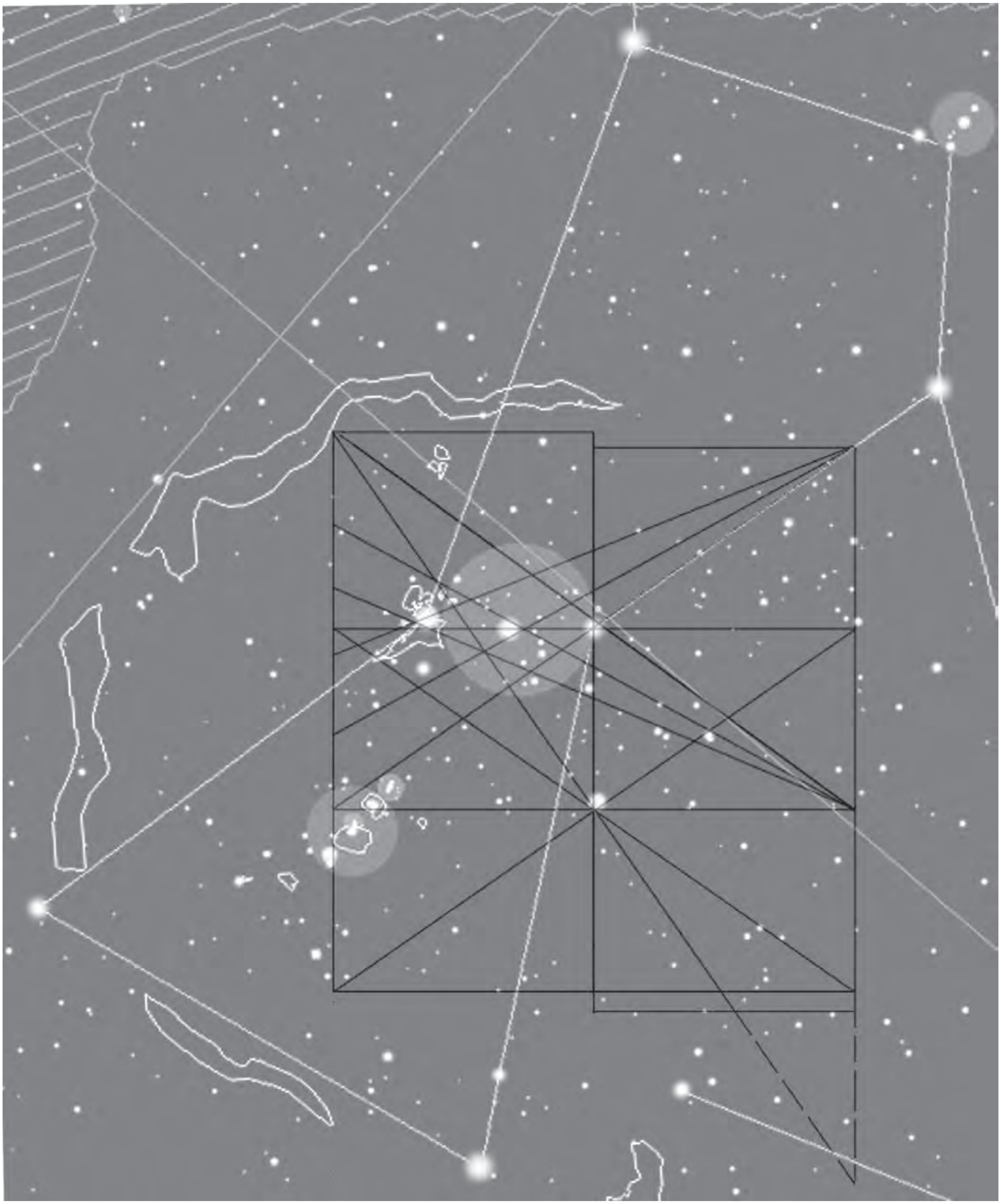
Aveni (2001:9-10) depicts illustrations from codices, presumably representing astronomical observation. Of particular interest are instruments with prongs that appear to have stars perched on them. According to Tedlock (2010:39-42,48-54,130-136), the Maya associated three stars in Orion as the celestial hearthstones that appeared at dawn on the first day of creation. Inspired by the attribution of the hearthstones of creation being part of the constellation of Orion, star maps were superimposed on the graphic to check for possible correlations. By registering the belt stars of Orion to the three extrema crossings, a fourth star falls exactly on the central node. The connection from Mintaka to Belatrix then aligns with the lunar minimum azimuth. The Pawnee are said to tattoo three offset dots on their wrist to designate three fire-drill holes, as are the Aztec (Sahagun 1953:60,62). Lankford (2007) attributes the belt stars to the wrist of a severed hand in Mississipian myth. By now it should be apparent that the diagram is much more than a simple geometric construction, it must be treated as a template that encapsulates sacred knowledge.



Star	Description
Betelgeuse	upper left star
Meissa	top middle star
Belatrix	upper right star
Alnitak	left belt star
Alnilam	middle belt star
Mintaka	right belt star, on the celestial equator, and registered to the lunar maximum
Eta Orionis	star just below Mintaka, registered to the central node
Saiph	lower left star
Rigel	lower right star
M-42 nebula	directly below Alnilam, centered in the celestial hearth.

Once geometric relationships have been proportionally defined, there is no problem with transporting them to any other location. Defining unique angles by trigonometric proportions of right-angle legs allows diagrams to be plotted at any size desired, while retaining sufficient precision to avoid confusion. For many of the Archaic mound sites, scaling factors seem to have been selected at near the lower limit for accurate representation. That suggests a precision of standardization adequate for unambiguous attribution. Stone beads could have provided reference dimensions sufficiently durable, easily transportable, and readily replicated. Other options include staffs, similar to what the Spanish reported seeing carried by native Maya and Aztec surveyors. We can assume that there would be plenty of opportunity to compare results and make corrections in order that the standard remained constant.

Constellation of Orion (as seen 5600 BP) superimposed on the mound geometry



3

Establishing Intent

There is no doubt that Middle Archaic mound arrangements in Louisiana are man-made because excavation reveals older living surfaces below the mounds, which are helpful in bracketing the times of construction and occupation. Spatial patterning however, requires a different kind of substantiation. Deducing a precise geometric basis for guiding the placement of scattered dirt mounds invites legitimate questioning about whether the pattern is conveniently chosen from a random welter of points and lines or is deliberately designed. Much of the concern arises when a proposed design is considerably more sophisticated and precisely executed than we might expect in relation to other archaeological evidence from the same time and region. This is where we must guard against allowing long-standing paradigms to blind our acknowledgement of ancient capabilities.

Middle Archaic period mounds of Louisiana challenge our notions of social complexity because their appearance as early as 6,000 years ago (Saunders, et al. 2005) is well prior to the expected development of communal organization sufficient to mount such large constructions (Gibson and Carr 2004). John Clark (2004) has argued that the sites were planned according to broadly-shared geometric principles of design that utilize standard units of measure also encountered in Mesoamerica, although he recognized uncertainties that needed rigorous testing before the design principles could gain broad acceptance. While inspired by Clark's work, this report takes a new approach to resolving how Middle Archaic period mound sites were planned and how they functioned. A structured approach shows how careful observations of mound site features and attributes can be used to replicate the original design principles and practices in a manner that may parallel ancient acquisition of knowledge.

Mound arrangements have been variously characterized as sociograms and calendars, whose placement on a geometric plan is guided by convention (Clark 2004; Sassaman and Heckenberger 2004). For the proposed planning to be generally accepted, mound placement must be shown to have followed consistent rules or guidelines that can be recognized and followed. Principles of geometry are apt to be unique to a culture, so we must consider persistence of shared traits along with their spatial distribution and apparent rules of format.

Unfortunately, archaeologists are not consistent in the manner they reference their site plats to cardinal directions. For most questions, it does not matter if a plat is referenced to magnetic north, UTM north, or true astronomic north. Only the latter is appropriate for investigations into how heavenly bodies were observed and aligned to. Not only is magnetic north commonly used, it can vary substantially through time and geographic location. Even UTM projections not on the central meridian are slightly tilted because of the convergence of lines of longitude. The problem is exacerbated by unclear attribution of orientation on published site maps. Faced by the ambiguity of true orientation, mounds nearest north-south in placement have been assumed to fall N-S of each other for this study. While the assumption allows multiple sites to be meaningfully registered to each other, there is yet another potential source of error related to precession of the ecliptic. After all there is no star fixed precisely at true north, and other stars besides what we now know as the North Star have been closest to north at various times in the past. If astronomical observations are postulated, true north at each site should be established by direct observation so that discrepancies can be resolved (Aveni 2003).

Recovery of original mound positions entails many potential problems, in part because we only know of about 14 Middle-Archaic sites with varying numbers of mounds (Saunders 2005). For one thing, mounds are indistinct and difficult to represent by discrete points due to many years of erosion and relatively recent earth moving. When site plans indicate magnetic north rather than true north, orientation may require force-fitting without knowing for certain what was intended by the builders. Larger numbers of mounds at a site sometimes provide clear interpretations, but not always. Topographic features in addition to what the site archaeologists define may or may not be man-made, but the possibility must be considered.

Finding Similarities

Four Archaic period mound sites appear to be relatively complete and intact enough to support investigations into whether meaningful patterns indicate shared principles for planning the locations of mounds in relation to astronomical observations. Once mound arrangements from the four sites are composited independent of scale, visible patterns of similarity demonstrate a grid-like framework organized by cardinal directions. The eastern mound-pairs appear to have been treated as focal points for observing solstice and lunar extrema, with setting bearings radiating to the west. Because lines are not expressed on the ground at any site, they should be considered as conceptual guides that position a substantial portion of mound locations. The highest or most central position of each mound has been represented as a point on its respective site map. Repetitious occurrence of north-south pairs of mounds at the east side of Caney Mounds (16CT5) and Marksville (16AV1) seem unlikely to be accidental alignments. That the summer solstice alignment from the northeast mound frames the western-most mound by the lunar minimum and solstice at Caney Mounds, McGuffee (16CT17), and Marksville sites further improves the case for intentional design. Although there are no north-south mound pairs at Watson Brake (16OU175), rotating the site map about thirty degrees clockwise reveals a strong similarity to the Caney Mounds site (Sassaman and Heckenberger 2004: 222-223).

Since so many sites are near water sources, the relationship of the geometry to river banks is more readily commented on than resolved. Casual comparison of site plans shows that mound scatters typically utilize the available space. Sassaman and Heckenberger (2004) focus on an approximate 1.4 to 1 setback of prominent western mounds from N-S pairs along river banks. Because composite registration of mound locations includes sites without the obvious N-S orientation of mound pairs, it appears that the river bank proportional setback was not particularly important to the planners.

Even though there are acknowledged problems with interpretations to confront, there are adequate reasons to think that intent can be recognized and even quantified. The practice of building a mound tangent to the winter solstice bearing from another mound is repeated at Caney Mounds, Marksville, Poverty Point, and DePrato mounds. North-south orientation of eastern mounds is evident at Caney Mounds, Marksville, Insley (16FR2), and McGuffee mounds. Astronomical observations require orientation to cardinal directions, but lunar and solar extrema are most easily described from the horizontal equinox line bisecting two north-south reference points. These and other repetitive patterns lead to the conviction that the patterns have deeper than aesthetic meaning, but establishing intent requires that the patterns reveal a deliberative logic that serves a purpose and fulfills a function.

Surveying Practices

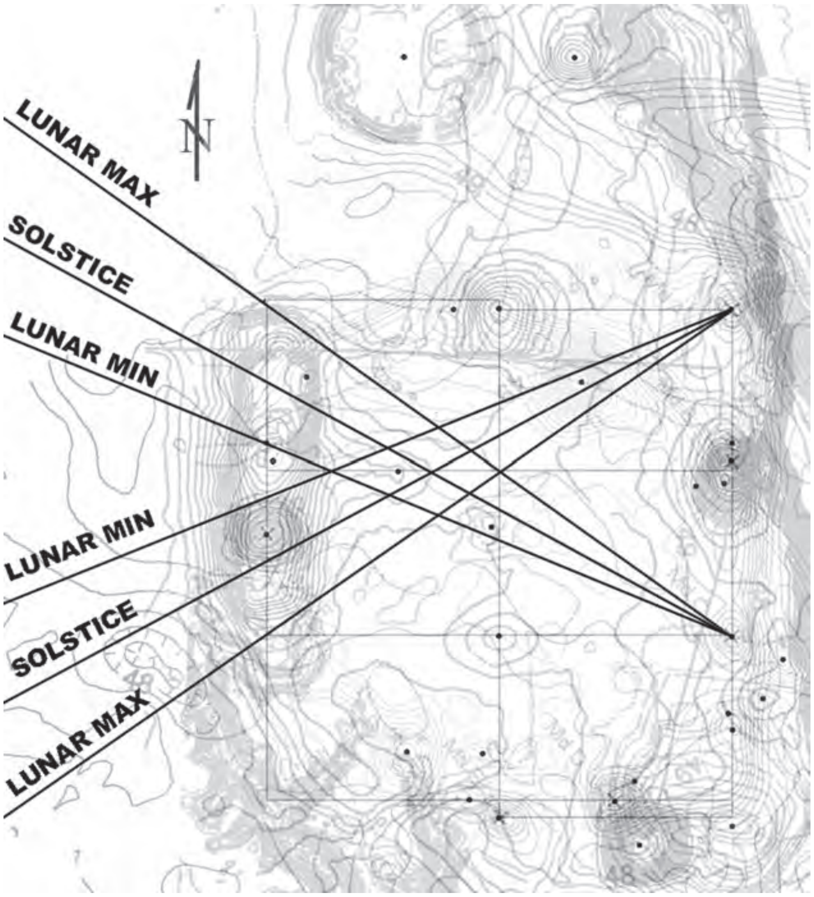
Lines and points are easily and unambiguously recognized when they are physically expressed, whether by painting, engraving, or in earthworks. However, Middle Archaic people made use of simple conventions that allowed clearly defined complex representations without requiring all points and lines to be present. Although those features can be termed virtual because they have not been expressed, it does not mean they are ambiguous.

Classic surveying techniques make use of a foresight and back-sight to indicate direction, but that line means little unless it intersects a third point or target. According to Sassaman and Heckenberger (2004:228), Middle Archaic mound groups frequently occur atop eastern facing bluff or terrace tops, facilitating a clear view of the morning lunar and solar appearances, unobstructed by forest. Sighting with a surveyor's transit from one of the cardinal mound pairs limits the distance between foresight and back-sight to the length of the telescope. To obtain the rays emanating from the mound tops as depicted on the template requires reversing the instrument 180 degrees. Lacking modern equipment, ancient surveyors would have likely have chosen to erect a gnomon post on the mound top and move observers into position along the west template boundary to capture the desired alignment. Conceptually, it is analogous to rays travelling through the aperture of a camera obscura onto a distant viewing stage. Placing temporary markers would have effectively recorded first dawn appearance of sun and moon as they appeared to travel north and south along the eastern horizon. In the case of archaic mound builders, the target was often astronomic and thus unreachable or "virtual." Unless the bearing was indicated by an earthwork, the line exists only as depicted on a plan. Clearly, using virtual points and lines reduces apparent complexity, but it also obscures the design from anyone who has not been briefed of the conventions.

It seems unlikely that sites were planned at the scale of construction; rather, it is most likely that the site was planned on portable media, such as a thin transparent membrane, perhaps from a drum head. Transparent overlays of the site plan could be registered to demonstrate the feasibility of picking points that satisfy multiple layout orientations simultaneously. By extension, it can be seen that a multitude of site plans could be designed by various combinations of astronomical bearings and point-to-point sightings. Each site seems to have been planned with a theme of some sort, which implies that basic rules of construction were followed with minor allowance for elaborations. Besides playing with multiple orientation possibilities, some sites display parallel bearings biased to a particular heading. Others display a preference for rays radiating from significant locations. Leaving virtual points unmarked is most likely a strategy for reducing clutter, presenting only meaningful locations out of a multitude possible. Standard trigonometrically-defined dimensions may have established a graphic grammar capable of surviving for generations. Site plans could then be constructed through a geometric syntax, stringing alignments together in a daisy-chain fashion from a set of established bearings in combination with point-to-point sight lines to generate new nodes. Cathedrals are still built with symbolically coded architectural orientation and feature placement dating back thousands of years. Built prior to known glyphs or written symbols of meaning, mound sites should be viewed as early documents of recorded knowledge whose complete message remains to be fully deciphered.

It is appropriate to consider related site plan questions at the Hopewell Octagon earthworks in Newark, Iowa, where Hively and Horn (2006) concluded that alignment to lunar standstills was intentional. Although the Hopewell constructions apparently did not retain the archaic geometric template, they did maintain the practice of orienting to lunar extrema.

Because differences of elevation in a landscape can markedly impact the observed azimuth of a heavenly body along the horizon, most investigators question how lines of visibility may impact sight lines. For purposes of this study, geometries that agree with the geographic ideal but not with local observations are considered to have been established primarily by trigonometry. More specifically, this means that the landscape is treated as having no topography that would change the time and place on the horizon where a heavenly body is barely visible. Hively and Horn (2010:132) advance the zero-altitude hypothesis as an explanation for astronomical alignments at the Newark Octagon in Ohio, by presuming that observations made from unobstructed high ground were transferred to sites where those sightings are physically impossible but are nonetheless clearly indicated by visible structures on the ground.

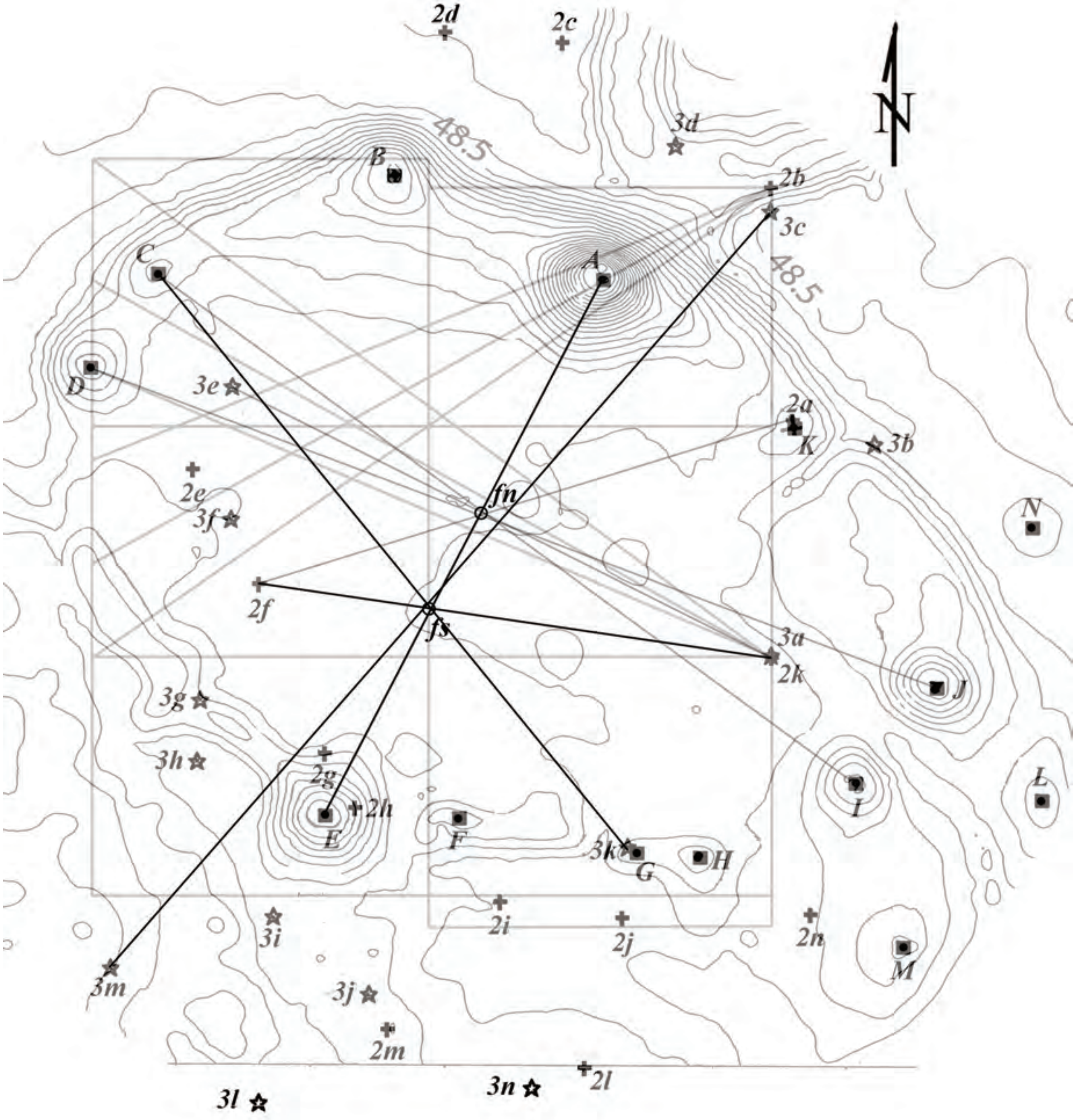


Comparison of multiple mound site plans reveals that a template relating common information appears to have served as a mnemonic, a visual or auditory aid to preserve the memory of important associations. Measuring proportional distances along cardinal directions would have been useful for predicting where astronomic events would appear on the horizon.

The special case of Watson Brake

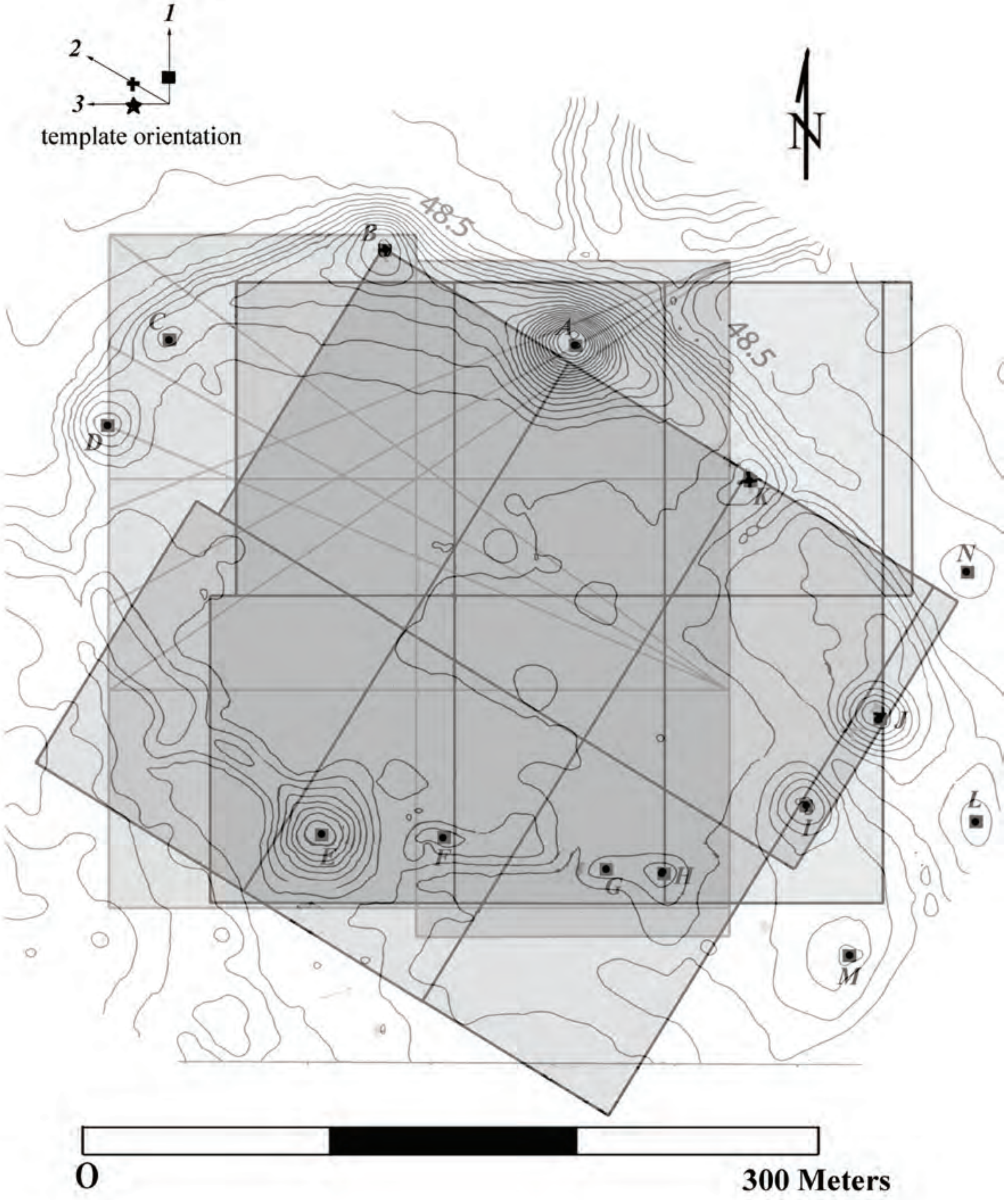
Claiming to know what ancient people were thinking may seem like the height of hubris, yet that is exactly what the Watson Brake mound site allows. Deductions for the inferred existence of a planning template that could have been widely used by builders of Archaic period mounds have been presented based on what would normally be too few sites for statistical confidence, so this section will methodically retrace the decisions and methods for laying out the original site plan of Watson Brake. Reverse engineering of the design process confirms a number of design and surveying principles that support intent and purpose of every defined horizontal location at Watson Brake. Key lessons will be reviewed as additional tools are brought into the analysis. Mounds are labeled according to the lettering designation assigned by Saunders (2005) and include two additional mounds ***M*** and ***N*** for reasons that will be apparent later. Lower case mound designations paired with template numbers identify virtual points introduced by re-orientation of the basic template.

Radial alignments



Even without considering horizon azimuths, the mounds can be shown to be self-organized by radial diagonals that define virtual points. Two radial focus points allow connecting pairs of mounds to be connected through a common virtual point, not represented by a permanent feature. The northern focus (***fn***) organizes mound pairs ***C-I***, ***D-J***, and *A*-***E***. A southern focus point (***fs***) unites mound pairs ***A-E***, ***C-G***, ***D-M***, and ***B-F***. Locations for eight of fourteen mounds are along radials passing through the focus points for easy line-of-sight surveying, while mounds ***D*** and ***C*** are locked in place because they are shared between the focus points. Mound alignment ***A-E*** then unites the focus points themselves. Finally, the winter solstice traces ***D-I*** near the center of an oval pattern formed by the mound grouping, at right angles to the ***A-E*** alignment. Secondary virtual points represented by lower case identification will be explained in the following section.

Template orientations

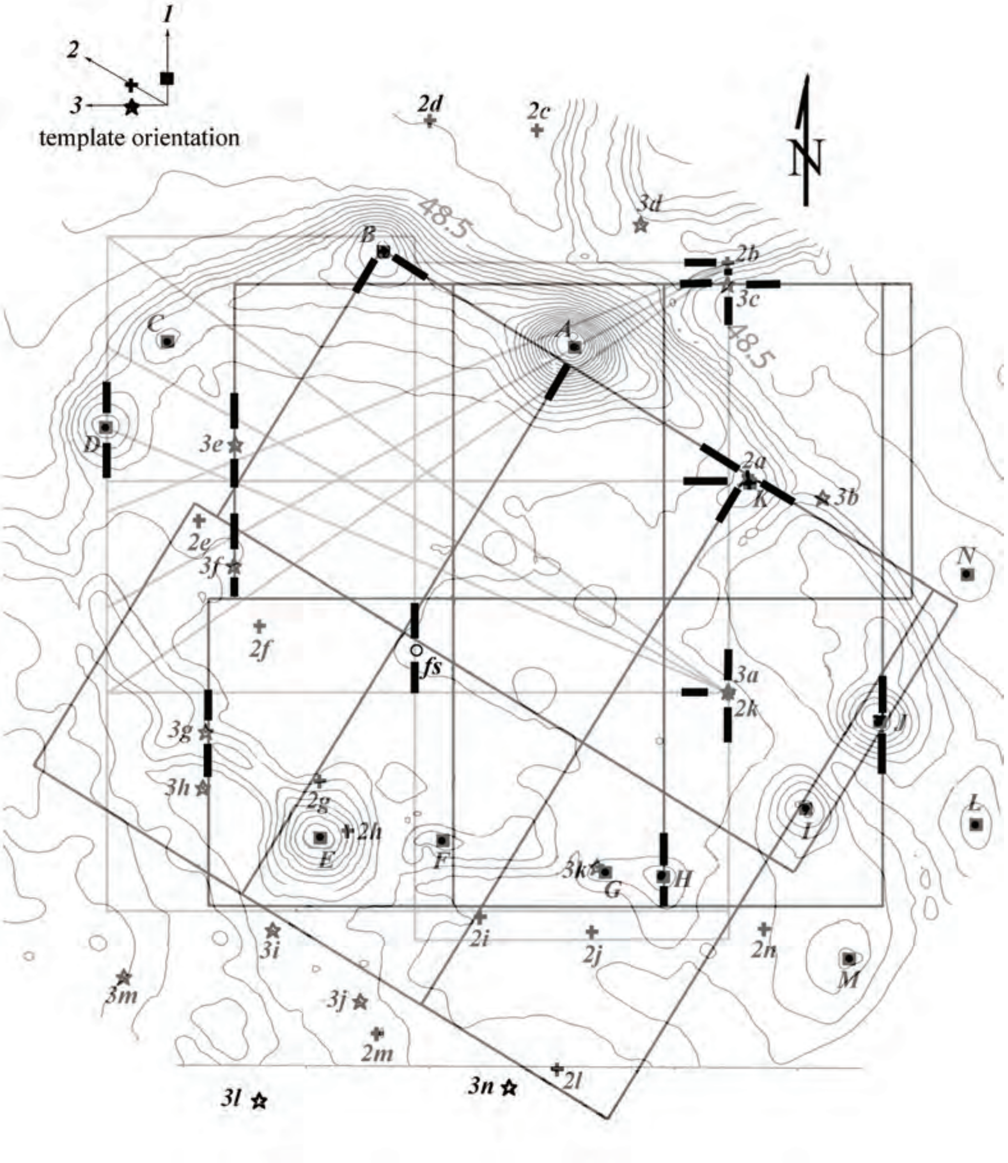


A master template was constructed by following the rules deduced from Caney Mounds, but applying the time-sensitive “ideal” swing-angle for the lunar maximum at the latitude of Watson Brake. While the template is very similar, its proportions are changed by the slightly different latitude. The template is registered by placing mound ***D*** where the solstice bearing intersects the west edge of the template, in accordance with the Caney Mounds template. The southern focus is then found to rest precisely on the major axis of the template. Mound ***A*** sits on the solstice bearing from the northeast corner of template 1. A line projected from mound ***N*** through ***fs*** locates the lunar minimum intersection with the west side of the template, while a line from mound ***J*** through the ***fs***, points to a solstice intersection, and a line from mound ***H*** through ***fn*** reveals the solstice intersection on the west side of the template.

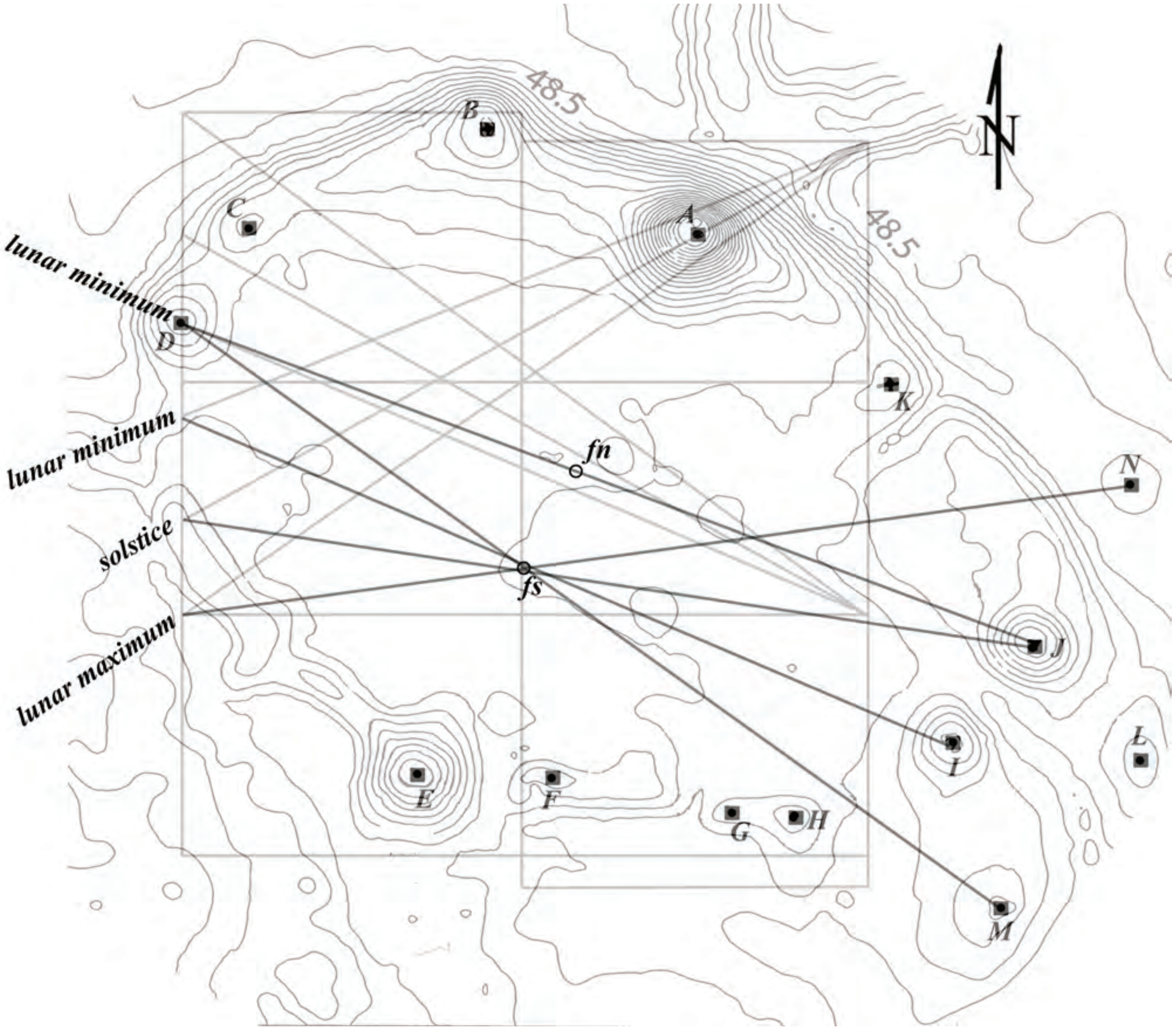
Template 2 can be oriented by rotating a copy of all fourteen mound locations clockwise, bringing a virtual copy of mound ***B*** to a new location at the upper right of template 1. Since template 2 has the same mounds as template 1, but in a new orientation, we will use the convention of labeling the new location of mound ***B*** on template 2 as ***2b***. The right side of template 2 can be fixed by setting the upper right corner on mound ***B*** and virtual mound ***2a*** at the second node down. Mound ***K*** does not share the location, although it falls very close. Virtual mounds ***2b*** and ***2k*** validate the origin points for projecting extrema ray bearings. Note the strong similarity of mound arrangements between template 2 and those of Caney Mounds.

For template 3, the mound locations are rotated ninety degrees clockwise from the original positions, with the effect that all bearings are now perpendicular to comparable pairs in template 1. Once virtual mound ***3a*** is placed with virtual mound ***2k*** at the southern ray projection point of template 1, virtual mounds ***3c, 3e, 3f, 3g***, and ***3h*** effectively define the shape and placement of template 3. In total, eleven points support the conceptual template structure by their positioning on lines and nodes as shown below.

Validating the template boundaries



Pointers to extrema



Mounds ***H, I, J, M***, and ***N*** each function as pointer origins for alignments through focus points ***fn*** and ***fs*** to redundantly indicate the intersection of extrema rays with the west edge of template 1. Focus points for template 2 are easily located by resecting the virtual mounds corresponding to template 1, but they do not appear to have been utilized.

Template frames and radial focus points are very helpful for transferring locations from a planning document to the ground by line-of-sight, but there is still some ambiguity possible as to where the mound should be positioned on a radial. Whenever possible, bearings to extema and their perpendiculars are found to have been used as one of many rule-driven procedures that redundantly position and certify every mound location, as well as the six virtual intersections by extrema rays on the west edge of template 1, as intentional. Templates would have provided conveniently standardized and codified extrema bearings during the design process.

To create a plan and then build it to specified proportion requires a system of measure sufficiently precise for creating a portable planning document and scalable for full-scale construction. Reverse engineering of the planning process at Watson Brake should settle any remaining questions of deliberative intent and encourage the application of the template concept for understanding the organization of other sites with multiple mounds. Use of specific astronomic bearings as a standardized surveying tactic argues persuasively that the twelfth mound ***L***, noted by Saunders (2004), is properly part of the Watson Brake complex along with mounds ***M*** and ***N***. Additionally, alignment ***D-I*** and the solstice line through mound ***L*** from the west edge form a pair of solstice bearings that frame the length of the central plaza of the oval grouping of mounds. Saunders (2005) observation that the central area was found free of occupational refuse and debris suggests that the inhabitants may have considered it a "solstice avenue." Therefore, trends of mound pairs on standard astronomic bearings should be considered as a viable investigatory tool at other multi-mound locations.

Planners at Watson Brake may have considered the terrace top location too favorable to ignore and so worked out a compromise to make the best of topography, setting, spirituality, and familiarity with movements of objects in the sky. One might compare the arrangement of templates used at Watson Brake to freeze-frame screen shots of the night sky, where stars wheel from one orientation at dusk to another at dawn. Mound sites must have been more important for the symbolic meaning embedded in their plan than for use as an "observatory." After all, the plan could not have been completed had not the observations already been performed. What remains at the end is a new mystery of why many locations were left unmarked in spite of their apparent conceptual importance.

Choosing a point location at the center of the highest contour of a mound may be the weakest part of this study. On the other hand, since the points are contained in a grouping over three hundred meters across, an error of one meter would change a bearing by only 0.2 degrees. While the final analysis suggests some possible adjustments to selected mound positions, none were made. Consequently, depicted alignments are sometimes less than perfect. Still, the differences are well within the uncertainty of where mound centers were originally intended to be located.

That said, the deduced process of planning, surveying, and construction indicates that each of the activities was conducted as part of a familiar routine. Focus points, probably occupied by a tall pole, expedited accurate transfer from plan to ground. Radial alignments were then anchored by building mounds to acknowledge template lines or intersecting bearings. Line-of-sight would have allowed bearings accurate within two hundredths of a degree, although Photoshop replication was limited to a tenth of a degree. While lunar extrema are not directly viewable without waiting for years between occurrences, it would have been simple to create reference bearings when they did occur.

Checking the trigonometric values of lunar maxima for the time when sites are thought to have been constructed adds yet another dimension to the investigation. Swing angles of lunar maxima, defined by integer ratios of the Mesoamerican calendar, occurred during the time of construction of Middle Archaic mounds. The only significant lunar maxima ratio (360:520) that residents of Monte Sano (16EBR17) and LSU Campus (16EBR06) could have seen occurred 6,000 years ago, within a thousand years of construction 5,050 years BP (Saunders 2010:67). Following Poverty Point times, there were negligible opportunities to observe the sacred ratios, although ratios just short of 360/520 could have been seen at the Woodland sites of DePrato (16CO37), Marksville (16AV1), and Stelly (16SL1). While these convenient viewing opportunities might have occurred by chance, it is likely that residents of those locations saw something propitious about the trigonometric relationships and memorialized them in the geometry of templates used to guide placement of their mounds.

Since the location of Watson Brake did not easily accommodate the northerly-oriented template, the occupants may have resorted to the multiple-template scheme to adhere to a rule demanding that a north orientation be followed. Using the templates to situate each mound may have been like using God's blueprint in lieu of arbitrary planning decisions. Whatever the motivation, every mound is purposely placed in accordance with consistent rules and conventions. Short-cuts were avoided and redundancy was valued. In fact, the redundant locators seem to indicate special areas of interest, like the extrema maxima at the east side of the master template. The complex interplay between radials, templates, virtual points, pointers, and extrema alignments may indicate an obsessive search for deep truth in a manner similar to alchemy.

Archaic sites, including Caney Mounds and Watson Brake, demonstrate a practice of arranging mounds in patterns consistent with the hypothesized template that may have persisted into the Woodland period. Continuity such as this suggests an accompanying set of shared spiritual beliefs that have been difficult to recognize in material culture. Far from being arbitrarily or capriciously placed, mounds were located according to keenly rational conventions guided by well-understood principles of geometry and widely shared rules of expression. Establishment of sites to take advantage of particular lunar maximum viewing opportunities, as precession altered their proportions by an integer unit every thousand years, strongly argues for spiritual motivation.

By revealing previously unrecognized competence in astronomy, mapping, and mensuration, the findings force consideration of additional aspects of social complexity. The mound sites presumably record the most sacred of cultural knowledge, hidden in full view. In order for an emerging semantics of geometric communication to be realized, new constructs need to be recognized in new regions. Tracing template lines on the ground may well lead to additional discoveries that could otherwise go unnoticed. Sufficient sequential steps have been reconstructed to account for the entire layout at Watson Brake, showing that instructions could have been shared to facilitate the design of other mound sites. Differences in layout revealed by superimposing other sites with the Watson Brake plan indicate that competing design schemes were applied, but similarities in scale hint at the continued use of a standard template.

Uneven distribution of material culture from one Middle Archaic mound site to another (Saunders 2005:662-663; 2010:73-74) has led some people to discount regular contacts, but the spiritual world evidently transcended barriers imposed by trade, migration, or conquest. Belief systems do not usually leave many tangible traces and so are easily overlooked, but the way in which people identify themselves shapes how they interact and subsequently guides their relationships with the “other.” Material aspects of a culture, like pottery, art, lithic technology, and food preferences are naturally tied to a great extent to the resources of a region. On the other hand, once you get a spiritual buy-in, ideological values are hard to dislodge. The modern world is not so different from the past, religious beliefs and values are still held fast in the face of substantive technical innovations and changes in material goods.

Establishing a standard unit of measurement

Having described the use of measured distances to represent proportions, it remains to be resolved whether the proportions resulted solely from an accident of astronomic alignment or if geometric constructions were given specific dimension by means of a standardized unit of lineal measure. Since each proposition may be logically defended, resolution requires building a hypothesis that can be tested with data. Proportions inherent in astronomically derived azimuths are coincidental facts of nature, but human intervention is required to exploit them by deliberate scaling of geometric constructs using standard units of measure. Between natural degradation and deliberate landscape transformations, the data available to settle this question is necessarily limited and requires assumptions that must be acknowledged and tested where possible.

Discerning standard units of measure requires measuring a sample of clearly defined intervals that may be unequivocally associated with a numerical value. The template used by Middle Archaic mound builders to lay out mound arrangements, provides a suitable reference with proportional geometric elements that correspond to day-count intervals of the Mesoamerican calendar system. North-South elements of the template are in multiples of 260 units while East-West elements are valued by multiples of 365. Diagonal aspects of the template are much more complex but, with viewing azimuths generated by computer for the time of construction, it is still possible to calculate appropriately valued distances by trigonometry.

While any geometric interval of known numeric value is useful, the best results come from the longest and most definitive intervals, preferably height, width, and diagonal intervals. Although the template has been described as a fully drawn geometric construction, Middle Archaic people often built sites by using disparate principles embodied in the template, seldom presenting the entire concept at one location. Consequently, data must be collected by measuring whatever appropriate geometric elements that may occur from site to site.

Site (designation)	Element measured	Length (M)	Proportional element value	mm/ element value	Site scaling factor	mm/unit scale
Bush	width	149.1	730	204.247	180	1.135
“	diagonal	182.9	896	204.129	180	1.134
“	N-S pair	105.8	520	203.462	180	1.130
Caney Mounds	diagonal	369.278	896	412.141	360	1.145
“	width	302.611	730	414.536	360	1.151
“	N-S pair	212.596	520	408.838	360	1.136
Hedgepeth	width	329.292	1460	225.542	200	1.128
Insley	N-S pair	309.653	520	595.487	520	1.145
McGuffee	width	340.3	730	466.164	400	1.165
“	N-S pair	243.8	520	468.846	400	1.172
“	diagonal	412.7	896	460.603	400	1.152
Watson Brake	height	274.98	794	346.322	300	1.154
“	width	252.77	730	346.260	300	1.154
Poverty Point	width	679.71	730	931.110	800	1.164
“	height	478.24	520	919.692	800	1.150
“	diagonal	831.296	896	927.786	800	1.160
“	diagonal	776.528	835	929.974	800	1.162
					Average	1.149
					Std Dev	0.013

Presuming that integer scaling factors were used to plan each site, then the data should indicate that similarly valued geometric elements can be measured by integer multiples of a shared base unit. Those integer scaling factors should be logically consistent and allow comparison to other presumed standards of measure.

The Caney Mounds site (16CT5) template was used as a guide to identify elements that could be assigned specific numeric proportions, without using the template for positioning. Photoshop measurements were then made on the longest of three basic elements: width, length, and the northeast trending lunar maximum. When possible, scale was determined from the longest grid intervals available. Eighteen data samples were evaluated from seven sites, using different orientations as often as possible to control for possible deviations from the expected template. Lunar and solar azimuths were determined by computer simulation of viewing conditions that existed when the site was in use. When the ratios of cardinal azimuth components agree with the lunar extrema, it indicates that the template assumptions were correct. During construction, the actually viewed azimuths were utilized for laying out mound arrangements by line-of-sight. For that reason, diagonal measurements must take prehistoric viewing conditions for the unique coordinates of the site into account when determining reference numeric values. Decimal values are appropriate as long as they have been trigonometrically calculated from integer cardinal values. Four measurements were collected along the northeast trending lunar maximum azimuth, bracketed by eastern and western template boundaries.

The 520-unit N-S interval between mound pairs on the eastern side of the master template is the most obvious choice of measurement. However, the best evaluation should come from the greatest length of measurement. For that reason, full width and height should be measured when they can be definitively positioned. A diagonal from the upper northeast corner of the template, whose value may be calculated by trigonometry from its relationship to the 520-unit pair of mounds, is a less obvious selection. Not only is the diagonal one of the longest dimensions, its azimuth is a function of latitude and its length is bounded between cardinal bearings from mounds on the template sides. Including as many measurements as possible from different geometric elements of the template allows scaling factors to be verified. Locational errors in both modern and ancient mapping may be compensated for by averaging scaling factors for a site.

Dividing measured length by the proportional numeric value of an element estimates a minimum millimeter per element value for each site. Comparing native units apparently used for each site can reveal when the units are integer multiples of a smaller unit. The goal is to identify the smallest common factor as the base unit from which all the larger units may be derived. Since the design of Watson Brake (16OU175) implies that portable templates must have been used, a base unit in the range of one millimeter is expected because that would allow a typical one-to-one scale site plan to fit within roughly a meter square. If a base unit of measurement is present, then each element to be measured must be scaled by the same factor. Progressively larger units, comprised of integer multiples of the base unit, could be utilized for convenient layout of large-scale sites. Data available for study at each of the seven sites is briefly described below:

The clearest picture of the conceptual template guiding mound builders of the Middle Archaic is found at Caney Mounds, where the northern lunar major azimuth trigonometric ratio is 365:520 and the swing angle is 262:520. Consequently, proportional numerical values are confidently assigned and measured.

Bush mounds (16FR163) have the appearance of Caney mounds, mirror imaged from east to west, but at half the size and scaling factor. Simply by recognizing the geometric similarity with Caney Mounds, along with the fact that size and scaling factors are two to one makes a strong argument for a standard of measure, even though the site is contemporaneous with Poverty Point (16WC51) and built a thousand years later than Middle Archaic mounds (Gibson 2010:80) Saunders (2008:74-75) thinks the site may have been occupied during the mound building hiatus.

In the case of Hedgepeth mounds (16L17), the template is mirrored outward east and west of the center, doubling the proportional width. Mound A marks the upper-center of the symmetry plane. Although no specific mounds mark the northern lunar maximum azimuth, a proportional value can be calculated to fit between the obvious template boundaries for the time of occupation.

For Watson Break, the template concept was applied by transferring mound positions to three separate templates that were given three different orientations in such a way that direct measurement between mounds is not numerically quantifiable. Therefore, the northern lunar maximum diagonal and its constituent cardinal components are measured from virtual points extrapolated from the reconstructed template overlay.

Concepts from the template used at Caney Mounds and Watson Break were applied at Poverty Point to create a radically different geometry. Although the appearance changed, previously recognized preoccupation with trigonometric geometry justifiess assignment of specific numeric proportions. In this case, the northern lunar major azimuth forms a trigonometric ratio of 320:520. Mound ***C*** was used as a pivot point for solstice azimuths, which also crossed mounds A and B. Lunar azimuths were projected eastward from the center of mound ***A***, with the northern lunar minimum passing through mound ***C***. Finally, mounds ***B*** and ***E*** were arranged directly north and south of mound ***A***, which appears to have been designed to be proportionally 360 units on the long axis.

Only the eastern N-S mound pair at Insley mounds (16FR2) could be measured since the site was too incomplete to associate any other element.

McGuffee mounds (16CT17) are contemporaneous with Poverty Point and may have been occupied during the mound building hiatus (Saunders 2010:74-75). An unusual pair of N-S mounds in the center of the site is assumed to represent 520 proportional units. Assurance that the assumption is warranted is provided by matching the ratio of cardinal elements to the lunar maximum azimuth.

For each site, the measured element length in meters is divided by the proportional numeric value of the element to obtain a site-specific meter per element value. This value represents the length of the element as it would have been represented on a hypothetical meter-wide portable planning document of one-to-one scale. From this exercise, it is evident that yet smaller units of measurement were utilized. Therefore, the computed site-specific millimeter per element value is divided by a series of likely three-digit integer scaling factors that included calendar numbers: 260, 360, 365, and 520. The results from that operation isolate a base unit of measure that can be multiplied by a scaling factor to explain the millimeter per proportional element value.

The average base unit of 1.149 mm ± 0.013 mm, when multiplied by 1300, agrees with the 147 cm ± 5 cm Maya standard unit of measure interpolated by O'Brien and Christiansen (1986) from architectural measurements. O'Brien and Christiansen chose to assume subdivision of the 147 cm unit by integer fractions but acknowledged a suggestion by Brotherston (1978:283) of a potential relationship between a calendric system and a measurement system. While examining how the Aztec measured their sacred spaces, John Clark (2010:150-169) found repeated instances where well-defined units of measure had been used to record day-counts of calendric and planetary cycles along with counts by hundreds. Scaling factors that have been found in mound dimensions are completely compatible with the Mesoamerican practices of deliberately imbedding important numerical values in architectural dimensions. Williams and jorge y jorge (2008) described an administrative use of standard lineal measures by the Aztec for surveying quadrilateral plots of land and calculating area, using some of the same units as described by Clark. From these examples, it can be seen that counts of astronomic phenomena and calendric intervals were routinely captured in dimensions of communal construction projects. Secular measures undoubtedly were utilized in day-to-day projects, but are far less likely to be recognized because they would have adhered to more individual conventions with less stringent requirements for precision, possibly using body-based equivalents as implied by named Aztec units of measure.

Having established a system capable of recording precise linear data begs the question of what precision might be reasonably expected. Useful insight is found in Department of Defense anthropomorphic data (DOD 1991), where the width of a palm at the knuckles is reported to be 8.9 ± 0.5 cm—very near the value of 78 units times the derived conversion scale, and a tenth of the template's proportional height. We can postulate measuring out multiples of 78 units by stacking hand-grips along a length of staff or rope to develop an interval with specified numeric value. If all grips were from the same individual, the deviation from the mean would be multiplied by the number of grips, but contributing each grip randomly from a representative population should lessen the standard deviation as more people participate. Stochastic modeling demonstrates that twenty grips can produce a standardized 1,500-unit ± 5 mm span representing 6 × 260 days. A 2,600-unit cord, 2.967 meters long and representing 10 × 260 days, would have provided a convenient means to measure even larger dimensions. Laying out the mounds would not require subdividing a long interval, but proportional graphic techniques can easily convert a long standard into very precise lesser intervals suitable for recording the smallest data in a compact distance. The ability to plot accurately at small-scale could allow creation of portable site-planning documents (Clark 2004:190) that would accommodate accurate transfer from place-to-place without having to establish every azimuth anew by direct observation. Such portable plans for large sites would not be feasible with any larger base unit of measure. For perspective, depicting 780 units of the west edge of the template at one-to-one scale would occupy about nine-tenths of a meter. Final site layout could then have been facilitated by using line of sight intersections which can be visualized by strings stretched over the plan and subsequently located on the ground at large scale by intersecting lines-of-sight rather than by measuring coordinates on a grid. One advantage of this approach is that a consistent measurement scale can be reliably reestablished at any time and any place without the need to construct and maintain a permanent reference standard. Building with such a high degree of accuracy would have assured that the information incorporated into the structure could be reliably extracted by another person. From the evidence of factorization of day-referenced counts in mound layout, it is reasonable to deduce the existence of named lengths of measure based on calendric counts. Multiple, named Aztec units of lineal measure are shown by Clark (2008, 2010) to have been used to indicate counts of synodic and calendric cycles in small-scale portable objects as well as metropolitan-scale arrangements of structures. Saburo Sugiama (1993) described an 83-cm standard unit of measurement that was used for laying out the entire metropolitan area at Teotihuacan. It must be pointed out that the 83-cm span would equate to twice 364 units if the base unit was the same as used in planning mound sites in Louisiana.

Applying the deduced standards of measure to much later Hopewell earthwork constructions shows that direct point-to-point distances factor to reveal calendar values. The 321.2 meter diameter of the great circle at Newark, Ohio (Hively and Horn 2006:284) can be interpreted to be 3 × 260 × 360 at a scale of 1.144 mm/unit—equal to the scale implied by using DOD data for the 78-unit width of a hand at the knuckles. An 870 meter-long axis uniting the great circle with an octagon translates to 8 × 260 × 365 at the same scale, while the 25 meter-wide connecting avenue equates to 60 × 365 units.

Several characteristics of mound sites interfere with finding well-defined features that can be used to deduce standard units of measure. Dirt mounds lack definition, but when they are separated by hundreds of meters, the resolution is sufficient. The many variations by which the template concepts can be applied present a challenge but also reinforce the fact that people were actively working to improve their science. Interpretation is aided somewhat by understanding that the trigonometric ratios used to characterize the azimuth swing angle influenced when and where sites were built. Later period constructions that could not be directly linked to the sacred ratios used proportional conventions more sparingly while N-S pairs of mounds and lunar maxima remained in use.

Six Middle Archaic sites in northeastern Louisiana share basically the same viewing conditions, combining a northern lunar maximum azimuth inclined at a ratio of 360:520 with lunar maxima swing angles at a ratio of 260:365. Those six sites also represent the most complex mound arrangements. Further south, other Middle Archaic sites would not have been able observe those swing angle ratios but built mounds nonetheless, without indicating alignments. Because mounds were built in both regions at the same time, we can suppose that residents shared an interest in monitoring swing angles but lacked the proper circumstances to honor them. It therefore seems likely that an interest in the heavens overrode differences in cultural paraphernalia and manner of subsistence.

Peacock (2013) used the bet hedging model to explain mound building as an evolutionary response to population growth that caused locations of early mound sites to progress from south to north. The same distribution of sites over time now can be attributed to people literally aligning themselves with the cosmos. Rather than wasting energy on mound construction, the effort may have been construed as a sensible investment to curry favor from the Creator. Inevitable disruptions due to precession, shifts in river flow, earthquakes, or weather were infrequent enough that mound building periods lasted for at least a thousand years at a time.

After a thousand-year hiatus in mound-building, sites are seen to align with swing angle viewing opportunities in which the ratios can be described as integer ratios of important calendric numbers. Presumably, during the hiatus in mound building, a more mechanical approach to astronomy supplanted the apparently spiritual interest in specific calendric ratios. During the Poverty Point era, mounds were much more evenly spaced in latitude, but with regularity that parallels an integer progression of swing angle ratios. Correspondence between azimuths visible during the end of activity at Watson Brake and the earliest building at Poverty Point suggest a possible continuity in the approach to site design. The most important innovation of the second mound building interval is integrating solstice observations at Poverty Point separate with lunar observations from a separate location.

All in all, it is remarkable that reality and simulation agree as well as they do. In part, it may be because observations can be repeated from generation to generation and the law of averages takes over. Scaling factors at Poverty Point show that factorization apparently was utilized when selecting the appropriate "ruler" length for measuring lengths beyond about 500 meters. Integer multiples of alternate possible reference lengths provided the theoretical capability of indicating values accurate to one in a thousand units. The calculated standard deviation per measured unit allows a potential lineal accuracy of one in 50 units and angular variation of half a degree. Tracking azimuths according to a culturally agreed upon ratio would require accuracy on the order of a tenth of a degree to distinguish a single digit numerator and half a degree to segregate the special primary calendric ratios.

Now that it is clear that a standard unit of lineal measure was used to graphically represent constituent numbers of the Mesoamerican calendar, timing of mound building near the start of consecutive counting by the calendar seems to be no accident. Importantly, there is a logical connection between the astronomic alignments featured in Louisiana mound sites and the mathematic structure of the calendar—which may actually have been the American calendar. Without writing or glyphic notation, the calendar could not enjoy the cultural prominence that later flourished in Mesoamerica and thus simply faded from use on the American continent. Before its abandonment, occupants of Poverty Point took advantage of its location on the Mississippi River to import large quantities of stone and minerals by boat (Gibson 2010) and were therefore well positioned to exchange ideas about workings of the cosmos as well. Unfortunately, the abandonment of Poverty Point was marked by a regional hiatus of communal habitation for hundreds of years (Gibson 2010) that may have hindered transmission of calendric knowledge, although Hopewell constructions in Ohio retain alignment and scaling concepts as late as A.D. 400. Concepts so well-developed in the Middle Archaic apparently lost their clarity, as reflected in increasingly chaotic site organization. Still, because the zero-date of the Mesoamerican calendar is implicitly imbedded in its structure, knowledge must be assumed to have been transferred through an unbroken chain and subsequently elaborated on to become the signature achievement of Maya society.

4

Poverty Point

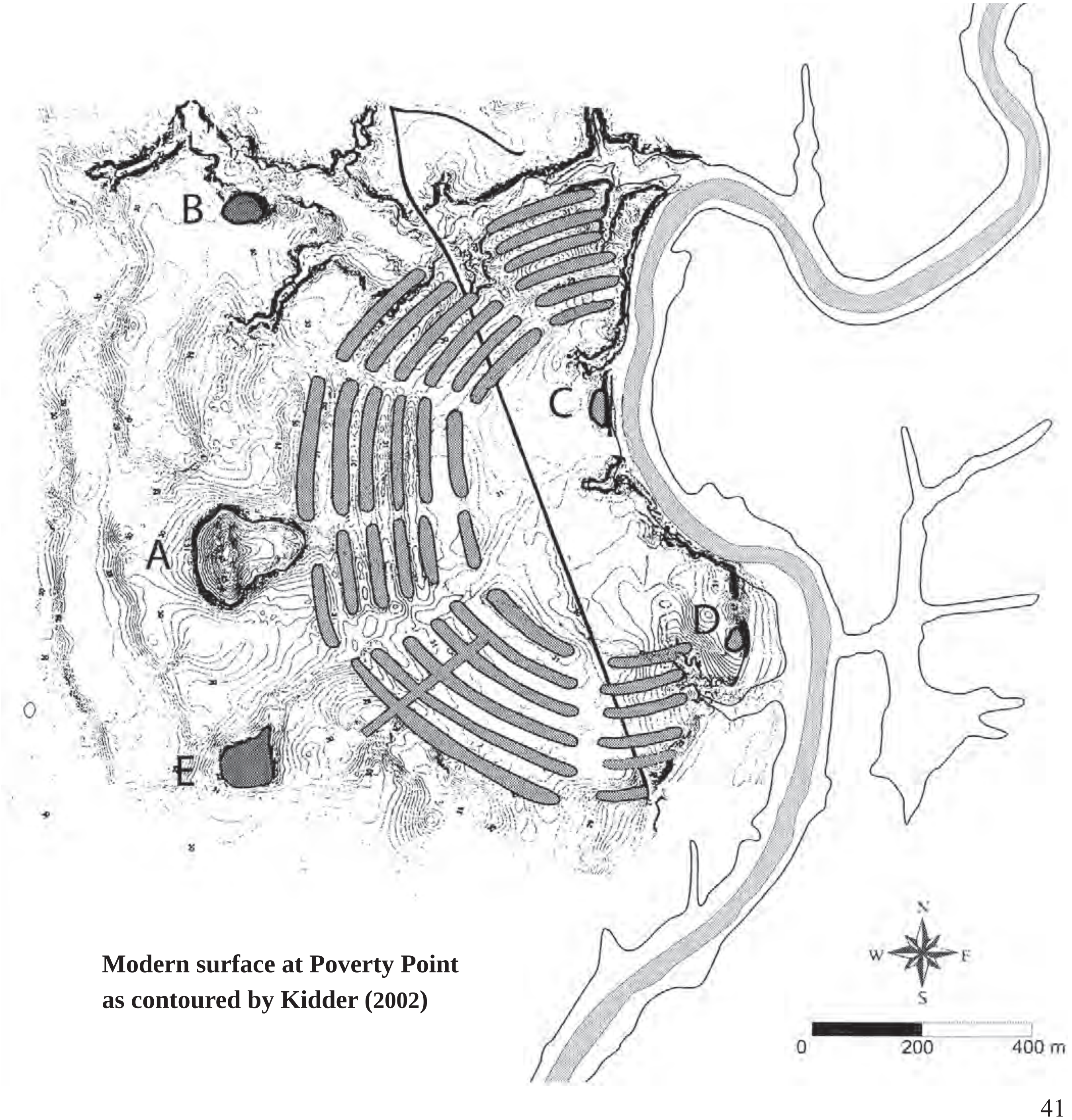
Mound sites were planned with an idealized template until about 4800 BP, only 300 years after the start of the current Maya epoch of 5,125 tropical years duration. After a hiatus of about 1,000 years, a new approach was used to build the most spectacular set of mounds in the western hemisphere at a place now called Poverty Point between 1730 and 1250 BC. Although the design of Poverty Point acknowledges the old latitude-specific idealized geometry, it introduces alignments along true bearings that may be applied anywhere to quantify the latitude where an observer stands. Most remarkably, the design compares solstice angles at the latitude of observation with solstice angles that would have been visible only at the equator.

Mounds were undoubtedly built for many reasons besides celebrating astronomic alignments. Most of them are near the Mississippi River, which flooded frequently and changed course during the time under consideration, and high ground would have been important. At the Burkett site, a mound was built atop a vent hole caused by a major earthquake (Thomas, Campbell, and Morehead 2004:124-125). Another example was reported by Saucier (1990) in the Cairo lowlands. The general area is underlain by the powerful New Madrid fault zone which is known to have produced extraordinary effects in 1812, but whose traces are only barely perceptible today. Sites located near the intersection of river courses may have been useful for defense or as highly visible markers encouraging trade. It seems reasonable that at least some mound building may have been timed to observe a change of era during the thousand years prior to the start of the current Maya era.

Comparing mound sites has shown that the founding template geometry persisted as recently as 880 AD at DePrato mounds. However, variations are increasingly noticeable with the passage of time. Major mounds occur at new points on the master grid, making correlation to the plan difficult to recognize. There are also supplemental elements that cannot be readily associated with the basic planning frame. Fitting mound site plans to the master plan described from Caney Mounds, makes it apparent that very subtle indications sometimes remain from modest monumentation of minor points. These indications are more noticeable in relatively recent sites, suggesting that it is prudent to map even the most subtle topographic variation. Disturbances from centuries of tree falls, erosion, and agricultural use make the interpretation of mound geometry difficult. Multi-spectral geophysical investigative techniques have shown at Poverty Point (Hargrave et al 2007) that once invisible features may be recovered and help complete our understanding of site organization.

John Clark (2004) noted standard intervals of distance at Poverty Point that correspond with multiples of measures common to Mesoamerica. Since Poverty Point is approximately contemporaneous with the earliest Olmec civilization and dates to about 1,300 years after the zero date of the Maya calendar, dimensional relationships at Poverty Point might provide useful clues to early development of mathematics and astronomy. Unfortunately, nature conspired to shift the course of the Mississippi River far from this otherwise auspicious place and occupants resumed their activities elsewhere. The mounds at Poverty Point, Louisiana have long been acknowledged as puzzling for their size and complexity, as well as being incongruous in a hunting and gathering society (Gibson and Carr 2004). My interest in Poverty Point began as a search for physical phenomena whose scale would mean the same to people anywhere, and I expected that astronomical observations suggested by mound arrangements could provide useful clues for understanding how and why people of other places arrived at similar design principles.

It is uncertain how the effort exhibited at Poverty Point could have been sustained by foragers who did not have domesticated crops. Aside from monumental piles of earth, the main industry seemed to involve accumulation of stone from far afield. Gibson (1998) estimates that 70 tons of chert were left at



Modern surface at Poverty Point as contoured by Kidder (2002)

the site, most of it imported from hundreds of miles away. But the indications of trade are sparse, with few items firmly identified as moving from Poverty Point to elsewhere. Estimates of earth movements totaling about 700,000 cubic meters (Gibson 2001) exceed the cumulative volume for the rest of the Archaic period. Projects of this scale have usually been thought of as possible only in a hierarchically structured society, but there are no cities or infrastructure to support the required labor force. We can be certain of one thing however; the construction was of great importance and to understand what could motivate people so markedly could be one of the turning points in archaeology.

Tracing structures at Poverty Point from an aerial perspective draws greatest attention to what are generally called earthworks. In actuality, the earthworks are low, elongated piles of earth situated like giant spectator platforms, complete with aisles, about a central plaza. Strategic mowing is responsible for present-day visibility of the features, but they are only a tenth the height of the mounds and much less prominent (Gibson 1990:207).

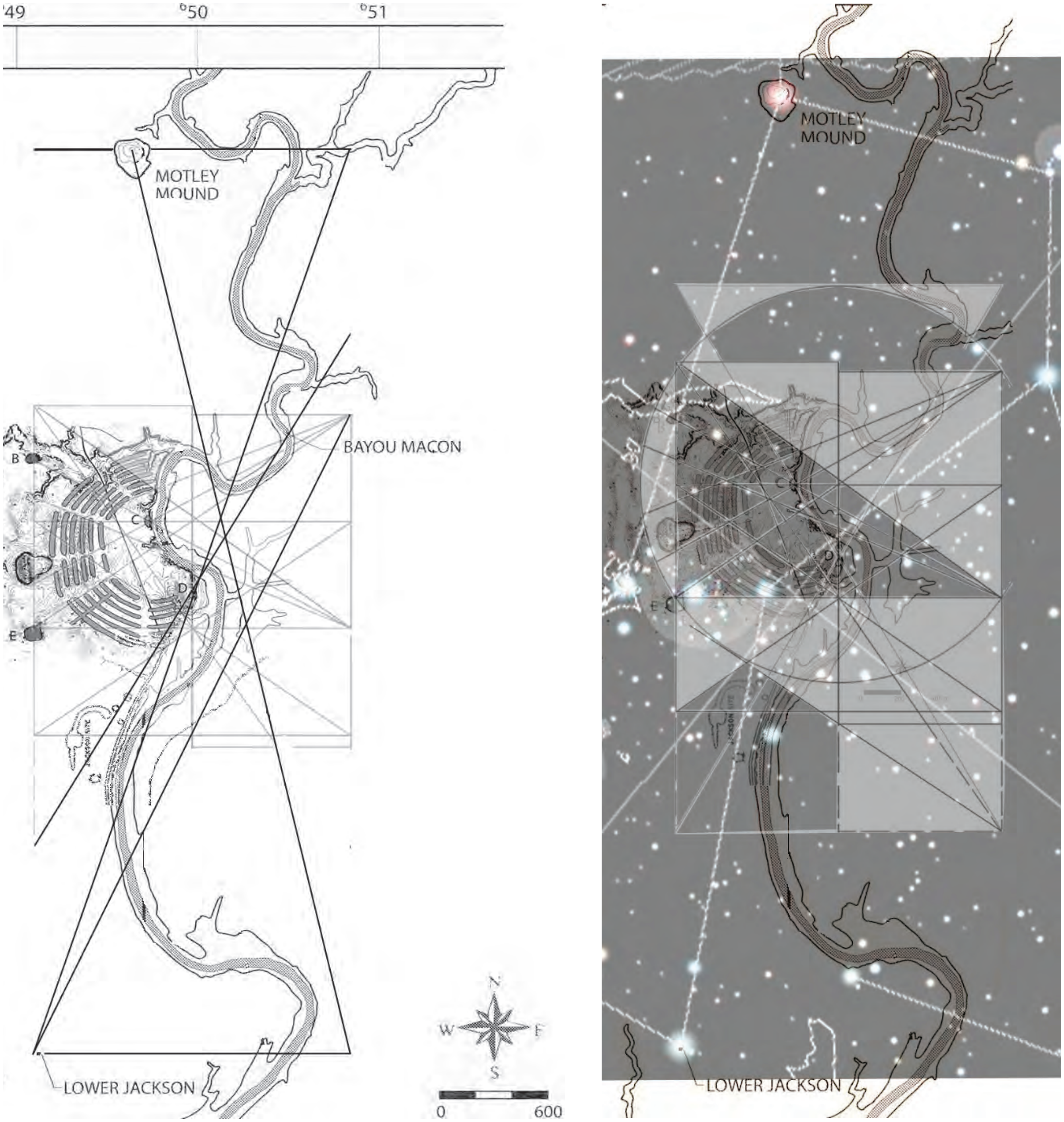
The relationship of mound placement at Poverty Point to the template is not immediately obvious. Obviously, Poverty Point lacks some of the most important locations of the template, but enough are present to allow confident registration with earlier mound sites. In particular, the large mound **A** at the west side of the site shares a cardinal alignment with Lower Jackson mound, contemporaneous with the initial mound-building phase. The same mound also occupies the same position in the template as the prominent western mound at Caney Mounds, with a solstice alignnment from the northeast corner passing tangent to the mound. Although the site covers an immense area, it occupies only a relatively small portion of the mnemonic geometry. Connecting extreme corners of the diagram positions mound **D** where the diagonals cross the central axis, and mound **C** on the upper left diagonal at the solstice crossing. John Clark (2004:170-176) has pointed out the apparent connection with Motley mound to the north and Lower Jackson mound to the south, spanning just over three miles. By geometry alone, Lower Jackson mound does fall nearly in line with the west side of the structure but, otherwise, the only obvious relationship is that the outlying mounds are approximately the same distance north and south from the main complex. When the star map of Orion is registered to the plan though, there is an unexpected correlation that seems to explain the mound positions. By shifting the star field down to the left and making a slight scale adjustment, Betelgeuse covers Motley mound, Rigel covers Lower Jackson, and Belatrix covers the northeast corner. The belt stars then straddle mound **E**. It appears that a stellar hierophany was imposed on the site plan and documented by large mounds. Note that the long axis of Motley mound is inclined in the direction of mound **D**, very nearly at a right angle to the inclination of mound **A**. One mound of the Jackson site falls directly on the lower left diagonal leg. The enhanced lines show how connecting prominent points of the idealized geometry allows positioning of Motley and Lower Jackson mounds.

Orion attracts attention for a number of good reasons. Not only do the belt stars have an unusually distinctive appearance, Mintaka happens to be situated on the celestial equator. Furthermore, the galactic equator, represented by the Milky Way, intersects the ecliptic, or orbital paths of the planets just above the constellation of Orion. In fact, the zenith of the proposed orientation of the star map points to the intersection of the Milky Way with the ecliptic. The constellation of Orion can be viewed in the illustrated orientation during the middle of the night near spring equinox. Each 18.6 years, the orbit of the Moon reaches nearest to Earth at equinox, causing it to loom as much as twenty percent larger than normal.

Apart from positions that correspond to the template, intriguing numerological convenience, and registration with a star map, there is no evident purpose to account for building such an intricate structure at such a grand scale. A completely new approach is required to explain the purpose behind the most complex mound arrangements at Poverty Point. As has been pointed out, the master geometry first recognized at Caney Mounds only applies to a specific latitude. While that inflexible geometry can be clearly traced at Poverty Point, we can detect another approach capable of being applied anywhere. Although the two are interwoven at Poverty Point, there is no good reason to expect that they would coexist for long.

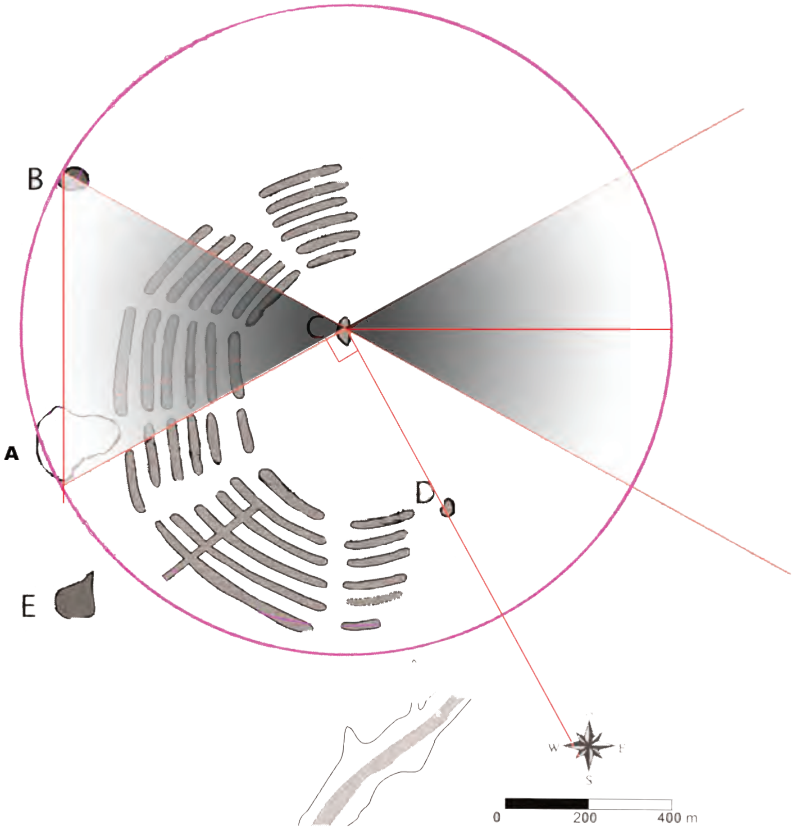
When the geometric alignments are recognized for their astronomic correlates, the diagram somewhat resembles an instructional diagram of the celestial sphere. If that impression proves correct, then the constructions at Poverty Point may represent a school for ancient astronomers.

Greater Poverty Point



To the left, a composite map shows how the template relates to mound placement at Poverty Point. Each large mound can be directly associated with a discrete node in the master plan. At the right, a star map of Orion, as it would have appeared 5600 BC, fits the geometry remarkably well, and provides a clue as to how Motley mound and Lower Jackson mound were positioned.

Solar alignments at Poverty Point

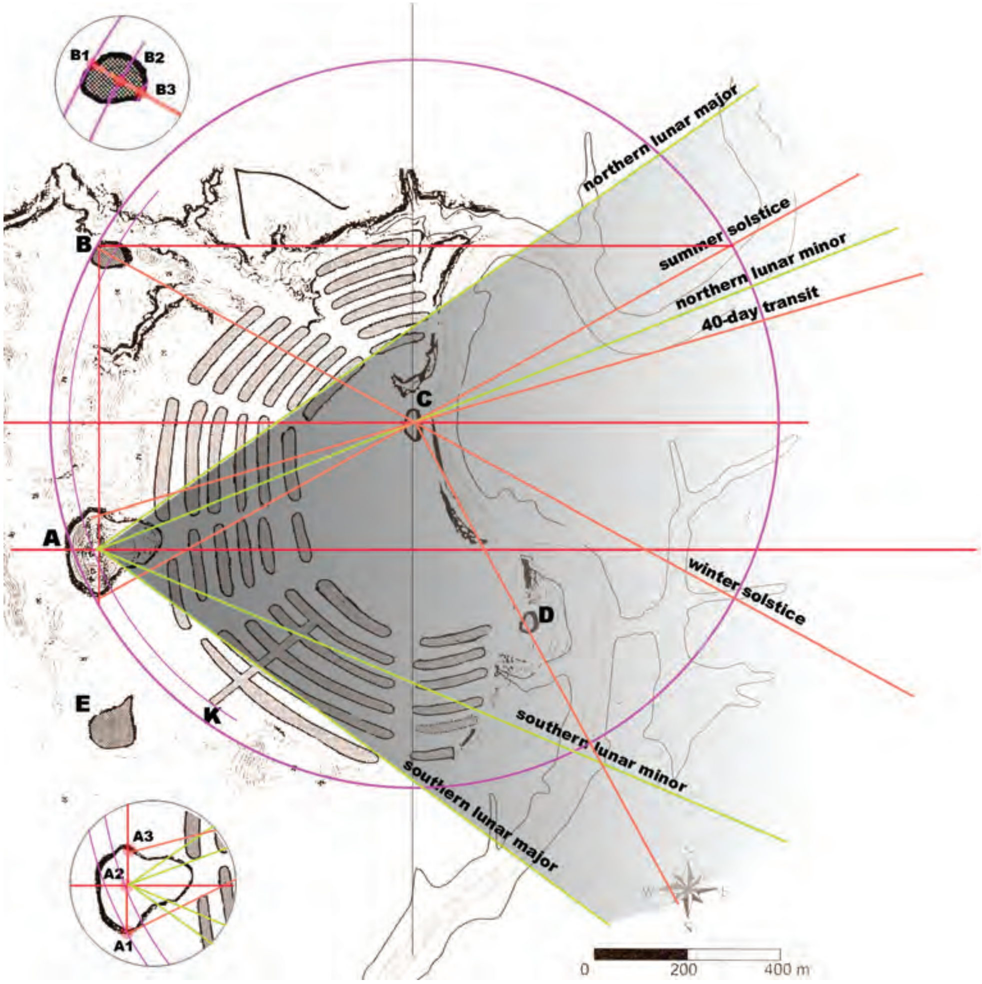


Of all the Archaic mound sites, only mound **C** at Poverty Point registers with the solstice intersction in the mnemonic geometry. There are also no mounds along the eastern side of Poverty Point from which to radiate lunar maxima bearings. A compass arc centered on the lunar maxima intersection cuts through the inflection of mound **E**. Consequently, a decision was made to analyze the mounds as if mound **C** were used to guide solar bearings and mound **A** were used for lunar bearings. Not only is mound **D** on the central axis of the master geometry, it also falls on a right angle to the winter solstice line through mound **C**.

When an observer at mound **C** uses trigonometry to measure the N-S dimension of mound **A** in terms of daily solar transit, it generates 3,796, or 4×949 units per day, while forty days of Sun movement represents 151,840. The value of 3,796 for a day's Sun transit on mound **A** is doubled through a full year of observation. Factoring 7,592 into 13×584 reminds us of the 5÷8 = Venus÷Earth synodic cycle equality. The appearance of near integer multiples of 13 Venus cycles equated with 21 Earth cycles may be an early source of the later Maya interest in 13÷21 proportions and the creation of the *Phi* ratio by consecutive Fibonacci numbers. Multiplying a day's solar transit value atop mound **A** by 360 produces the Maya "super" number of 1,366,560 that is commensurable with the greatest quantity of cycles.

Altogether, as viewed from mound **C**, the Sun would have set in contact with mound **A** for 80 days near winter solstice, when the Sun sets at its steepest angle in regard to the horizon. The Moon changes position on the horizon by an average 3.9 degrees a day (2×57.6÷29.53), and would transit mound **A** in 3.23 days as viewed from mound **C**.

Lunar alignments at Poverty Point

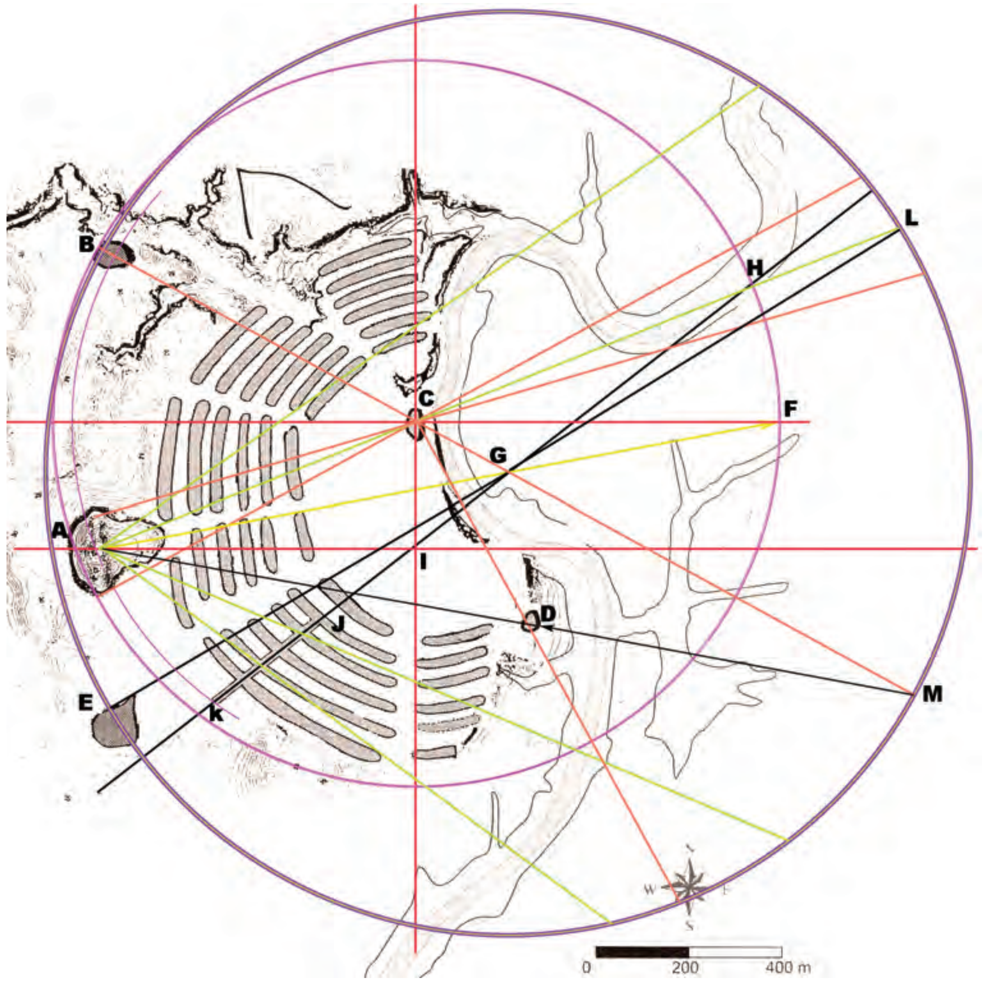


We know that solar and lunar bearings change with latitude but computer simulations show that lunar bearings for Tikal in Guatemala vary by no more than 5 degrees from bearings in Louisiana. The data also reveal that, regardless of latitude, 20 days of angular solar transit remains within 4 degrees of the arc between the northern lunar minimum and the summer solstice. At Poverty Point, the bearing from mound **C** 20 days after solstice matches the lunar minimum alignment drawn from the center of the ridge on mound **A,** within three tenths of a degree. With that encouragement, the remaining lunar bearings were drawn from the same point on mound **A** due south of **B**$_1$. A second arc from **A**$_2$ and centered on mound **C**, defines **B**$_2$ where the arc crosses the solstice.

Only at the equator are summer and winter solstice bearings completely symmetrical north to south. Curvature of the Earth distorts those bearings increasingly with higher latitude. The remaining geometry has the effect of rectifying the distortion introduced by observation at a latitude away from the equator.

Since it takes just over eighteen and a half years to witness all extremes of the Moon's position on the horizon and return to the same date of the tropical year (7,592÷365.2422), 20.8 solar years is sufficient to cover that period. The arc from mound **C** that joins mounds **B** and **A** has a radius of (949×730). When the radius is measured between mounds **C** and **A**$_1$, using the line between mounds **B** and **E** shortens the distance to match (720×949), in effect honoring the multiple of eighteen to create a 360-day *tun* year. Geometry at Poverty Point thus provides a unique and unmistakable record showing the explicit valuing of the *tun* level of Maya time.

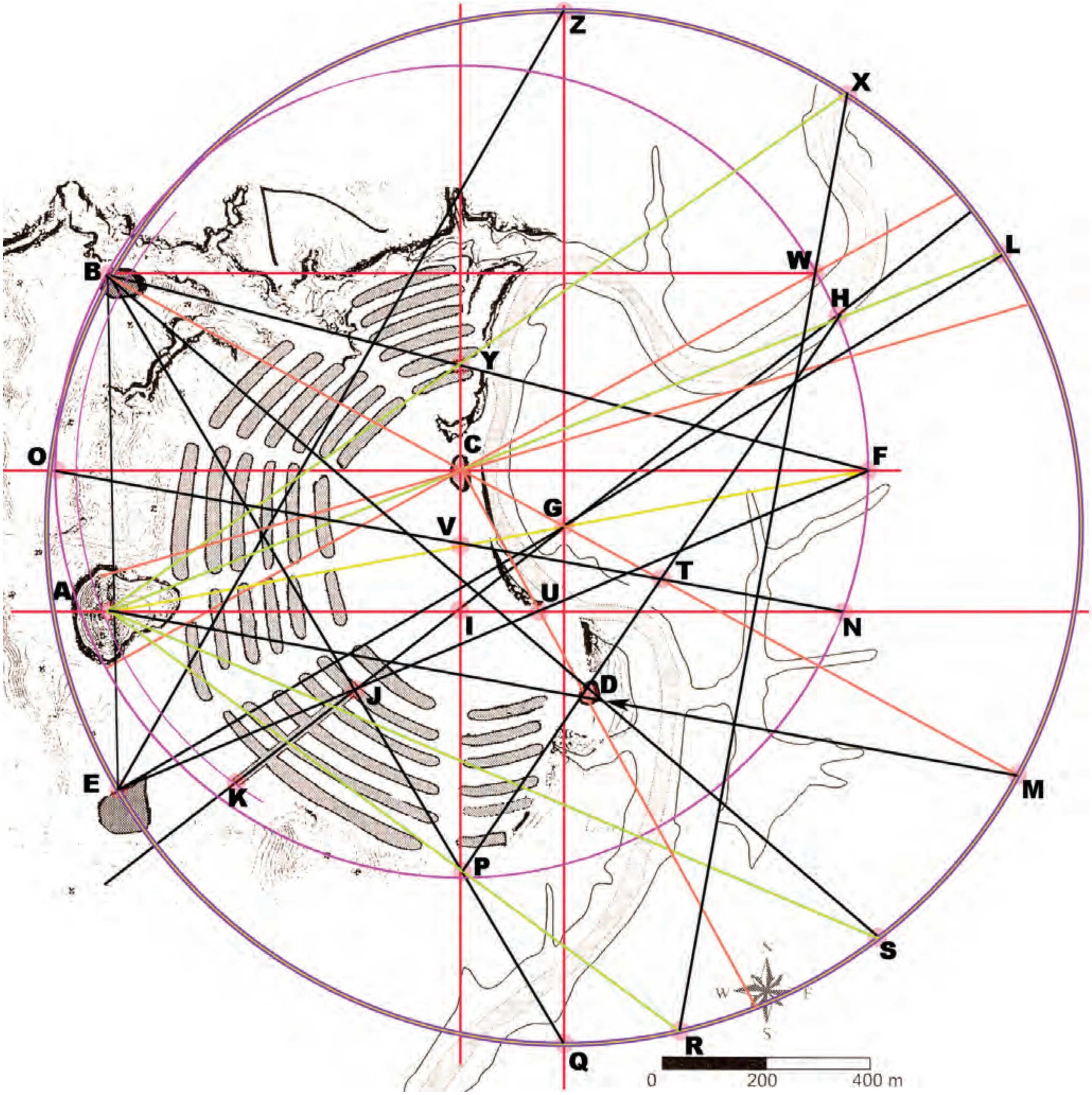
The causeway



Since the remaining steps of construction are non-intuitive, they will be listed in bullet form:

- Draw a sight line from center of mound **A**$_2$ to **F**, at the intersection of outer arc and equinox. Point **G** is defined where the line crosses the winter solstice alignment through **C**.
- Draw a large arc centered at **G** and tangent to outer arc at mound **B**$_1$.
- Locate mound **D** on perpendicular to summer solstice from mound **C** and line from center of mound **A** to **M**.
- Locate causeway bearing by line from **H** (intersection of the first arc and north lunar minimum) through **G** to **K**. The causeway is the only linear earthwork from this early period.
- Point **E** can be located by extending a line from **F** through **U** and **J**.
- Define the north edge of mound **E** by extending a line from **G**. Note that the east side of mound **E** follows a bearing to **B**$_1$.
- Sighting from **E** through **A**$_2$ inclines the minor axis of mound **A** about 5.3 degrees west of true north.
- Connect remaining intersections with n-point lines, for a total of 26, 13 points are above the mound **A** equinox and 9 points are below. Maya artwork is known to demonstrate similar counting of elements.

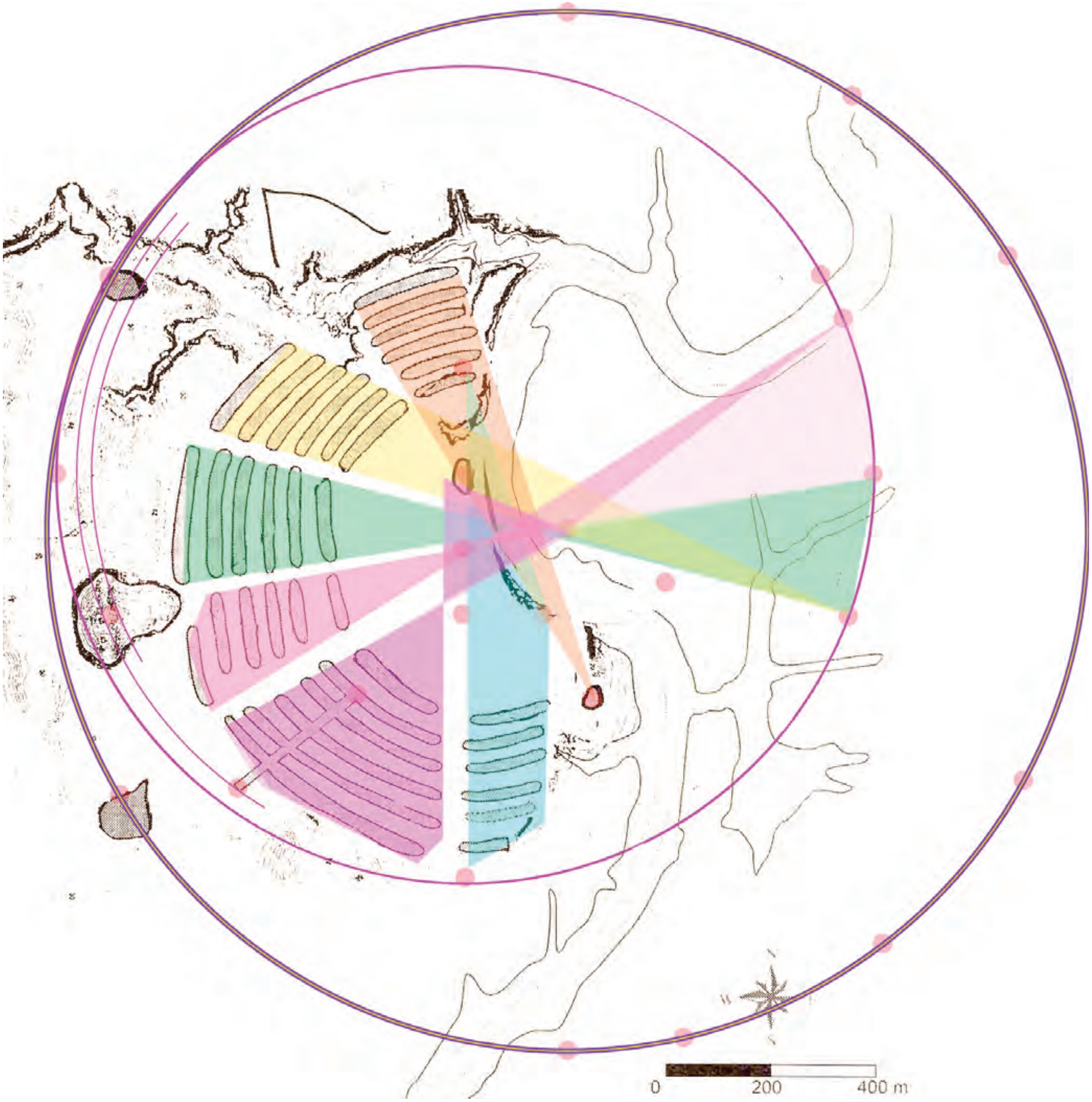
Intersections



As complicated as this geometry appears, it may be replicated from a minimum of three starting points at mounds **A**, **B**, and **C**. Furthermore, the geometry applies at any latitude. Aside from the earthworks, five mounds and the causeway provide sufficient clues for recovering the full rule set. Presuming that the construction was used elsewhere, there are a large number of options for monumentation, which makes it difficult to recognize a variant of the site plan. However, templates constructed for specific bands of latitude, may identify possible applications. It should be noted that the earlier template represented by Caney Mounds would not likely occur at another latitude, especially if an alternative were available.

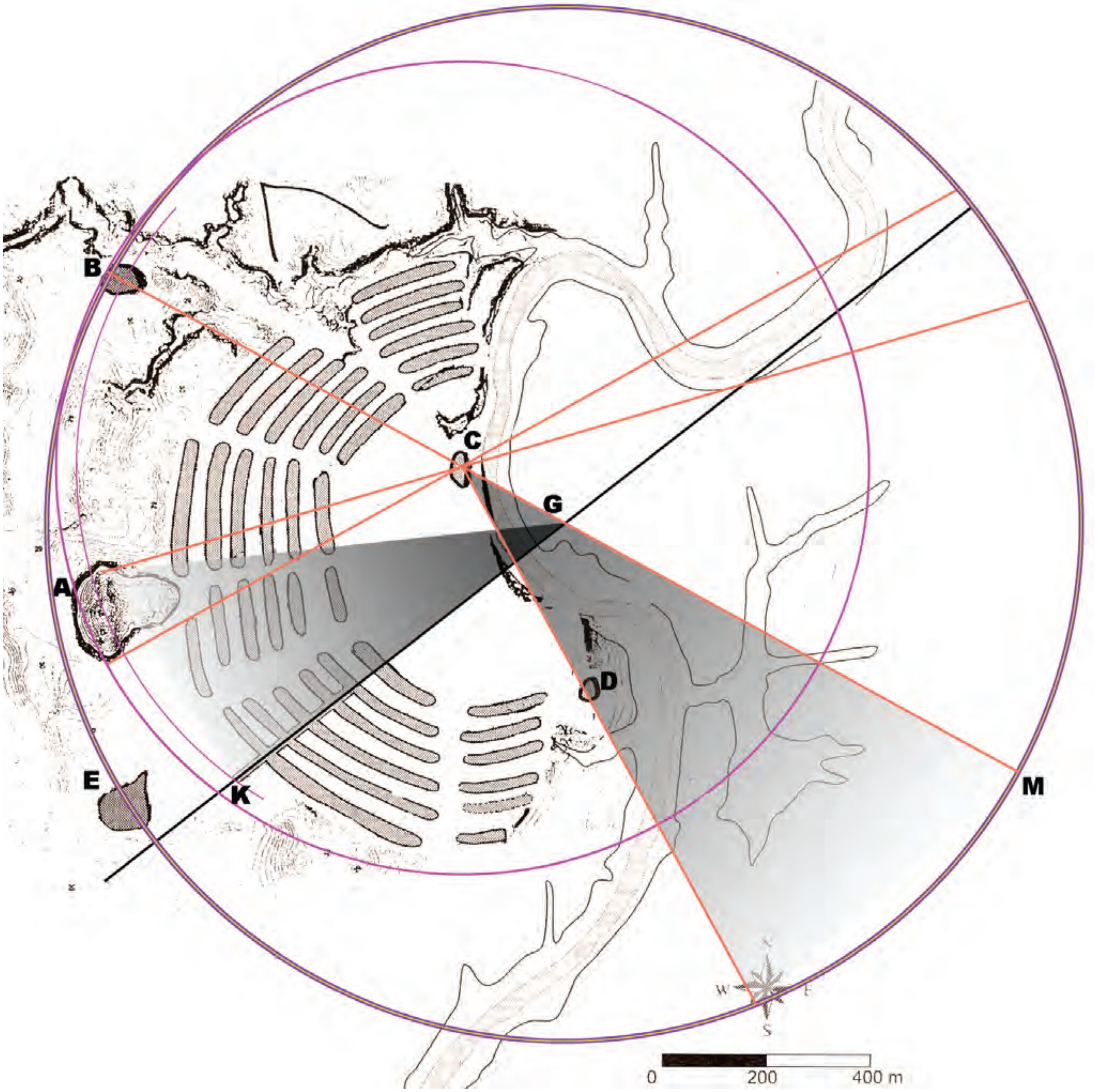
Decreasing latitude moves points **C** and **G** together. E-group pyramids in Mesoamerica would correspond to monumenting points **H**, **F,** and **N** on the east and point **G** to the west.

Earthworks



The repeated alignment of earthwork sector edges with constructed intersections argues that the proposed geometry is the same as intended by the original designers at Poverty Point. Aligning to thirteen of twenty-six significant intersections is not likely due to chance. Keep in mind that none of the intersections were defined by using earthwork features. Earthworks are roughly symmetrical about the central axis of mound A.

Latitude



No matter where on Earth the geometry is applied, the true latitude can be read directly from **A_3-G-K**. The angle **M-C-D** matches the true latitude only at the latitude of Poverty Point. While the complete geometry is complex, the latitude can be captured with no more data than the solstices, northern lunar minor, and true cardinal directions. Obviously, the latitude can be more directly and accurately determined by observing the inclination of the pole star, but finding the latitude revealed in the geometry suggests that the site design may reveal an understanding of celestial mechanics.

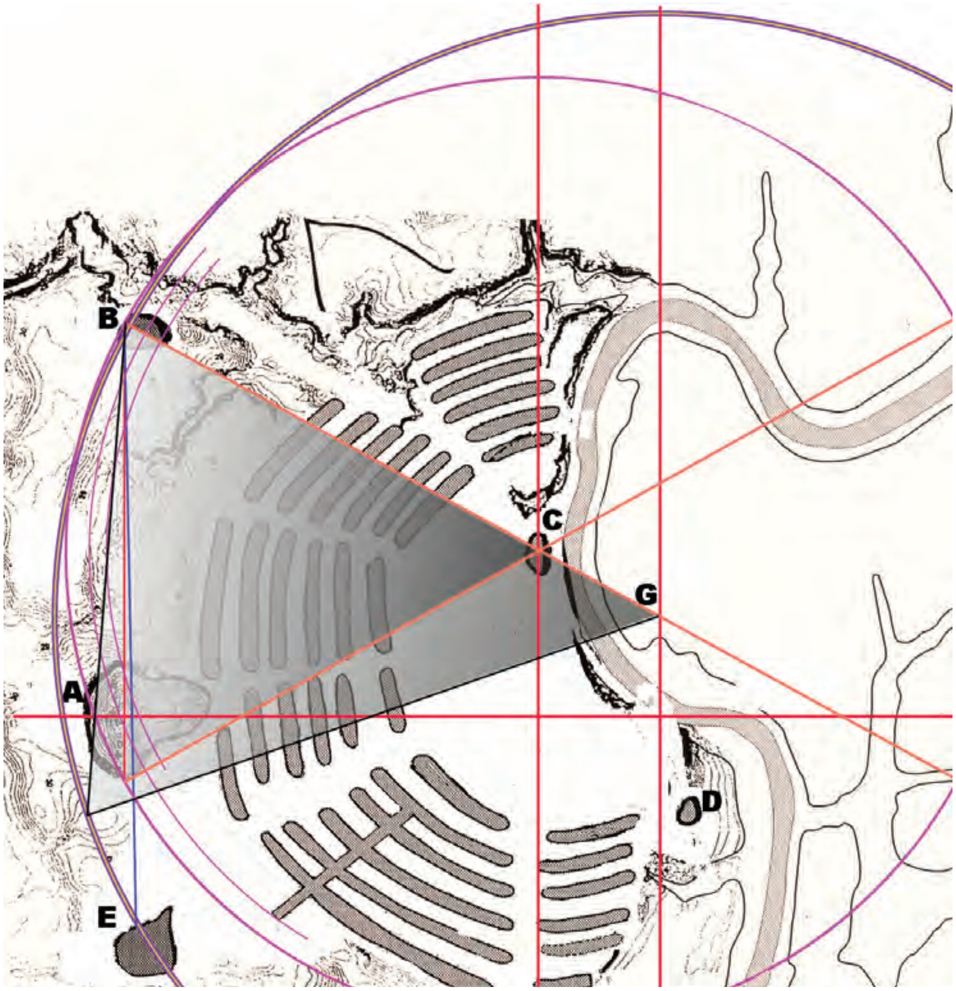
We know the latitude at Poverty Point to be 32.635 degrees, but a variance of one degree equals 111.3 kilometers on the ground. An accuracy of one-tenth percent leaves an uncertainty of 11,130 meters. Therefore, given a specified capability of observation, groups of mounds may share the same relative latitude.

The site plan shows that locations **F** and **G** are crucial for understanding the site organization. Although they are not marked on the ground, the causeway points directly to **G** while one side of mound **E** points to **G** and **L**. With the exception of mound **C**, the mound edges are at least as important as centers, if not more. Mound **E** is perhaps the best example, where the primary intersection is at the north edge and other edges confirm alignment directions. A similar preference occurs later in Mesoamerica, where doorways and corners frequently define alignments.

An observer at point **G** would have been able to read the latitude directly by measuring the angle between point **A**$_3$ and **K**. The fact that only at this particular latitude another angle measured from mound **C** between the summer solstice and the perpendicular to the winter solstice also corresponds to the latitude is likely an intentional coincidence.

The diagram below shows how the observed solstice angle from **C** relates to the theoretical solstice angle observed at the equator, represented by the angle from **G**. Because the winter solstice bearing remains fixed, the apparent N-S bearing at the equator is tilted about 5.1 degrees, which happens to be the amount of inclination of the Moon's orbital plane to the ecliptic. Furthermore, the equatorial N-S line passes through **A**$_2$ and line **B-E** passes through the intersection of the first arc and the equatorial winter solstice. Obviously, the geometry rectifies the observed and the theoretical aspect of solstice alignments, including the increasing refraction of light rays with latitude. Because the Moon orbits the Earth, lunar alignments remain the same for both projections despite precession of the Earth's axis.

Solstice rectification



Poverty Point shares the range of traits noted for earlier mound sites. The additional geometric representation of the celestial sphere indicating the ability to quantify effects of changing latitude on astronomic observation is hugely significant because it secures a theoretical basis for the astronomic knowledge. The correlation of virtual nodes to Maya myth is also important for verifying that myths change but little over many thousands of years. With such firmly established and mature principles of astronomic observation and mathematical treatment, there can be no doubt that the practices had already been in use for thousands of years. However, why would such intellectual leverage not be exploited better in that span of time? As always, answers generate more questions.

Sources of error

At least two potential sources of error must be considered. The first measurement errors were introduced by making an artifact. The second source of error occurs when a modern observer measures the artifact. Modern and ancient measurements apply different standards, use different scales, and achieve different levels of precision. One way to measure closeness of results is to compare the standard deviation to the mean. A more serious error occurs when the wrong reference points are used, an especially vexing problem until we better understand ancient conventions. Some errors are systematic, which means they measure something not intended. For example, if the measuring instrument stretches or contracts, it introduces an error not related to the properties of the item being measured. Similarly, improper calibration of the measuring tool or indistinct divisions can introduce systematic errors. Errors of precision are random and relate to typical closeness of repeated measurements. In other words, it indicates how small an increment an observer can reliably discern. Bureau of Standards guidelines recommend multiplying estimated standard deviation by three or four to obtain uncertainty of measurement. Multiple occurrences of elements (e.g. sides of a square) help show precision by their degree of agreement or deviation.

5

Maya Mnemonics

It would be wonderful if a clear progression could be presented to show the evolution from Archaic mound layout to Mesoamerican architecture and art, but the developmental linkage is unfortunately missing or at least not yet recognized. Still, by following how dimensional information was presented in Mesoamerica, some clues emerge that eventually may illuminate developments from those elusive formative periods. Just as a template characterizes the site plans of Archaic mounds in Northern Louisiana, another graphic mnemonic forms the basis for much of Maya design. Undoubtedly, many more mnemonic guides are waiting to be discovered.

Many studies have been conducted to sort out the details of Maya measurement. They generally are predicated on accounts of Maya surveyors, linguistic clues rich with terms usually associated with quantifiable dimensions, and a conviction that such magnificent architectural achievements could not be accomplished without at least some rigor of measurement. As O'Brien and Christiansen (1986: 144) point out though, deducing our own system of measure from sampling distances around a typical modern house is equally as difficult as deciphering the Maya system from a similar sampling out of their construction. Such samplings, however, reveal that certain intervals are more common than others. The quandary is whether measures are applied inaccurately or if yet smaller base units introduce the variation. While the conversion from metric to native units described in Louisiana could be used to quantify Maya measurements, they must be independently legitimized.

The Spanish destruction of written records removed the richest and potentially most informative data that we might wish for. Remaining evidence continues to degrade as organic materials rot and development disturbs the landscape. But, as destructive as the Spanish were, they also created new records documenting things that the Maya might not have thought to remark about themselves. Fortunately, cultures are more durable than their social structure, and ethnohistorical investigations resurrect many activities and beliefs that persisted long after vanquished rulers. Language, myths, and tradition hold many clues to past beliefs and practices. For example, Brinton (1885:197) documents the Yucatan Maya use of *oc* for foot, *checok* for footstep, *kab* for hand, and *zap* for the distance between extended arms.

Lands were the property of the state, but ceding rights of use required some form of surveying to be used. From a study of the *Book of Chilam Balam of Tizimin*, Edmonson (1982) notes that sun priests surveyed, divided, and registered lands. Likewise, Roys (1933:65) found reference to "land surveyors with walk sticks" in the *Book of Chilam Balam of Chumayel*.

Sighting stations, along with stakes, vents, door edges, and distant monuments have been mentioned as tools of astronomic observations, but some means of marking out fine divisions and record keeping must have been necessary in order to compare one observation to another. For observers to compare notes, a standard would be essential. Since the science of astronomical observation seems to have been shared readily among Mesoamerican cultures, it seems reasonable that the standards of measure would have remained intact as well.

Golden rectangle

The preamble of a post-conquest document, the Popol Vuh, (Tedlock 2010:306-319) has been interpreted by Chris Powell (Schele and Mathews 1999:35,330) as constructing a golden rectangle by means of a cord. Powell believes that proportions were of primary importance, and only body measurements were used.

> *There is the original book and ancient writing, but hidden is the face of the reader, interpreter. It takes a long performance and account to complete the lighting of all the sky-earth, the fourfold siding, fourfold cornering, measuring, fourfold staking, halving the cord, stretching the cord in the sky, on the earth, the four sides, the four corners, as it is said, by the Maker, Modeler, Mother, Father of life, of humankind: Giver of breath, Giver of Heart, who gave birth, who gave heart to nations of lasting light, to those who are born in the light, begotten in the light; worriers, knowers of everything there is in the sky-earth, lake-sea.*

Later, in chapter eleven of the Popol Vuh (Edmonson 1971), we find reference to key landmarks of creation.

> *Grant a good life to Thee, Heart of Heaven, Bundle of Majesty. And Thou Tohil; Thou Avilix; Thou Hacavitz, Arch of the Sky, Surface of the Earth, The Four Corners, the Four Cardinal Points. Let there be but peace and tranquility in Thy mouth, in Thy presence, oh God.*

The following passage from the *Book of Chilam Balam of Chumayel* (Tedlock 2010:279) appears to associate Heaven with the east and the Underworld with the west, and justifies stepping off the dimensions heel-to-toe, as well as associating linear measurement with the passage of time.

> *According to what was recorded by the first sage, Melchisedek, the first prophet, Napuctun, the priest, the first daykeeper, this is the song of the birth of the twenty days long ago. When the earth had not yet awakened he began to walk alone, on his own. Then his mother's mother said, then his mother's sister said, the his father's mother said, then his sister-in-law said, "What are we going to say when we see a man on the road:" So they said while they walked long ago. There were no men long ago. When at last they arrived in the east, they started talking. "Who walked this way? This is someone's footprint. Measure it with your foot." Filled with delight were the words of the Lady of the Earth. Then they measured the footprint of Our Lord God the Father. This is the origin of the saying, "Count the width of the world," which signifies the day Twelve Foot. This was the count when the days were born, and for this reason, it was Thirteen Foot when the print of his other foot appeared. The days arose over there in the east as he spoke their names, long ago when there were no names for days. He walked along with his mother's mother, with his mother's sister, with his father's mother, with his sister-in-law. The twenty days were born, the names of the days were born, the sky was born with the land, the stairway of water, land, stone, and wood. The things in the sea and on land were born. One Artisan was the day when he revealed himself to be divine, he made the first stairway, which he descended from the heart of the sky to the heart of the water when there was no earth, or stone, or wood. Three Lack was the day when he crafted all things, as many things as there are, the things in the sky, and the things in the sea, and the things on the land.*

Evidence has been presented that the earliest known use of the twenty-day *winal* interval occurs in Northern Louisiana, along with physical measurement, about 6,000 years ago.

Specific dimensions associated with the act of creation in chapter sixteen of the *Book of Chilam Balam of Chumayel* (Roys 1967) indicate that a geometric path may be recreated. Distances measured on earth correspond to distances in the heavens, but the scale is obviously different.

> *13 Edznab* was the day *when the land was established. 13 Cheneb was when they measured off by paces the cathedral, the dark house of instruction, the cathedral in heaven. Thus it was also measured off by paces here* on earth *. Thirteen ka'tuns was the total count, that is, thirteen feet in heaven. Four feet, and from there nine feet, the total count of its extent in heaven. Then it is again measured off by feet from the face of the earth. Four feet separate it from the face of the earth.*

A floor of square tiles provides an ideal basis for demonstrating integer geometric construction of a Fibonacci spiral. Starting with a single square as our base unit, one side is extended to equal the sum of two sides immediately preceding it. After the leg has been extended, another leg is dimensioned by summing the previous two legs, at right angles to the first, always turning the same direction. The infinite series just described uses Fibonacci numbers to create a series of rectangles whose sides approximate a logarithmic spiral. Dividing any leg by its smaller neighbor produces an approximation of the irrational number *Phi*, which improves as the expansion grows.

The accompanying diagram shows the construction through seven expansions, but the series can be extended to infinity. Imagine following this construction with your footsteps on a floor tiled with foot-square tiles. The beginning of the Fibonacci spiral bounds a spiral on all but one edge, strongly resembling a niche representing the cave of origin mapped during Mesoamerican ritual reenactment of Creation (Paxton 2010:298). At the end of thirteen steps, you are ready to turn the sixth corner. After stepping off another four legs, you have approximated a golden rectangle thirteen tiles wide by 21 tiles long. Henceforth, we will call this a “heavenly rectangle.”

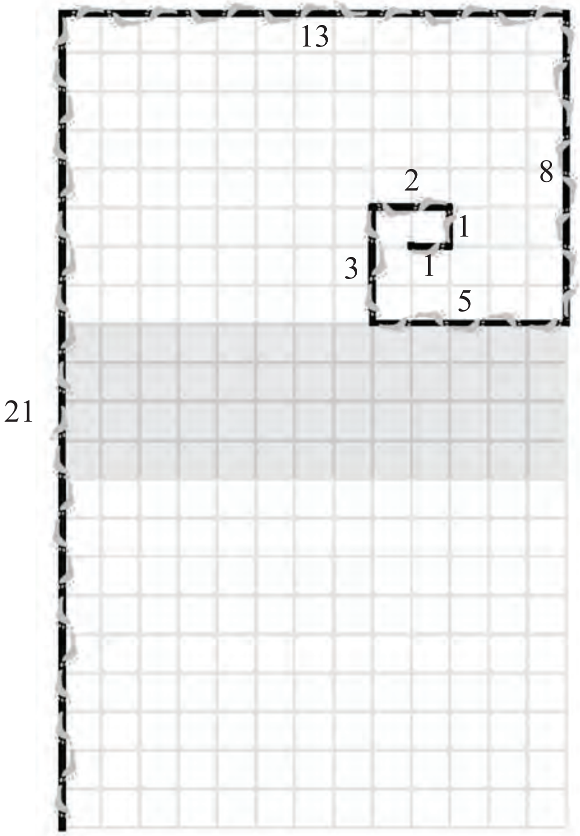
Let's follow the recipe for mapping creation to see what it produces. From the starting point, thirteen steps spiral out to an edge of Heaven. Turning about, it takes four steps to come even with the starting point. Another nine steps arrive at the far edge of Heaven. In all, there are thirteen layers of Heaven.

Mirror-imaging the construction to fill four quarters completes the depiction of heaven, sky and earth. Heaven is the upper eight by thirteen portion. A band four squares deep separates the face of the Earth from Heaven—the arch of the sky. The lower spiral origin is embedded within nine levels of the underworld. East is to the right and west is to the left.

Two more rectangles can be defined inside the heavenly rectangle by tiles corners nearly coincident with the primary diagonal. The smallest rectangle is three by five cells. Adding the 68-unit perimeter of the heavenly rectangle to the 36-unit perimeter of the seven by eleven-unit rectangle produces 104—the number of years between adjustments to the calendar. But adding the smallest area gives 52—the number of *haab'* years to complete a full cycle of the *tzolk'in* count. The area of the seven by eleven-unit rectangle is 77. Most importantly, adding area of the three rectangles produces 365; the integer number of days in a *haab'* year.

It is tempting to think of the heavenly rectangle as a model of the Maya concept of creation, but it falls far short of being accurate or complete enough. A better perspective is to think of it as a

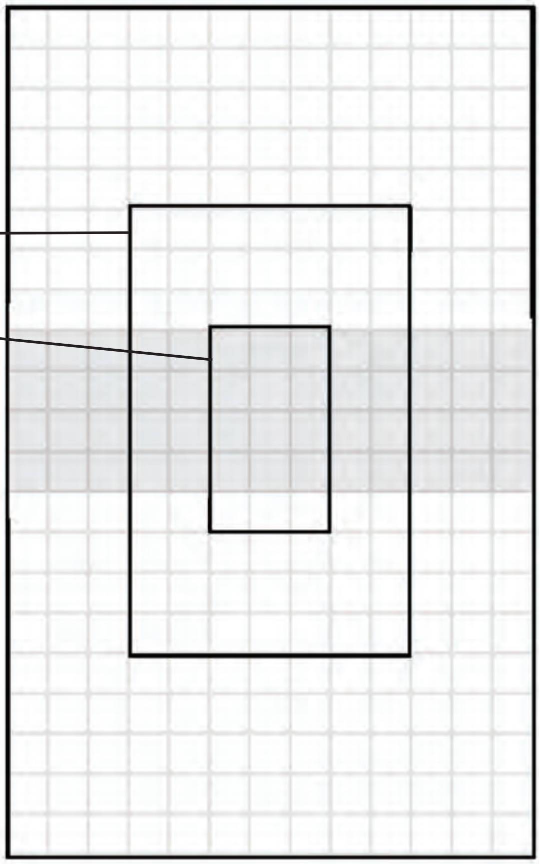
Pacing off the dimensions of the World



Nested heavenly rectangles

Area

13×21 = 273
7×11 = 77
3×5 = 15
——
365



Perimeter

2×(13 +21) = 68
=> 36 +68 = 104
2×(7 +11) = 36
=> 16 +36 = 52
2×(3 +5) = 16
——
120

clever mnemonic that promotes retention of sacred knowledge. In the case of Pacal's sarcophagus and the seven-faced chert eccentric, the heavenly rectangle provided a meaningful pattern onto which additional information could be attached. Especially in pre-writing times, such a mnemonic would be most effective if it were ingrained through constant exposure. One possibility is that it formed the basis for household layout, or even the plan for a community. Clark (2004:204) points out that intermittently recurring themes in the plans of large ceremonial centers separated by hundreds of years are most readily explained as patterns retained in everyday use.

When the Pythagoreans discovered *Phi* in the 5th century BC and recognized its irrational nature, they were horrified that mathematics no longer described an orderly world. *Phi* is considered irrational because it can never be represented by the ratio of integers. That means rational and irrational numbers cannot share common factors, and thus are considered incommensurable. Other irrational numbers include square roots, represented by diagonals of integer rectangles, and *pi.*

The following table clarifies the relationship between Fibonacci numbers and Maya heavenly rectangle geometry.

step = heel-to-toe along tile edges.
pace = leg of infinitely expandable spiral.
Fibonacci numbers [F(i+2) = F(i+1) +F(i)]

paces from the start [leg number]
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, **13**
tile edges included in two previous legs [lists Fibonacci numbers]
1, 2, 3, 5, 8, **13**, 21, **34**, 55, 89, 144, 233, **377**

13 = next important module of measure above one unit.
34 = half the perimeter of heaven.
52 = sum of Fibonacci numbers 2 through 21
68 = perimeter of golden rectangle.
377 = quarter of the 1,508 day interval between alignments of the *haab'* with the tropical year.

Like the Pythagoreans, Maya mathematicians would have been very aware of incommensurability. Unlike the Greeks, however, they may have recognized the property as useful. Perhaps the Maya wanted to insure that compound measures, like perimeter of a quadrangle, would not be confused with other measures. If so, deliberate inclusion of incommensurable dimensions would be useful to insure that only the perimeter could carry a meaningful value. Most significantly, 68 is one hundredth of the lunar nodal cycle. It would be appropriate indeed if the mnemonic was intended to model the founding cycle of the calendar.

Remember that the Creator measured a total of 13 *ka'tuns,* composed of 7,200 days each; more than 256 years. The first seven Fibonacci numbers happen to total 20, the number of days in a *winal.* A statement in the *Book of Chilam Balam of Tizimin* reads "thirteen makes seven, said the word of the Devil to them" (Aveni 2002a:176). This phrase may merely be acknowledging the arithmetic fact that subtracting thirteen from twenty leaves seven. However, if the first seven paces map heaven and earth, and the next thirteen complete the creation of the world, the total steps contained within twenty legs is evenly divisible by thirteen. Three hundred sixty steps, equaling a *tun* period of eighteen *winals,* are accumulated within the thirteenth leg, which consists of 377 units (13×29), just over 360. To reach the *ka'tun* number of 7,200, equal to twenty 360 day *tuns,* requires counting steps within 20 Fibonacci rectangle legs. A more productive observation comes from dividing ten times the heavenly rectangle's perimeter by thirteen and realizing that it is nearly the same as dividing the great calendar round of 18,980 by 360. When factored, the ratio incorporates nearly every important factor of the Maya calendar, including 13, 52, 72, 73, 260, 360 and 365.

By itself, the foregoing exercise might merely be reasoned rhetoric. However, the premise can be readily quantified and tested. If the Maya routinely made their heavenly rectangles by the proposed formula, dividing the shortest side by thirteen should reveal their basis of measurement. Actually, the product of division shows which intervals were used for laying out the geometry. If successive modules were nested to accommodate larger and smaller division of length, they can be easily factored from the remainders of the division.

Representations of the heavenly rectangle geometry of the path of creation have been found to contain standard units of measure that both confirm the existence of the unit and refine our knowledge about how precisely it was applied. The greatest obstacle to conducting such a study is the long-standing conviction that Maya craftsmen lacked standard units of measure. Consequently, archaeological data may have to be re-observed in many cases. Width seems to be the most stable dimension, having thirteen units, while length is sometimes deliberately distorted.

One of the most notable of Maya rectangles is the sarcophagus lid from the tomb of Pacal at Palinque. When the 13 by 21 unit map of creation is imposed on the lid, it agrees comfortably with the carved design, whether registered at the top or at the bottom, the familiar interpretation of Pacal lowering into the underworld is vividly brought to action. With the lower registration, Pacal's wrist is at dead-center and he is seated atop the heart of the earth. The upper registration places the surface of the underworld at chest level, and the edge of heaven passes through the center of the cross on the tree of life. Conceptually, it is reminiscent of freeze frames from an action scene showing Pacal being drawn into the underworld.

The lid measures 379 by 220 cm according to Robertson (1983:55). Applying the standard conversion of 1.144 mm per unit and dividing the width by thirteen produces a Maya value of 147.9 for each cell side. Interestingly, the long side contains 22.4 grid cells instead of the expected 21. Apparently, the diagonal was manipulated to be exactly twice the width to form two equilateral triangles with their tips meeting at dead-center. The unit of measure for the grid seems meaningless at first, but on closer analysis it matches well with five lunations, or 147.655. That happens to be a time frequently elapsed between eclipses, a very important bit of Maya knowledge. The extra amount added to the long side of the lid exactly equals seven lunar months. Treating each cell edge as representing 5 lunations gives a perimeter of 354 lunations, using Robertson's dimensions, the same number as days in a lunar year. If each standard unit is considered to be a day, the perimeter accounts for just under 29 years.

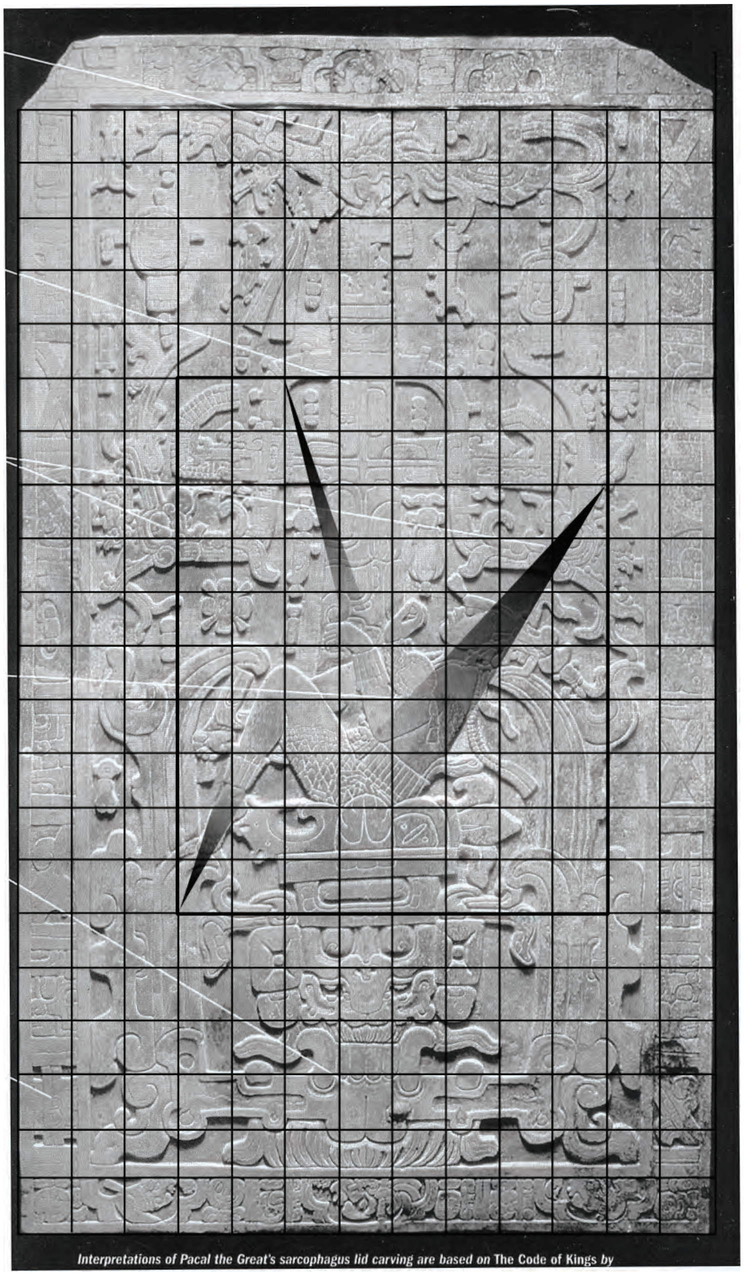
It turns out that the rulers of Palenque rested their authority most clearly on their relationship with the planet Venus, so why would the sarcophagus lid use a lunar relationship? Aveni (2002a:107) notes that the Maya grouped cycles of full Moons to forecast the first rise of Venus following an eclipse. Furthermore, the ecliptic table in the Dresden Codex, which immediately follows the Venus table, predicts total eclipses of the Sun by the Moon by grouping full moons in sets of fives and sixes (Aveni 2002b:102). On further investigation, the cycle of Venus can be correlated with eclipses and the double calendar round of 104 years.

Venus (583.92×65) +5 = 37,960 = lunar node interval (173.31×219) +5

Sun (365.2422×104) -25 = 37,960 = 104×365 = 65×584 = 40×(584 +365)

These relationships now make the choice of measurement interval a perfectly sensible representation of the founding triad of gods at Palenque: Venus—Sun—Moon, particularly when reinforced by the double calendar round. Remember that the same triad is united by factoring the lunar standstill cycle, apparently responsible for the structure of Maya calendrics.

Antonio Prado Cobos (1999:187) noted that bracelets and skirt of Pacal contain straight lines laid out with radials. When the creation grid is in place, it can be seen that the radials originate at grid intersections consistent with the lower registration. Tedlock (2010:39-42) provides a comparable example that directly relates to positioning of three hearthstones in the constellation of Orion. The radial nodes



Interpretations of Pacal the Great's sarcophagus lid carving are based on The Code of Kings by

Sarcophagus lid of Pacal showing lower registration of 13 by 21 unit grid overlay. Radial elements, emanating from bracelets and belt in the design, point to grid nodes and aid in justifying the grid.

position an 8 by 10 unit rectangle with a perimeter of 36. In fact, most of the interior design registers well with the central seven grid columns. There are also seven portraits in the lid, three at the top, three inverted at the bottom, and the central figure. This evidence reinforces the earlier speculation that the central seven-by-eleven rectangle had special significance to the Maya. Examination of details shows repeated use of the basic unit, as well as one and four-tenths of that unit, often applied as a ratio—the same as 365 divided by 260.

A large chert eccentric effigy from Guatemala, described more fully in the *K'awiil* effigy case study, produces a tile width of 10×1.144 mm when the width is divided by thirteen, showing that the tiles were divided into intervals of ten units each. The effigy also produces the base unit directly when dividing twice the width by 260. When a thirteen by twenty-one grid is imposed on the figure, it registers to the geometric construction of the heavenly rectangle. In fact, grid nodes within a millimeter of the effigy edges correspond to the significant numbers of the creation myth; thirteen in heaven, four in the arch of the sky, and nine in the underworld. This means that the heavenly rectangle was not just proportions of an empty frame, it was conceived as fully tiled. Other occurrences of heavenly rectangles now should be studied for their registration to the smallest details of the path of creation as well as the measurement of their major dimensions.

That the *K'awiil e*ffigy conforms to the heavenly rectangle is not immediately obvious. Because the artifact was constructed to record a wealth of information, the features could not register entirely with the path of creation, but the artist attempted to follow as much of the underlying geometry as possible without compromising the integrity of the message. Superimposing a thirteen by twenty-one grid on the effigy shows that at least twenty-six grid nodes coincide exactly with the design edges. Such a correspondence can only be achieved intentionally. Another implication is that heavenly rectangles were thought of as complete grids rather than just empty frames. A particularly telling detail appears at the bottom of the drooping right-hand headdress, where it is cut off precisely at the top of the underworld. An important radial alignment, shown by a dashed line through dead-center, starts and ends at grid corners, but still falls tangent to the back of the central figure on page 64.

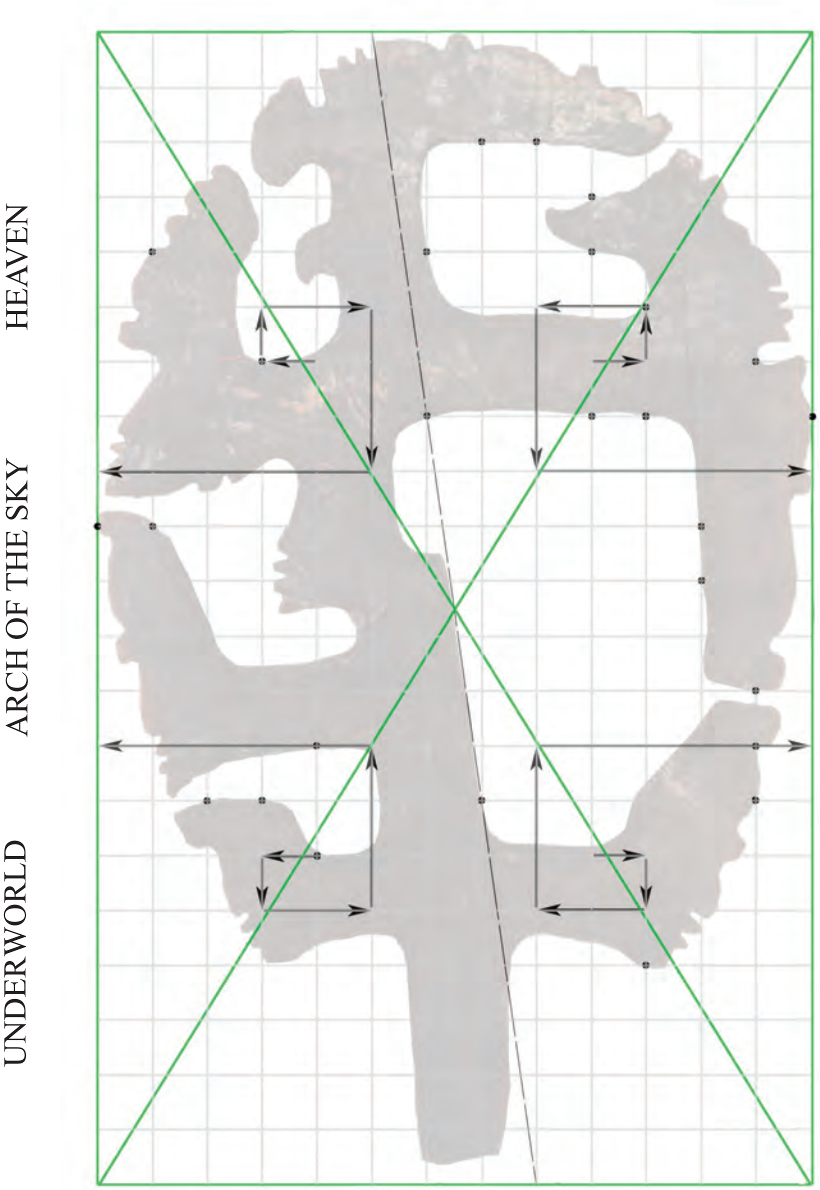
Each example differs radically in execution, but they both frame a central figure in the four-tile-deep band of the arch of the sky. The height of each example first appears to be at odds with the mythical proportion, until the design is dissected. Is it a matter of deception, misdirection, or gamesmanship? More examples will be needed to resolve the questions. In the meantime, I call attention to the apparent reluctance to explicitly acknowledge the value of twenty-one. Such an omission seems notable in light of the central role of the number 21.

Geometry at Poverty Point, Louisiana generates similar nodes with the 13/4/9 pattern. Based strictly on astronomical alignments, the Poverty Point pattern may be the earliest evidence pointing to the source of the nodal pattern, some 3,500 years ago.

The geometry of the proposed construction can be seen to be remarkably familiar in proportion and structure to elements common to Maya architecture. It is not at all unlikely that designs were used to reinforce religious themes and doctrine. At the very least, a review of architectural proportions in light of the proposed scheme should be enlightening. Duality of meaning should not be treated with dismay because the Maya delighted in word plays and redundant expressions. The Maya apparently had a very real and concrete understanding of the path of creation, rooted in the geometry of the heavenly rectangle. By mapping the circuit taken during creation, they had a simple abstraction that allowed comparison to cycles viewed in the sky. Now, words from the Popol Vuh, *"... fourfold siding, fourfold cornering, measuring ...."* can be seen as a literal description of how special constructions were imbued with a numerical essence representing a celestial entity. The principles will be shown to extend far beyond measuring the edges of golden rectangles.

Once the smallest base unit is known, the length of a foot (11.75 inches) described by Greg (1885) is within four millimeters of 260 standard Maya units. Counting continually through successive legs of the golden rectangle series replicates Fibonacci's numbers, and happens to place the number 260 in the cumulative count of the thirteenth expansion. By association, the 260 day divination cycle is also the length of God's footprint. An arm span of 1,487 mm, near the 1,470 mm proposed by O'Brien and Christiansen (1986), works out to be five times 260, or 1,300 units. In Maya astronomy, synodic cycles of the planets were conveniently related through a lowest common denominator of 260 (Peden 2004). Thus, dimensions of time were kept in harmony with those of space, both by human-scale units on earth and by godly astronomical units in the heavens. In *A Maya Grammar,* Tozzer (1921:290) notes that the word *"kotz"*, used as a suffix to show what class counted objects belong in, refers to lengths of threads, cords, rods, and staffs, as well as pieces of time. Therefore, we should not be surprised to find distances indicated in units of time.

Nodal intersection of grid with effigy edges



Pleiades figure

Maya geometric conventions for measuring and imparting numbers are neatly represented by a simple chert eccentric on page 65 that looks like a snake with a face and a headdress. This eccentric figure is part of a cache of thirty-three, and one of seven that have faces chipped into them. At first glance, there is nothing particularly remarkable about the figure, but continued examination reveals a host of interesting features. A key finding is that the figure has a hidden symmetry about its major axis. When an ellipse was generated in Photoshop™, it was tangent to the eccentric body in several places. Iconographically, the snake image reminds us of a rattlesnake, and we know that the Pleiades constellation was known to the Maya as *tzab,* the rattlesnake's tail. Since seven visible stars are usually attributed to the Pleiades, a search was made for possible references to the number seven. Ultimately, seven instances of seven repetitions were noted in the design. Seven rays connect tangents or significant elements, as do seven diagonals, seven verticals, seven openings in the body, seven body bulges, seven sharp inflections and seven tangential matches of the bounding ellipse to the body.

Layout of the figure might lead one to believe that the outline was artistically arranged merely to fall within the rectangular and elliptical frames. However, extending tangential alignments reveals a complex geometric structure. Seven planning points are distributed along a line level with the top of the elliptical frame. Twenty-one rays from the planning points each connect at least two tangents or inflections of the figure. Ray intersections then form 21 nodes that coincide with the effigy edge, evenly distributed to each quadrant. Other alignments show that the outline was subtly adjusted to conform with connections between significant points. The use of phantom points and lines to position a significant number of virtual points along the effigy edge is reminiscent of the geometry already described for Archaic mounds in Louisiana. N-point lines and converging rays must be considered deeply seated conventions that may well be rooted in principles of astronomic alignment.

As has been cautioned earlier, ancient conventions may be quite alien to our current way of thinking, which makes it difficult to decipher meaning. The redundancy of the message led me to realize that the perimeter of the rectangle bounding the ellipse represents seven cubed at a scale of 1.148 mm per base unit. A series of triangles formed by the planning points and the bottom of the figure have perimeters that sum to multiples of seven. Most notable are perimeters of: 399 (7×57), 364 (7×52), and 343 (7×7×7). Now we have a Maya unit of measure nearly identical to units found in Louisiana. Numerical values were deliberately included in the artifact, but it is also the most subtly hidden of the messages so far described.

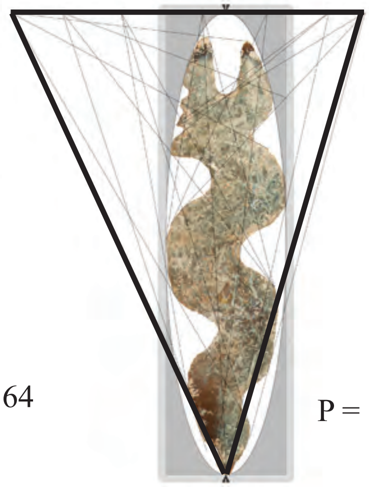
Upon careful examination of the remaining eccentrics, it could be seen that ellipses were used often. Based on the Pleiades example, it seems prudent to use the quadrilateral tangent to an ellipse extending beyond the physical frame of an artifact as the primary frame of reference. When the major axis of an ellipse foundation is truncated, the dimensions of the extended quadrilateral are the relevant references for measuring the frame perimeter. As subtle as Maya designs may be, they also incorporate redundancy and context that helps to verify the values intended by the craftsman.

Cache item C-7

P = 343

P = 343

P = 364



P = 399

6

Maya Eccentric Cache Study

A remarkable, intact cache of 33 chert eccentric items from Guatemala affords a penetrating insight into non-written communication. See Appendix B for true-scale images. Eccentrics, in this case, are bifacial chert objects that have been flaked into fantastic shapes. Even a superficial evaluation suggests that the artifacts were intended to convey important messages that we are ill-prepared to interpret. Unfortunately, because the cache was looted, important supplemental contextual information regarding spatial arrangement and additional offerings is missing. On the other hand, so much detailed geometric structure is perfectly captured by the strong edges of the eccentric artifacts that more messages may remain than we might reasonably expect. At first glance, the geometry appears to lack the discipline or clarity needed to convey useful information. Frankly, the unfamiliar iconography could easily be taken as aesthetic art containing no more than symbolic messages.

The field of study known as *semiotics* treats communication, from language to gesture, as a framework of coded signs that serve to limit the range of possible meanings. Coincidentally, the most notable aspect of the cache is that every item can be shown to be designed to fit within a unique quadrilateral frame oriented to the major and minor axis of symmetry. While searching for meaning in eccentric artifacts, we will do well to recall how Archaic messages embedded in mound site templates were found to require a “decoding key.”

Within the quadrilateral frame, a large number of attributes occur with enough frequency and semblance of structure to be treated as coding elements. Many of the coding elements have relatively understandable functions, while others are less clear. Most importantly, the coding elements are generally recognized because they are applied according to consistent conventions. Such consistency suggests that a grammar and syntax guided the making and assembling of the cache. Finding conventions in common with geometry used in Archaic mounds of Louisiana should come as no surprise since geometry has been so clearly tied to the Mesoamerican calendric structure.

Symmetry plays a major role in organizing the geometry. Orientation to major and minor axis is visually evident in most instances, but it is often reinforced by mathematically-correct ellipses corresponding to those axes. An ellipse is a conic section that may be simply delineated by projecting the shadow of an inclined circular cutout. When an ellipse is used to bound the perimeter of an eccentric, it imposes mirror or radial symmetry. Even when decorative elements are created by notching, the quality of symmetry is preserved by the bounding ellipse. On occasion, the ellipse extends beyond the physical bounds of an item. Note that while an ellipse cannot be forced into just any box, you can expand an ellipse until it is tangent to three sides and then construct the missing side. The quadrilateral frame may touch the artifact in as few as three points. Occasionally, a secondary elliptical frame is established within a larger frame, as exemplified by item C-1, which includes at least three guiding ellipses. Simple compass arcs of equal radius define a knife-like vesica shape at the tip. Those arcs could be produced by chipping the artifact to fit a section of broken pottery. When I first suggested the hypothesis, an archaeologist commented “Maybe that explains grooves I see incised in broken pottery.”

Connecting the corners of the master frame defines a dead-center point, seemingly trivial until we realize that alignments between key landmarks along the physical periphery of eccentrics intersect dead-center repeatedly. Just as described for Archaic mounds geometry, eccentric alignments may be characterized as n-point lines joining at least two physical points with a third virtual point. The virtual points are recognized in turn as n-point ray origins. Only intentional design can explain repeated instances of alignments passing through dead-center. As a consequence, there can be no doubt that quadrilaterals are correctly defined, *even though they are entirely virtual.* Positional elements for alignments include notches, spurs, cardinal axes, internal and external tangents, or even inflections in an edge. Maya artisans seem to have compulsively sought opportunities for n-point lines, where three or more well-defined points fall on a meaningful straight line. By doing so, they left clues that conclusively reveal an otherwise invisible guiding pattern. One of the most useful examples is where the dead-center point of the bounding rectangle is the focal point for a series of radial 3-point lines that connect inflections and tangents to curves. Persistent acknowledgement of dead-center is as useful for justifying the rectangle frame as if the lines were actually drawn in. Artifact C-1 utilized three ellipses, which can be validated by finding n-point radials precisely coincident with the ellipse and the artifact edge. Some alignments are between like elements, exemplified by a line tangent to two curves, while other alignments may utilize unlike elements, as in connecting a serration point with a curve tangent.

While axial orientation is relatively obvious, determining which face should be facing up is very subtle. Antonio Prado Cobos (2003 noted that these artifacts have perfectly plane edges. When the correct face is placed upward, the artifact is most stable and allows the edge to parallel the table on which the artifact rests. When precise measurement of key landmark features are made, this convention minimizes distortion due to parallax.

Alignments occasionally reveal otherwise invisible grid backdrops that are usually rectangular but sometimes radial. When grids are present, they may have dimensional significance, as will be explained later.

The remaining coding elements are largely artistic in nature and thereby less objective than geometric elements. Many of the eccentrics appear to represent iconic themes that may be sorted into groups. Realistic depictions, such as a *ceiba* tree and bats, are relatively easily categorized. Other items appear to have been assembled from a grab-bag of elements. There are faces, but they may be placed on a snake body or combined with long legs, pincer tops, or highly serrate bodies. Notches are generally “V” or “U”-shaped subtractions from a sharp edge, but they were sometimes enlarged to form large holes in the body of the artifact. Those large openings may have significance on their own, but are also used at times for tangential alignment. While grouping the artifacts by obvious characteristics, it became clear that other characteristics served to purpose of distinguish the relationship between various artifacts. That sense of lineage will be elaborated on later, but is facilitated by a fairly extensive inventory of distinguishing features. Cortical elements unite some artifact groupings while others are related by distinctive inclusions in the stone. Patterning of notches and arrangement of decorative elements give familial identity to many items.

Yet another class of distinguishing features remains enigmatic. False axial indicators appear on some of the eccentrics, with well-defined tips falling just a few millimeters from the true major axis. Those shifts are often accompanied by an inflection where the major axis encounters the physical frame of the artifact, a tacit acknowledgment that the variant alignment was deliberate. Violations of symmetry are so out of character as to attract notice, but defy explanation so far. That includes "legs" that do not match from side to side. Remnants of paint are common but, regrettably not sufficiently preserved to help with interpretation.

Considering the scope of conventions encountered, nearly half have parallels in Archaic site geometry. Given the vast differences in time, place, scale, and media, that is an extraordinary correlation. Enough indications are present to make the case for a "language" of geometric expression that we should now turn to the challenge of extracting meaning from the coded elements by first building on our experience with dimensional coding.

Thinking about the box

Although the Maya used the same base unit of measure as the Archaic mound builders of Louisiana, they did not continue to use aspects of the original template for site layout. The "E-group" template used by the Maya is reminiscent of the Louisiana pattern, but lacks the solstice tangent. Since there is no evident prospect for comparing site layout geometry, other avenues are needed that allow meaningful comparison. Two Maya artifacts made of chert have been independently demonstrated to share the same base unit of measure as used in Louisiana. With that in mind, the 33 cached eccentric artifacts show promise for bridging the gap between regional geometries. Item C-7 has already been described since it can be independently shown to use a base unit of 1.148 mm to redundantly carry the message that this particular artifact has something to do with the number seven. Supported by this initial correlation, the cache was subjected to a multi-pronged analysis seeking to better define Maya principles of geometry and quantify their adherence to a standard in dimensional coding.

Note that most measurements conveying explicit information are defined by reference lines or points that the observer has to provide, while other measurements are directly between tangible points—exactly as was the case for deciphering Archaic mounds. A cache provides an excellent opportunity for exploring the Maya practice of applying precision measurement as a means of communicating numerical data. This study is designed to analyze the unit of measure independently from the other evidence.

To uncover the hidden system of measures incorporated in chert artifacts requires that we view working with chert as entailing a greater level of skill than has previously been apparent. Breaking away portions of stone while simultaneously maintaining sharp edges and precision placement of features is far from trivial.

Validating a base unit of measurement

Summing the perimeter side of a quadrilateral bounding a symmetrical chert artifact seems to produce meaningful Maya numbers. In light of the previously discussed origins of the measurement standard in Louisiana, it is evident that lineal measurement values frequently reflect counts of astronomical and astrological units. The goal is first to verify that the Maya standard of measure is close to the Louisiana standard, then we want to quantify *how* close the standards really are.

It is difficult to define a quantifiable unit of measure by factorization because the presumed base unit is just fifteen percent larger than a millimeter. Inevitable errors by both the original craftsmen and a modern researcher can easily exceed the difference. However, there is potential for additional factoring clues.

As a test, each perimeter was assigned a likely value representing the largest common denominator, drawing on significant Maya numbers listed in the appendix. Thirty-five perimeter measurements produced a median scale of 1.144 millimeters per assumed Maya unit, plus or minus a maximum of

0.008 mm. Not only does this provide independent derivation of a base unit, it supports the validity of assigning numeric values to rectangular frames from what we know of Maya astronomy. Sixteen instances of astronomical cycles provided the most significant correlation by using decimals to the thousandths place when multiplying. Other correlation came largely from factors of seven, or from residuals of seven. Use of 7, 17, 27, 37, 47, 57, and 77 as factors indicate that Maya numbers were modularized by tens as readily as twenties, and that a residual of seven was an important message. Recognizing that the presumed heavenly rectangle has an area of 77 units may be an important clue. The fact that the Maya actively tracked cycles of seven heavenly bodies surely contributed to the status of the number seven. Item C-7 invited special attention because of its highly redundant indication of the importance of the number seven. A pure number that can be factored by seven also sidesteps the potential objection against assuming synodic cycles.

A separate analysis showed that numbers significant to the Maya, listed at the end of the chapter on math, are evenly divisible by thirteen at a rate many times greater than normal. By comparison, nearly 40 percent of the list of assumed values for each perimeter can be evenly divided by thirteen. This property raises the possibility that multiplication tables for the number thirteen were used as an expedient means to represent otherwise complicated arithmetic operations. Another useful notion is that dividing data recorded as integers should produce the fewest remainders near 0.5. Inaccurate measures of one millimeter can change remainders for the base module by nearly nine tenths, but the same error only changes the remainder for a thirteen-unit module by 0.07.

When metric measurements of each eccentric quadrilateral perimeter were divided by one thirteenth of a series of potential base units, the non-integer decimal remainder was found to be minimized at a value of 1.148 millimeters. Plotting *variance* (square of the standard deviation) for each potential base unit, incremented by hundredths of a millimeter, produced a peak at 1.146 millimeters. The average deviation of the cache shows that measurements are accurate within a millimeter for every 300 units. Correlation of the base unit determined by factorization, independent of assumption, with that determined by assigning best-fit values is sufficient to assure that we are dealing with a valid unit of measure. Inevitable measurement error must be acknowledged in both the past and present.

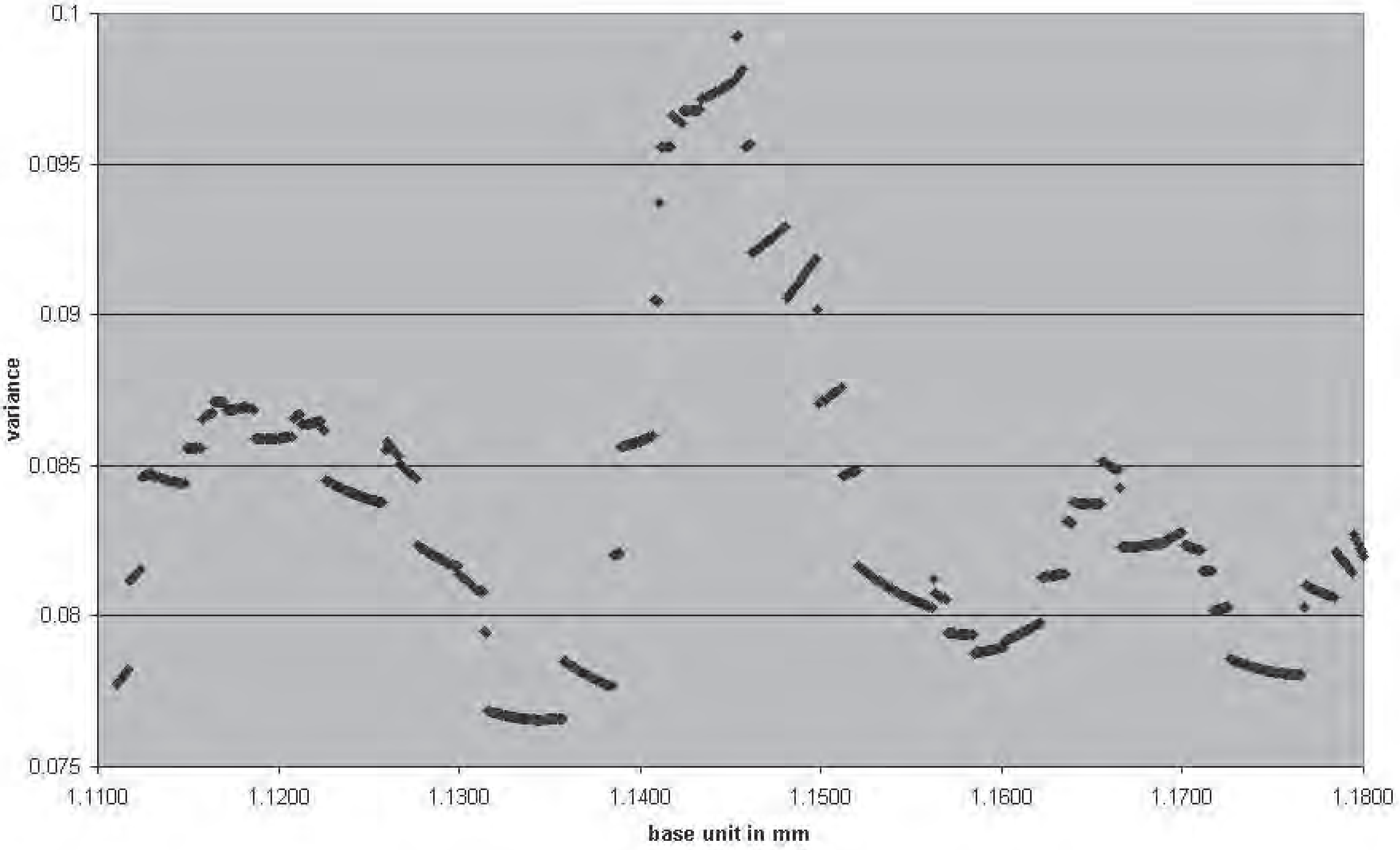
Now that a standard unit has been thoroughly established, it should have its own designation. Because the unit appears to be so widely adopted, it should be called the American unit, or Au. In my mind, that makes it the “gold standard.”

Results indicate that linear measurements were applied to represent analogs of astronomical observations by graphic construction. That does not mean that all measurements are values of time, but a preoccupation with astronomy leads naturally to a bias toward synodic cycles. Scales invariably fit best when precise decimal values of synodic cycles are used in preference to integer truncation. Such a result strongly suggests that we have a great deal to learn about Mesoamerican arithmetic. Graphic techniques of recording data and solving mathematical problems could explain the lack of notational evidence for arithmetic operations, as well as apparent decimal precision.

Inside the box

The designs are generally symmetrical and can be characterized as bounded by boxes whose major and minor axis fall roughly within three dimensional ranges equivalent to hand span, hand width, and multiples of finger widths. No stand-alone measurement between two tangible points on an artifact have produced meaningful associations as yet. However, when perimeters of the box frame are measured, significant associations are found for virtually every instance. Care was taken to extend the framing

Isolating a base unit



box to include ellipses that were clearly part of the design. Redundant indication of a dead-center point allows unambiguous definition of the bounding quadrilateral frame.

Redundancy, insuring that the message is correctly understood, seems to be an important part of Maya design. When the perimeter of the Pleiades figure sum to seven base-units cubed, it echoes a by now familiar theme. Even though the Pleiades message of seven has been encoded to excess, only the snake icon is readily evident. The design of the snake figure uses repetition of elements to make the number seven stand out. As will be shown later, the bounding rectangular perimeter is valued at even multiples of seven. Despite the repetition, the importance of seven is whispered more than shouted. At the same time there is a tendency toward misdirection, perhaps to keep certain information from unqualified observers. Redundancy can be seen most notably by alignments that reinforce a dead-center of the design. Straight-line segments are excellent indicators, seen in items C-1 and C-33, that bring attention to significant alignments because straight lines are difficult to achieve in chipped stone. When geometric elements converge at the edge of the chipped artifact, intent is indicated, as illustrated by items C-1, C-7, and C-33. In general, redundancy seems to serve the function of delivering the message accurately. At least some individual artifacts exhibit redundancy that potentially preserves information even if damage occurs.

Cached item C-7, with its repeated message of seven, has a perimeter equal to seven cubed, making it a stand-alone solution for a standard unit of measure. The pair of items C-21 and C-22 contain 260 notches, equal to the sacred almanac number, but their perimeters also sum to 1,000 units. Therefore the set may also be considered a reference scale of sorts.

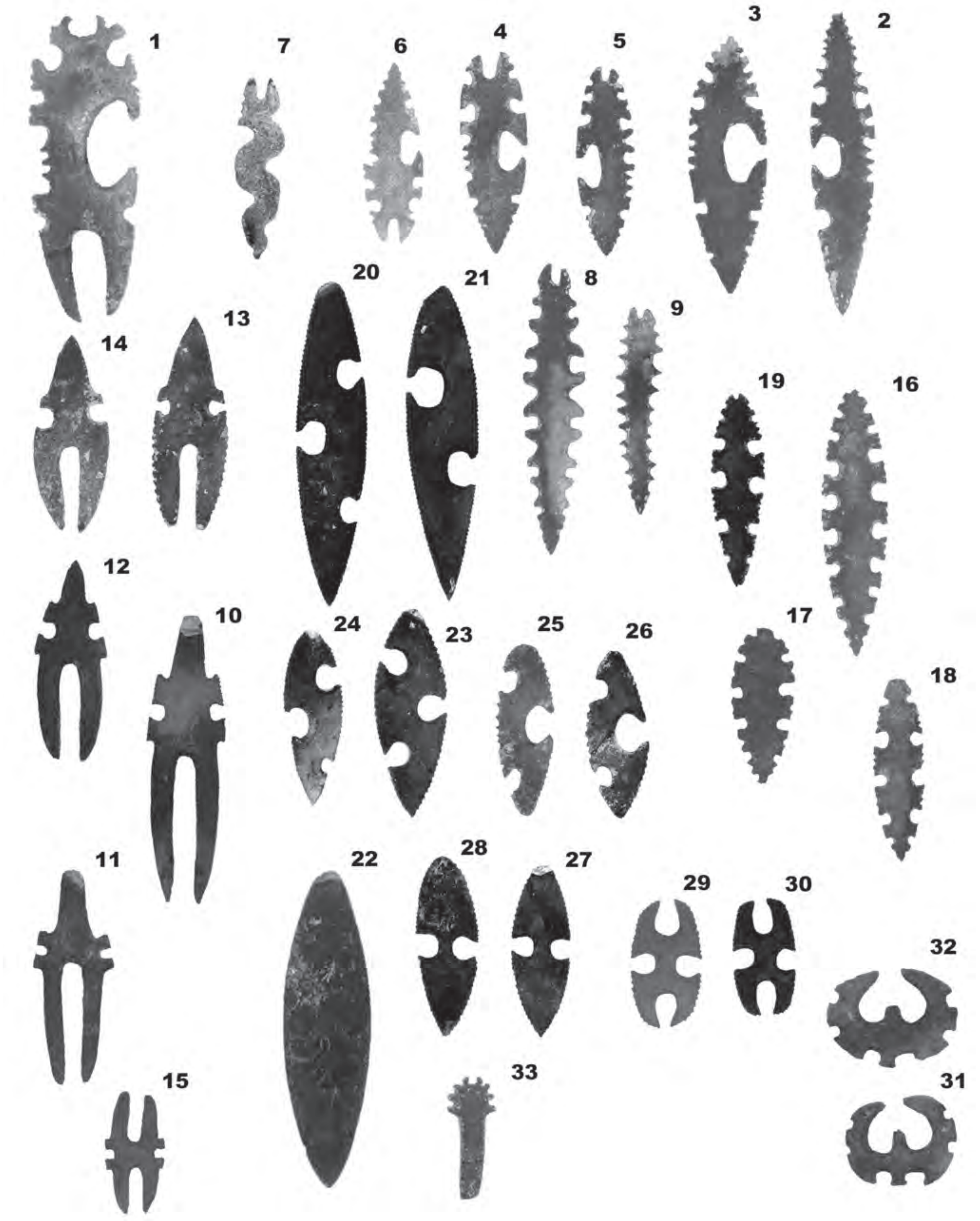
There are instances where the design appears to have been guided by a grid, leading to the potential for using grid intervals as part of an exercise to recover standard units of measure. Item C-31 in particular fits an 8 by 8 cell grid, with the width equal to 80 standard units. Detection of underlying grids is difficult, so grids may play a more prominent role than is now evident.

The most difficult artifacts to read are ones where symmetry is most subtly violated. This includes instances where one side has longer legs than another, or when subtraction from the basic form is severe. A most insidious violation of symmetry occurs when the tip-to-tip orientation is deliberately shifted to one side by as much as three millimeters or two units. Although every effort has been made to reconstruct reasonable interpretive rules, it must be kept in mind that we lack the thorough cultural indoctrination of original Maya craftsmen.

Flaking around the perimeter of the guiding frame was completed to exacting standards, producing an acute edge that lies in a plane. Only after the symmetrical frame was completed were the remaining design features constructed by flaking away carefully selected portions. The practice of treating the intermediate frame outline as a completed work allows accurate orientation of the final eccentric. Items 23 and 24 were completed as simple laurel leaf forms and painted black before being notched, as revealed by the notching flakes cutting away the painted areas. Uniformly spaced notches may have a different intended meaning than irregularly spaced notches.

Interruptions of the symmetric frame typically take the form of gaps, limbs, slots, indentations, and serration. These elements are usually combined to create a distinct iconographic image. At this stage of study, there is very little to guide us in interpreting iconographic meanings. Many effigies are readily seen to represent bats, water bugs, centipedes, snakes, and trees. Other representations are less obvious. Although there appear to be tall legs on some items, they may actually represent the erect Milky Way,

Cache of 33 Maya chert eccentric artifacts
(See Appendix B)



with the crocodile's head at the bottom. Those items tend to have arms that could be interpreted by association as the intersection of the Milky Way by the ecliptic. Further enlightenment is obtained from the Quiche Maya language (Leon 1954), with the Milky Way being called *sac bey i*n the summer and *xibal bey* in the winter when it is bifurcated. Thus, the legged figures may represent duality of summer and winter seasons as well as heavens and underworld.

Taube (2003 points out that centipedes aided passage through the death realm of the underworld, its pincer-like maw being regarded as the entry to the underworld. Of special interest is that classic Maya texts precede the term for centipede with the number seven, the apparent numerical theme of the cache. Serpents occupy an opposite role to centipedes, appearing in scenes of celestial assent. To have the serpent depiction so thoroughly imbued with the number seven appears to play with the dichotomy of roles. Considering the heaven-underworld bifurcation between serpents and centipedes leads to the observation that sixteen items have distinctly underworld motifs, including bats, centipedes, and night birds. Aside from the *ceiba* tree, that leaves another sisteen that are not obviously heaven related but include a serpent, day-sign, vesicas, and tall legs. The *ceiba* "tree of life" may be considered to have its roots in the underworld and foliage in the heavens, uniting the two realms.

Frequent association of an ellipse with a bounding rectangle whose perimeter represents a significant numeric value warrants exploration to better understand the underlying purpose. The daily path of the Sun, Moon, and many planets describes half of an ellipse. Radial symmetry implies the unseen half of the ellipse and predicts timing and placement of the next visibility. Presumably, early people could have realized that an ellipse represents a projection of a circle onto an inclined plane. It would take only a slight leap of imagination to understand orbital tracks as representing circles on the plane of the ecliptic. Doubling the major and minor axis of the ellipse allows quantification of an elliptical shape by the perimeter of its rectangular frame. Deliberately choosing dimensions to portray significant astronomic quantities is a reasonable way to impart symbolic power to the ellipse/rectangle.

Subtraction from a regular frame is used to hide messages in plain sight. The ellipse is a common starting shape, but by the time it becomes a scorpion or other figure, the ellipse foundation may be nearly unrecognizable. The rectangular frame surrounding the ellipse is even less obvious. In some cases, the remnants of the ellipse may constitute part of the message. For example, the seven sections of the Pleiades figure that touch the bounding ellipse reinforce a message already conveyed in multiple ways. One function of an ellipse may be to contain symmetry, even though subtractions might appear to destroy symmetry. The use of tangent points to define bounding quadrilaterals minimizes the difficulties with achieving precision in chipped flint because it is much easier to position three to four edge points than to create perfectly straight lines in flint. Therefore, when a straight-line segment is located, it usually draws attention to an important alignment.

Careful examination of the remaining eccentrics show that ellipses were used often. The Pleiades example shows that it is prudent to use the quadrilateral tangent to an ellipse extending beyond the physical frame of an artifact as the primary frame of reference. When the major axis of an ellipse foundation is truncated by the physical rectangular frame, the dimensions of the extended quadrilateral are the relevant references for measuring the frame perimeter. Enough markers and alignments are retained to capture the starting ellipse.

Apparent disregard for right angles in Maya architecture has led to an attitude that the Maya were not concerned with right angles. Site plans may be more concerned with positioning architectural elements such as doorways and exterior corners than with squared sides on buildings. The treatment may have much to do with context. Household symbols are less apt to be given the same special treatment devoted to royal architecture and monuments.

Even though rectangular bounding frames are not visible in the chert eccentrics, the accuracy evident in associating significant numbers to frame perimeters rests on accurate right angles. I use a computer to digitally orient and measure those invisible reference frames consistently and reliably, but it is not at all clear how the Maya could have enforced such rigid control over geometry.

Messages contained in an artifact may sometimes conflict with each other. It is not clear if misdirection is involved, or if multiple messages are included. Counting notches is sufficient to show an observer that astronomical information is present. However, counting notches is limited to integer values and sometimes gives answers out of registration by one or two.

Outside the box

When this cache was viewed for the first time, it was obvious that thematic groupings were present. Most noticeable were the seven faces but sets, serration, and long legs were also present. As sorting progressed, artifacts fell into groups of seven, and some items appeared to fit with more than one grouping. Curiously, each family grouping revealed one member that stands apart from the rest.

Artifacts were sorted into eleven family groupings of seven members each, as shown on page 76. A twelfth grouping of seven members consists of misfit family members while a thirteenth family is composed of exemplars, whose physical characteristics are restricted to their primary family. Frame perimeters commonly factor to multiples of thirteen units, but even closer fits to true astronomic values were noted. As individual items were re-measured to comply with emerging understanding of measurement rules, the scale adherence of family perimeter sums improved. Thirty three artifacts might have also been meant to signify thirteen plus twenty, the primary day-counting intervals. Conjoining the family having faces with the family of long legs produces a group of thirteen artifacts, with twenty remaining.

Perimeters of thirty-three individual cache artifacts could be matched to important numbers and other numbers that adhered to patterns typical of Maya arithmetic. When values were accumulated at the family level, significant correlation persisted. While family groupings could easily fit by 13-unit modules, the largest significant denominator meeting the apparent precision of 4 mm per thousand was judged to be more appropriate. The fact that summing perimeters by family produces significant correlation with astronomical observations provides a cross-check of sorting decisions.

Mathematics

Because so many measurements correlate to significant numbers by a factor of thirteen, multiples of 13 should be considered significant even when the use is not clear. Multiplication tables may have been used to conveniently represent special values as factors of thirteen. Factors having a residual (last digit) of seven were common, the reason is not known although repetition of the number seven has already been established as a theme for the cache. Multiples of three successive integers in succession are common, as is summing an integer with its square and its cube. Such numbers may have been considered aesthetic. Gaussian methods for solving modular arithmetic make use of multiplication tables to reconcile remainders between cycles of different modules. This means that Maya multiplication tables could serve a purpose far more meaningful than an effort to avoid arithmetic.

Cycle values appear to be expressed precisely in decimal terms, rather than as integers. Furthermore, accumulation of physical distance from defined vectors agrees remarkably well with numeric sums.

These two facts combine to show that Maya mathematics was much more versatile and robust than previously imagined. Graphic math may account for the precision.

Measurement of some artifacts was straightforward and unambiguous, however it was seen that the use of ellipses made it difficult to reconstruct the intended frame of reference. Subtle clues sometimes could be followed to resolve ambiguities, but interpretation of a few artifacts remains in doubt. As new caches come to light, they should provide insight as to how to best represent the intent of the original artists.

As principles of design used in constructing chert eccentrics are recovered, it suggests new ways of examining community site plans (Harrison 1999:187-189). Integral right triangles were used to locate the primary axial point on the central axis in the doorway of a new building, even with the facade. Intersections of bearings from architecturally important points of existing buildings, and applying symmetry allows the entire floor plan to be determined. The lack of square corners in buildings can no longer be attributed to a lack of skill in making right angles, it is more likely due to priorities of placing architectural features in specific locations related to a master plan. Maya designers had a penchant for subtle misdirection and secrecy that may have reinforced the divide between the elite and commoners. Body-based measurements provide a good example of such a divide, where the difference between precision and expediency would not be apparent to the uninitiated.

Measurements of the perimeter are a natural extension of known practice. In fact, the major dimensions of the seven-faced eccentric match the heavenly rectangle geometry exactly. Had only cardinal dimensions been used, the artifacts would have needed to be much larger to represent the same numbers at 1 to 1 scale.

The seven-faced eccentric containing synodic cycle data justifies measuring quadrilateral frame perimeters, but it also justifies extending the frame to compensate for “missing” parts. The rattlesnake quadrilateral frame, C-7, obviously had to be extended to include the bounding ellipse. Offsets of tips from the frame axis appear to have been used as characteristics by which family identity can be established.

Most importantly, there is no discernible variance between the systems of measure practiced along the Mississippi River or in the Yucatan Peninsula, even though mounds are scaled to as much as 2,100 to 1, and eccentrics are scaled at 1 to 1. Not only does the standard unit remain constant, it is used in the same manner to document astronomic data. The next logical step is to inventory individual values and compare them to modern standards of resolution.

Matrix of family characteristics

#	**F1** p. 174	**F2** p. 175	**F3** p. 176	**F4** p. 177	**F5** p. 178	**F6** p. 179	**F7** p. 180	**F8** p. 181	**F9** p. 182	**F10** p. 183	**F11** p. 184	**F12** p. 185	**F13** p. 186
1	x	{x}	{x}									x	
2	x			{x}					{x}			x	
3	x								x				
4	x	x											
5	x	x											
6	x	x					{x.5}					x	
7	{x}	x					{x.5}				x	x	
8		x		x									
9		x		x				{x}			{x}	x	
10			x			x				x			
11			x			x		x			x		
12			x					x	x		x		
13			x				x.5				x		
14			x				x.5				x		
15			x										x
16				x					x	x			
17				x									x
18				x									x
19				x							x		
20					x	x			x				
21					x				x	x			
22					{x}	{x}	x.5			x		x	
23					x	x	x.5			x			
24					x	x	x.5						
25							x.5						x
26					x		x.5			x			
27					x	x	x.5						
28							x.5						x
29							x.5	x	x				
30							x.5						x
31							x.5	x					
32							x.5	x					
33								x		{x}		{x}	{x}

Brackets indicate {misfit} member that stands apart from the rest of a family of seven members. Family 13 is determined by items that share no other physical family characteristics beyond that of their primary family.

The matrix illustrates how thirteen attribute families with seven members each have been recognized. Embellishments, like serration, within family groupings sometimes consist of elements that create attribute families. Each family has six members that clearly share the same attribute, and one member that stands out from the rest. Brackets indicate the {misfit} member(s). Six misfit family members combine with the *ceiba* tree, which does not belong to a family otherwise, compose a family of misfits.

Family groupings

Family 1 ***God face***— Sum of perimeters = 10 Jupiter cycles.

Six faces are depicted in the central portion of the eccentric. Nose and lip protrusions are defined by notches. The lower tip of the large gap in the opposing edge usually aligns with the lips of the face. The snake god is the only one with its face at the top.

Family 2 ***Small pincer*** —Sum of perimeters = 14 Tropical years.

Seven items have small pincer elements at their top. The pincer in item 1 is significantly wider and in-curved, until framed by a narrow ellipse. The pincer may represent a volcano.

Family 3 ***Tall legs***—Sum of perimeters = 6×364 = 4×819.

Of the seven items with tall legs, item 1, with its god face, is clearly different from the other family members. The “legs” may actually represent bifurcation of the Milky Way (Leon 1954 , with arms depicting intersection with the ecliptic.

Family 4 ***Symmetric notches***—Sum of perimeters = 66 lunar months = 11×177.185

Seven items are distinguished by deep symmetric notches. Some have lesser notches in the intervals between major notch pairs. The outlier in this family appears to be a tall god face (C-2, with significant symmetrical notches.

Family 5 ***Symmetric leaf frame***—Sum of perimeters = 7 Jupiter cycles.

Nine pieces are built with symmetrical frames that may be described as intersecting compass arcs, although all are blunted at one end. Items 25 and 28 are asymmetrical and are considered not part of the family. The only un-serrated piece in this set is the outlier, item 22.

Family 6 ***Cortex at top***—Sum of perimeters = 7 Jupiter cycles.

Of the seven pieces with cortex clearly left by purpose at the top, item 22 stands out as the only un-notched item. Although the pincers of the snake god face (item 7 have a hint of cortex, it apparently is not enough for inclusion to the family.

Family 7 ***Sets***—Sum of perimeters = 26×173.31.

Seven sets are evident in the cache, with each set counted as a unit. Sets are distinguished from the other families by their inclusion of other attribute-family members. Six are united by the geometry of the starting frame. Items 6 and 7 are a different kind of set because of unique inclusions in the stone. Items 20 and 21 are *not* considered a set because one has three large holes and the other has two. The set of items 25 and 26 may represent the lunar cycle. One set looks like bats. Another is the *k’in* (day or Sun symbol. Sets may signify the mythic hero twins of the Popol Vuh.

Family 8 ***Seven notches***—Sum of perimeters = 7×360.

Seven items have seven distinct notches. Item nine, with seven notches isolated by shortening the spurs, is the odd member of this family.

Family 9 ***Offset tip***—Sum of perimeters = 10×377.

Each member of this family has a tip that is out of vertical alignment with the surrounding frame. Item 2 appears to be odd member.

Family 10 ***No alignment through dead center and unbounded by ellipse***—Sum of perimeters = 25 Mercury cycles.

Members of this family lack alignments between physical features that pass though the frame's dead center. None of this family can have an ellipse controlling the exterior artifact shape. Item 33 is the odd member because it has an internal ellipse.

Family 11 ***Bounded by ellipse but no alignment through dead center***—Sum of perimeters = 14×177.185.

This family also lacks alignments through dead center, but an ellipse controls the artifact shape. Item 9 is judged to be the odd member, being asymmetric and contacting its bounding ellipse a minimum amount.

Family 12 ***Misfits***—Sum of perimeters = 25 Mercury cycles.

Each family has one member that stands apart from the rest. The only item that does not belong to any other family of attributes is a broken representation of a *ceiba* tree. In Maya cosmology, the *ceiba* tree is considered the sacred tree of life. The seven notches defining the foliage may count attribute members.

Family 13 ***Exemplars***—Sum of perimeters = 6×360.

Armed with the realization that twelve families are uncharacteristic of Maya numerology, the characteristics matrix was revisited. The thirteenth family can be defined as those items which do not share any physical characteristics beyond those of their primary family.

Observations

The primary outcome of this study is a statistical validation of a native standard unit of measure commensurate with a standard of measure used thousands of years earlier in Louisiana. However, the study raises more issues than it resolves. While selected items in this cache exhibit an underlying grid system, there is no readily apparent consistent geometric framework. From the scope of variation, we may be justified in assuming a rich tradition capable of using a great many sets of coding conventions. With so many layers of message, how can the central theme be separated from the rest? Perhaps there is really nothing to separate—the objective could be simply to see how much meaning can be incorporated into an artifact. The "game" may be to impress the Gods with how many "secrets" have been compromised by mortals.

Some of the information is in dimensional form but iconography, symmetry, notches, and n-point lines play a role as well. N-point lines are known from Archaic mounds in Louisiana, where they seem to have been related to observations of star patterns which may be mapped by defining n-point lines. Ancient practices of transmitting knowledge without the use of glyphs evidently survived as an independent form of communication.

Dimensional values were created by rule-driven accumulations, primarily through measuring quadrilateral perimeter frames. Additional summing of individual artifact values by groupings to generate yet another numeric value is quite remarkable. Non-integer precision suggests a practice of graphic math that has not yet been acknowledged in another context. The low variance of scale may be attributed to the items being generated from a single workshop, where conformance would be relatively easy to maintain. Factorization observed in the data indicates how integers were manipulated arithmetically. Redundancy built-in by the quadrilateral framing, use of ellipses, symmetry, and alignments allows unambiguous reconstruction of the craftsmen's intent, even if some damage occurred.

The recognition of data content places chert eccentrics on an entirely new level of importance. More than being just a pretty artifact, an eccentric contains numeric meaning. In the context of a cache, groups of artifacts are demonstrated to convey additional numerical significance. The levels of precision and accuracy will force a re-evaluation of the capabilities of Maya math. Although glyph notation is restricted to integer values, the measures of planetary synodic cycles indicate decimal precision. In fact, the system of measure appears to have an accuracy of better than four millimeters in a thousand. As more records can be discovered, the results should reveal the true precision of cycle determination in the past.

Elevating this class of artifacts from aesthetic curiosities to durable records has other important implications. Efforts to maintain the integrity of cache contents take on new urgency since looted finds are frequently dispersed and the data is most relevant in the context of an intact cache.

Cache measurement data

Item	Representation	Hgt (mm)	Width (mm)	ellipse frame Hgt (mm)	ellipse frame Width (mm)	Perimeter (mm)	Perimeter (Au)	Scale (mm/ Au)
1 F1	*large ellipse*, 19 lunar months	229.5	84.5	235	87	644	561.08	1.1490
1 F2	*pincers*, 3×177.185	229.5	84.5	235	71.4	612.8	531.56	1.1528
1 F3	*legs*, 3×173.31	229.5	84.5	235	61.6	593.2	519.93	1.1409
F1>F3	14 Mercury cycles					1850	1622.00	1.1406
2	6×77	217.8	46.9			529.4	462	1.1459
3	**13**×33	185.4	57.7		60.3	491.4	429	1.1455
4	**13**×26	144.9	48.8			387.4	338	1.1462
5	12 lunar months	154.2	47.9	155		405.8	354.37	1.1451
6	7 cubed	145.8	49.2	147.5		393.4	343	1.1469
7	7 cubed	148.2	40.6	156.3		393.8	343	1.1481
C6>C7	2×7^3					787.4	686	1.1478
8	15 lunar months	209.3	45.1			508.8	443.00	1.1486
9	377 = **13**×29	167.5	41	173.7		429.4	377	1.1390
10	4 Mercury cycles	206.7	57.7			528.8	464	1.1409
11	**13** lunar months = 3×2^7	154.6	59.1	160.8		439.8	383.9	1.1456
12	12 lunar months	144.3	52.9	150.4		406.6	354.37	1.1474
13	**13**×30 = 6×65	152.7	55.2	167.3		445	390	1.1410
14	2 lunar nodes	142	54.9	143		395.8	346.6	1.1419
C13>C14	2 solar years					840.8	730.5	1.1510
15	5×52 = **13**×20 = 4×65	99	49.5			297	260	1.1423
16	420 = 7×60	191.8	48.7			481	420	1.1452

17	6×52 = **13**×24 = 3×104	126.2	52.9			358.2	312	1.1481
18	9×37	148.5	41.9			380.8	333	1.1435
19	12 lunar months	156.9	44.9			403.6	354.37	1.1389
20	17 lunar months 7×8×9	233.7	52.5	235.4		575.8	502	1.1470
21	**13**×38	227.1	53.5	229.5		566	494	1.1457
C20>C21	10^3 ~ **13**×77					1141.8	1000	1.1418
22	**13**×38	221.8	60.2			564	494	1.1417
23	12 lunar months	150.1	53.5			407.2	354.37	1.1491
24	**13**×23	126.5	44.1			341.2	299	1.1411
C23>C24	10×65 = **13**×50					748.4	650.00	1.1514
25	6×7×8	139	48.5	142.7	49.5	382.4	336	1.1381
26	11 lunar months	53.2	132.9			372.2	324.837	1.1458
C25>C26	**13**×51					754.6	663	1.1382
27	Venus÷2 ~ $6×7^2$	123.5	43.3			333.6	291.961	1.1426
28	2×173.31	145.6	52			395.2	346.62	1.1402
C27>C28	**13**×49					728.8	637	1.1441
29	**13**×22	104.3	58.5			325.6	286	1.1385
30	2^8	94.5	52.6			294.2	256	1.1492
C29>C30	20×27 ~ $11×7^7$					619.8	540	1.1478
31	7×41 ~ **13**×22	72.4	91.4			327.6	287	1.1415
32	7×47	80.7	107.3			376	329	1.1429
C31>C32	7×8×11					703.6	616	1.1422
33	11 lunar months	111.3	45.2	140.7		371.6	324.837	1.1440
33	top oval, lunar node		45.2	53.7		197.8	173.31	1.1413

Item	Representation			Perimeter (mm)	Perimeter (Au)	Scale
F1	10 Jupiter cycles	God Faces		4555.8	3989	1.1422
F2	9 Tropical years	Small pincer		3791	3282	1.1533
F3	9×364 4×819 = 13×63	Tall legs		3735.2	3276	1.1402
F4	66 lunar months 11×177.185	Symmetric notches		2232.4	1949	1.1454
F5	7 Jupiter cycles	Symmetric leaf frame		3208.4	2792	1.1491
F6	7 Jupiter cycles	Cortex at top		3217.4	2792	1.1524
F7	**26**×173.31	Sets		5147.8	4506	1.1424
F8	7×360	Seven notches		2859.6	2520	1.1348
F9	10×377 = 13×29	Tip offset		4314.8	3770	1.1446
F10	25 Mercury cycles	no ellipse	No physical alignment through frame dead center	3318.6	2897	1.1455
F11	14×177.185	ellipse		2851.8	2481	1.14957
F 12	25 Mercury cycles	Misfits		3314.4	2897	1.1441
F 13	6×360	Exemplars		2480	2160	1.1481
7	rays, 700 ~ **13**×54			803.8	700	1.1483

Using individual measurements only

count	44
median	1.1446
avg	1.1444
avg dev	0.0032
max	1.1528
min	1.1381

7

K'awiil Effigy Study

This spectacular artifact chipped out of chert, commonly referred to as an eccentric, raises some intriguing questions about Maya math and geometry, not to mention flint-knapping skills. The place of origin is unknown because the artifact was looted and later sold to a collector in Guatemala City, Guatemala.

Without knowing anything else about this artifact, it is clearly made to a special plan that goes far beyond depicting seven faces. That plan will be revealed layer by layer.

The artifact is 236.4 mm high and 148.7 mm wide.

As an expert flint-knapper, I am in awe of the incredible command of lithic technology. Simultaneous management of symmetry, acute edges, narrow notch openings, large interior openings, and artistic design are magnificent achievements. Upon closer inspection, a comparable display of mathematics and geometric knowledge becomes evident. The accuracy of feature placement would be amazing in any medium, but in chipped stone it is simply beyond comprehension. Likely there is yet another level of equally impressive symbolic meaning that we are ill equipped to appreciate.

That the seven faces match the number of orbital cycles tracked by Maya astronomers is more than coincidence. In fact, the effigy contains at least three encoded records of the synodic cycles of seven heavenly bodies that could have been observed by the naked eye. When we consider how central astronomy was to the development of Maya mathematics and calendrics, it seems reasonable that astronomy provided the basis for the artifact. Additionally, monitoring astronomical alignments would have led naturally to geometric alignments in art and architecture. Whatever information this artifact might add to our understanding of Maya standards of measure would be enormously helpful.

By backtracking the elements of design and construction, we will establish a body of knowledge that the craftsman drew upon. The design utilizes several principles of geometry not previously described, while other elements are generally shared by Maya artists working in other media. So, after we figure out what this artist knew and did, we will make some comparisons to see how widely Maya craftsmen shared their secrets.

Deciphering rules of construction

The outer frame of the artifact could only have been designed by using a bounding rectangle frame with near golden-mean proportions. Repeated instances demonstrate that landmarks at the perimeter of the rectangle also played a crucial part in orienting feature after feature. Near golden rectangles are commonly found in Maya architecture.

Even with computer graphics, precision alignments are daunting. If we rely on computer graphics without question, mismatches of one or two millimeters can appear overly significant. Another concern is that so many alignment possibilities can lead to uncertainty about which alignments are legitimate and which are due to coincidence. Redundant indicators often eliminate ambiguity.

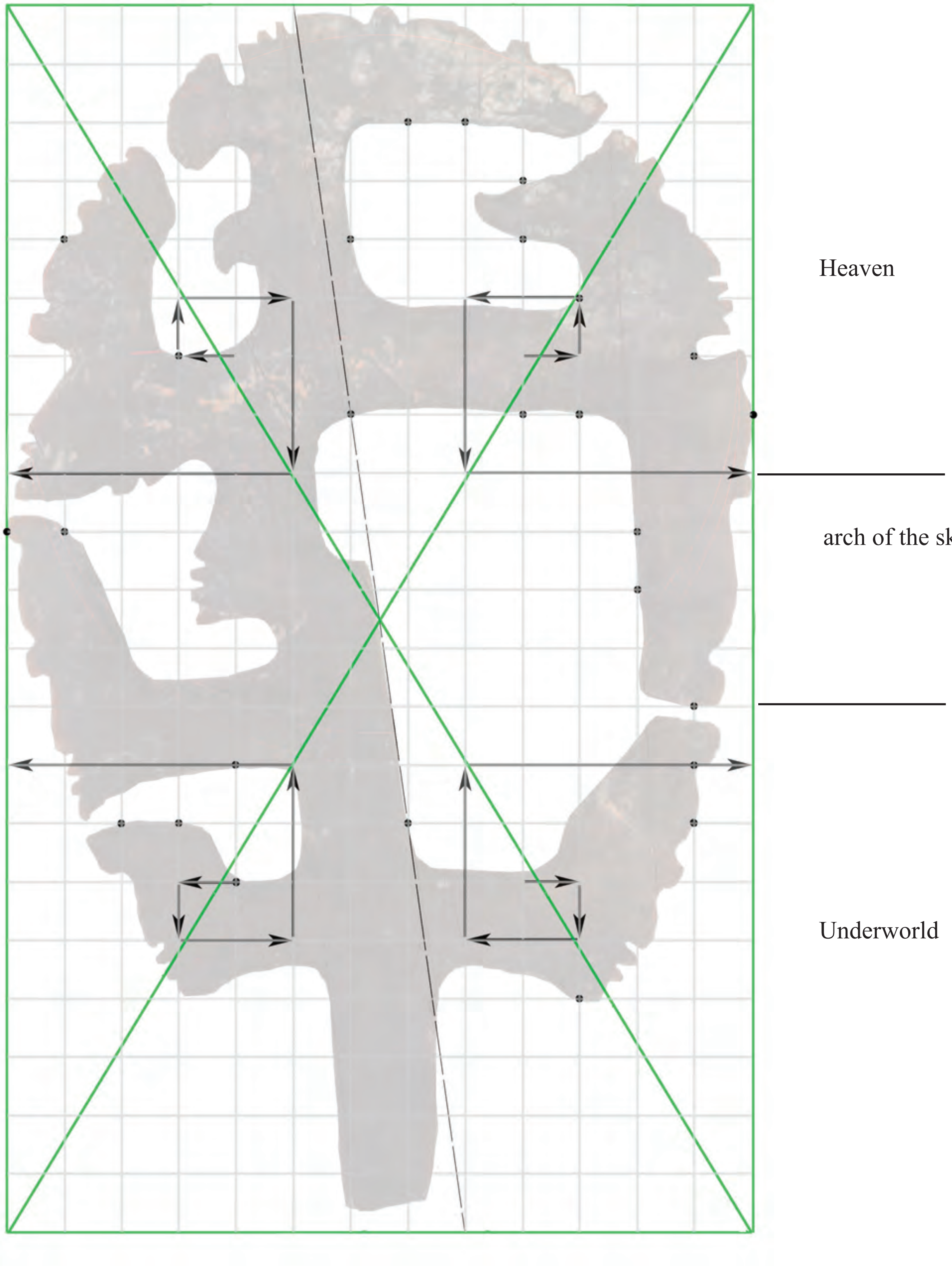
Here, the artifact has been properly oriented so that it fits neatly within a rectangle tiled with 13 by 21 squares. The upper portion of the design fits a perfect ellipse in the proportion of 13 to 15, and the lower portion is defined by two compass arcs of equal radius. The broken stem is assumed to have originally touched the rectangle.

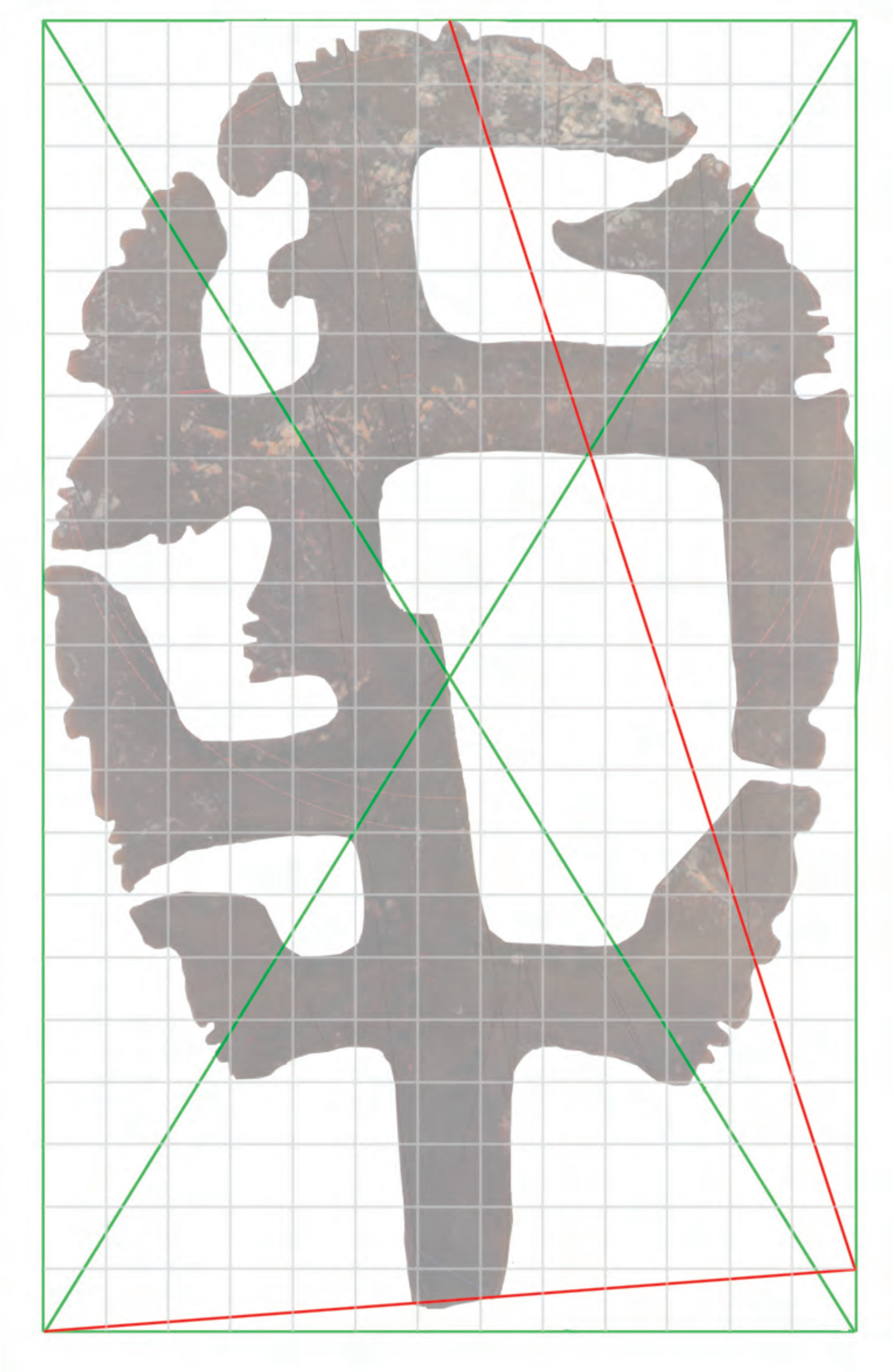
Frame dimensions = 148.7 mm wide, 240.2 mm high
Frame perimeter = 777.8 mm

Three alignments between features at opposite edges intersect perfectly to create a central planning point that coincides with the dead-center of the rectangle. These lines cut the image into six roughly equal segments. The near vertical alignment begins and ends at nodes of the 13 by 21 pattern.

The Fibonacci-based path of creation is overlaid on the tile grid on the facing page. Artifact edges fall exactly on twenty-six grid nodes. Thirteen grid nodes in the upper section apparently represent heaven. Nine nodes at the bottom nine cell rows can be associated with the Underworld, while four nodes at the level of the face mark the arch of the sky.

The path of creation (90% actual size)





A line drawn from the lower left corner of the heavenly rectangle, through corners of the broken stem, cuts the right side of the heavenly rectangle one grid node above the base, at the same place as a line from the top point through an intersection of heavenly rectangle construction with the effigy edge. The relationship of the effigy to the heavenly rectangle is reinforced, while reaffirming the intentional inclusion of a “broken” stem. Note the distinct jog in the arm leading to the upper right face (Jupiter), which helps signal the requirement to keep those edge positions fixed in place.

Designing the frame

The bounding rectangle frame was designed along previously described principles of the heavenly rectangle with thirteen by twenty-one unit proportions. Using precise values for synodic cycles would increase the millimeter per day scale by only a thousandths of a millimeter per day. Because it can be determined with a minimum of data and had to be in place prior to the remaining features, this scale must be considered more reliable than any other scale derived from the resulting construction. Note that the scale is consistent with that deduced from Archaic mounds in Louisiana.

	Heavenly rectangle grid units	Scaling the perimeter to Mars cycle	Scaling 2×height = 550	Metric measure
2×Width	**(20×13) 260**	298.14	340.5	2×148.7 = 297.4 mm
2×Height	**(20×21) 420**	481.7	**550**	2×240.2 = 480.4 mm
Perimeter	**(10×68) 680**	**779.936**	890.5	777.8 mm
mm/day	1.1438	0.9975	0.8735	
day/mm	0.8743	1.0025	1.1449	

Bold numbers indicate assumed significant values.

Heavenly rectangles produce scales very close to those derived independently from synodic cycle values in the following section. Also note that the two derivations depend on separate sets of measurements. The standard scale is assumed to be represented by the heavenly rectangle. In terms of grid divisions, the perimeter is a tenth of the lunar standstill cycle.

Scaling the height to 550 American units inverts the scale found by solving for the heavenly rectangle. That inversion approximates the scale used for the presentation measured radially from the central chin. While honoring the number 550 appears to be artificial, there are 550 complete lunar standstill cycles in two Maya epochs.

Scaling the perimeter to Mars synodic cycle produces a scale midway between the inverted scales. Lacking a supporting reference scale, this result cannot be confirmed as intended by the Maya.

Documentation of astronomical cycles in stone

A record of seven planetary cycles observable by the naked eye is preserved by dimensions proportional to the cycles. Web documentation by Robert Peden (2004), provides excellent background for understanding how Maya astronomers interlocked cycles by recognizing that 260 is the lowest common denominator. Peden is also my primary source for the time required for each body to reappear at a specific place on the horizon. The 260-day calendrical divination cycle, called a *tzolk'in*, may have originated from its importance as a common denominator.

The craftsman used various points on the artifact as origins for recording cycle data. The chin of each face was placed aesthetically, so multiple records of cycle data could be contained. Each choice of measurement origin and target feature theoretically could be brought into agreement by separate sets of corrections camouflaged in the design. When multiples of 260 are subtracted from the known periods of rotation, the residual values equal to or less than 260 can be proportionally correlated with the artifact measurements. Removal of multiples of 260 is readily explained by clock arithmetic. Think of a clock with 260 divisions, tracking the time required for each synodic cycle to complete. The only reading you can make is the number of days elapsed since the hand passed the zero point. Ignoring the base cycle of 260 days, the reading is the residual. Logically, the largest residual provides a potential scale of presentation through dividing the measurement in millimeters by the residual count in days.

When all cycles are matched to the artifact, it is possible to identify each face as corresponding roughly to a particular celestial body. Of all the possible features, chins maintain the best proportion to planetary cycles. Full synodic cycle values for the planets are:

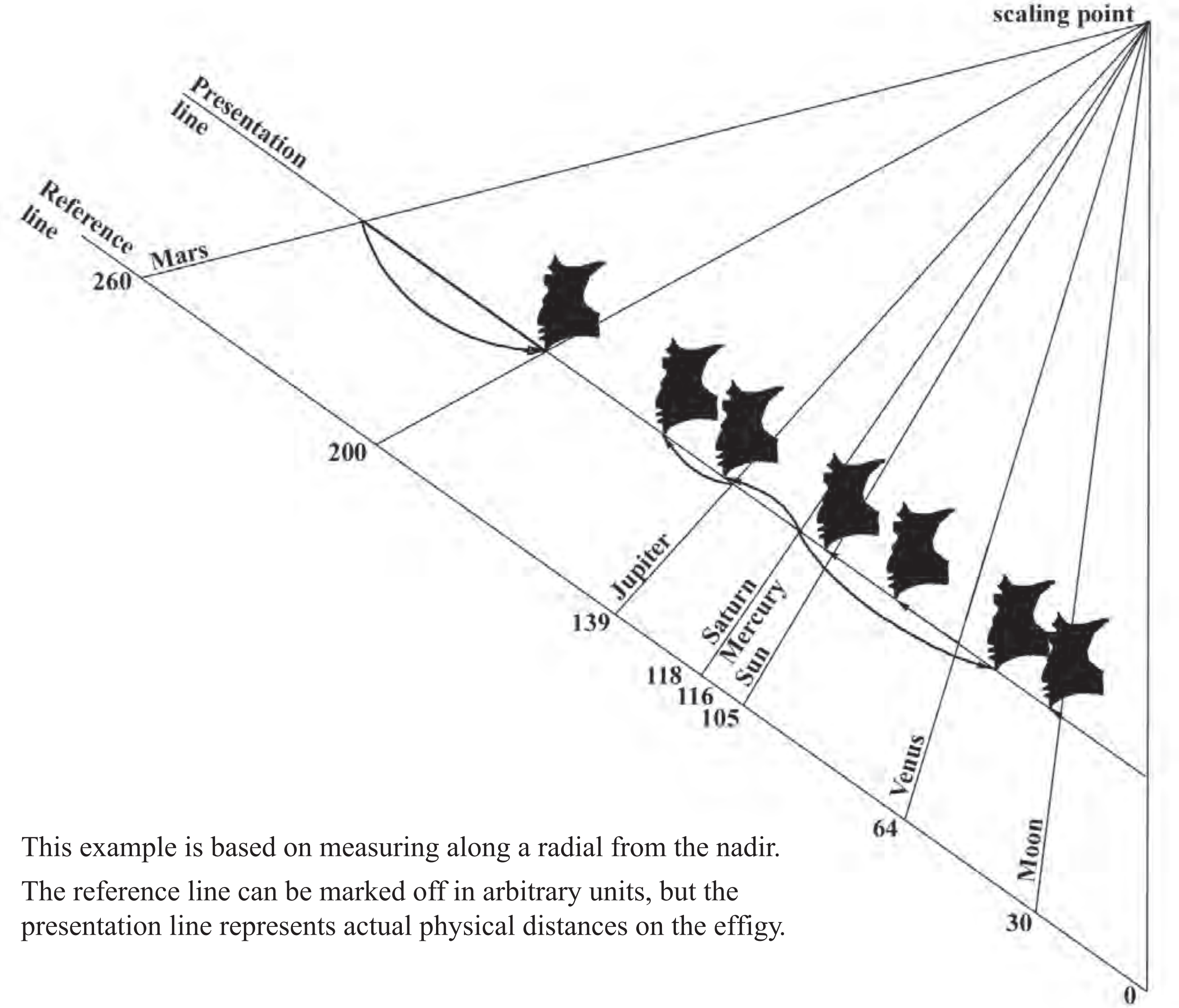
object	**period in days**	**integer day-count**
Mars	779.936	260 +260 +**260**
Venus	583.922	260 +260 + **64**
Jupiter	398.867	260 +**139**
Saturn	378.0919	260 +**118**
Sun	365.2422	260 +**105**
Mercury	115.877	**116**
Moon	29.5306	**30**

Preliminary measurements are made from each of three reference datums—bottom frame center (nadir), bottom frame edge, and central chin. Proportioning raw measurements to known residuals provides the conversion scale from millimeters to American units, using decimal residual values. Data is presented in tables at the end of this report. Because preliminary measurements fail to match residuals accurately, corrections have to be applied as described on the next page.

Because this design uses unfamiliar methods of encoding data, it behooves us to clearly distinguish intent apart from coincidence. To avoid forcing a desired fit, a consistent rule set had be followed. Fortunately, the Maya used redundant pointers that help rule out fortuitous accidents. They also limited themselves primarily to chins, tangents, and well-defined landmarks. Details of the three presentation schemes in the following pages demonstrate each of these principles. Spareness of design reduces the chance of spurious alignments. Hardly any notch or protrusion does not serve a specific purpose. After corrections are applied to the starting measurements, the precision of fit to known synodic cycles leaves virtually no remaining tolerance for error. That three modes of presentation agree so well further argues against misinterpretation.

This simple diagram shows how the proper dimensions and corrections could be anticipated. First, plot the known cycle residuals on a reference line, using any convenient unit. On a parallel line, plot the measured points at a desired presentation scale. Drawing a line through the highest and lowest values defines an origin that can be used to transfer accurate cycle data from the reference line by extending rays to the presentation line. Mismatches require corrections or re-locations. Using new origins and targets allows redundant recording of cycle information, as long as new corrections are also provided.

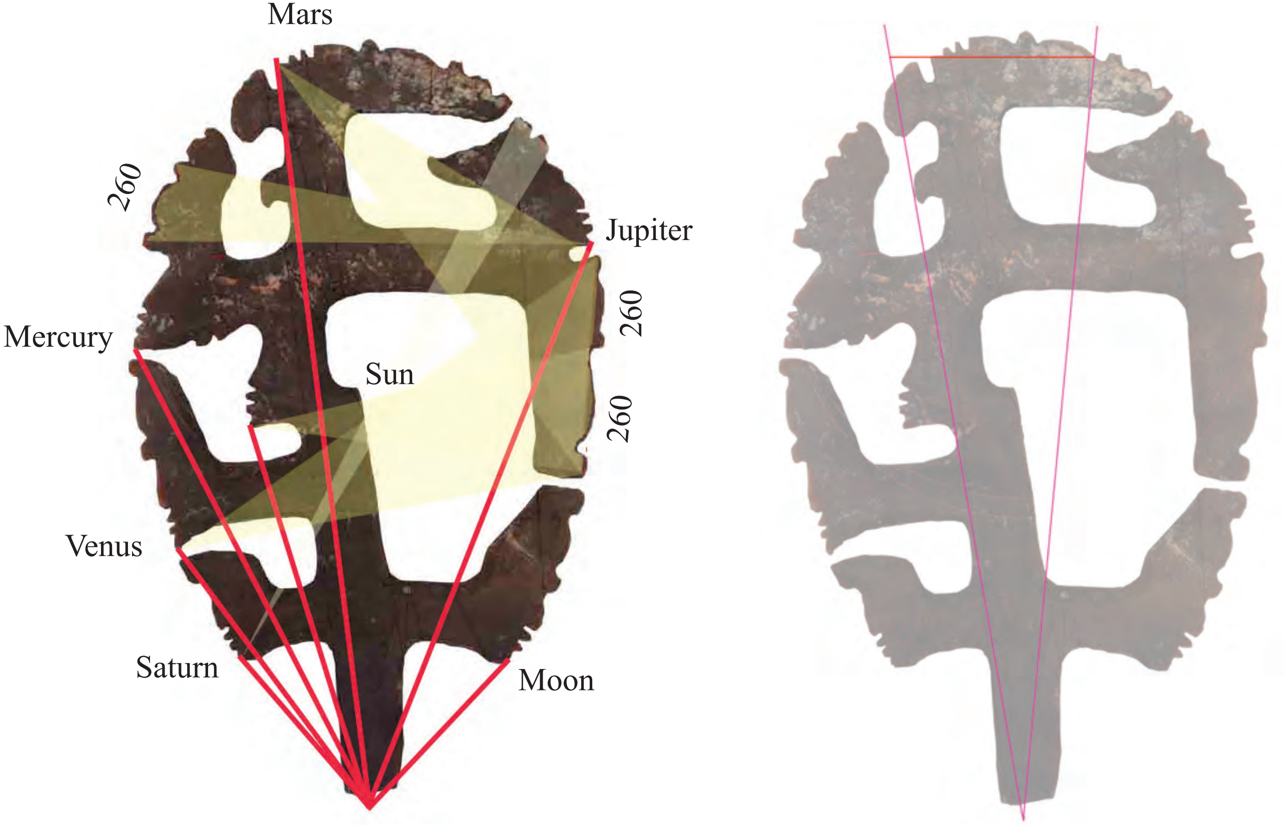
Each presentation uses a different rule for measuring a correction value along the ray from dead-center to the chin related to the primary measurement. A cut-off point is defined by connecting key features of the effigy. Arcs indicate discrepancies between precise proportion and desired synodic cycle remainders. The discrepancy differs for each presentation and can be measured along rays from dead center to each chin when appropriate cutoff lines are projected. While the scheme for indicating corrections described in the following pages might seem obscure to modern eyes, it could have been quite familiar and sensible to an ancient Maya.



This example is based on measuring along a radial from the nadir.

The reference line can be marked off in arbitrary units, but the presentation line represents actual physical distances on the effigy.

Radial from nadir



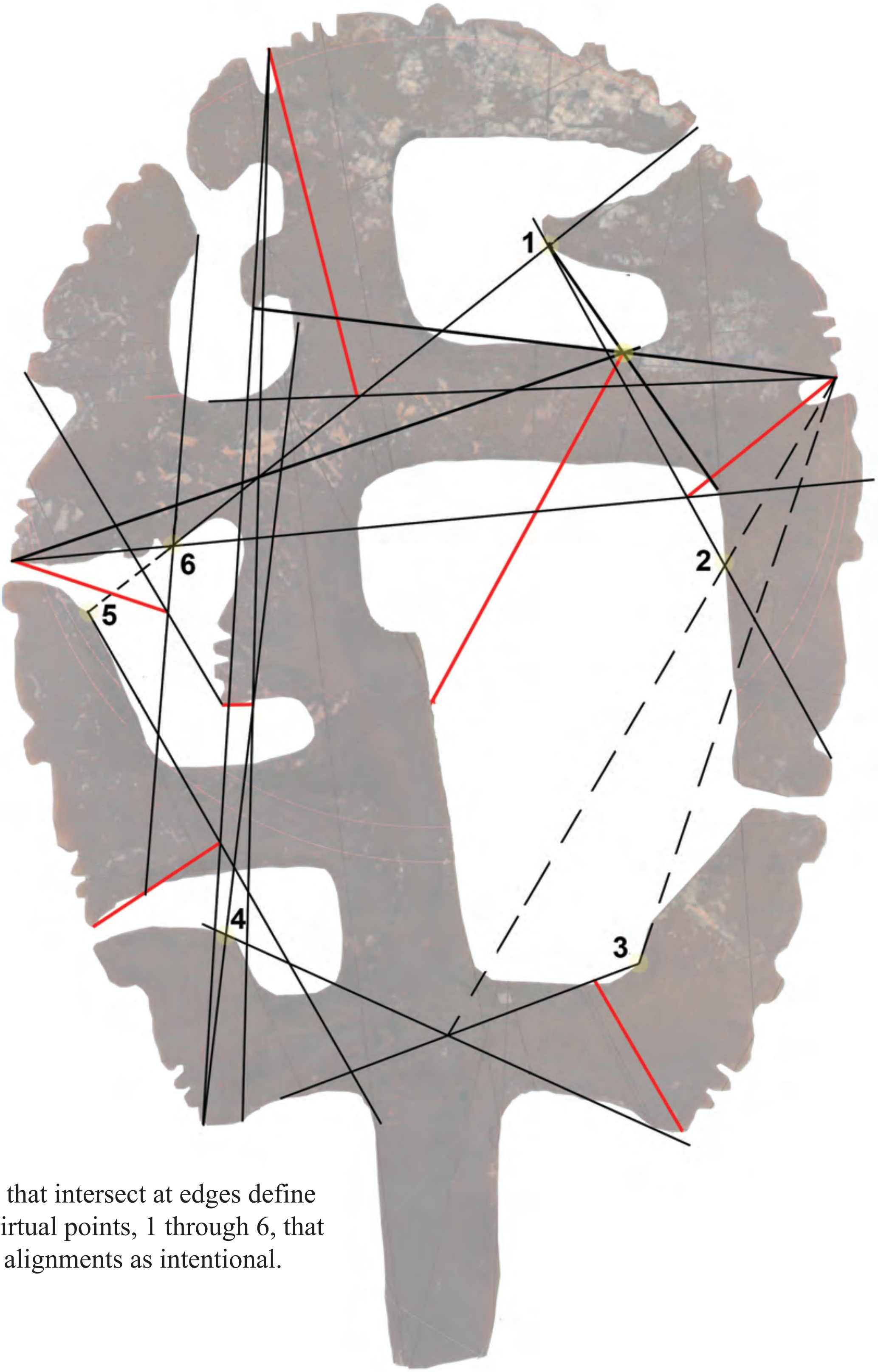
Raw measurements from the nadir at the bottom center of the bounding rectangle, as shown at the upper left, produce synodic cycle counts as much as 21 days in error.

Bracket-like symbols on the headdresses identify the number of 260-day modules that must be added to residuals. The corrections required to match cycles may seem capricious, but they follow consistent rules and appear to be the best option that would not require changing the frame of the design. In other words, this artifact would have required operating instructions in order to extract the fullest meaning possible. A radial wedge reaching back along each neck, but avoiding the central nape, indicates the proper 260-day cycle module on the opposing headdress: one for the Sun, one for Jupiter, one for Saturn, two for Venus, and two for Mars.

Corrections measured on rays from chins to dead-center, indicated by cutoff lines, are shown on the following page. The primary rule is to draw a tangent from below a neck to an inflection point on a headdress. Additional cutoff alignments reinforce all but the measurement for the Moon. Edges were then forced to correspond to those points. No corrections are required for Mars if a 260-day residual is used. Otherwise, the rule-driven corrections provide the same result. The scale of presentation is 1.1411 mm per day, but the synodic cycle record remains accurate within 4.6 days.

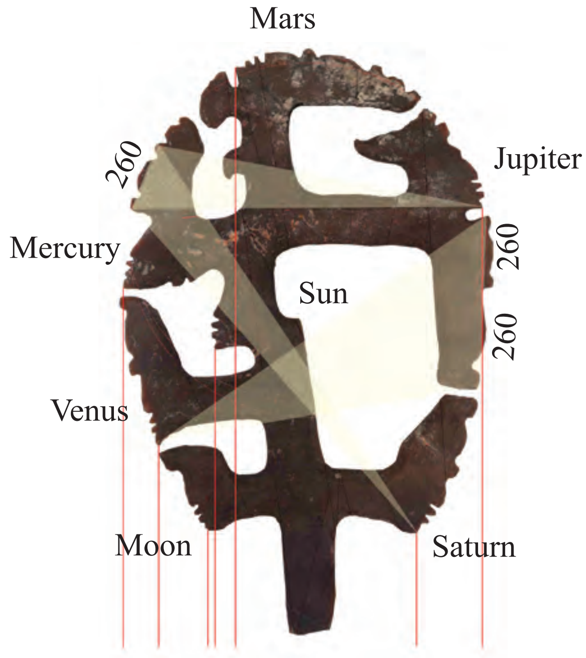
The residual cycle values would have allowed using the central location for either Mercury or the Sun. By placing the Sun at the center, the artist may have signaled movement of the other planets centered about the Sun, or simply that the Sun dominates the other visible heavenly objects. Clockwise from the lower left, the remaining objects can be identified as Saturn, Venus, Mercury, Mars, Jupiter, and the Moon.

90% actual size



Cutoff lines that intersect at edges define numbered virtual points, 1 through 6, that confirm the alignments as intentional.

Vertical from base



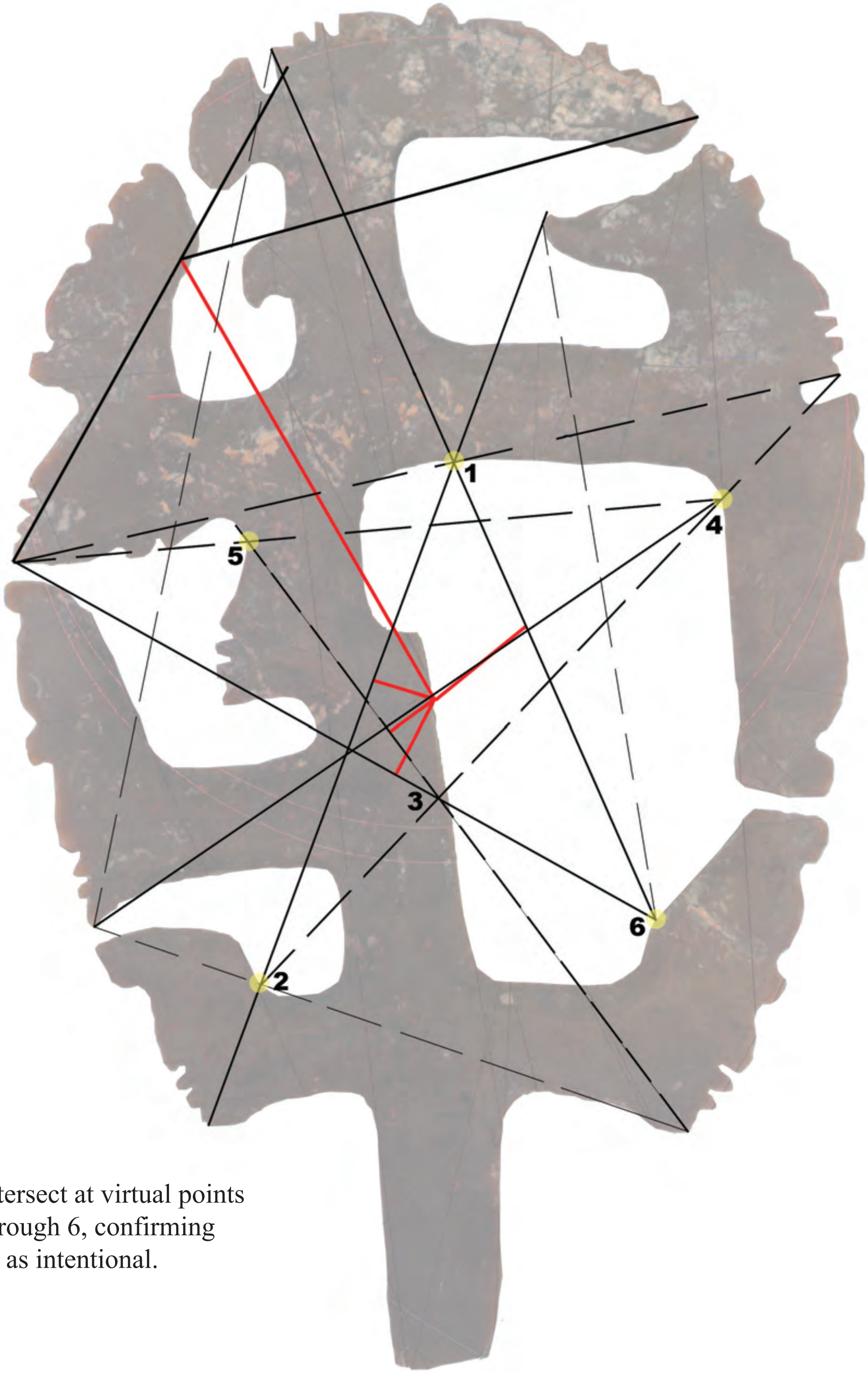
Measuring the vertical distance of each chin from the base produces synodic cycle remainders in error by as much as nineteen days.

The maker of this effigy achieved a condensed layout by using 200 days for the Mars cycle remainder, and had to indicate the extra distance to make the data equal 260 days. Radial lines from the bottom center, that subtend 62.4 mm at the level of the top chin, are positioned by making them tangent to the tip of the right headdress and the down-turned beak at the upper left of the central stem. There is no confusion that the extra measurement, illustrated at the upper right, needs to be applied to the upper figure because the lines bracket no other faces. Interestingly, if the addition is ignored, so can the correction—yielding the same answer either way.

Bracket-like symbols on the headdresses identify the number of 260-day modules that must be added to residuals. A radial wedge reaching back along each neck, but avoiding the central nape, indicates the proper 260-day cycle module on the opposing headdress: one for the Sun, one for Jupiter, one for Saturn, two for Venus, and two for Mars.

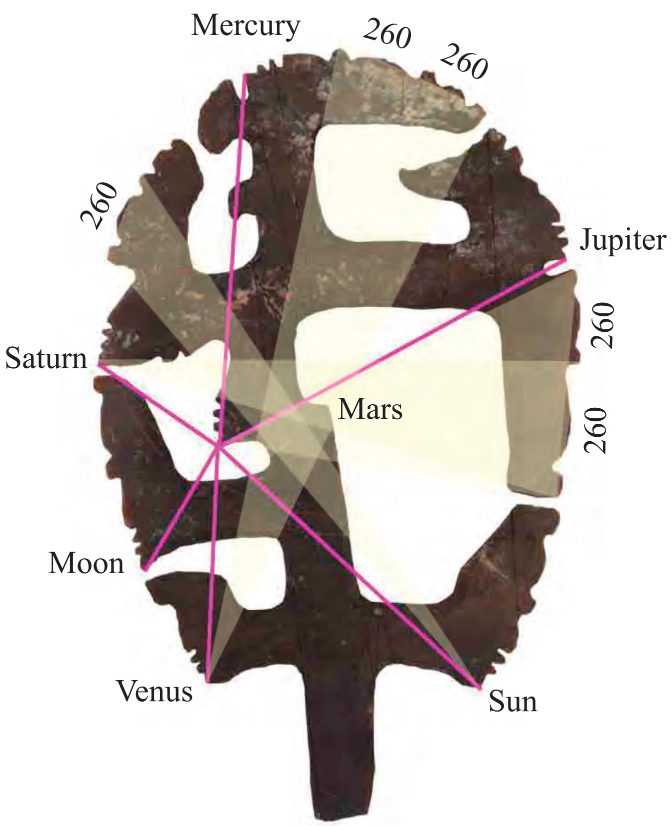
Cutoff lines that indicate corrections for this presentation also position points on the headdress edge. The first line passes from Moon's chin to the tip of Jupiter's headdress, defining points **1** and **2** on the artifact edge. The next cutoff goes from point **2** to Jupiter's chin, defines point **4** at the artifact edge. Point **3** can then be defined by a ray from Saturn's chin to a tangent on Mercury's throat. The ray from Mercury's chin to point **4** defines point **5** as the intersection of two rays and the artifact edge. A line from Mercury's chin through point **3** defines point **6** on the artifact edge. A ray from Mar's chin contains both point **1** and **6**. The line from Saturn's chin to point **5** also passes through point **3**. Finally, connecting the chins of Mercury and Jupiter reinforce the position of point **1**. Dashed lines reinforce the correct alignments, but do not serve as cutoffs. Interior edges of the effigy were carefully adjusted to coincide with pre-planned intersections indicated with numbers, leaving no doubt as to intent. Point **3** was too far into the main stem to force an edge to meet it. No corrections are required for the Sun and the correction for Mars is slight.

90% actual size



Cutoff lines intersect at virtual points numbered 1 through 6, confirming the alignments as intentional.

Radial from center chin



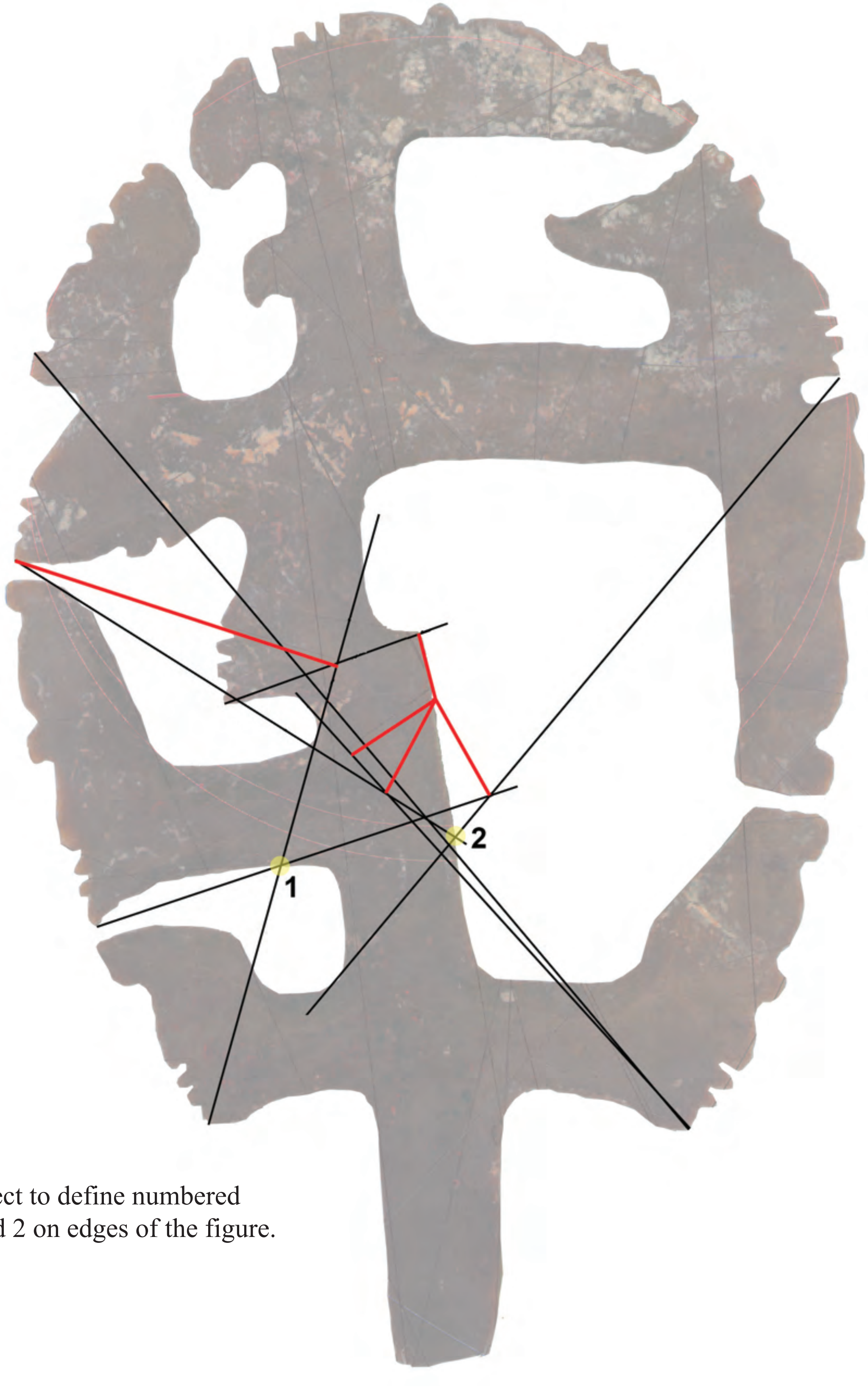
Measuring from the central chin places Mars at the center, and fits synodic cycles within 18 days, prior to applying corrections. This solution is completely independent of the bounding quadrilateral.

Because this presentation assigns a new identity to some of the faces, the number of 260-day modules that must be added to residuals requires a different rule. However, the results remain the same as before. The corrections required for this presentation are found by projecting a radial wedge expanding no more than 25 degrees, and just touching the central neck nape to indicate the proper 260-day cycle module on the opposing headdress.

Only three cutoff lines are needed to indicate corrections measured on rays from chins to dead-center. The primary rule is to connect chins with neck tangents, but other alignments are provided for reinforcement. Just two intersections reinforce edge location in this case. No corrections were needed for Mars or Jupiter. After corrections, a presentation scale of 0.869 mm per day gives cycles accurate to a day.

Scale values depend on accurate measurements, so an error of one millimeter in the largest reference value of 260 can change the scale by 0.0038 mm. Nonetheless, the data presented on pages 108 and 109 allows two units of measure to be postulated. The first is between 1.131 mm/day and 1.141 mm/day. The other is 0.869 mm per day. The two scales are inverses of each other. The variation of scales parallels decisions made while laying out the starting quadrilateral frame.

90% actual size



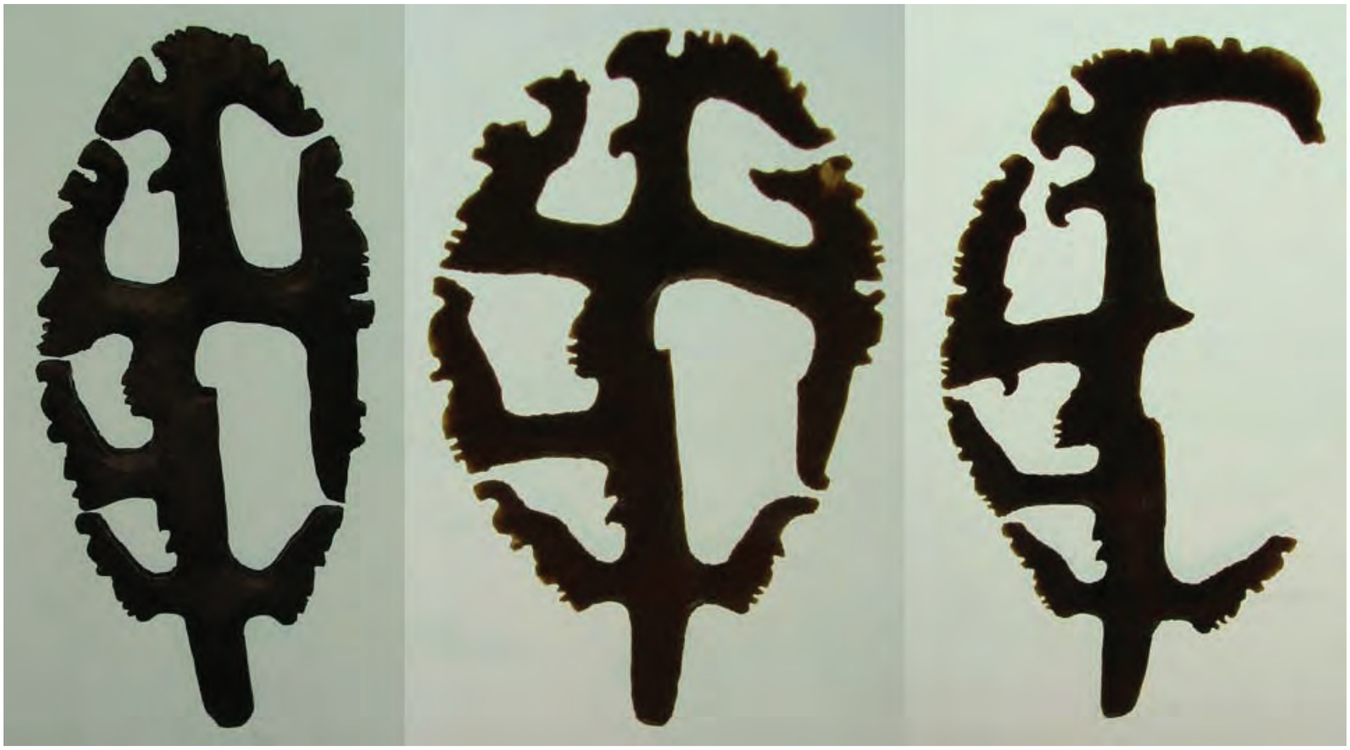
Cutoff lines intersect to define numbered virtual points 1 and 2 on edges of the figure.

Reference scale

While scale can be recovered based on modern astronomical knowledge, a 260-day reference ray that matches the scale determined from the heavenly rectangle perimeter was included at the center of the figure. Rays drawn from the upper chin and headdress tip to touch the stem base intersect at O, 1.3 mm to the left of the central axis. Measuring vertically from that point reaches the top at *exactly* the distance required to match the Mars-centered presentation scale. The central reference scale is nearly independent of the heavenly rectangle, but the vertical line requires true orientation to give the correct reading.

Comparable works

Under the direction of William Fash, David Stuart (Stuart, 1986) discovered three chipped stone figures underneath the hieroglyphic stairway at Copan in Honduras, dedicated in the year 755 AD. Marvelous works of art, each of the artifacts contains seven faces. A major element containing a face was broken off one example and a replacement face was added to the upper left segment. Overall proportions do not adhere to the heavenly rectangle, and the design elements differ in subtle ways. The variations highlight the difficulties in extrapolating Maya principles from too restricted a sample. The general iconography remains the same, but decipherment is difficult due to individual treatment and each eccentric seems to have its own system of coded measurement.



Copan Village Museum of Archaeology. Photos by Barbara McKenzie mayaruins.com/copan/a1_1138.html.

The center figure from Copan accommodates seven quadrilateral/ellipse frames, each validated by dead-center alignments as shown below. Orientations change by 9.1 degrees between frames.

Discussion

The inclusion of so much information in chipped stone is beyond redundant, it has the feel of someone exploring the limits of his craft. In fact, each craft necessary for creating the artifact has been demonstrated at the highest level of proficiency.

A previously unrecognized basis for the Maya calendar can now be linked with a tangible geometric expression. That the basis of design agrees with the Maya myth of creation as mapped to a thirteen by twenty-one tile grid means that the artifact is likely intended as a replay of the creation myth. Since Maya rulers represented themselves as gods on earth, demonstrating godlike abilities would be necessary to validate their authority. The extensive intertwining of data must have been worked out incrementally over generations, challenging each new ruler to prove their worth. Surely this effigy passed the test.

While a true golden rectangle can be precisely defined by simple geometry, the heavenly rectangle demonstrated here uses a completely different approach. Mathematical calculations show that the height of the rectangle varies by only four tenths of a millimeter between the two concepts. Because such slight deviations in positioning the missing rectangle base are not recoverable, we cannot resolve directly which rules were used for layout. However, acknowledgement of grid nodes in design placement makes a compelling case for a thirteen by twenty-one grid basis.

Not only does this artifact constitute a record of seven synodic cycles in a way unique to Maya archaeology, it provides a measure of the precision to which the Maya represented the average of each cycle. There can be no doubt that they commanded a level of detail far beyond integer notation. Confirmation of a standard unit of measure demonstrates an unsuspected ability to replicate observations and document plans. Precision of feature placement in the sub-millimeter range while working in flint most likely parallels their capacity for accurately observing and recording astronomical data.

For the cycle records to be recovered accurately to the day requires feature placement and subsequent measurement to be within one millimeter. The Photoshop™ program accommodates measurements to the nearest tenth of a millimeter. When measurements are combined to produce significant numerical values, the accuracy requirement rises. For example, measuring the frame perimeter calls for an accuracy of 0.5 mm per side. The appearance of numerous scales on the final page is somewhat misleading because each millimeter of measurement error changes the scale by about 0.004. In other words, the craftsman did not necessarily use a different measuring devise for each presentation.

A number of applications have been explored. Scale determined by correlating the perimeter with the creation myth is entirely independent of the scales measured to each chin. Three presentations that correlate to known physical phenomena provide unambiguous references. A pronounced tendency for measuring from intangible reference points shows that the rules of Maya geometry will need considerable clarification before declaring that precision is lacking. Highly symmetric flint effigies, regardless of proportions, need to be viewed as potentially having numeric data contained in the perimeter of their bounding quadrilateral frame.

Deliberate inclusion of the broken stem means that the dimensions of the heavenly rectangle were established before the chert outline was flaked into shape. It also means that the entire presentation must have been planned prior to flaking the effigy. We have seen that the scales of presentation and units of measure were deliberately chosen rather than adopted for convenience. The exhaustive permutations used to portray the data serve to reinforce the mastery of accuracy and precision. Redundancy of alignment served to maintain accuracy, but it also leaves no doubt as to the intent of the craftsman. An enormous amount of advance planning must have been conducted and a larger model of this figure is not unlikely.

The means of compressing the data by subtracting modules of 260 provides explicit evidence that clock arithmetic was utilized in Maya mathematics. Clock arithmetic, or modulo math, facilitates precise determination of the alignments between various cycles over thousands of years by integer manipulation.

A superb acumen of geometry has been demonstrated by the use of the heavenly rectangle, ellipse, symmetry, and scale manipulation. While many more impressive chert effigies have been documented, mastery of lithic technology in this instance is well beyond that previously demonstrated.

It might be appropriate to compare Maya geometry with medieval alchemy. The Maya had plenty of precious metals and stones—their mission was to understand the cosmos. Their calendar and astronomical records testify to considerable success in the quest for knowledge. Alignments of crucial features seem to be coy signals to prove the existence of advanced geometry, but direct evidence was deliberately concealed. Perhaps the feeling was that Supreme Beings would appreciate the hidden message, while peers and subordinates would be appropriately mystified. Although over sixty measurements have been shown to convey intended values, no measurement between two tangible points of the artifact have been recognized as containing meaning by itself. Inferred geometry and projected intersections are necessary to unveil the hidden data. The data recorded was well known so there was no evident reason to hide it, but creating this artifact obviously symbolically re-enacted the creation myth. Deliberately incorporating a broken stem as a pointer exemplifies subtle mis-direction and multi-tasking of features. While searching for meaningful correction values, it was seen that clearly consistent rules were used, but multiple indications reinforce each value. The use of nearly forty pointers to position effigy edges reiterates the importance of reinforcing meaningful relationships.

It is unlikely that any thought was given to someone deciphering this artifact in the future, however it parallels our modern efforts at communicating with alien life by sending our own artifacts into space. In fact, the artifacts may not have been intended to be "read" by any but the Gods they acknowledge. In this case, we are an alien culture trying to tease out information about a mysterious way of thinking of the universe.

So many revelations from a piece of chipped chert tell us that, as remarkable as the artifact is, the real treasure is the recognition of a previously unknown mode of recording information. Data has been encoded in a way that has escaped notice for thousands of years. Such information is likely encoded in other art, and even site plans, as has been demonstrated for mound sites in Louisiana. Until comparative works are discovered and evaluated, we remain limited in our interpretation.

Footnote: The path of discovery regarding the use of this artifact started when I first saw it, and intuitively knew that it was much more than art. Next came the thought that since astronomy was probably the most important of Maya concerns, seven faces could represent seven planets. The hard part was figuring out how to collapse planetary cycles into such a condensed presentation. Recognition of an underlying grid that provides a linkage to a documented creation myth occurred only after all the other content had been recognized.

Measurements radial from the nadir at the rectangle base, with 62.4 mm added to the Mars distance for the purpose of establishing the correct ratio. Scale (on Mars) = 0.8764 day/mm, or 1.1411 mm/day.

ID	period (days)	residual (days)	radial nadir-chin (mm)	measure in Maya units (Au)	correction required (Au)	correction required (mm)	measured correction (mm)	cycle of record (days)	error (days)
Mars	779.936	259.936	296.6	259.936	0.0	0.0	0.0	259.936	0.000
Jupiter	398.867	138.867	189.3	165.900	-27.033	-30.846	-33.7	136.366	2.501
Saturn	378.0919	118.0919	60.8	53.284	64.808	73.949	68.7	113.492	4.600
Mercury	115.877	115.877	161.2	141.273	-25.396	-28.979	-28.1	116.647	-0.770
Sun (ctr)	365.242	105.242	124.4	109.022	-3.780	-4.314	-5.5	104.202	1.040
Venus	583.922	63.922	99.6	87.288	-23.366	-26.662	-26.4	64.151	-0.229
Moon	29.531	29.531	62.6	55.862	-25.331	-28.904	-30.4	28.193	1.338

How the data was processed, using radial measurements from the nadir as an example.

1) Calculate the scale as:
residual in days ÷ measured distance from reference pont to chin in mm = days/mm.

259.936 ÷ (234.2 +62.4) = 0.8764 days/mm.

2) Calculate the cycle of record as:
(measured reference distance - measured correction) × days/mm scale.

(189.3 -33.7) × 0.8764 = 136.366 days for the recorded cycle of Jupiter.

3) Compute difference between true residual and calculated cycle of record.

138.867 days -136.366 days = 2.501 days error for cycle of Jupiter

Vertical measurements from base to chin. Scaled by assuming zero correction on the Sun.
Scale (on Sun) = 0.8844 day/mm, or 1.1307 mm/day.

ID	period (days)	residual (days)	vertical nadir-chin (mm)	measure in Maya units (Au)	correction required (Au)	correction required (mm)	measured correction (mm)	cycle record (days)	error (days)
Mars	779.936	259.936	295	260.894	-0.958	-1.083	-0.9	260.098	-0.162
Jupiter	398.867	138.867	175.9	155.564	-16.697	-18.879	-16.4	141.060	-2.193
Saturn	378.0919	118.0919	46.2	40.859	77.233	87.330	86.3	117.181	0.911
Mercury	115.877	115.877	143.9	127.263	-11.386	-12.875	-12.0	116.651	-0.774
Sun (ctr)	365.242	105.242	119	105.242	0.000	0.000	0.0	105.242	0.000
Venus	583.922	63.922	80.5	71.193	-7.271	-8.222	-9.6	62.703	1.219
Moon	29.531	29.531	45.2	39.974	-10.443	-11.808	-12.6	28.831	0.700

Radial measurements from center chin to remaining chins.
Scaled by assuming zero correction for Jupiter.
Scale (on Jupiter) = 1.1505 days/mm, or 0.8692 mm/day.

ID	period (days)	residual (days)	radial chin-chin (mm)	measure in Maya units (Au)	fit in Maya units (Au)	correction required (mm)	measured correction (mm)	cycle record (days)	error (days)
Mars (ctr)	779.936	259.936	0	0.000	0.000	0.000	0.0	259.936	0.00
Jupiter	398.867	138.867	120.7	138.867	0.000	0.000	0.0	138.867	0.000
Saturn	378.0919	118.0919	44.3	50.968	67.124	58.343	58.6	118.388	-0.296
Mercury	115.88	115.88	114.2	131.389	-15.509	-13.480	-12.6	116.892	-1.012
Sun	365.242	105.242	108.7	125.061	-19.819	-17.226	-18.1	104.237	1.005
Venus	583.922	63.922	72.9	83.872	-19.950	-17.340	-17.5	63.738	0.184
Moon	29.531	29.531	43.9	50.508	-20.977	-18.232	-17.4	30.489	-0.958

Comparison of scales

ID	Measured reference (mm)	mm/day scale	unit/mm scale	Reference value (days)	Location
O-A	297.4	1.1441	0.8740	259.936	central vertical
	296.6	1.1411	0.8764	259.936	Radial from nadir, Scale on Mars
	119.0	1.1307	0.8844	105.242	Vertical base to chin, Scale on Sun
	120.7	0.8692	0.1505	138.867	Radial center chin to chin, scale on Jupiter
box Width×2	297.4	1.1441	0.8740	259.936	2 × width of box frame
box Width×2	297.4	1.1438	0.8742	260	2 × width of box frame
box Height×2	480.4	1.1438	0.8743	420	2 × height of box frame
box Height×2	480.4	0.8735	1.1449	550	2 × height of box frame
box Perimeter	777.8	1.1438	0.8743	680	Perimeter of exterior box frame
box Perimeter	777.8	0.9973	1.0027	779.936	Perimeter of exterior box frame

For consistency, all scales are calculated with synodic cycle reference values. Note that three scales are offered for the box frame, depending on which dimension is used for reference.

8

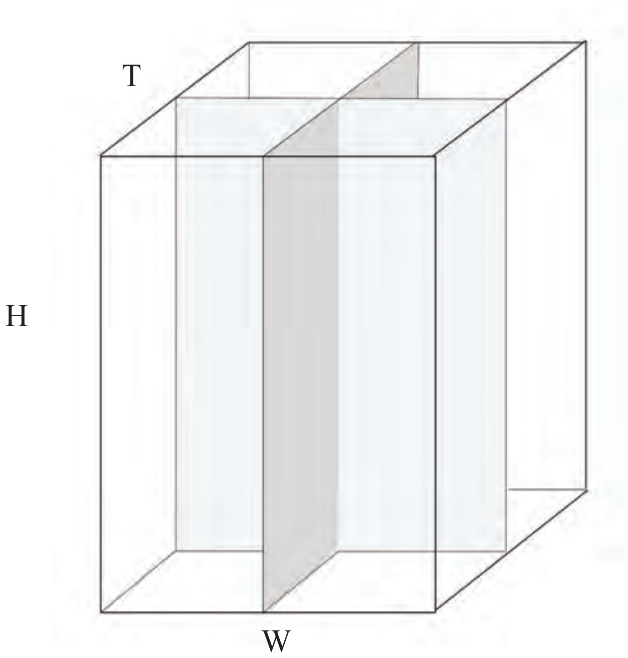
The Third Dimension

Through time, variations in conveying sacred information by measurements served to mask the system's cultural transmission. Similar geometric principles can be demonstrated to explain the layout of mounds along the Mississippi River and chert eccentrics in Guatemala, but no clear audit trail appears to reveal how those principles came to be shared. Where better to look for answers but in the leavings of the Olmec civilization, halfway in time and geography between the other major lines of evidence and often thought to be the progenitors of the Maya.

However, Olmec site layouts are not readily linked to Archaic practices in Louisiana and chert eccentrics are lacking. So, what clues might be deduced from known applications of measurement? Of the applications examined so far, two common aspects seem to stand out as particularly important. Power is evident in massive constructions of great scope and magnificent scepters of leadership. Spirituality is evident in linking heavenly messages to earthly recipients by myth and numeric acknowledgement of planetary cycles. Where power and spirituality intersect would be ideal.

Massive stone monuments and thrones built and transported by the Olmec over daunting terrain qualify themselves for special attention. Thrones, in particular, are obvious seats of power (Grove 1973), located prominently in relationship to occupational sites. Furthermore, they typically depict a person of influence crouched in the representation of a cave, signifying mythic origin stories. It is quite possible that the artifacts were built to contain dimensional "power," and were subsequently modified to disguise that power. If that were the case, interpretation is doubly difficult because none but the "gods" were intended to read the message. Made of basalt, the stone sculptures offer to be insensitive to alteration and are large enough to convey important numbers without ambiguity.

Principles of symmetry that allow interpretation of chert eccentrics by measuring a hypothetical bounding frame are suggested by mirror symmetry on each face of a throne, but how should the three dimensional aspect of a sculpture be treated? As shown on the following page, after adding height, width, and depth of an object, multiplying by four represents the cumulative dimensions of all edges in the bounding cube. The throne at El Marquesillo (Doering 2007:239-241) reveals the lunar cycle presumably responsible for the adoption of the primary calendric cycles. Four thrones from San Lorenzo (SL) show multiples of 260 and 365 in the perimeter values. A pure number of ten thousand is indicated in a throne from Loma del Zapote (LZ) (Coe and Diehl 1980:366-368). The throne from Estero Rabon (ER-8) (Cyphers 2004:273) uses a multiple of 365 just half of the value for throne #18 at San Lorenzo. Each of these sites was occupied during the Early Formative Period of the Southern Gulf Coast between 1200 and 500 BC. The numbers indicate a central role of calendric practise commensurate with later manifestations in Mesoamerica. As importantly, they show that counts of 260 and 365 were integrated at that time, despite lack of glyphic evidence.



Perimeter = 4 × (H +W +T)

Millimeter per unit scales average to nearly the identical values seen in a set of Maya chert eccentric artifacts, showing that precision and accuracy of measurements were controlled to the same standard and precision that would be exhibited over a thousand years later by the Maya.

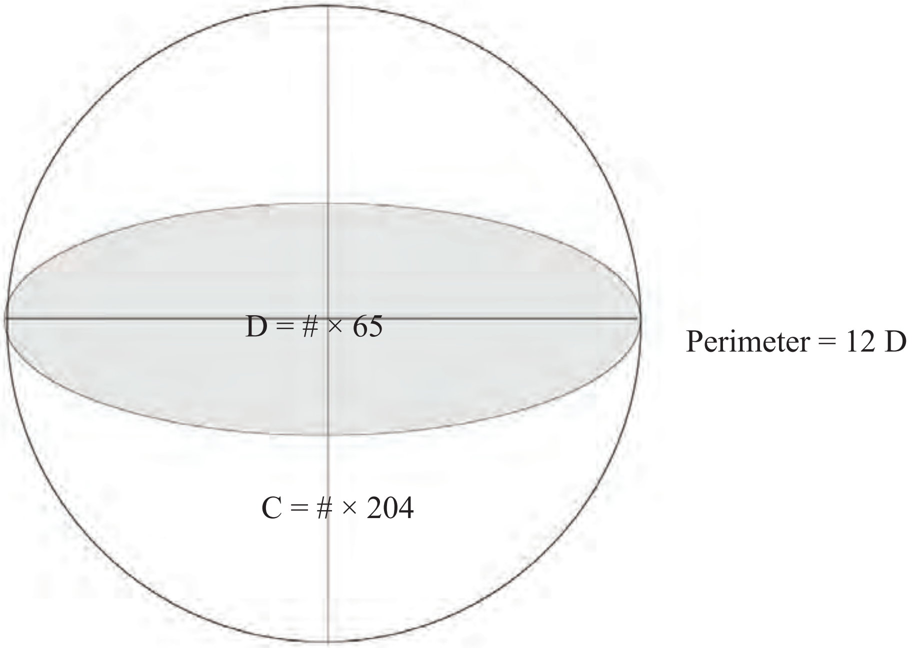
Throne	Width mm	Height mm	Depth mm	perimeter mm	value Au	mm/unit scale	representation
El Marquesillo	2495	1245	1130	19480	16,993 98×173.3 2.5×6797	1.1414	lunar node lunar cycle
SL #14	1830	3480	1520	27320	23751 65×365	1.1503	*haab’* multiple
SL #20	1670	2250	1500	21680	18,980 52×365 73×260	1.1423	calendar round *haab’* multiple *tun* multiple
SL #53	1850	2700	1350	23600	20,800 80×260	1.1316	*tun* multiple
SL # 17	1260	1670	1670	18400	16,060 44×365	1.1457	*haab’* multiple
LZ #2	940	1290	640	11480	10,000	1.1480	pure number
ER-8	1300	750	250	9200	8,030 22×365	1.1457	*haab’* multiple
						1.1447	average mm/Au scale

The Wooden Offering Container of Aj K'ax B'ahlam of Tortuguero was first reported by Michael Coe (1974) and well described by Marc Zender and Karen Bassie in an undated web page (http://www.kislakfoundation.org/tortuguero_discussion1a.html). This elongated rectangular container and lid are fashioned from hardwood. The base sits on four small feet, and has a raised inner lip that seats the lid securely. It is 153-mm long, 35.4-mm wide and 43.7-mm high, with carvings on the top, sides and bottom. Following the procedure used to analyze chert eccentrics, the major dimensions were summed and multiplied by four to produce a three-dimensional perimeter of 928.4 mm. At the scale of 1.144 mm per unit, the perimeter comes to 811.54 units, falling short of the 819-day *K'awiil* cycle by less than eight units and producing a scale of 1.134 mm per day. Assuming that the box has suffered shrinkage from drying and possible erosion, adding just 1.25 mm per face would match the 819-day cycle at 1.144 mm per day.

Another carved wooden box, recovered in poor condition from Tobasco, Mexico, (Anaya, Guenter, and Mathews 2001), has a three-dimensional perimeter within a couple millimeters of 1,300 American units—equivalent to the *zapal.*

Rubber balls illustrated in Maya art are labeled with a number and a glyph representing the word *nahb* for "handspan," according to Coe (2003:199-200) and Zender (2004). Zender assumes that the label represents an integer number of hand spans contained in the circumference. His sources suggest that a handspan measured between 208 and 234 mm, roughly 8 to 9 inches.

An alternative interpretation is to approximate the value of *pi* with an integer ratio. The closest ratio using familiar Maya values is 204÷65 = 3.1385. This proposal has the effect of applying a single integer to describe both the diameter and the circumference of a sphere. It is similar to assigning glove sizes. The diameter would be the integer label times 65, and the circumference would be found by multiplying the integer times 204. Multiplying 204 times the standard American unit length of 1.144 mm produces 233.376 mm, at the upper end of the range for a hand span suggested by Zender.



9

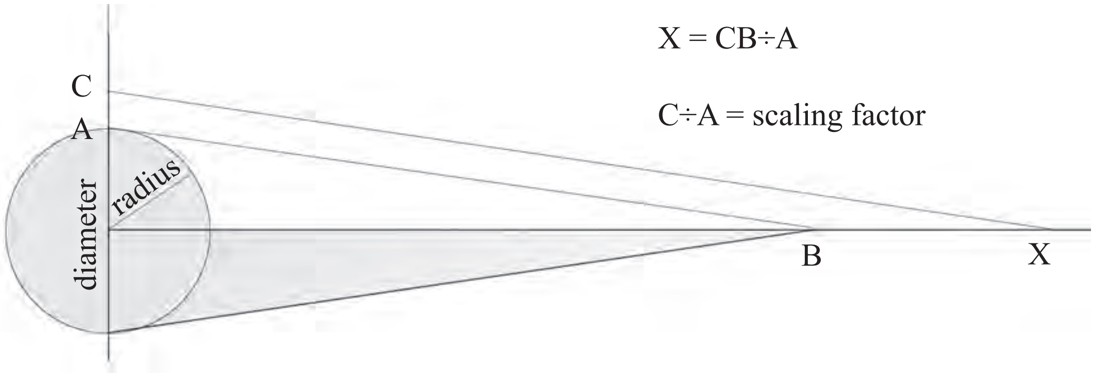
Math

Much has been made of the mathematical acumen of native Mesoamericans, including bar and dot notation as well as sets of data. Despite the acknowledged accomplishments, limited explanations have been advanced for how arithmetic operations were conducted. Even in codices, where data is presented and instructions are provided for using data that detail synodic cycle periods and predict eclipses, no record of simple arithmetic much less higher operations is visible. Spanish records have suggested the use of an abacus-like manipulation involving seeds moved within a grid, but such a system has not been successfully replicated or demonstrated by archaeology. Another possibility might be a finger-counting style of arithmetic like chismbop, as practiced by the Koreans.

It is easy to dismiss unfamiliar arithmetic relationships as numerology, particularly when the relationships appear to be inaccurate. However, such irregularities are often deliberate, tolerated for their convenience as computational shortcuts. Other relationships may seem to be parlor tricks although they are legitimate mathematical principles that are better suited to manual computation than computers. For example, the ratio 78:474.5 that is responsible for standardization of measurement can also be expressed as 949:5773. Dividing 5773 by a series of three-digit numbers: 111, 222, 333, ... yields a new set of numbers related to factors of thirteen and the lunar node value of 173.3. No claim is being advanced to suggest that Maya mathematicians used these tricks, but if they had, would they represent numerology or good math?

Deciphering and interpretation of numeric information embedded in artifacts by early Americans points to the possibility that earliest math was inherently graphical. The lack of notational computation is suggestive of a graphic approach, and tangible records of math in early site layouts use graphic construction to derive a related set of significant values. It is more logical to postulate that the construction was designed to produce the values than to claim that the values were transferred onto a complex geometry that just happened to accommodate the data. The *K'awiil* effigy study demonstrates some of the versatility possible with graphical techniques.

Graphical addition is as simple as setting two measured objects end to end, like splicing lengths of string. Multiplication takes a more structured approach that is most easily accomplished on an orthogonal grid. After measuring out one unit (A) and a number of units (B) to be multiplied on the Y axis, it is a simple matter to read the answer (X) on the X axis. In this example parallel lines transfer proportional values between perpendicular reference axes. Another simple graphical technique uses radial lines from a reference point to transfer proportional values between any two straight parallel lines cutting the rays. Whatever the means of solution, to be of lasting use, it requires three more characteristics. First, there needs to be a standard unit of measure, as we have demonstrated. Secondly, the measure must allow repeated application of the requisite value. Thirdly, the measure must be sufficiently adaptable to accommodate any scale of presentation. Such a capability has already been demonstrated but more is needed to establish how the values were manipulated.



If B÷A = *pi*, it is easy to graphically find the circumference of a circle of any other diameter. Making B÷A = *pi*÷2 greatly condenses the construction. The mirrored appearance could help explain why the Maya associated 819 with the *K'awiil* mirror scepter.

The principle of graphic multiplication suggests a limited number of natural identities that lead to the concept of *Phi*. Algebraically, the geometry can be expressed by X = CB÷A. Division requires setting A to one. If X = 1 and A = 1, aside from the trivial solution of 1 times 1, the values for CB can be 1.618 times 0.618, or *Phi* times *phi.* Since the synodic cycle ratio of Venus to earth is 584÷365 or 1.6, it invites special attention. Multiplication is accomplished by setting B equal to one and thus X = C÷A. Substituting values of *Phi* and *phi* for C and A gives 1.618÷0.618 = 2.618, which is *Phi* squared and also close to a hundredth of 260. Another convenient set of substitutions assigns the almanac value of 260 for C, 365 for A, and (365 +584) for B, to make X = 94,900÷949 = 100. These basic relationships could have been easily discovered through graphic means to provide an early impetus to explore the mathematical structure that became the hallmark of Mesoamerican mathematics and calendric science. There are various graphical means to divide lines precisely by the golden proportions of *phi,* but because the relationship is irrational, it cannot be demonstrated exactly by manipulating integer notation. However, dividing *Phi* squared by one plus *Phi* is nearly identical to dividing 360 by 260. Such convenient mathematical relationships were surely exploited.

Christopher Powell describes a simple method of using string to construct the golden proportion (Schele and Mathews 1999:35,330) that is still used by native people and has been found in graffiti form in Maya ruins. Close approximations to the golden proportion are readily constructed by counting squares on a grid and expanding a Fibonacci series inherent in Maya myth. Perhaps most compelling evidence for the use of a grid is the discovery that treating Maya chert eccentrics as having thirteen columns of ten units each has been remarkably successful for recovering the base units needed to decipher the remainder of their numeric content. The fact that rectangular frames tangent to the artifacts have perimeters equal to significant numbers, such as synodic cycles, indicates a practice of joining physical representations of numbers. One artifact also combined seven rays to produce a composite value of seven hundred while using the same scale to define its rectangular perimeter as seven cubed. Because the component rays are non-integer values, we are led to believe that the physical distance was accumulated on a reference line of known distance and divided graphically. Repeated occurrences of meaningful values scattered throughout mound sites and chert eccentrics can be best explained by graphical construction that allowed proper integration of elements obviously meant to be "read" in a series of different orientations. The site plan at Watson Brake in Louisiana and a chert eccentric from Copan both have been demonstrated to have been designed as if there were transparent overlays that could be registered to each other at specific inclinations. Complex mathematical equations required to design such registration would require a computer to perform algebraic manipulation, but can be easily understood by invoking the use of portable transparency copies to achieve the right fit graphically. Particularly since numbers are demonstrated to be represented in artifact dimensions for several thousand years prior to the appearance of numeric notation, it seems prudent to accept graphical math as the foundation for early American mathematical practice and perhaps lasting to historical times. Elsewhere in the world, advanced mathematics are accompanied by algebraic equations, while none are physically evident in the Americas.

Algebraic calculations in the design of the long count calendar are perhaps the clearest indication that the principles of algebra were understood and applied. Every indication is that the referenced algebraic operation preceded any known glyph notation.

Simply the fact that the Maya practiced and recorded arithmetic operations is compelling evidence that standards of measure were applied. The precision of records further suggests the ability to measure with comparable precision. Vigesimal notation leads naturally enough to division by twenties but, since calendric intervals use additional divisions, it behooves us to consider other options as well. Anderson (1971) demonstrates that integer notation can accommodate any calculation required, without a decimal place holder. Using modulo math and adhering to the same basic intervals, whether calculating astronomic or domestic values, would be relatively easy. The few surviving codices contain extensive specialized multiplication tables that avoid the labor of repeating commonly encountered arithmetic operations.

Mathematical principles such as *Phi* and Fibonacci numbers are readily apparent in geometric construction. It is not so evident whether the Maya were aware of more abstract concepts involving equations, although many important numbers are the result of cross-multiplying simple equalities.

When working with cycles, clock arithmetic is very useful. Let's use a simple example comparing the Moon with the Earth, whose synodic cycles are 29.5306 and 365.2422 days in decimal notation. In terms of clock arithmetic, that measure uses a solar day to represent a full revolution of the clock dial. Using integer notation, the cycles are 29 and 365 days, with the decimal portion being the residual. Each time the Earth clock turns two revolutions, the Moon clock turns about 25. Precision is gained by comparing counts over progressively longer times. Thus, after four years, 1,461 revolutions of the Earth clock are paired with 18,058 revolutions of the Moon clock.

The ability to relate radius to circumference of a circle has been demonstrated, but chances are good that similar relationships remain to be explored. Proportional graphic techniques can be applied to pick appropriate radius or circumference.

Perhaps the best place to appreciate the potentials of graphic math is in the site designs of Archaic mound groups. We have already seen how circles of 365-unit radius, even though there are no visible traces on the ground, explain the organization of site features. Since the whole exercise is about finding meaning, there is no reason to suspect that the circumference of a 365-unit radius circle is close to a third of the lunar standstill cycle should not have piqued their curiosity. A large physical model of such an important long-term cycle would have facilitated an understanding of how other cycles might be reconciled. Other interesting relationships between diameter and circumference include:

If $D = 6\times365$, then $C = 6{,}880$, 83 days more than the lunar nodal cycle.
If $D = 6\times360$, then $C = 6{,}786$, 11 days short of the lunar nodal cycle.
If $D = 6\times361$, then $C = 6{,}805$, 8 days short of the lunar nodal cycle.
If $C = 364$, then $D = 115.865$; near the synodic cycle of Mercury.

Such comparisons surely included realizing that drawing another circle, with a diameter equal to the circumference of a 365-unit diameter circle, produced a circumference of 3,602-units; very near 10 times 360.

365 *pi* = 1,146.6
1,146.68 *pi* = 3,602

One might be drawn to place great significance on the similarity between the number 1147 and the fact that the American unit is 1.144 millimeters. However, because 1147 is a product of *pi* means that it is dimensionless and cannot be meaningfully associated with the metric system.

Conveniently, the product of 365 *pi* is mirrored by the daily advance of the Sun along the horizon by an angle equal to a tenth of *pi,* further justifying the division of a circle into 360 degrees. In modern algebraic terms, 3,602÷*pi* equals 365 *pi.* But, since integer representations are easier to communicate, the relationship could be represented by *pi* = 817÷260, good to four decimal places. So why did the Maya consider 819 to be more important than 817? The answer may reside in an integer sidereal relationship noted by J.Q. Jacobs (http://jqjacobs.net/archaeology/maya_astronomy.html), where 819 solar orbits equal 10,949 lunar orbits. Not only are the numbers numeralogically significant, the relationship is accurate to ten decimal places. There should be no reason that sidereal relationships could not have been recognized and utilized.

Because 819 factors into 7×9×13, when it is used in four-part cycles to install *K'awiil* mirror scepter monuments, the first day of each 819-day cycle always starts with day one of the trecena count. Likely, the incorporation of 819 into ritual stems from this hierophany involving an already useful number.
At the end of the 4×819-day cycle, the Moon cycle is only out of register by two days after nine years. Furthermore, as Tedlock (2010:65) remarks, the Moon would have shifted by one position in the 13-sign zodiac. Factoring of four cycles of 819 days reveals a series of potentially useful numbers:

4×819 = 3276, but 332 pi^2 = 3277.

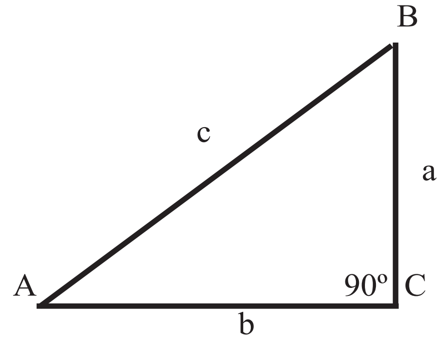
3276÷13 = 252
3276÷ 9 = 13×28
3276÷7 = 13×36
3276÷6 = 13×42

Christopher Powell (1997:12-18) proposes that 819 was utilized to commensurate synodic cycles of Saturn and Jupiter. However, the cycles of Saturn and Jupiter have already been shown to be integer factors of the lunar standstill cycle. Recall as well that 819 is present in the factored dimensions of the master geometry at Poverty Point, so its importance may be signified in multiple ways. For example:

365×2,600 = 949,000 = 819×1,159 = 819×10×Mercury synodic cycle.

Reconciling an array of cycles by integer factors would have been much more useful than precise algebraic calculation, particularly since graphical math does not require explicit recognition of *pi.*

Trigonometric relationships

A +B +C = 180º		
Given	Sought	Formulas
abc	A	tanA = a÷b
	B	90º -A or cos B = a÷c
	C	90º
	Area	ab÷2
aAC	B	90º -A
	b	a cotA
	c	a÷sinA
	Area	$(a^2 \text{ cotA})\div 2$
acC	A	sinA = a÷c
	B	90º -A or cosB = a÷c
	b	$\surd(c^2 - a^2)$
	Area	$(a \div 2)\ \surd(c^2 - a^2)$
abC	A	tanA = a÷b
	B	90º -A or tanB = b÷a
	c	$\surd(a^2 + b^2)$
	Area	ab÷2

Trigonometric relationships describe proportions of right triangles as indicated above. We use computers or tables associating functions with their decimal values to solve the relationships mathematically. Ancient people needed only to measure the triangle legs to represent the angle by an integer ratio, usually a÷b or b÷a. They could have assigned numerical values to angles as we do by dividing a circle into 360 parts, but no direct evidence for recording angles with numeric values is known.

Clock Arithmetic

Those of us who rely on a calendar to anticipate when events of the seasonal year will occur can find the long count bewildering. After a few years, the misalignment between the *haab'* and the seasonal year seems impossible to manage. How might ancient people have dealt with the problem? Surely they needed to know when to prepare for harvest and were interested in knowing when solstice would manifest, not to mention an eclipse.

Integer counting by days ignores the discrepancies, or slippage, between the count and the actual decimal intervals. A completed integer cycle is formed when the accumulated fractional surplus caused by slippage adds one to the integer count. Even though numeric notation is restricted to integer values, decimal equivalences are represented by precise linear measurements, showing that the concept of fractions was well understood.

The ease by which we can position cycles to decimal precision by calculators tends to blind us to the challenges of performing the same operations without modern aids. We too easily lose track of the difficulty in determining the appropriate decimal representation of a tropical year when we can just plug the constant in from a convenient lookup table. Calculators are helpful in confirming our results, but simple arithmetic operations are readily available to illustrate how ancient people could achieve accurate results. It helps to think in terms of a clock, where each of the hands track a different cycle of time.

Finding the number of days required for cycles to regain perfect registration with each other is expressed algebraically by:

$$\text{cycle}_1 \div (\text{cycle}_1 - \text{cycle}_2).$$

Dividing cycle_1 by the difference between the cycles shows how quickly they diverge from each other and lets us determine the number of days to accumulate slippage equal to cycle_2. For an appropriate example, 365.2422 -365 = 0.2422, and 365.2422÷0.2422 = 1,508.019 tropical years. In 1,507 *haab'* years, the day count advances by 365 to keep the tallies reconciled. Over the course of 13 *b'ak'tuns,* there are seventeen such calibration intervals, or 17×1,508 *haab'* years = 25,636 *haab'* years. As the following table shows, integer intervals may be easily added and subtracted to accurately position cycle breaks in regard to the seasonal year.

Elapsed time	Tropical year-*haab'* slippage	Elapsed time	Tropical year-haab' slippage
1,508-day *haab'* count	1 day	1,508 *haab'* years	1 *haab'* year
25,636 days	17 days	25,636 years	365 *haab'* years

In order to determine how many days are left over at the end of the 5,125 year epoch, we can start with the full epoch period of 1,872,000 days and subtract out three intervals of 1,508 years that remain neutral to the seasonal year.

1,872,000 days minus 1,651,260 (3×1,508×365) leaves 220,740 days remainder, from which we need to subtract 604 full *haab'* years to find the number of days remaining in the last incomplete *haab'*.

220,740 days minus 220,460 (604×365) leaves 280 days remainder, but we have to subtract an additional slippage of 146 days (220,740÷1,508) to find the actual remainder of 134 days.

Note that the basis for these calculations is easily obtained by careful observation and comparison of counts from various cycles. Once the fundamental patterns have been realized, the principles may be applied to short-term intervals or thousands of years with equal facility.

A similar analysis of the lunar cycle shows that combining two cycles makes 59.0612 days a convenient interval that fulfills its first integer completion in 965 lunar cycle pairs taking 57,016 days. Various multiples of that number can be used to accurately position a future full Moon nearly as accurately as we positioned the solstice through simple integer arithmetic. Once the technique is mastered, any astronomical cycle that can be observed and counted can be accurately positioned in time.

Important numbers in Maya cosmology

37,960	Double calendar round of 104 *haab’s,* least common multiplier of *haab’, tzolk’in,* Mars, and Venus cycle (40×(584 +365)) = 40×949 = **13×2,920**
18,980	Calendar round, least common denominator of *haab’* and *tzolk’in,* 52 *haab’* years (73×260 = **4×5×13×365** = 52×365 = 65×2,920 = 20×949)
11,960	405 lunations, (46×260 = **13×920**)
7,670	(21 years = 65×118 = **13×590**)
7,200	*K’atun* (20×360)
6,797	Lunar nodal cycle
6,760	**13×520**
6,585	Saros eclipse cycle
4,400	149 Moons in period covered by Dresden codex.
4,095	(9×65 = **13×315 =** 5×819)
3,276	**(13×252 =** 9×364 **=** 4×819)
2,920	8×365 = 5×584 = 99 lunar months. Earth, Venus, Sun, and stars line up in previous positions
2,792	(7× Jupiter = 8×349)
2,393	(6× Jupiter)
2,392	(81 lunar months = 46×52 = **13×184**)
1,820	Five rounds of the zodiac = 7 rounds of 260-day cycle. (5×364 = 7×260 = **13×140**)
1,560	(27×780 = 9×173.31 = 6×260 = **13×120**)
1,508	Interval at which the tropical year is seasonally matched with the *haab’* (4×13×29 = 4×377 = **13×116**)
1,300	*Zapal,* arm span (25×52 = **13×100** = 5×260)
949	(584 +365) = **13×73** = number of 20-day *winals* in a calendar round
819	(7×9×13 = **13×63** = 7×117) cycle timing raising of a *K’awiil* monument, (9 +9^2 +9^3), (Sum of numbers 2 through 40)
779.936	Mars synodic cycle (780 = 3×260) ~ (**13×60**)
583.922	Venus synodic cycle (584 = 8 +8^2 +8^3 = 8×73 = 365×8÷5)
519.93	Three eclipse half-years (519.93 = 3×173.31) ~ (**13×40**)
398.867	Jupiter synodic cycle (399 = 7 +7^2 +7^3)
378.0919	Saturn synodic cycle
377	Quarter leap year interval, (**13×29**), 365 +13
365.2422	(~5×73) Tropical year (modern value)
365	Vague year, (5×73) *haab’*, 18 months of 20 days plus five unnamed days
364	Accounting year, with 28 days between each of thirteen zodiac signs, (**13×28**)
360	*Tun* (5×72 = 3×4×5×6)
354	(12×29.5) days in 12 lunar months
346.62	Eclipse year
324.841	(148 +177) interval between eclipse of Sun and Moon (**13×25**)
300	(3×4×5^2), useful for interlocking cycles of Venus.
260	*Tzolk’in*, (4×5×13) Maya 260-day divination cycle, interlocks Venus, lunar month, Jupiter, solar year (**13×20**)
225	Integer value of Venus sidereal cycle = 15^2
224.701	Venus sidereal cycle

221.5385	Half Venus passage cycle
177.1854	(177) Six lunar months between eclipses
173.31	Lunar-node interval, where eclipses are possible
147.6545	(148) Five lunar months between lunar eclipses
118	Four lunar months
117	(**9×13**), near Mercury cycle, area of underworld
115.877	Mercury synodic cycle (116 = 4×29)
104	Interval for 5-day correction to calendar (2×52 = **8×13**)
99	Number of lunar months in 8-year Venus-Earth cycle.
91	One season, factor used in Dresden codex, (sum 1 through 13 = **7×13**), one-quarter of 364
73	365÷5
72	360÷5 = 8×9
65	One-quarter *tzolk'in* (**5×13**), factor used in Dresden codex
59	Two lunar months
52	One-fifth *tzolk'in,* (**4×13**), factor used in Dresden codex, related to Mars 780-day cycle
29.53059	Lunar month
28	Days between each of thirteen zodiac signs
27.21222	Draconic month
20	Number of days in a *winal,* sum of Fibonacci numbers 1 through 8
18	Number of 20-day *winal* months in a year
17	Integer difference between tropical year and *haab'* after 25,636 days
13	Number pairings with 20 day-names in 260-day divination cycle, layers of heaven
9	Levels in underworld, Lords of the Night
7	Seven orbital cycles tracked by the Maya
5	*Wayeb*— last 5-day month of year

10

Unification

The system of measurement in use by Maya and Aztec people when the Spanish arrived matches that used to position mounds in Northern Louisiana thousands of years earlier. Not only do the case studies agree that a standard base unit near 1.144 mm was used to record numerical information, they uniformly demonstrate a preoccupation with astronomical and astrological values. Although the Maya use of the heavenly rectangle provides a common denominator that ties multiple examples at a scale of 1 to 1, it does not explain how the Maya dealt with larger scales.

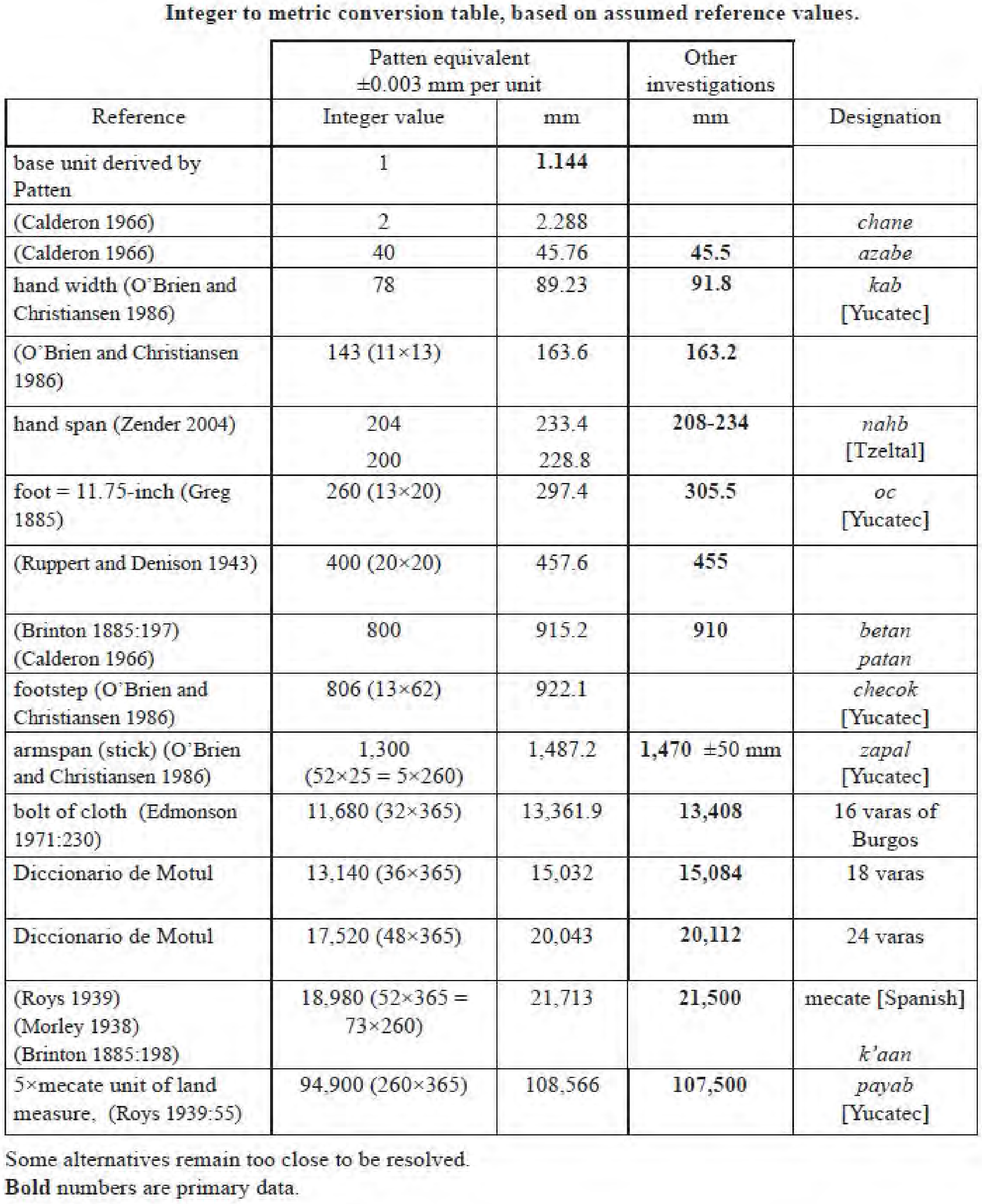
Statistical correlation has already shown that measured intervals from dirt mounds and chert eccentrics can be plausibly associated with a known set of astronomical values. It stands to reason that measures of other items should follow the same pattern. Now we need to question how measurements at various scales might be interrelated.

The following tables show how various proposals for Maya units of measure appear to correlate. Note that associating intervals with numeric values produces different results from assuming that the arm span interval was divided into regular sub-units. Inspection reveals that certain intervals served as convenient sub-units that were expanded as integer multiples. In some cases, those intervals correspond to divisions previously postulated by other researchers. The most important aspect of my proposal is that each measurement has a significant numerical value associated with it. Dimensions of objects now can be related to astronomical observations through numeration. Integer notations are seen to be a minor handicap with near-millimeter units. Not only can the standard unit can be recovered from archaeological measurements, we have seen that it can be replicated to the observed precision.

Comparisons to the Spanish vara of Burgos arrive at a Maya value of 2×364, or 14×52. Larger units of measure appear to have been designed as multiples of significant numbers. Even as early as 6,600 years ago, large mounds were constructed with equivalent units of measure, from the Mississippi River Valley to Peru. Through time, the emphasis shifted from one basic component factor to another. It is typical to divide units of measure as there is a need to quantify smaller intervals. While it may seem reasonable to expect halves or thirds, the Maya apparently preferred increments of thirteen. Analysis of the large cache of chert eccentrics supports the trend of measurements that are multiples of thirteen. Not until measurements are given Maya numeric values do the underlying factors become evident.

Experience with most modern measuring systems would suggest expansion and contraction of scales to follow regular multiplication and division by regular intervals, like tenths or twentieths. However, the Maya use of variable expansion intervals is not fundamentally different than moving progressively from inches to feet to yards and miles. Each series is simply recognized by convention as most appropriate for specific circumstances. Mound plans in Louisiana were scaled similarly to fit the available landscape. Modules of 13, 20, 52, 260, 364 and 365 are apparent. The ability to incorporate modules of lower intervals into higher level modules seems to have been viewed as almost magical, it certainly highlights the interlock of various cycles. The 1,300-unit *zapal*, for example factors by 13, 52, and 260. The 94,900-unit *payab* factors by 13, 52, 260 and 365. Surprisingly, few intervals lend themselves to explanation by base 20 factorization.

Tables of documented Maya measurement intervals on the following pages show that defined intervals represent meaningful numeric values, but best fits may be difficult to resolve. As examples discussed previously have shown, other measurements are given meaning by tallying the number of base units included between start and end of a line. Comparisons with other researchers indicate that the interpretations of unit values are plausible. Many of the measures deviate by little more than the range of variation already acknowledged for the proposed scale. A quantifiable level of precision does much to improve the study of measurement. Among other advantages, it accommodates a logical means to determine the precision appropriate for recording archaeological data.



Integer to metric conversion table, based on assumed reference values.

	Patten equivalent ±0.003 mm per unit		Other investigations	
Reference	Integer value	mm	mm	Designation
base unit derived by Patten	1	**1.144**		
(Calderon 1966)	2	2.288		*chane*
(Calderon 1966)	40	45.76	**45.5**	*azabe*
hand width (O'Brien and Christiansen 1986)	78	89.23	**91.8**	*kab* [Yucatec]
(O'Brien and Christiansen 1986)	143 (11×13)	163.6	**163.2**	
hand span (Zender 2004)	204 200	233.4 228.8	**208-234**	*nahb* [Tzeltal]
foot = 11.75-inch (Greg 1885)	260 (13×20)	297.4	**305.5**	*oc* [Yucatec]
(Ruppert and Denison 1943)	400 (20×20)	457.6	**455**	
(Brinton 1885:197) (Calderon 1966)	800	915.2	**910**	*betan* *patan*
footstep (O'Brien and Christiansen 1986)	806 (13×62)	922.1		*checok* [Yucatec]
armspan (stick) (O'Brien and Christiansen 1986)	1,300 (52×25 = 5×260)	1,487.2	**1,470** ±50 mm	*zapal* [Yucatec]
bolt of cloth (Edmonson 1971:230)	11,680 (32×365)	13,361.9	**13,408**	16 varas of Burgos
Diccionario de Motul	13,140 (36×365)	15,032	**15,084**	18 varas
Diccionario de Motul	17,520 (48×365)	20,043	**20,112**	24 varas
(Roys 1939) (Morley 1938) (Brinton 1885:198)	18,980 (52×365 = 73×260)	21,713	**21,500**	mecate [Spanish] *k'aan*
5×mecate unit of land measure, (Roys 1939:55)	94,900 (260×365)	108,566	**107,500**	*payab* [Yucatec]

Some alternatives remain too close to be resolved.
Bold numbers are primary data.

Clark (2008) developed metric conversions for native Aztec units of measure based on reported equivalence of the Castilian vara to Aztec units. The following table associates numeric values with Aztec intervals based on the presumption that Maya values were transformed by first multiplying the Maya value by 365 and then dividing by 360 to obtain a measure that was presumed to represent degrees rather than days. Expanding and contracting 3,600 units by intervals of 15 provides a set of integer values much better suited for domestic application than the cycle-based Maya system.

Structural patterns imposed by the manner of breaking basic units into equal fractions makes a solid case for the proposed metric conversion. Four intervals that were noted by Clark as having particularly uncertain attribution of metric equivalence do not conform well with the fractional structure and are indicated by a question mark. Otherwise it is interesting to note that the remaining units can be characterized as integer subdivisions of the *cemmatl*. Five orderly divisions by fractions still allows great precision for any practical measurement task. It should therefore come as no surprise that any of the standard units could be used to symbolize a numeric value.

The nature of fractional subdivisions was anticipated by Williams and Jorge (2008) from a study of colonial period land documents recorded with native units. Tract sides were recorded by an integer number of *tlaquahuahitl* land rod units plus a separate fractional unit to make up the remainder. Areas were then recorded as an integer of the primary unit squared.

Work by Sugiyama (1993) and Clark (2008:2010) shows that Aztecs built their own graphic mnemonics on a grand scale at Teotihuacan, Mexico. Comparing various intervals used by the Aztec (Clark 2008:3) to Maya values reveals an interesting structure. While the Maya saw intervals as cumulative counts of their base unit from the starting point, the Aztec system used an array of units that could be factored into larger and smaller units. Distances are often recorded as integer counts of one kind of unit that were added to integer counts of a smaller unit to complete the whole.

This cascading of units counts from large to small would have made measurement by wheel very convenient. The smallest named Aztec unit was the width of a finger, approximately 15 times larger than the smallest Maya unit. Measuring seems to have been an engineering exercise for the Aztec, with no apparent concern for the number of units represented from “zero.”

For the Maya, measurement was a way to celebrate the interconnection of the universe. For now, there is no detectable difference in the fundamental standardization of lineal measurement between cultures, only a difference in how the measured intervals were expressed. Notably, Olmec measures conform to Maya precision and accuracy while applying cumulative values at the same time that Poverty Point was constructed along the Mississippi River.

Because the Aztec measurement system appears to be directly adapted from the Maya, there may well be examples, yet to be discovered, that conform exactly to Maya usage.

Comparison of Aztec and Maya measures

	Aztec intervals	mm	**A**	**B**	**C**	**D**	**E**	Aztec value	Maya value
	20 *niquizantli*	41,756	2400	300	200	100		36,000	36,500
	mecate	20,878	1200	150	100	50		18,000	18,250
	matlacmatl	16,703	960	120	80	40	10	14,400	14,600
	naumatl	15,032	864	108	72	36	9	12,960	13,140
	chicuematl	13,362	768	96	64	32	8	11,520	11,680
	macuiquahuitl	12,526	720	90	60	30		10,800	10,950
	chicomatl	11,692	672	84	56	28	7	10,080	10,220
	chiquacenmatl	10,022	576	72	48	24	6	8,640	8,760
	macuimatl	8,351	480	60	40	20	5	7,200	7,000
	namatl	6,681	384	48	32	16	4	5,760	5,840
	yematl	5,011	288	36	24	12	3	4,320	4,380
	omatl	3,341	192	24	16	8	2	2,880	2,920
	matlacicxitla [10 feet]	2,784	160	20				2,400	
	tlaquahitl [wooden rod]	2,505	144	18	12	6		2,160	2,190
	niquizantli	2,088	120	15	10	5		1,800	1,825
E	*cemmatl* [hand]	1,670	96	12	8	4	1	1,440	1,460
?	*cenequeztalli* [stature]	1,601						1,380	
	mitl [arrow]	1,253	72	9	6	3		1,080	1,095
	yollotli [heart]	835.1	48	6	4	2	1÷2	720	730
?	*ahcolli* [shoulder]	777						670	
?	*ciacatl* [armpit]	719						620	
	tlacxitl [step]	695.9	40	5				600	
D	*molicpitl* [elbow]	417.6	24	3	2	1	1÷4	360	365
?	*mazotzopaztli* [forearm]	382.8						330	
	omitl [bone]						1÷5	292.4	
	xocapalli [footprint]	280.7	16	2			1÷6	242	
C	*macpalli* [palm]	208.8	12		1		1÷8	180	182.5
?	*cenmiztitl*	185.6						160	
B	*centlacol icxitl* [half foot]	139.2	8	1			1÷12	120	
A	*mapilli* [finger]	17.4	1				1÷96	15	

? = lacking cross-correlation.

Maya unit (1.144 mm) × (365÷360) = Aztec unit (1.1599 mm)

11

Conclusions

The incredible accuracy of the Mesoamerican calendrical system can now be squared with a newly recognized knowledge of its development? Based on earliest appearance of glyphic notation, the origin of the integrated calendar is generally attributed to around 500 BC although the 260-day *tzolk'in* count appears as early as 900 BC with the Olmec. Rather than accept that various independent counting cycles were somehow stitched together over centuries, it is time to recognize that they were integrated from the beginning. The lunar standstill cycle not only provides the mathematicl basis for the Mesoamerican calendral system, but is also implicated in Archaic mound design and in heavenly rectangles of the Maya culture. Success in decyphering Maya glyphs has perhaps inadvertently steered archaeologists away from alternative sources of information that are less definitive. Similarly, the absence of mathematical operations not only blinds us from understanding how calculations were accomplished, it has hampered us from actively pursuing their role in developing a calendar.

The Maya calendar demonstrates a consistent day-naming convention, but the best evidence for early calendrical expertise relies on a precise standard unit of measure that conflicts with conventional interpretations. Previous efforts to determine a standard unit of measure have focused on an arm reach (Clark 2009, O'Brien 1986, Sugiyama 1993), but have largely been ignored because the intervals measured to great precision by early people are not the same as favored by modern conventions. Consequently the interval equivalent to an arm reach has been treated as a measure that is as variable as the difference between stature in humans. Accepting a base unit 1,300 times smaller requires a significant shift of paradigm.

We should free ourselves from assuming that ancient people were hampered by inferior intellect and technical capabilities. Alignment strategies of mound arrangements reveal that basic tenets of early astronomic observation initially focused on horizon markers and were then elevated to address the heavens as a whole. Cross-cultural correlation makes it clear that information was shared through spiritual concepts that transcended geographically-based identity of groups. Assembling the clues from disparate cultures demands that we we find an appropriate context to bridge the gaps.

Cultural affiliations between the Lower Mississippi River Valley and Mesoamerica have long been remarked on. Now, there is need to trace those elements in regard to intellectual contributions, so comparisons with cultures such as the Pawnee may provide important clues as to timing, routes, and lineage. Numbers coded into Olmec stone monuments of the Formative Period show that the calendrical structure was thoroughly imbedded in community planning and administration as early as 1500 BC. Variations need to be explained, as well as differences in how the values are coded. Hopefully, connections will be found to relate mnemonics with myths. At the least, it should be possible to find good associations between glyph notation and dimensional values expressed on the same artifact.

People of the past needed a unique observational perspective to make the discoveries we have been examining. Special aptitudes for mathematical processing were also essential to reconcile complex relationships between a multitude of astronomical cycles. No matter how brilliant the conclusions however, without a mechanism to transmit the knowledge, they would have been doomed to be forgotten. Particularly in advance of notation to represent verbalized thought, the problem seems solvable only by extraordinary feats of memorization. Fortunately, humanity is endowed with an inherent capacity to visualize patterns that appear to simplify even extremely chaotic phenomena.

The heavens, in particular, present a vast disorganized array of points of light with varying degrees of distinctiveness and position in the sky. Mapping such a complicated subject without a physical image is daunting. Selected groupings of stars that we call constellations have been characterized as representing familiar images when lines are visualized to connect them. Around the world, many of the same star groupings are depicted with unique descriptions that draw on deep, regional tradition. The most consistent usage occurs near the ecliptic band traveled by the planets because constellations provide useful seasonal points of reference. Most cultures have divided the ecliptic into twelve or thirteen roughly equal zones that conveniently portion the year, each with its own constellation. A constellation characterization is a mnemonic devise to aid recall and standardize points of reference for reliable communication. Furthermore, each characterization has an elaborate story that captures mythic elements from ancient tradition. Included in that narrative tapestry are characters whose names are attached to individual stars. By such means, the heavens are given surprising order without requiring written documentation or a plotted chart.

Organizing observable solar and lunar standstill events on the horizon by means of a geometric convention allows trigonometric relationships between cardinal directions to be measured. A central observation point might seem desirable, but there is no reason not to observe solar phenomena from one vantage and lunar phenomena from another, and that is what appears to have been done in Archaic Louisiana. Presumably, individuals were assigned responsibility for counting days between appearance of objects at prescribed locations along the horizon, accumulating a knowledge base of astronomic cycles. Comparing cardinal measurements in a trigonometric ratio may have stemmed from a much more ancient practice designed simply as a method of replicating azimuth locations from one location to another. Changes in trigonometric proportions due to changes in latitude would likely have been common knowledge. While most mound sites share a common underlying design, each site was treated uniquely as to where mounds were placed in regard to the master plan.

Mound arrangements at several Archaic sites in Louisiana correlate with a hypothesized ideal that would have produced a 365÷260 tangent relationship for the lunar nodal cycle that is unique to a specific latitude. Any unit of measure would have sufficed if only proportions were to be described, but a standard unit of measure provides a capability for exact replication and depiction at a prescribed scale. Standard units of measure also avoid ambiguity.

That such a vibrant mode of communicating precise observations has remained hidden after more than 7,500 years of existence seems to defy logic. It is not as if evidence were not left behind, plenty of that remains scattered over twenty degrees of latitude. It is also not that clues were overlooked—they occur in some of the most attention-grabbing site plans and artifacts imaginable. The problem is that we are overly committed to symbolic representation of concepts such as writing, glyphs, or technical drawings. Before those now-familiar modes of expression were adopted, people took note of important objects by relating lines of sight to reference points such as hills or rocks. For example, noting that the summer solstice sun always sets over a certain hill on the horizon defines a three-point line joining the observation point, the hill, and the sun.

Line-of-sight orientation radial from a central observation post is effective and easy to understand if all you need to know is direction to other points of interest. By integrating observations from multiple observation locations, a network emerges that describes points of interest in graphically-expressed spatial relation to each other. Adding linear units of measure locates things exactly in relation to each other. Since only one spot in the sky remains at the same location relative to an earth-based network, it fixes orientation of the network. In the northern hemisphere, we currently approximate that point by Polaris, otherwise known as the North Star.

Continued mapping of things on earth and stars in the sky show that each remains fixed relative to an invisible axis, on a schedule we call a day. A third category of things is much more problematic. The sun, moon, and planets move according to recognizable cycles, but wander between limits that can be related on the maps of the stars and the Earth. Without a good positional reference, the best way to describe the “wanderers” is to count days elapsed between cyclic location markers. With math, it is possible to factor the cyclic periods by common scaling factors.

Noting movements of the Sun and Moon along the horizon during their long-term cycles requires at least two physical reference markers on the ground. The location on the horizon can be observed but not readily monumented and therefore can be considered virtual. Similarly, the “wanderer’s” path among the stars is virtual. We refer to the band traveled by the planets as the ecliptic, and approximate the celestial equator as the Milky Way. Those important celestial grid lines cross near one of the most easily recognized grouping of stars, the constellation of Orion, so it should come as no surprise to find geometry at Caney Mounds and Poverty Point that appears to signify Orion.

Consolidation of Archaic mound arrangements in Louisiana reveals a graphic template that can be logically associated with specific numeric values. The appropriate relationship of mounds to each other becomes clear only when each mound is considered to be an observation post. Then, other mounds are seen to sometimes serve as horizon markers that acknowledge lunar and solar extremes and produce three-point lines when the astronomic event is included. Erecting mounds or monuments to mark the location of a natural hierophany essentially creates an artificial hierophany. Assembling the separate hierophanies into a master template transforms the site into a complex document. Since the Mound sites only register to each other by applying integer scaling factors derived from the same basic numbers used by the Maya to count time, it is possible to quantify the unit of measure responsible for site layout.

Built near the current era start, Poverty Point integrates the old template geometry with a new geometry that appears nowhere else. When measured by the same base unit, both geometries yield calendric numbers and appear to show deliberate correlations with the constellation of Orion. Especially important is that the orientation of Orion at equinox generates an azimuth coincident with the graphic template ray that points to the lunar extreme, while also positioning stars at important intersections of the template. Precise intersection of rays at critical nodes on the Poverty Point geometry suggest that the site design may represent a diagram of the celestial sphere, depicted on a grand scale.

Descriptions of star groupings are oral mnemonic devices couched as myth. When constellations are projected onto graphic depictions of hierophany, we should expect the intersection of graphic and oral mnemonic devices to yield a particularly rich mix of spiritual tradition.

Recognition of mnemonic expressions offers to greatly expand our ability to trace intellectual achievements prior to notational records. Tentative steps have been taken to show how rich a data trove awaits. Already, there seems to be far more potential for future study than confirmed findings. With scarcely a half-dozen verified graphic mnemonic diagrams having been recognized from several thousand years of practise, there are surely many more to be revealed. Granted that relatively few examples have been explored so far, it still appears that hidden mnemonic keys are often referenced in creation stories, myths, star maps, and iconography. Each new mnemonic has the potential for associating quantifiable phenomena such as intervals of calendar time, astronomic cycles and sacred numbers. The more direct the correlation, the greater our confidence in interpretation will be. Simply continuing to examine new examples of previously described mnemonics should refine our understanding of data content as additional alignments are explored. When excavation is conducted at predicted locations, virtual points may be found to be marked better than it otherwise appears, and angular values may gain importance for their place in clock arithmetic.

It is now apparent that the Maya recognized strong parallels between earthly and heavenly cycles, which were reinforced by counting out earthly units of distance in proportion to heavenly units of time. Ultimately, the geometric relationship was incorporated into mythic stories that can be used to backtrack much of the development of Maya astronomy and calendric science. The story of creation as related in the Popol Vuh and the Books of Chilam Balam probably relates the most important achievement of Mesoamerican civilization, as they perceived it themselves. Linking heavenly cycles to earthly phenomena was akin to mastering the skills of the gods, and must have been the foundation for sovereignty. Each competing dynasty presumably would have been pressed to demonstrate an increasingly sophisticated command over the forces of gods and nature. Such a sturdy foundation had been laid though, that the simplest units of description remained unchanged from their beginnings. Equally remarkable is that the mythic story of creation can be so clearly traced even after more than six thousand years. Unfortunately, the collapse of dynasties that exercised exclusive control of sacred knowledge left the system of measures without a means of continuation. Today, all that remains are body-based measurements that have lost connection with their underlying meaning and definition.

Through examining design and lineal measurement standards evident in various artifact caches, it may be possible to isolate workshops responsible for making the artifacts. Iconography may be found to be local expressions but they might adhere to broader standards. It will be interesting to see how often artistic flourishes turn out to be meaningful content. Continued evaluation of standard units of lineal measure will be required as new data becomes available. Improved evaluation of coefficients of variation will undoubtedly lead to upgraded protocol for appropriate precision in archaeological feature location. For example, because of the demonstrated importance of site orientation for deciphering graphic templates, site maps should include accurate true-north data.

Among the Maya rules of geometry observed so far, the tendency to define objects by a bounding symmetrical quadrilateral perimeter that is treated as a cycle seems predominant. If two cycles can be factored by a common value, they evidently are viewed as sharing important qualities. The more common factors shared, the greater the symbolic content.

Thorough analysis will require a better defined syntax of geometric expression than exists presently. The lines at any of the Middle Archaic mound sites create a suite of virtual intersections, many of which have no obvious meaning, but were selectively marked anyway. Comparable sets of nodes are seen in many Mesoamerican works, with lines directed as visible lines of sight, tangents, corners, projections, and discrete features. Astronomical azimuths are quite often prominently included in the array. Similar geometric intersections occur in chipped chert, most notably where synodic cycles of seven heavenly bodies are redundantly recorded. Counts of intersection nodes sometimes appear to be deliberately manipulated as a form of data; for example, using 13 for heaven, 4 for the Earthly plane, and 9 for the underworld. Our extremely small sample size at present can illuminate only an intriguing sample of the enormous potential for variety in how the system could be applied. After all, during the long period the system was in use, the Maya likely devised a considerable number of applications. Preliminary work is limited by our rudimentary knowledge of the Maya system of astronomy and mathematical operations as deciphered from glyphs. A much greater volume of data is waiting to be explored as we learn the rules for recovering numerical information built into dimensions of special artifacts.

Acceptance of the geometries described requires that they be demonstrated to have been guided by consistent rules, guidelines and conventions. Statistical tests have been offered to validate observations whenever enough examples of the artifact class are available. Enough independent tests are available to state conclusively that the system of measure is capable of recording to a precision of four significant figures. Individual artifacts that contain redundant depictions of the same data may not be considered as persuasive, but still continue to build the case that geometric conventions were universally applied. Often, conventions are first recognized because of their context, whether it be astronomical, ritual, or related to administrative power. Many formats have been recognized, with some master templates being favored by specific cultures. Other formats appear in more than one cultural setting, like measuring perimeters of enclosing rectangles. Rays connecting points of templates often reveal nodes where multiple rays intersect precisely and indicate deliberate incorporation of related measurable elements in the design.

Recognition that the Maya used the Fibonacci series to develop rectangles near golden mean proportions leads to an independent means of assigning integer values to the perimeters of those values. One outcome is to validate the standard unit of measure. Another is to associate rectangles with mathematically correct ellipses—justifying the measurement of rectangle perimeters when only the bounded ellipse is present. Additionally, text in the Book of Chilam Balam is recognized as corresponding to Fibonacci-based rectangles—tying aesthetic art to the mythic story of creation and giving mystic meaning to artistic creations.

Many of the solved graphic mnemonics yielded their secrets because it was apparent that key elements of the design were applied according to well-defined convention. For that reason, any rule-based features deserve special attention to discover what meaning they might contain. As an example, rotation and superimposition of graphic designs spans the entire duration of the system, but we still do not understand the purpose. Even when we know something of the content, we often are unsure of how the original coding algorithms were expressed or whether alternative rules exist.

Once the overall system of tracking time and using geometry to record data is explained, traces of that system are visible throughout its journey from Louisiana to the Yucatan Peninsula. For many generations, people placed their most sacred knowledge in plain view, where it was seen by all and understood only by the select. Multiple messages are frequently contained in artifacts, from iconic representation, to perimeter framing, to carefully dimensioned rays that are organized to convey numeric meaning. Multiple interpretations from the same artifact may parallel stories of myth that frequently reveal multiple aspects for various deities.

Shared among myriad conventions used to code meaning is the underlying thread that a “decoding key” must be imposed by the observer in order to access the secret. Hearkening back to the development of a guiding template that unites Archaic mound placement, the secrets of the observable universe may have been thought of in a similar fashion. Only when humans fashioned a key, did they gain the leverage to impose order on their observations. The practice of omitting key elements may have given people the sense that, by constructing their own hierophanies, they gained spiritual connection with the Creator. Mnemonic conventions imbued artifacts with special spiritual meaning that permeates nearly every creation. From arranging massive site plans, to proportioning thrones, to intricately designed eccentrics;

nearly every application was also a communion with the deities.

Part and parcel with sacred geometry, math is obviously present in the design of the grand cycles of time without any demonstration of the actual calculation. No computations remain, no equations, no formulas, only a mysteriously wonderful structure of time. Time has qualities of symmetry, repetition, order, and quantity; in common with the qualities of sacred geometry. Thus time and space appear to be united as central elements in a grand scheme, utilized to capture spirituality in a manner that transcended political boundaries and cultural traditions.

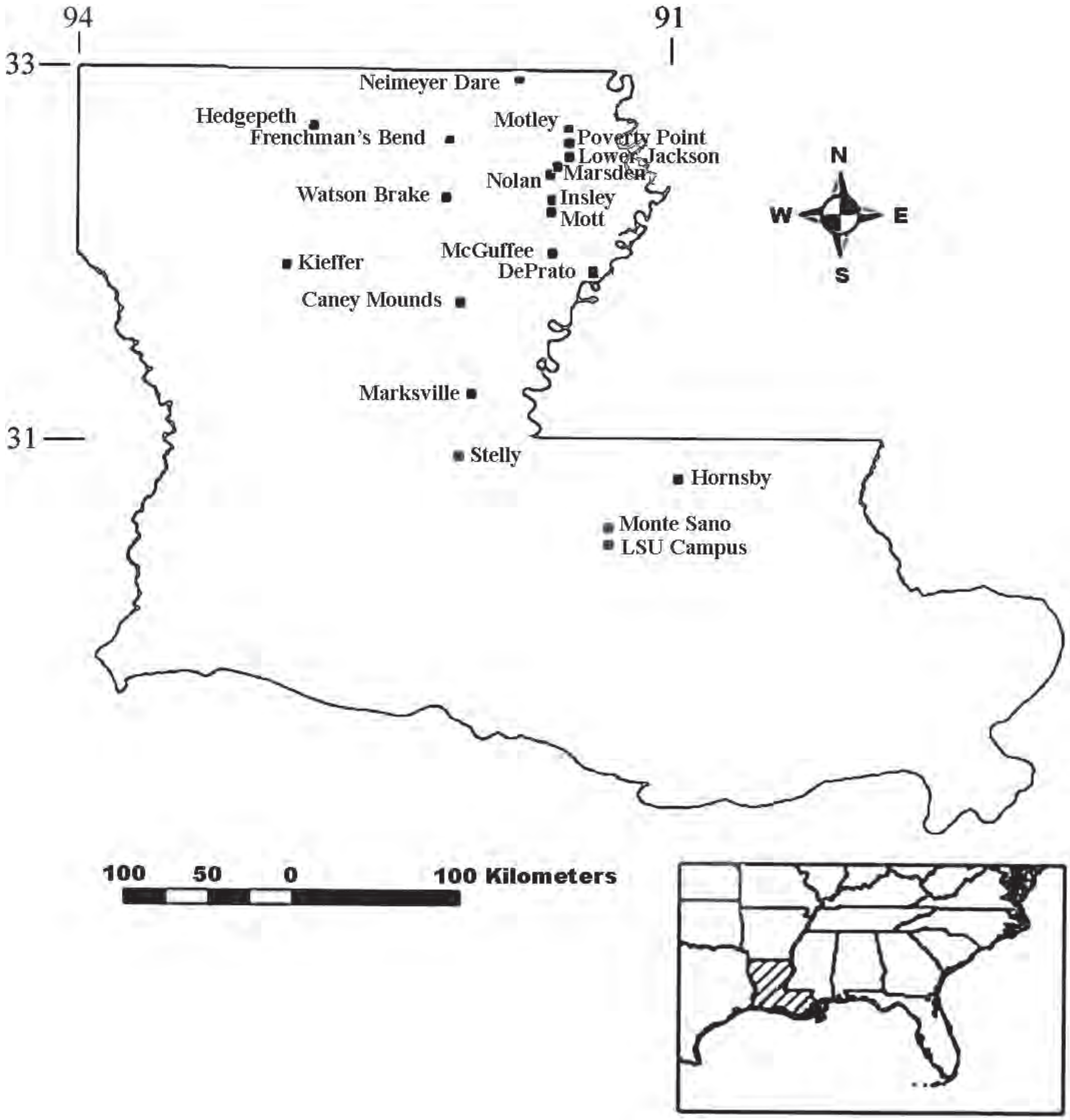
Aztec measures (Clark 2008; 2009) seem to be uniquely explicit in terms of tangible point-to-point intervals of measure. While the Aztecs retained significant elements of the spiritual system, they appear to have been taking steps towards transforming into something we might more readily recognize as similar to our modern science. Units of measure were redefined in lay terms relating to body parts, tracts of land were surveyed and administered, and at least some numbers were depicted with direct point-to-point measurements without the need for a decoding key.

To sum up, early Americans appear to have emulated what they took to be the Creators's way of communicating with them. Nature does not come with an operating manual, but leaves the observer to work things out for themselves. Consequently, no explicit record could be interpreted directly. The recipient of sacred knowledge always was responsible for providing a key, usually graphic, to complete the picture. Finding that the same data was recorded throughout the duration and scope of the system shows a continuing preoccupation with cycles of orbiting bodies and confirms the reverence accorded to such information. Why should people be so circumspect about coding knowledge that had been known for thousands of years? If it were a matter of political power, wouldn't the information be stored out of view rather than incorporated in the most public constructions? One prospect is that people felt challenged by their Creator to measure up and show their own creativity by fresh expressions. Conversing in public without giving away entrusted secrets may have contributed to a leader's authority. In his discussion of the Popol Vuh, Tedlock (2010:354-360) points out that the Maya believe that because the Gods took their knowledge back from humans, messages from God require an act of interpretation. The first four humans of Maya myth overcame those limits by studying what was in front of them, as can we.

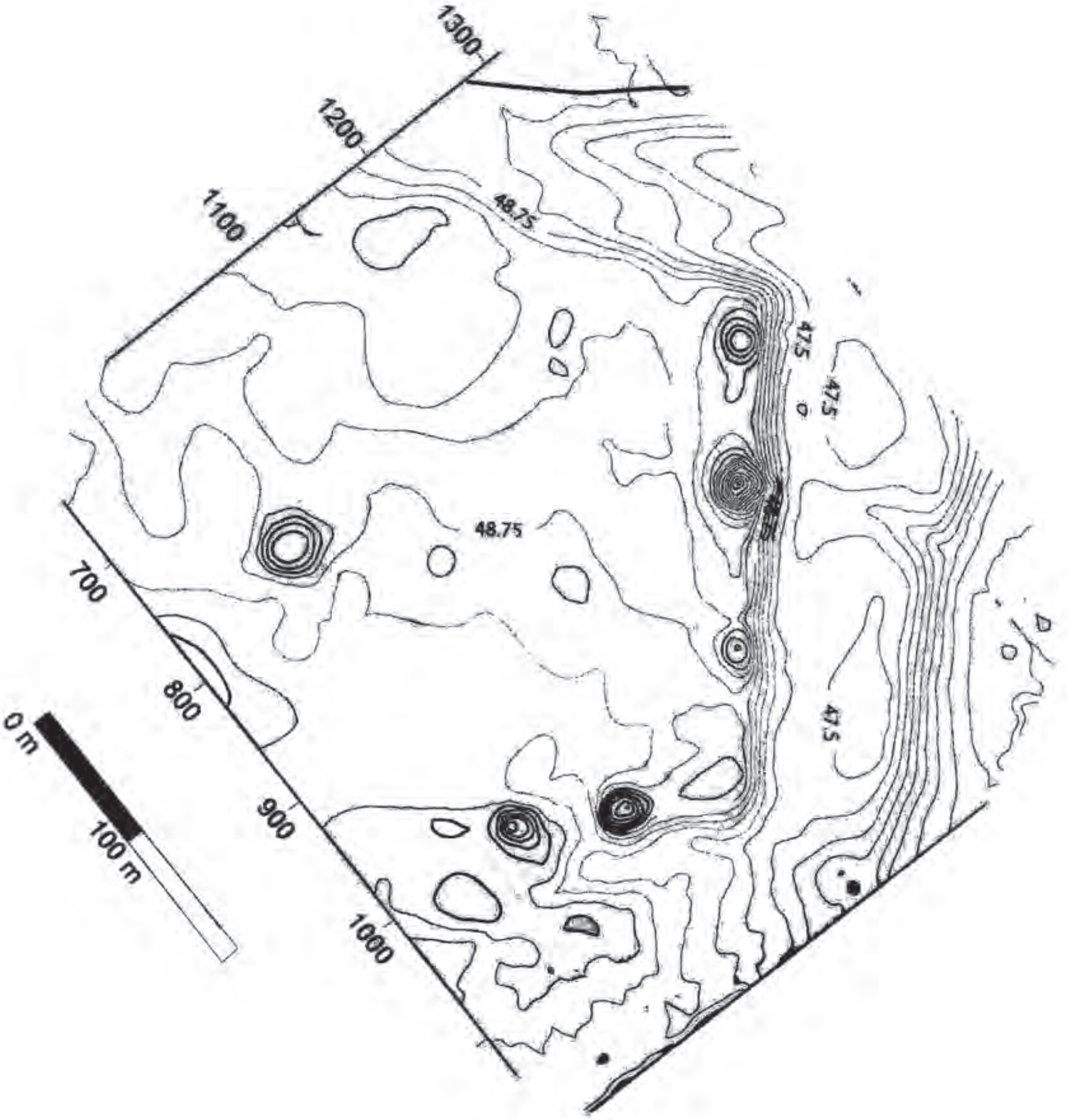
Appendix A

Stand-alone plans for sites used in this analysis are shared for independent consideration of alignment orientation, or potential overlay. Unaltered plans provided by the Louisiana Department of Archaeology are presented with the interpreted primary cardinal directions corresponding to the horizontal and vertical alignments of the page.

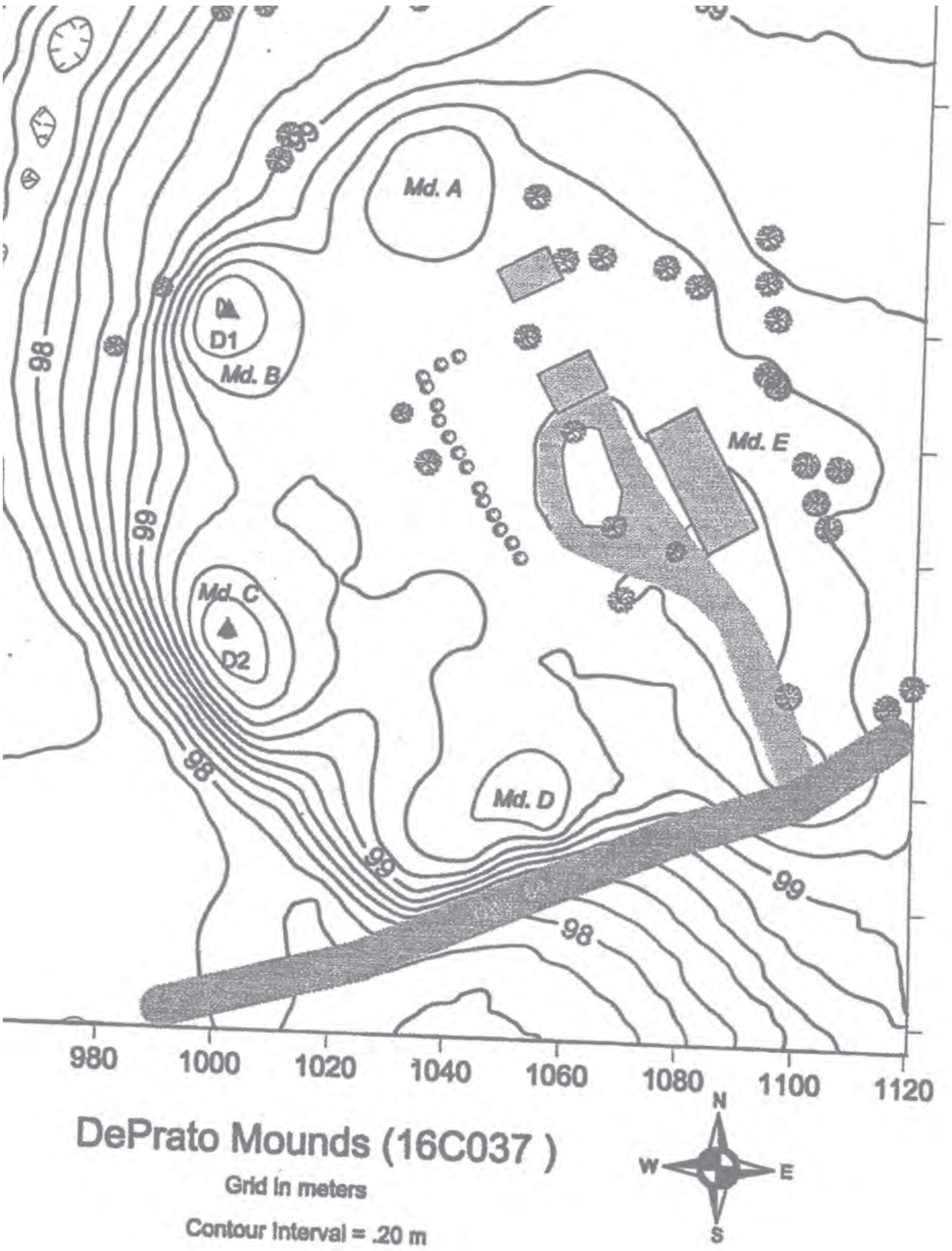
Locations for additional sites provide useful context. Not all Archaic mound sites are preserved or recorded in a way that contributes to studying their organizing patterns.



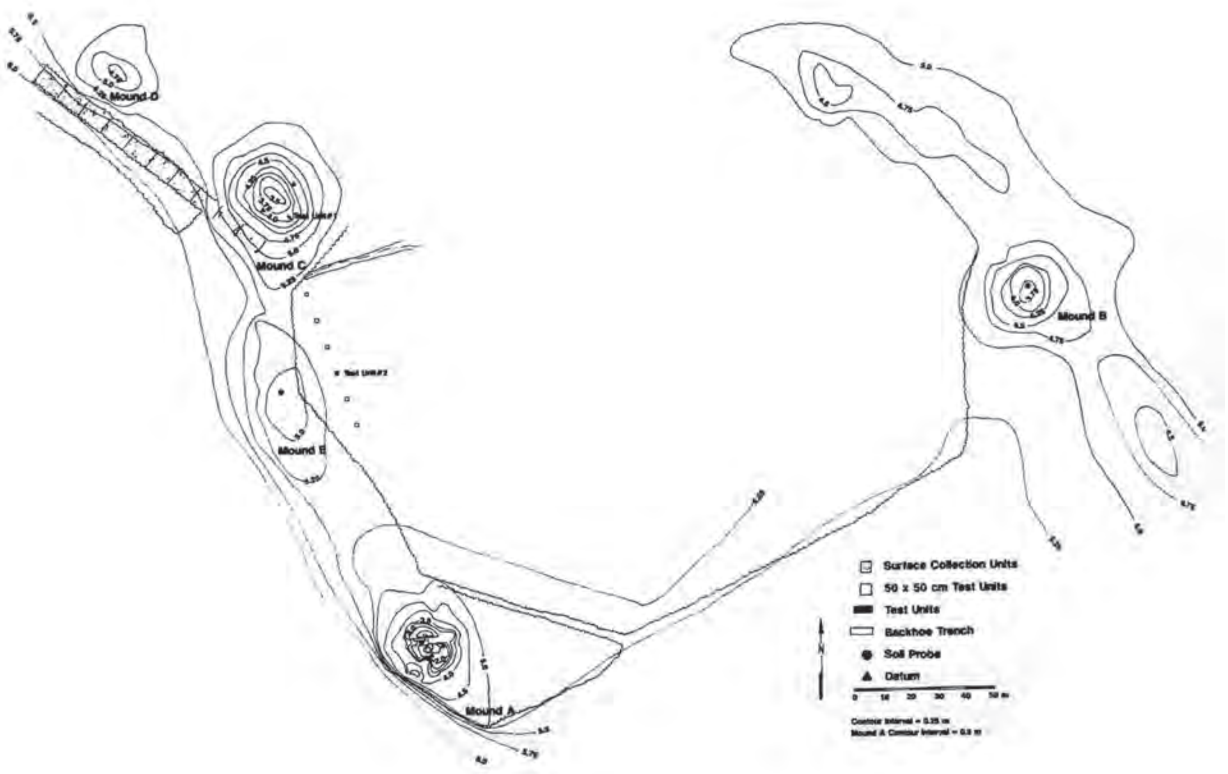
Caney Mounds 16CT5



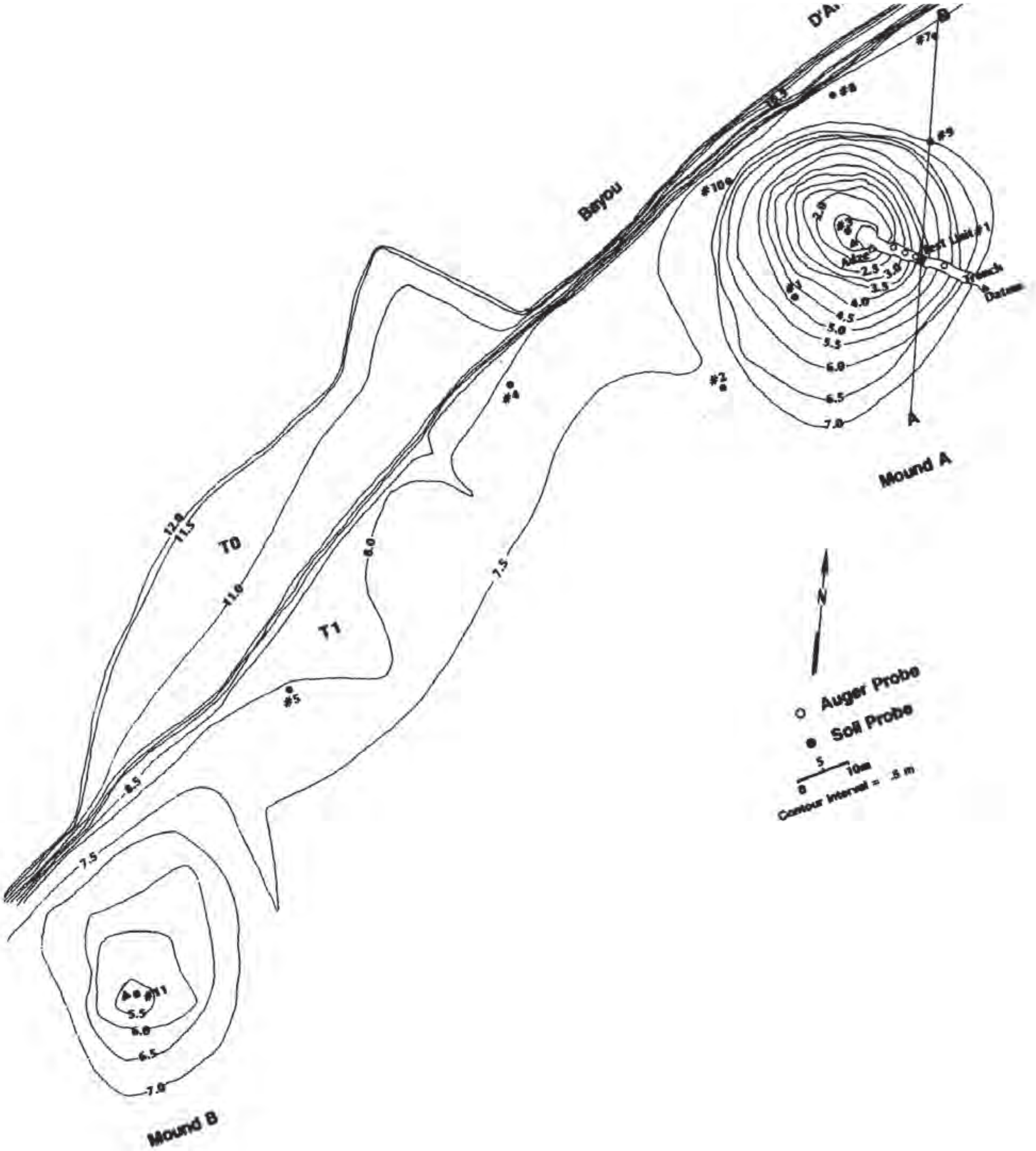
DePrato mounds 16CO37



Frenchman's Bend 16OU259

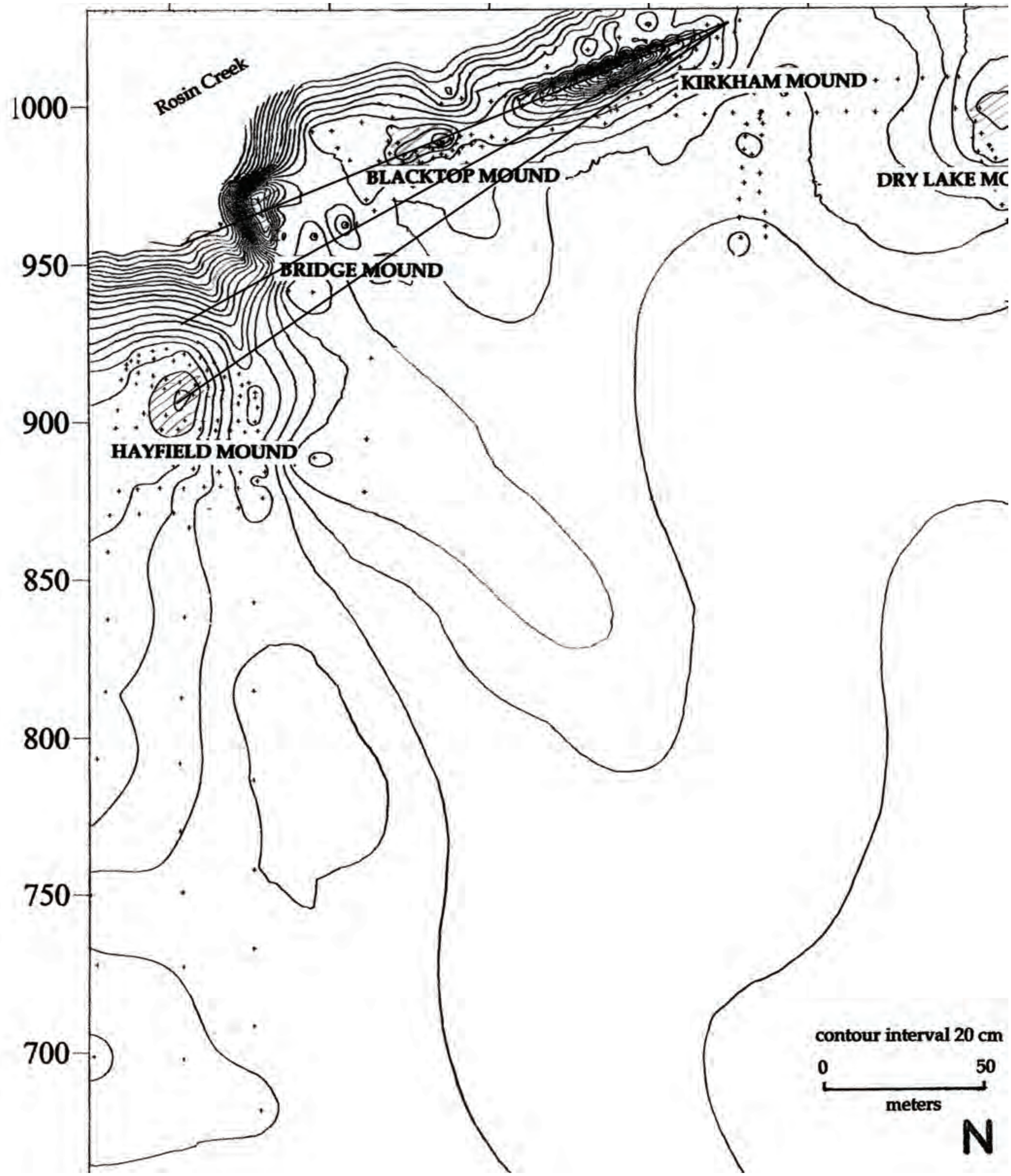


Hedgepeth mounds 16LI7

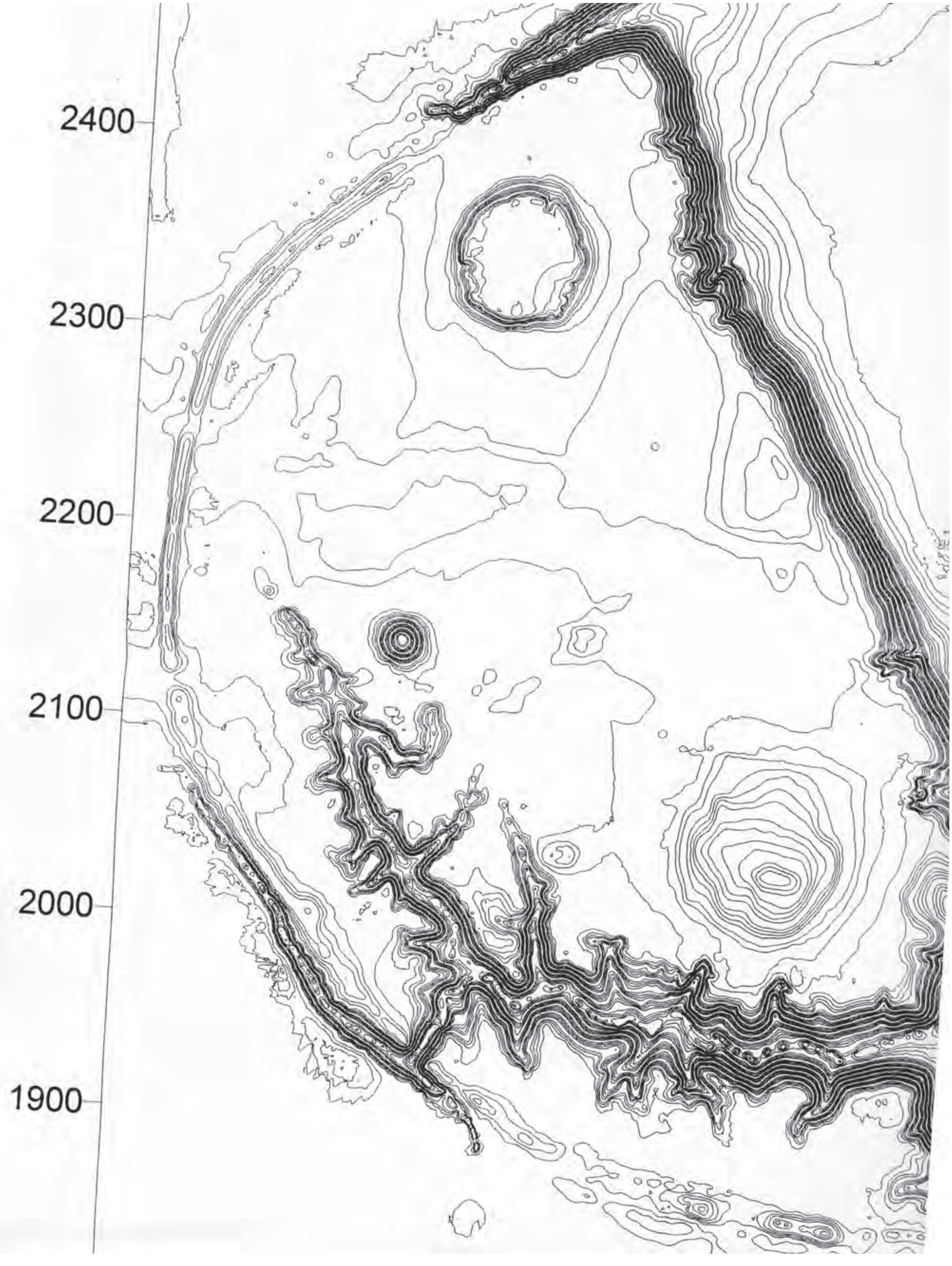


Kirkham mounds

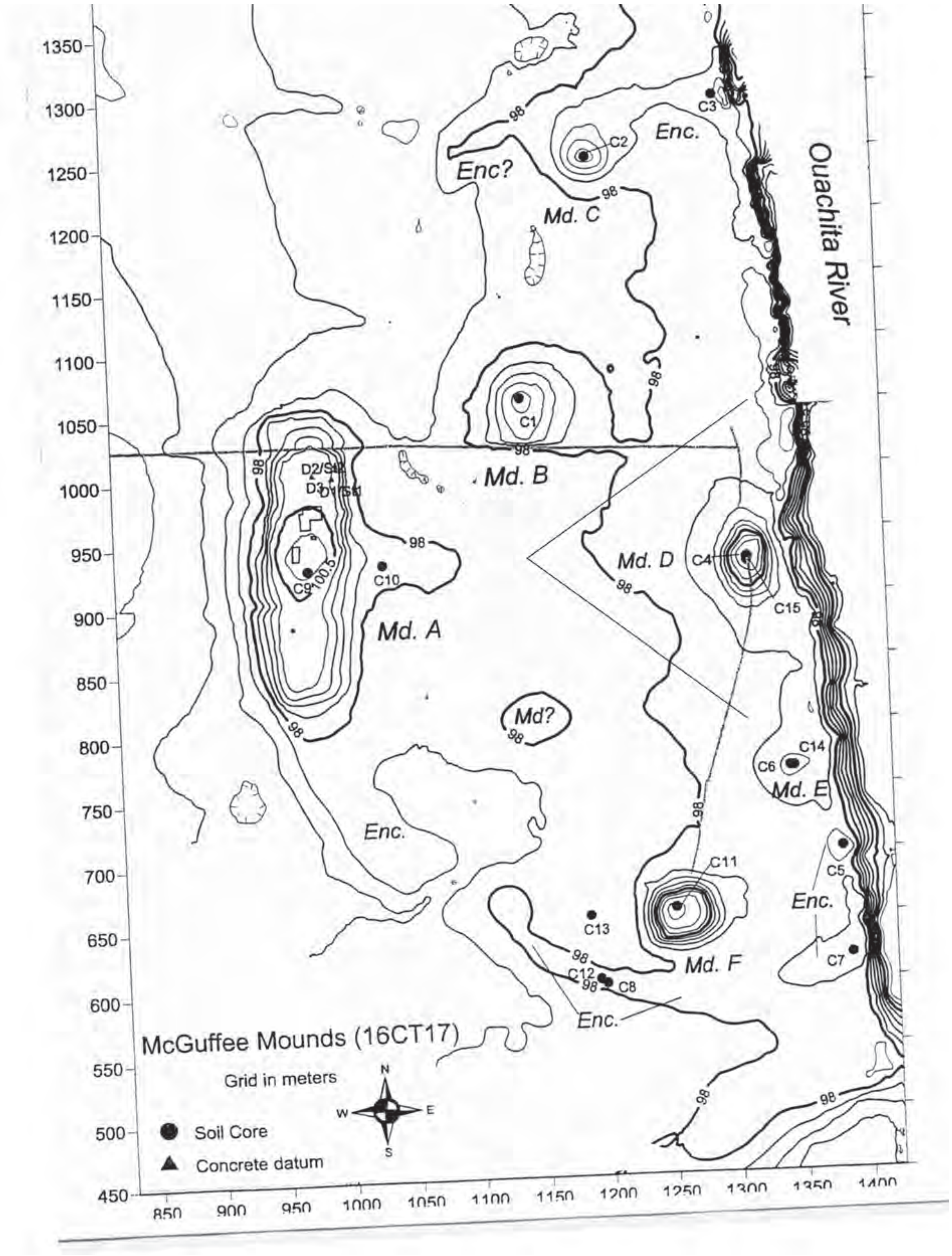
Lunar extrema are indicated by the radial-line overlay.



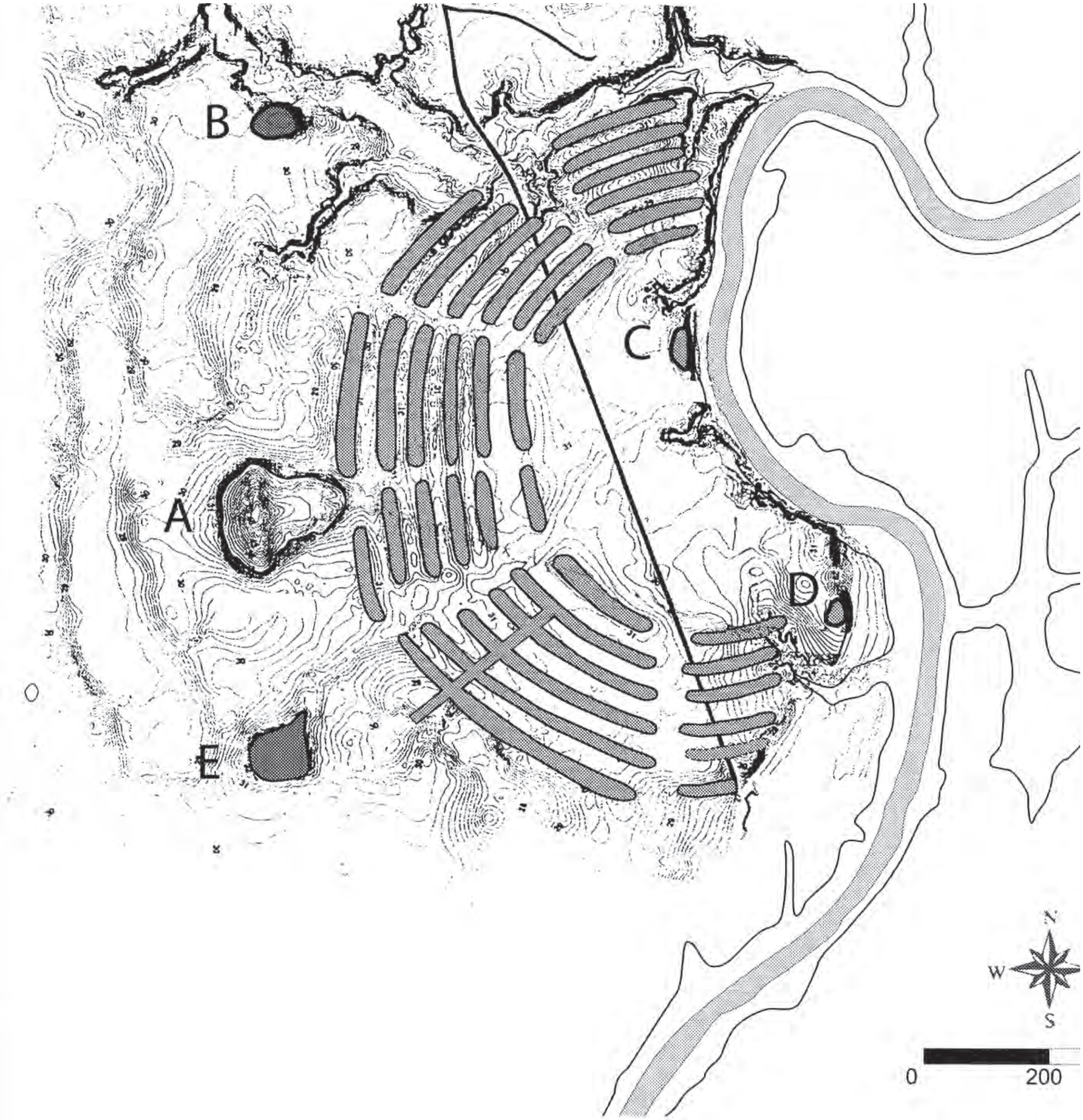
Marksville mounds 16AV1



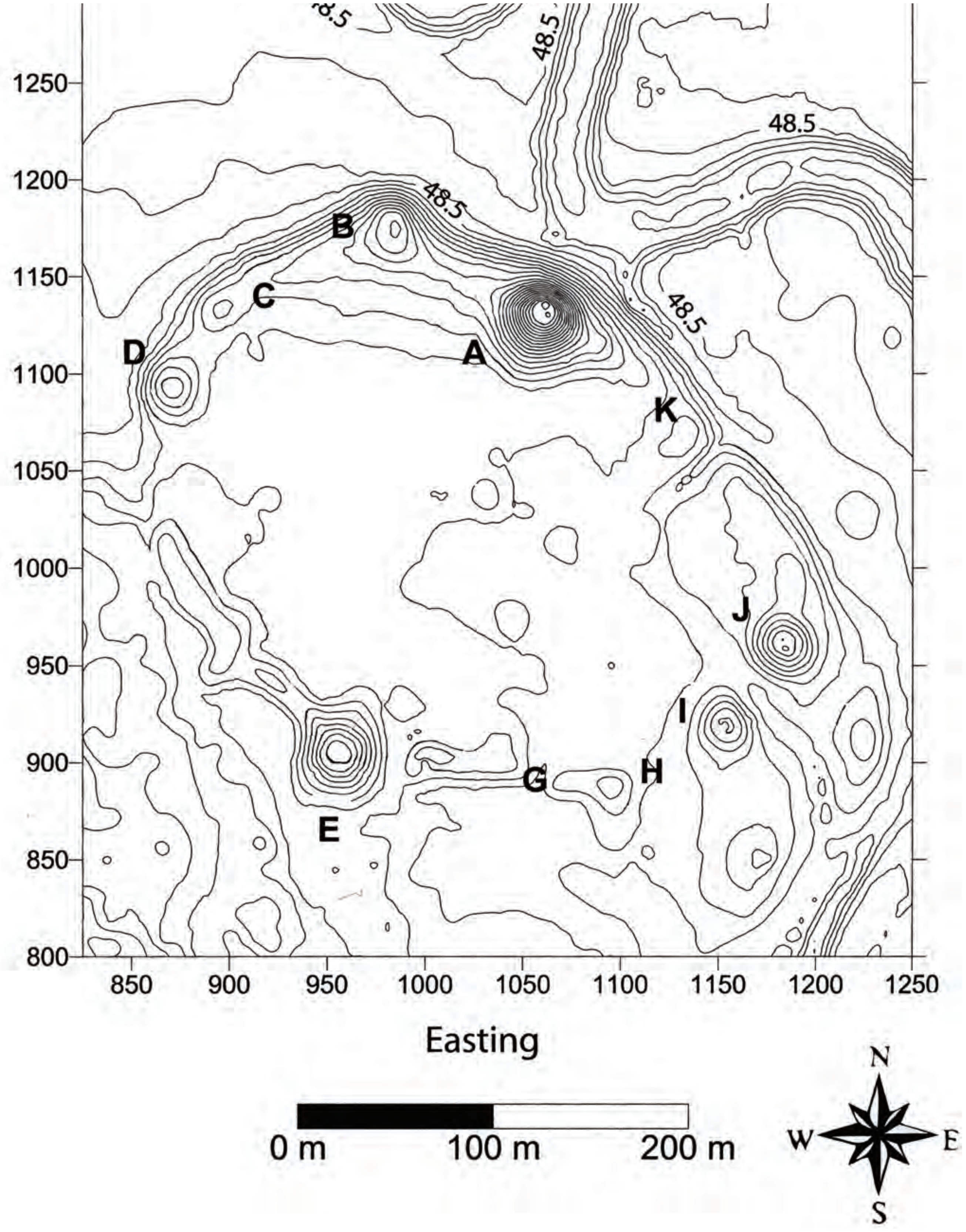
McGuffee mounds 16CT17



Poverty Point 16WC5



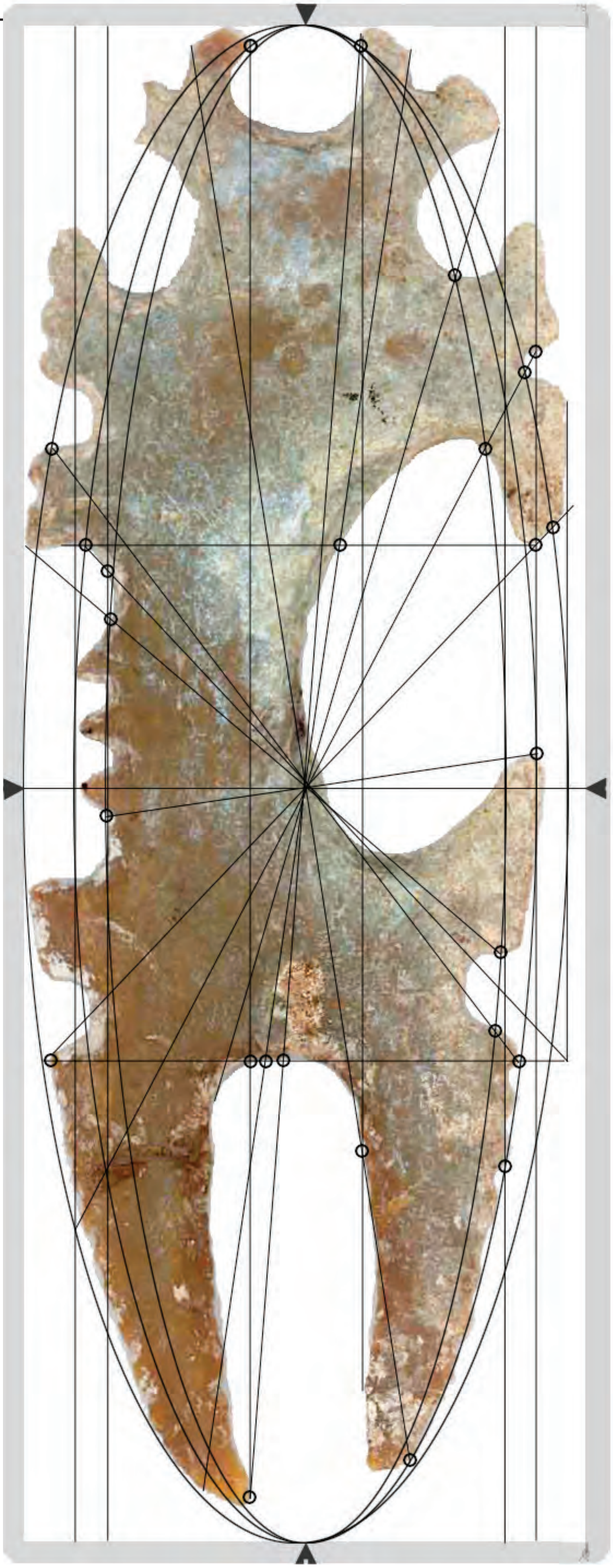
Watson Brake 16OU175



Appendix B

Each item in the cache of 34 chert eccentrics is shown within a surrounding rectangular frame after having been carefully oriented for horizontal and vertical symmetry. An exact ellipse is drawn whenever it explains the shape of an eccentric. Cardinal horizontal and vertical divisions through dead-center are indicated by a caret. Significant alignments are considered to be those that generate n-point lines, especially through dead-center and sometimes on cardinal planes. Some alignments seem important because they are indicated by inflections, but can not as yet be explained. In a few instances, intersections of significant alignments form a numeric pattern that corresponds with the Maya creation myth. American units of measure (1.144 mm/unit) are indicated by Au.

C-1 Actual size



Very large eccentric with face. The maker of this complex artifact had to overcome tough stone with crystal pockets. Six verticals and three horizontals divide an oval frame. Remnants of black paint remain.

The rectangular frame is just three times as high as it is wide, perhaps signifying three manifestations in family membership. Two interior ovals that define many of the interior positions were used to delimit frames appropriate for families 2 and 3.

This artifact poses a difficult challenge in measurement. The vertical orientation is not obvious until parallel lines are drawn between top and bottom pincer tips. When nested ellipses are fit to the artifact, the rectangular frame is seen to extend to the right of the physical frame. The central ellipse axis is offset 2.9 mm from the physical frame, but is tangent to the largest opening and bisects notches at either end. Twelve radial n-point lines connect inflections and curve tangents through dead-center.

P = 19 lunar months. (2×width = 147.73 Au)
(2 × physical height = 401 Au ~ Jupiter cycle)

P of first interior ellipse = 3×177.185

P of small interior ellipse = 3×173.31.

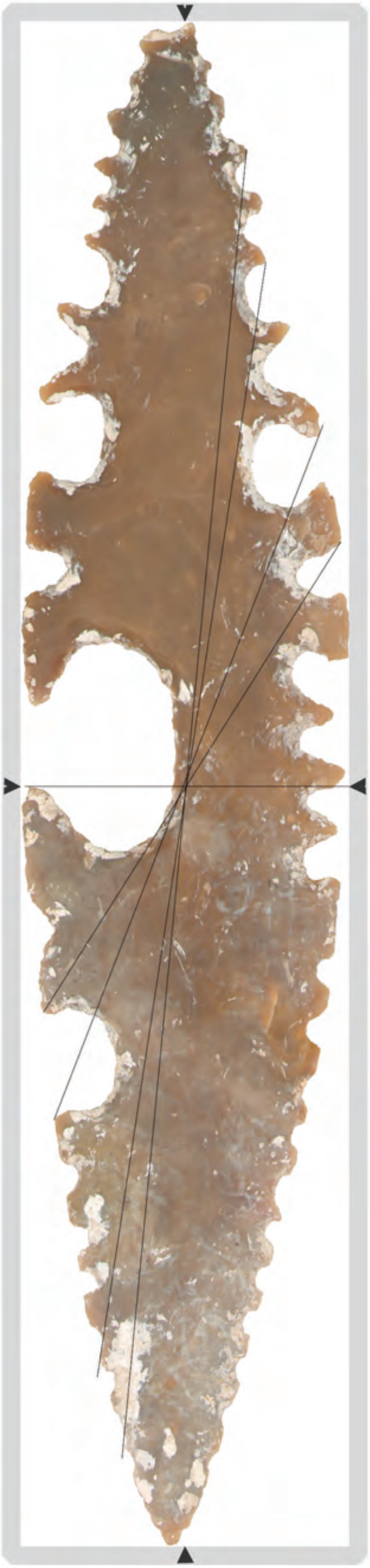
33 notches = number of cached items.

The eclipse prediction numbers are remarkably precise when expressed as decimal equivalents rather than integer notation.

Verticals, horizontals, radials and ellipses intersect with the artifact outline at twenty-six nodes. The same pattern occurs in effigies with seven faces, with nine at the bottom, four in the center, and thirteen at the top.

Nine alignments pass through dead-center.

C-2 Actual size



Tall and narrow, with face. Made on large, ~260-mm radius vesica.
Figure is 4.6 times as tall as it is wide.

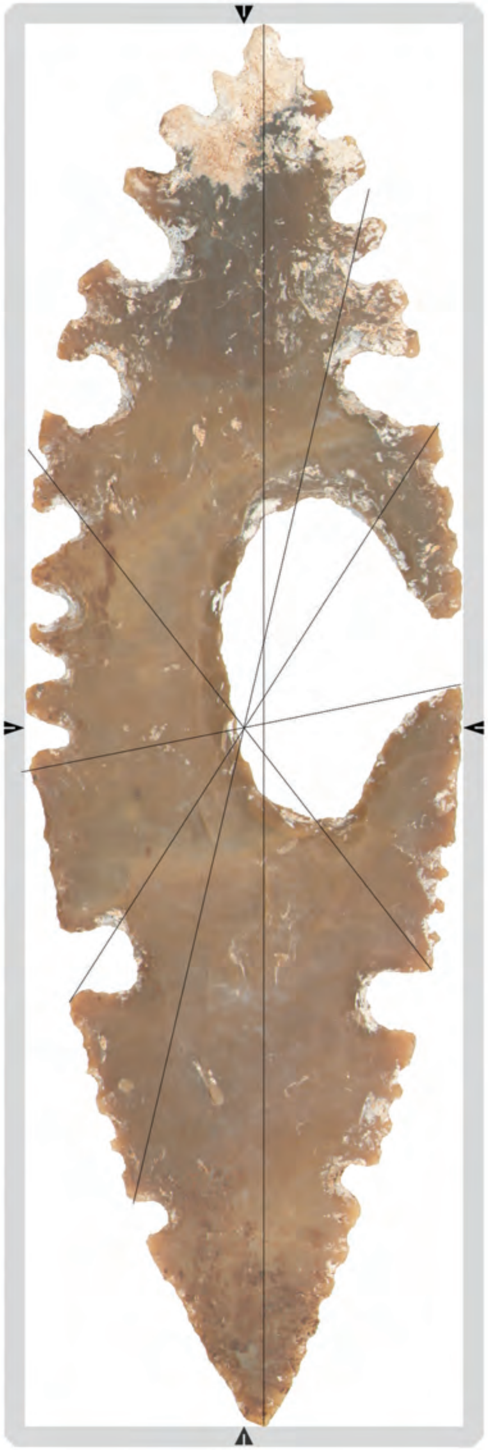
P = 6×77.

44 notches

Tips are shifted 1.8 mm from the frame axis.

Four alignments pass through dead-center.

C-3 Actual size



Large and broad, with face. Outer frame planned with ~160 mm radius vesica arcs. The tips are deliberately offset from the center line by 2.6 mm.

P = 429 = 13×33, (2 × height = 324 Au)

Notches = 40

Five alignments pass through dead-center.

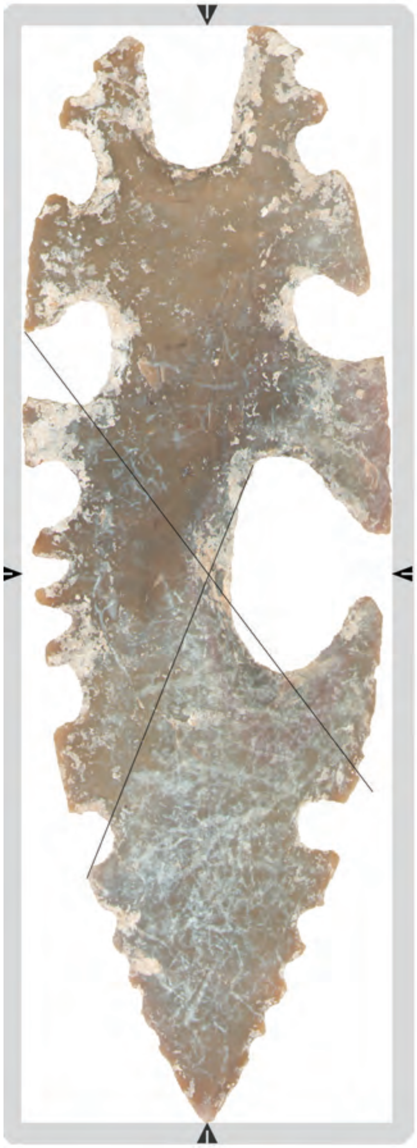
C-4 Actual size

Three times as tall as wide. Tip is formed as a vesica.

P = 13×26 (2×13^2)

Twenty two notches, including large opening.

Two alignments pass through dead-center.



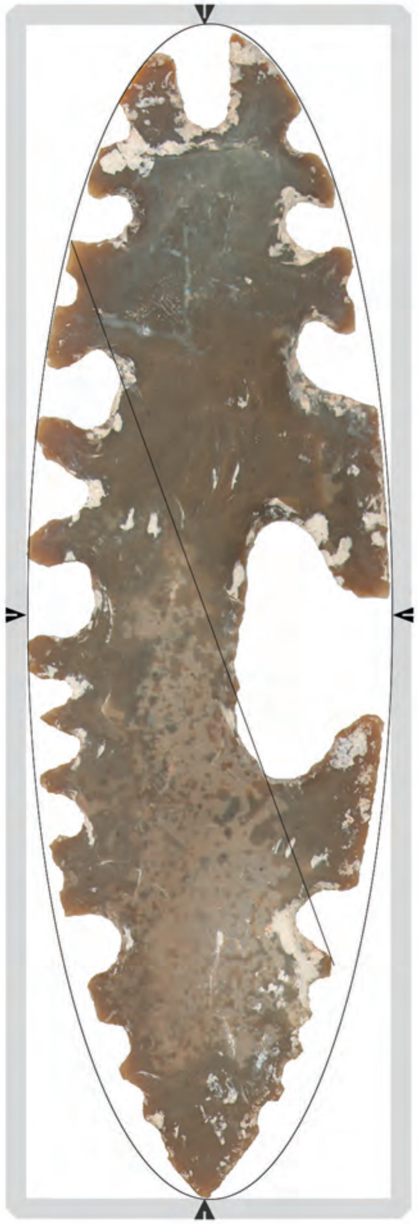
C-5 Actual size

Vesica tip ~80 mm radius arc. Ellipse top, length = 2×*phi*×width.

P = 12 lunar months.

Twenty three notches.

One alignment through dead-center.



C-6 Actual size

Vesica top, with rest in 2.4:1 ellipse. Pairs with C-7 based on web-like inclusions and matching perimeter.

Lower portion follows an ellipse shorter than the physical frame.

P = seven cubed = 343.

Twenty three notches.

Two alignments pass through dead-center.

C-7 Actual size

Pleiades

Made out of stone with web-like inclusions. The seven stars in the Pleiades star cluster are known as the rattlesnake's tail, *tzab*. The Pleiades can be occulted by the moon, and are obscured by the Sun around the first of June. Renewal of 52-year synchronization periods is marked by passage of the Pleiades directly overhead.

Despite its pleasing appearance of a free-form design, a high degree of planning went into forming each feature. The most basic design element is an ellipse constructed within a rectangle. There are seven repetitions of seven design elements:

Seven radial ray tangents.
Seven vertical alignments.
Seven breaks in the frame outline,
disregarding notches that form the face.
Seven sharp inflections, including face and
ends.
Seven body bulges.
Seven matches of ellipse to body.
Seven virtual planning points (see page 71).

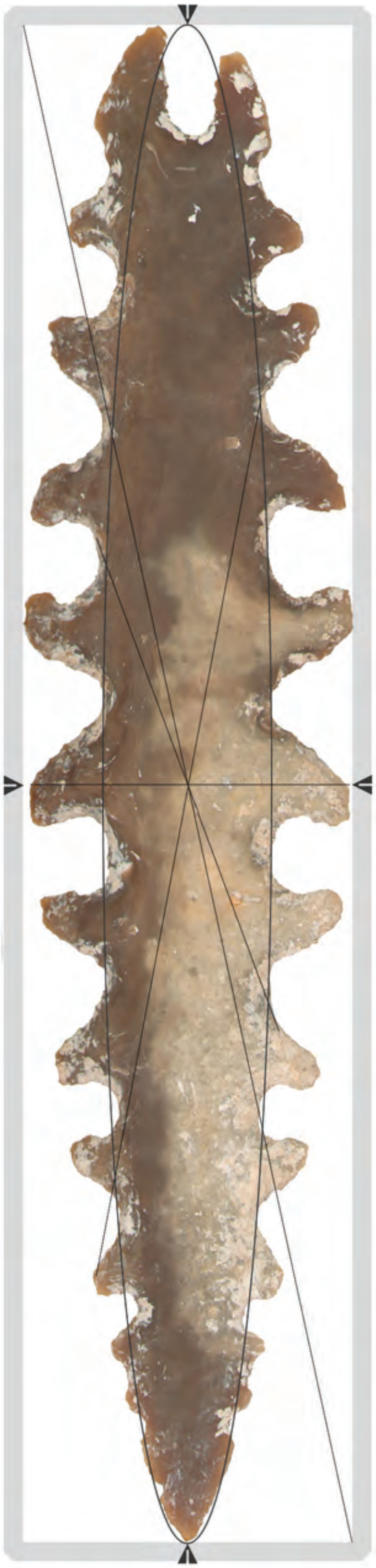
Pairs with C-7, based on web-like inclusions and matching perimeters.

P = 7 cubed = 343.

Triangles formed by connecting planning points have perimeters of 343, 364, and 399 units.

No alignments pass through dead-center.

C-8 Actual size



Roughly ellipse top, and vesica tip.

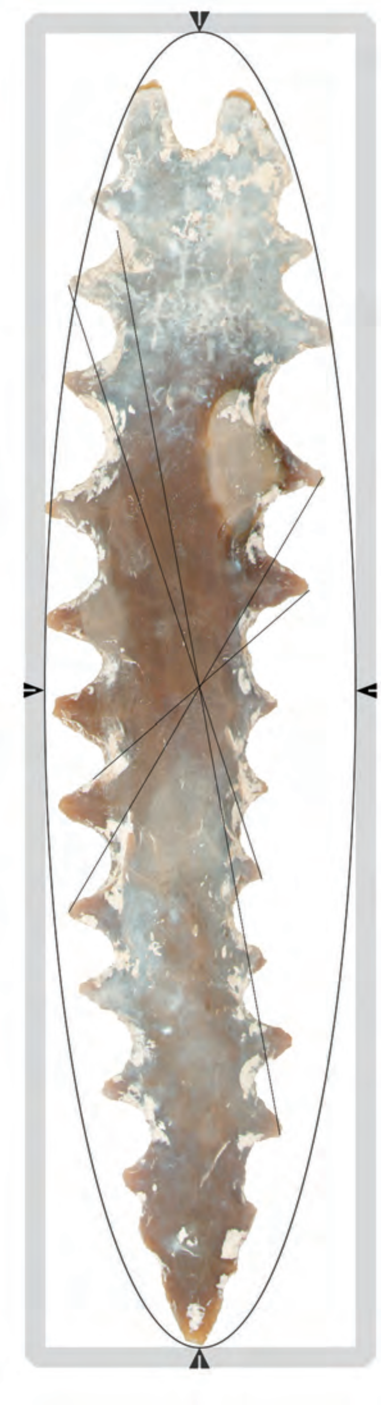
Notch bottoms generally follow a narrow ellipse.

P = 15 lunar months.

Notches = 26 = (2×13)

Three alignments pass through dead-center, one alignment coincides with a frame diagonal.

C-9 Actual size



Adapted from ellipse top, vesica tip. Left side ~180 mm vesica. Diagonal guides were used to position limb tips. Each set may have different alignment. Shortened spikes on the right side isolate seven notches.

P = 13×29 = 377.

Thirteen notches on each side.

Four alignments pass through dead-center.

C-10 Actual size

Cortex at top of 7-limbed mirror-symmetry form.

Best vertical orientation is found on a vertical joining the inside of the right leg with the upper right inflection formed by a break. No ellipses could be found that fit comfortably.

P = 4 Mercury cycles.

Thirty seven notches.

No alignments pass through dead-center.

C-11 Actual size

Cortex at top of 7-limbed mirror-symmetry form.

P = 13 lunar months = 3×2^7.

Seven notches.

No alignents through dead-center.

C-12 Actual size

7-limbed mirror-symmetry form.

The vertical alignment is found by drawing a line between the inner right leg and the upper right inflection. This places the top on the center axis. The apparent vertical axis is offset 1.2 mm from the true vertical axis. When an ellipse is drawn tangent to the lower left leg, it cuts the right leg in such a way to regain symmetry.

P = 12 lunar months

Seven notches.

No alignments through dead-center.

C-13 Actual size

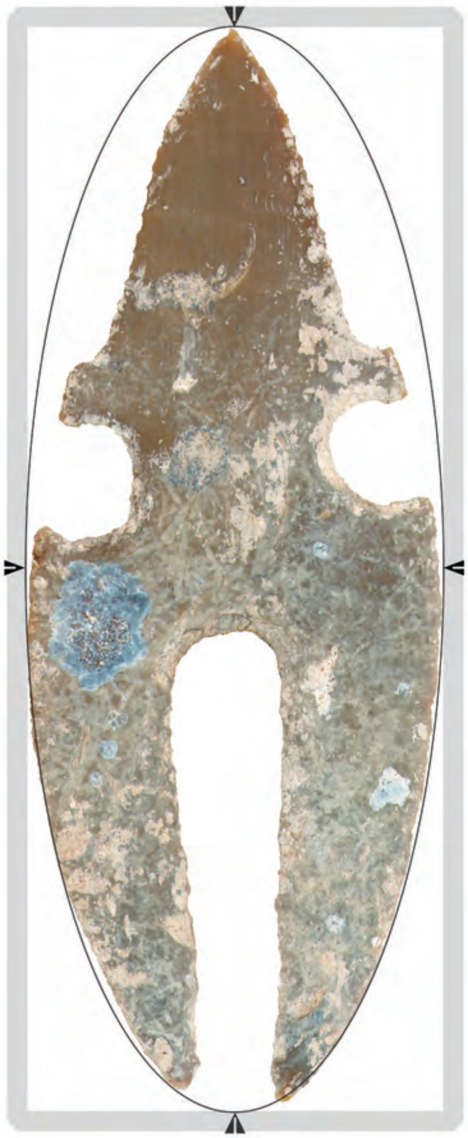
5 limbed mirror-symmetry form. Pairs with C-14.

P = 13×30 = 390.

Thirty one notches.

No alignments through dead-center.

C-14 Actual size



5-limbed mirror-symmetry form. Pairs with C-13.

P = two lunar nodes.

Five notches.

No alignments through dead-center.

C-15 Actual size

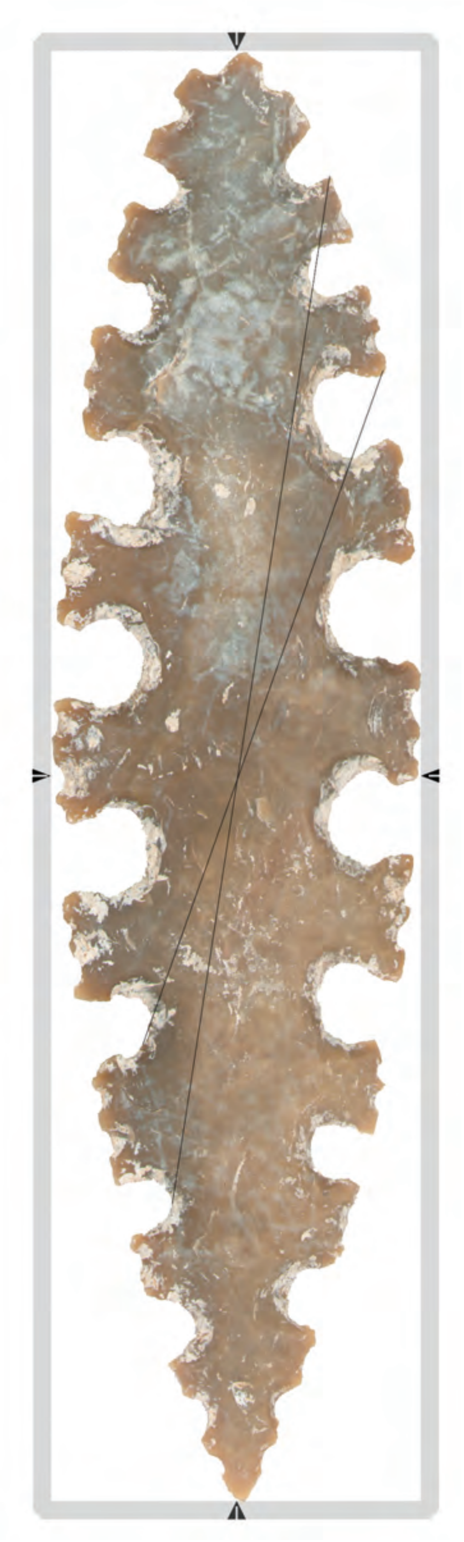
8-limbed, lateral mirror-symmetry form.

P = 260 = 5×52 = 13×20.

Eight notches.

Two alignments pass through dead-center.

G-16 Actual size



Vesica frame, 11 leg pairs aligned diagonally.

Tip-to-tip alignment is offset 0.7 mm from vertical center line.

P = 420, 20 times the long side of the heavenly rectangle.

Fourty nine notches.

Two alignments pass through dead-center.

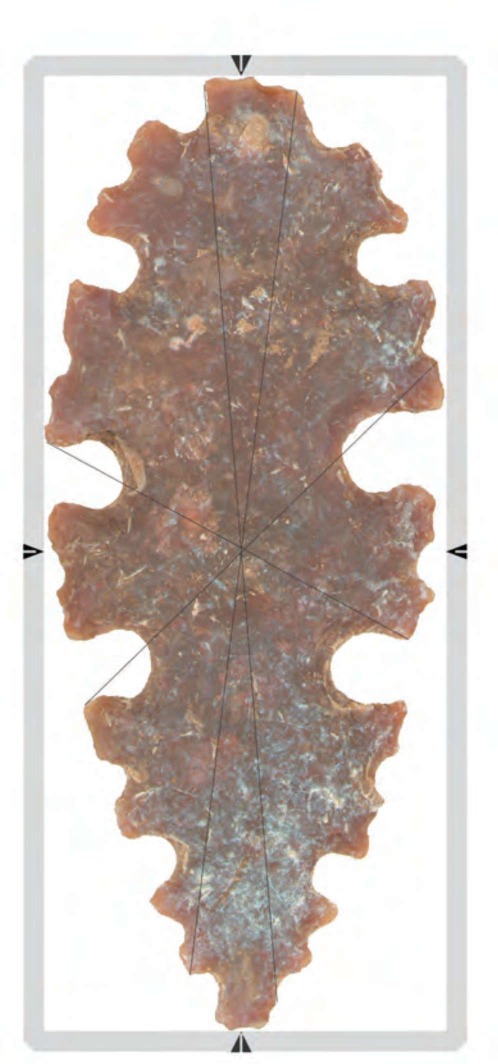
C-17 Actual size

10-limbed.

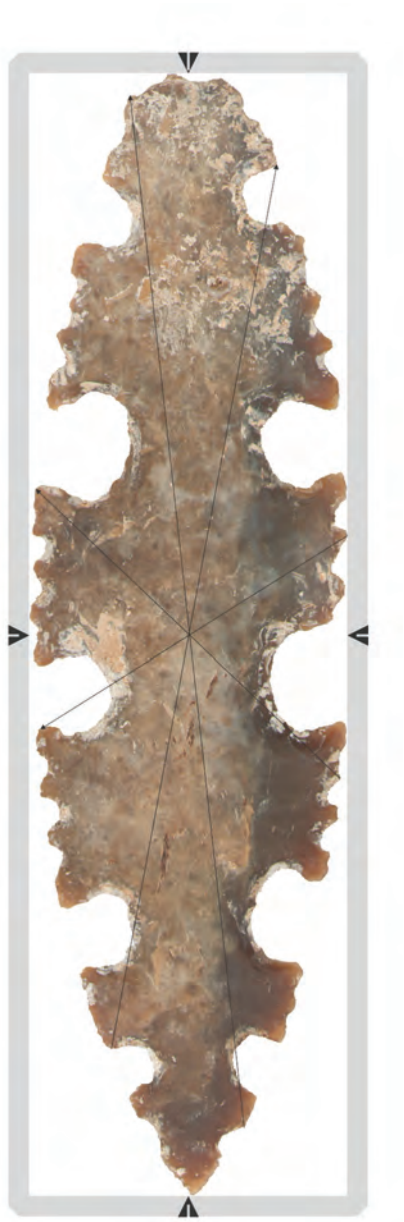
P = 6×52 = 3×104.

Twenty two notches.

Four alignments pass through dead-center.



C-18 Actual size



8-limbed.

P = 9×37.

Thirty one notches.

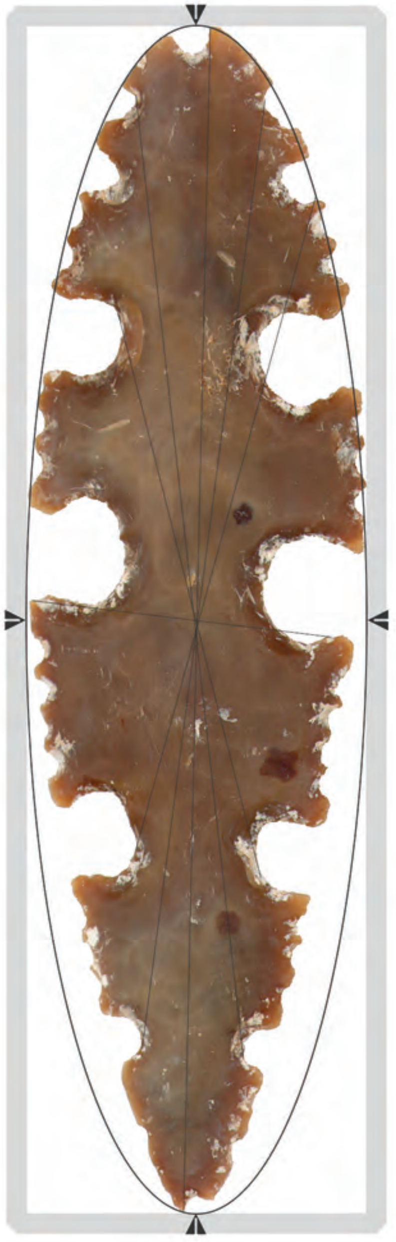
Four alignments pass through dead-center.

C-19 Actual size

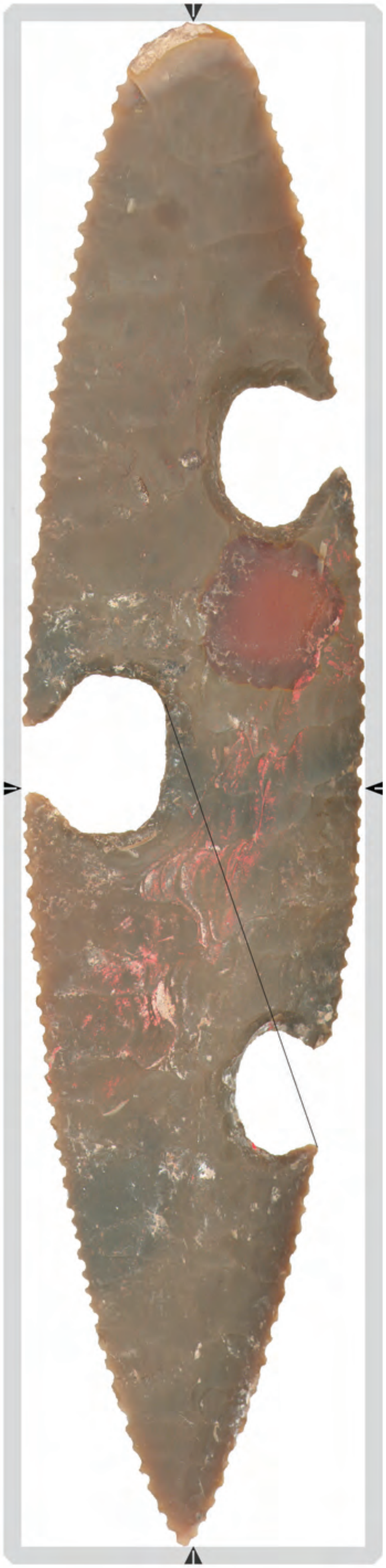
Ellipse top.

P = 12 lunar months.

Six radial alignments pass through dead-center.



C-20 Actual size



With C-21, half of almanac pair.

The tip-to-tip axis is offset 1.6 mm from the physical vertical axis. Small notches cut away black paint.

Cortex at top of vesica frame with 3 gaps.

P = 17 lunar months

One hundred thirty two notches

$P_{20} + P_{21} = 1000$

Five holes times 260 = 1300

1300 times 1000 unit perimeter = 1,300,000

One alignment passes through dead-center.

C-21 Actual size

With C-20, half of almanac pair.

Cortex at top of ~280 mm radius vesica frame with two gaps. Small notches cut away black paint.

P = 13×38, (height = 200 Au)

One hundred twenty eight notches

No alignments pass through dead-center.

C-22 Actual size

Mirror-symmetry vesica frame with no notches, gaps, or serration. Cortex at top. Appears to have remnants of white paint.

P = 13×38 = 493 = calendar rounds in Maya epoch.

No notches.

No alignments pass through dead center.

C-23 Actual size

Cortex on top of 132 mm radius vesica frame. Pairs with C-24.

P = 12 lunar months.

Sixty one notches.

No alignments pass through dead-center.

C-24 Actual size

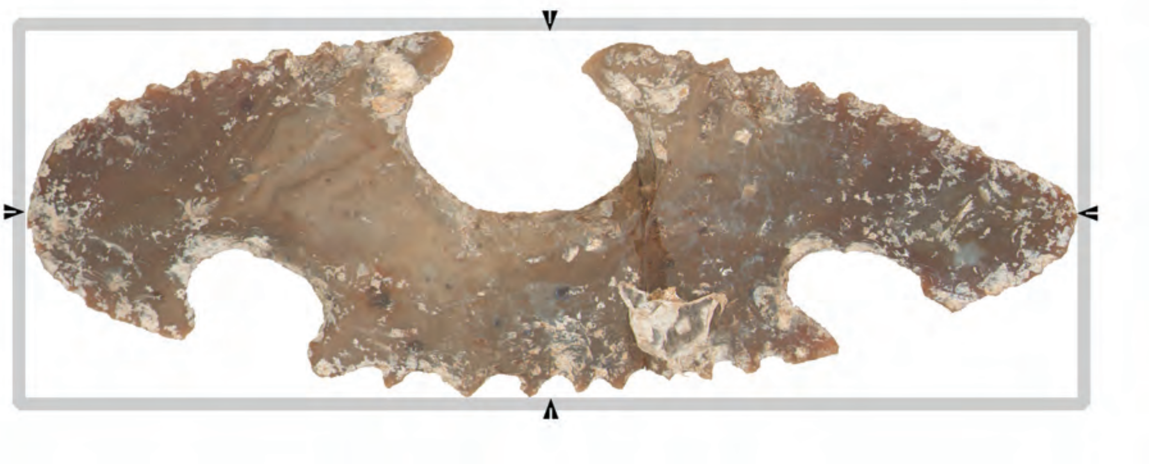
Cortex on near-ellipse top, tip defined by separate arc on each side. Pairs with C-23.

P = 13×23.

Sixty notches.

No alignments pass through dead-center.

C-25 Actual size Night bird?



Major and minor axis cross at edge of central opening. Pairs with C-24.

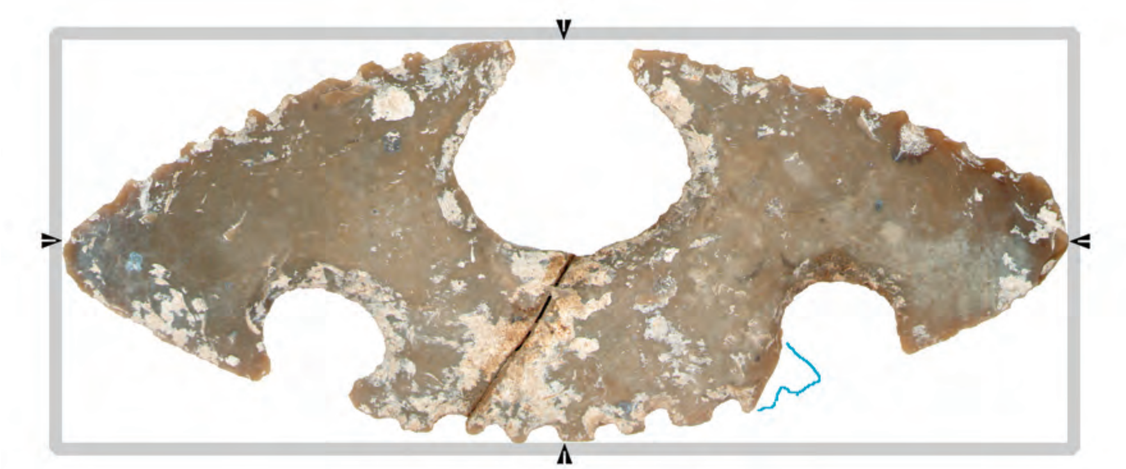
Tail is defined by an arc of about 112 American units radius.

P = 6×7×8.

Twenty-nine or thirty notches used as a lunar calendar?

No alignments pass through dead-center.

C-26 Actual size



Repaired break may distort the short dimension. Pairs with C-25.

Tail is made by an arc of about 70 American units radius.

P = eleven lunar months.

30 or 31 notches.

No alignments pass through dead-center.

C-27 Actual size

Paired with C-28.

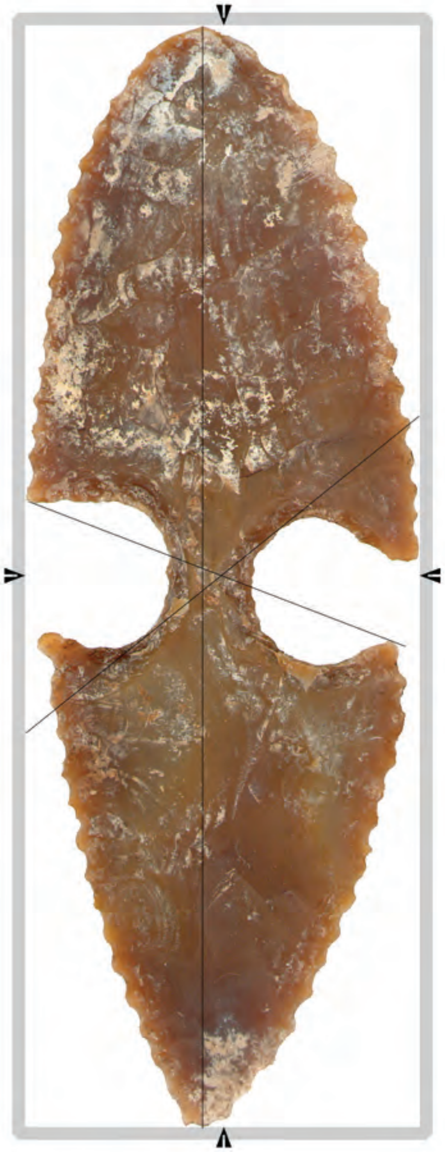
Asymmetric, with cortex at top.

P = half Venus cycle ~ 6×7^2.

Fifty five notches.

Two alignments pass through dead-center.

C-28 Actual size



Paired with C-27.

Asymmetric artifact appears to have been salvaged from one with an ellipse frame. Two non-symmetric arcs define the tip. Two more oversized notches leave a narrow central stem.

Tip-to-tip alignment is offset from the frame vertical centerline by 2.6 mm.

P = 2×173.31 = sidereal year, two eclipse nodes

Sixty one notches?

Two alignments pass through dead-center.

C-29
Actual
size

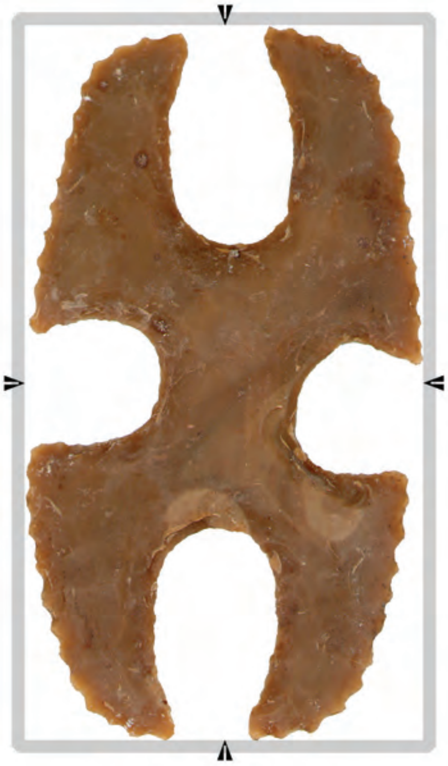
***K'in*/Sun** symbol. Pairs with C-30. Mirror symmetry form.

P = 13×22 = 286

Fifty four notches.

No alignments pass through dead-center.

C-30
Actual
size



***K'in*/Sun** symbol. Pairs with C-29.

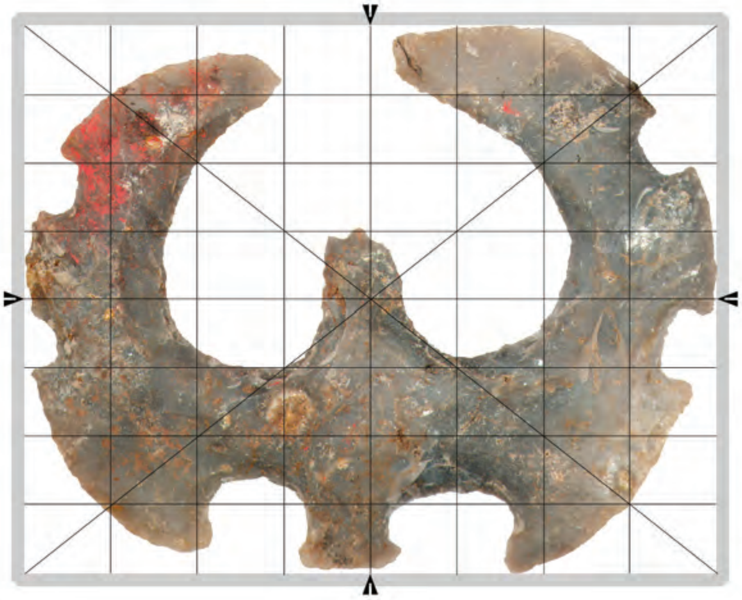
Mirror symmetry form. Sides conform roughly to an ellipse about 1.5 times the width.

P = 2^8 = 256

Fifty five notches.

No alignments pass through dead-center

C-31 Actual size



Bat
Mirror-symmetry, with seven openings.

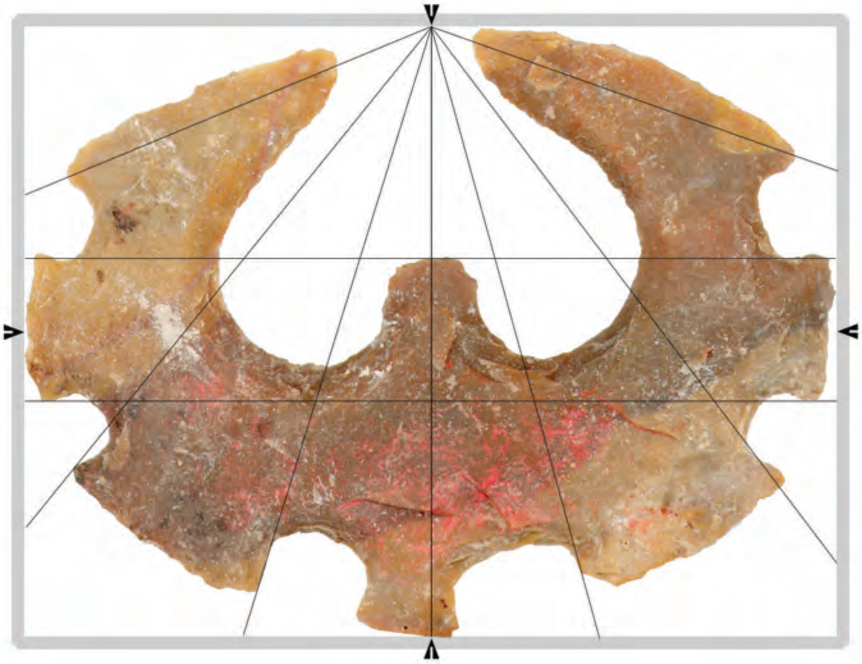
P = seven times 41, (width = 80 Au)

Seven notches.

Coarse match to 8 by 8 grid.

No alignments pass through dead-center.

C-32 Actual size



Bat
Not quite an ellipse, mirror-symmetry with seven openings.

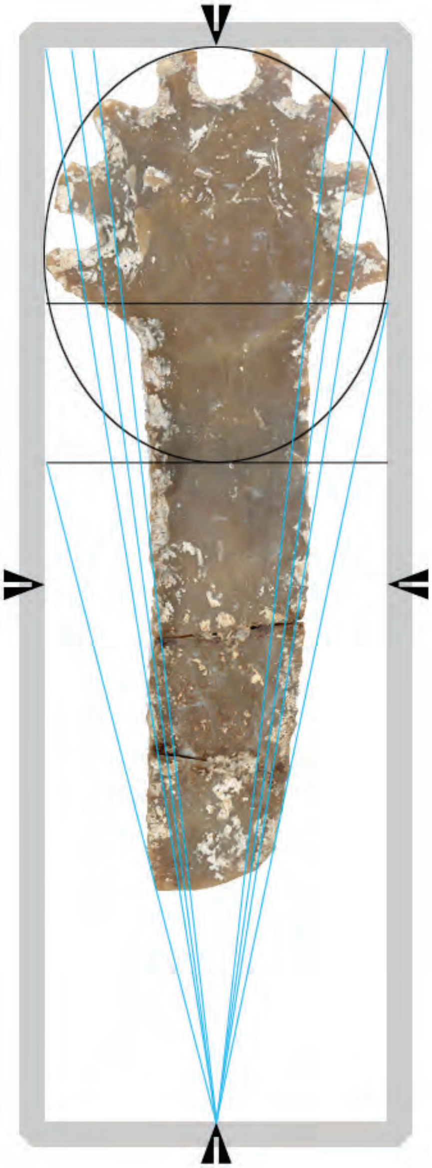
P = seven times 47.

Seven notches.

Six symmetrically arrayed radials.

No alignments pass through dead-center.

C-33 Actual size



***Ceiba* tree,** symbol of life.

The lower part of the trunk is missing, but geometry allows a good estimate. Foliage is depicted with seven notches, and eight spikes. The design is more symmetric than it first appears.

A horizontal alignment is indicated by very subtle “lugs” on either lower side of the foliage, as if they are there to rest on a horizontal string. Radials drawn from the nadir to the upper corners of the box intersect the lug edges precisely. Projecting the remaining straight portions of the broken stem intersects on the physical central axis.

P = eleven lunar months, (width = 40 Au)

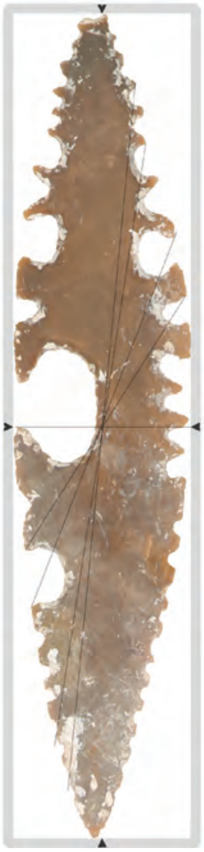
An ellipse about top foliage is controlled by a box whose perimeter is very near the lunar node value of 173.31.

Seven notches.

No alignments pass through dead-center.

FAMILY 1 - faces

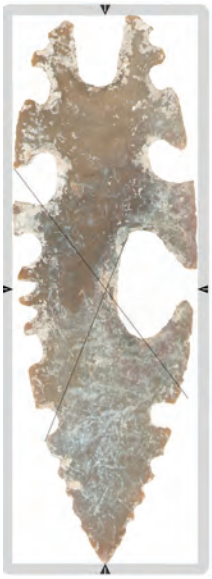
C-1



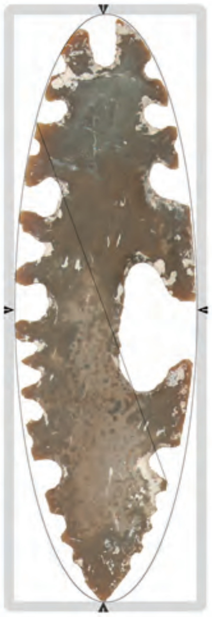
C-2

C-3

C-4



C-5

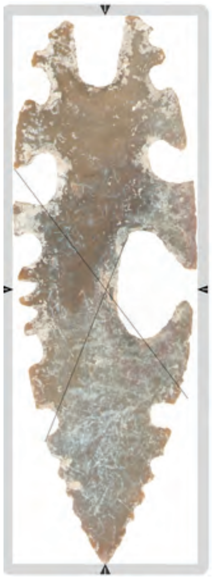


C-6

{C-7}

FAMILY 2 - small pincers

C-1



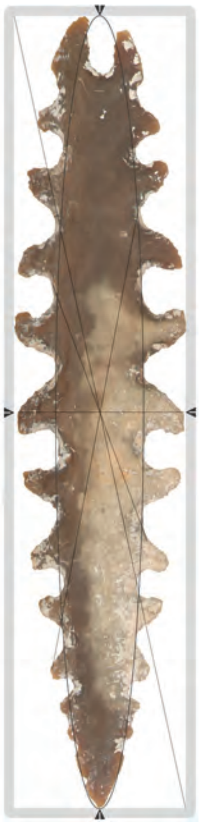
C-4

C-5

{C-6}

C-7

C-8



C-9

FAMILY 3 - tall legs

{C-1}

C-10

C-11

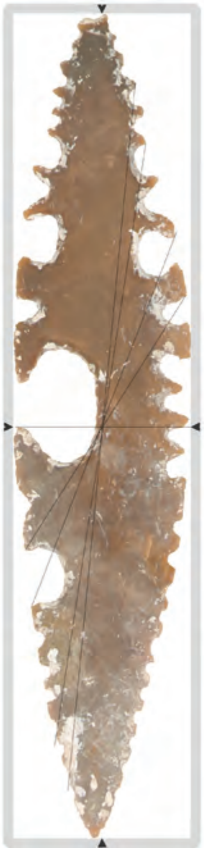
C-12

C-13

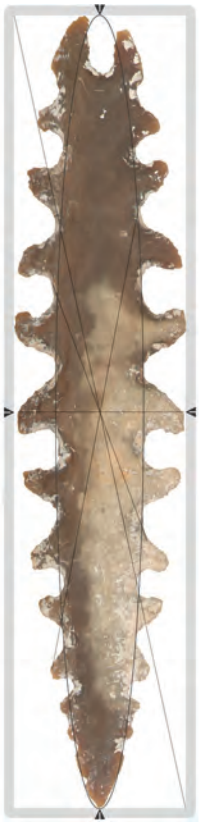
C-14

C-15

FAMILY 4 - symmetric notches on leaf frames



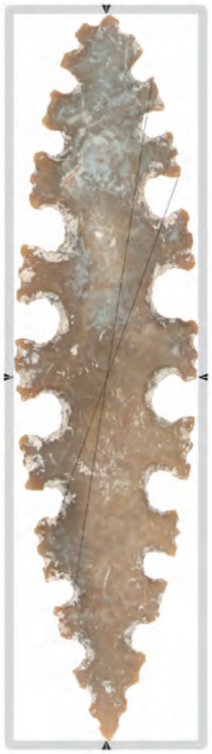
{C-2}



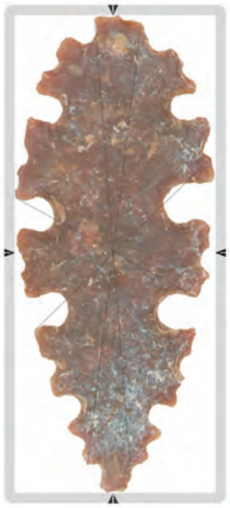
C-8

C-9

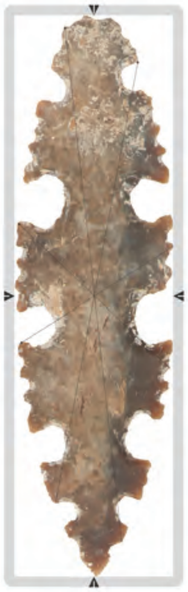
C-16



C-17

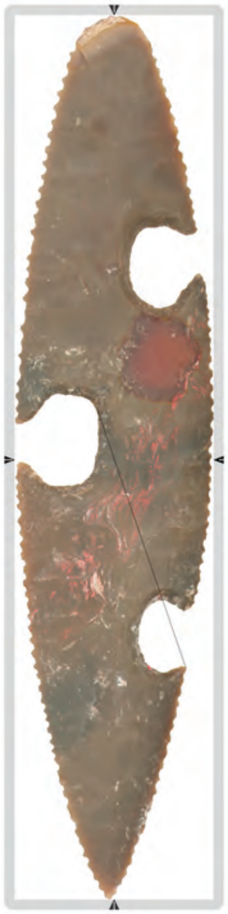


C-18



C-19

FAMILY 5 - symmetric leaf frame



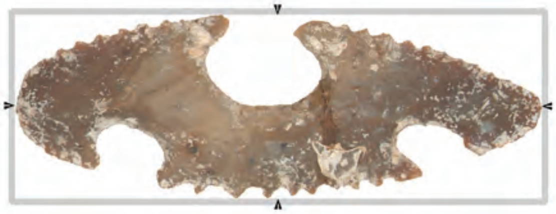
C-20

C-21

{C-22}

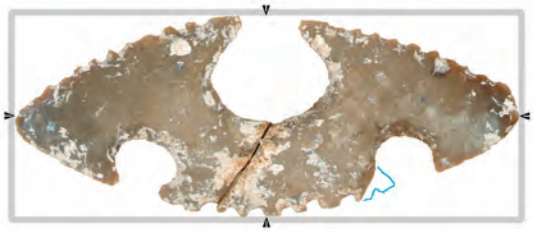
C-23

C-24



C-25

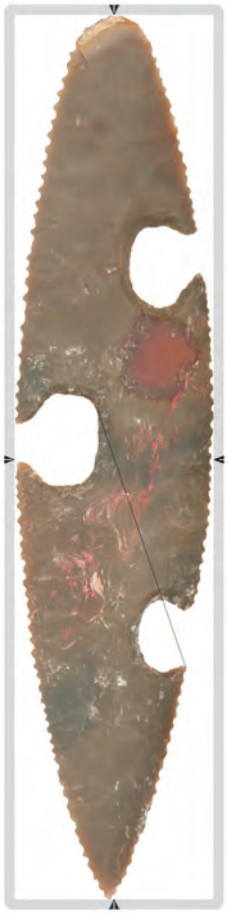
C-26



FAMILY 6 - cortex at top

C-10

C-11



C-20

{C-22}

C-23

C-24

C-27

FAMILY 7 - pairs

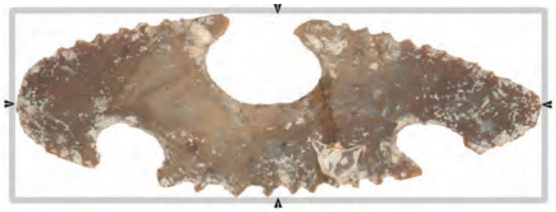
{C-6}

{C-7}

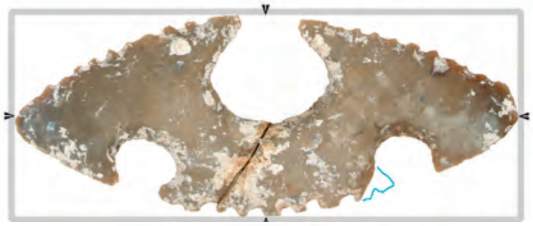
C-13

C-14

C-25



C-26



C-28

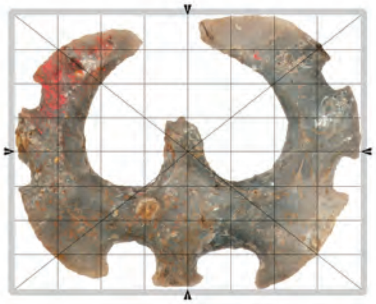
C-23 C-24

C-27

C-30

C-29

C-31



C-32

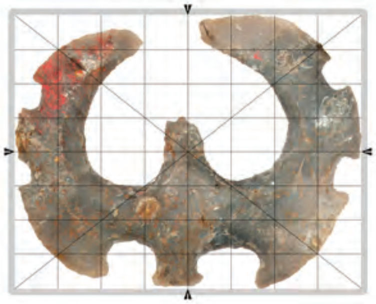
FAMILY 8 - seven notches

{C-9}

C-10

C-11

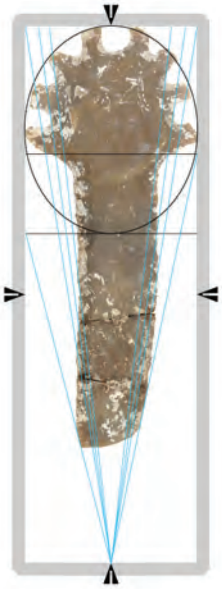
C-32



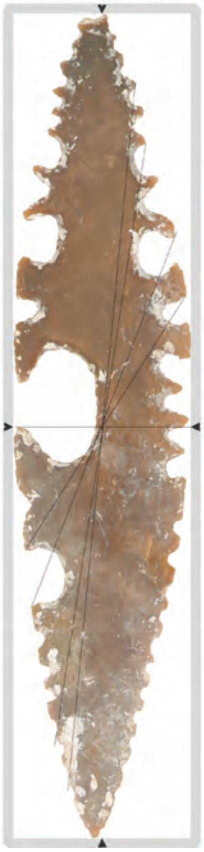
C-33

C-12

C-33



FAMILY 9 - Offset tips



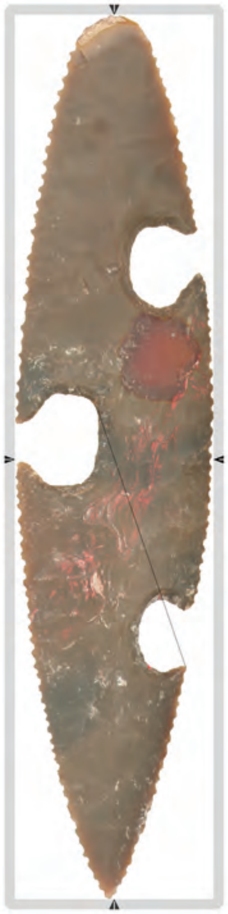
{C-2}

C-3

C-12

C-16

C-29

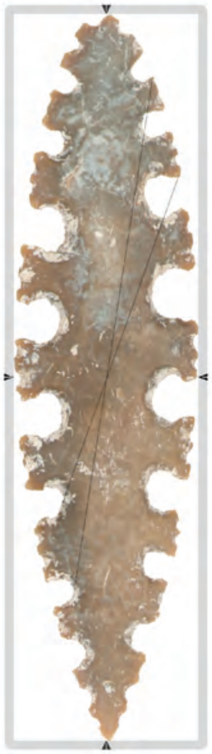


C-20

C-21

FAMILY 10 - No alignment through dead center and no bounding ellipse

C-10



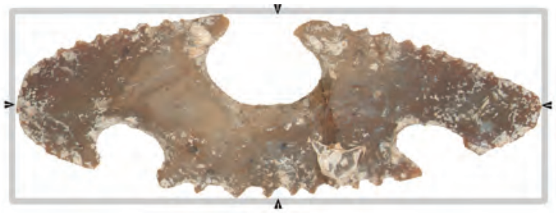
C-16

C-21

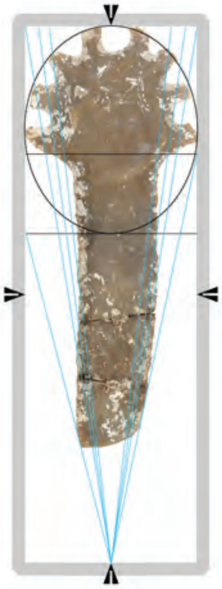
C-22

C-23

C-25



{C-33}



FAMILY 11 - No alignment through dead center and with bounding ellipse


C-7


{C-9}


C-11

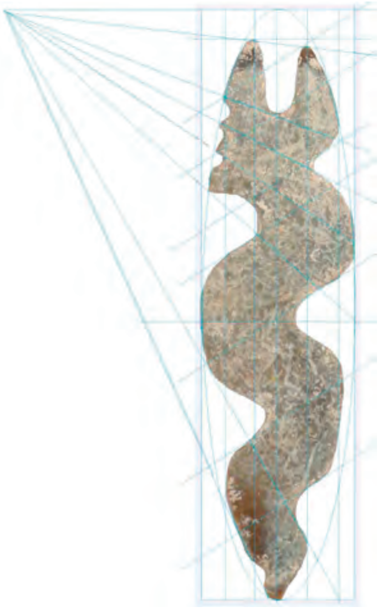

C-12

C-13

C-14

C-19

FAMILY 12 - misfits



F1--F7--C-7

F2&F7--C-6

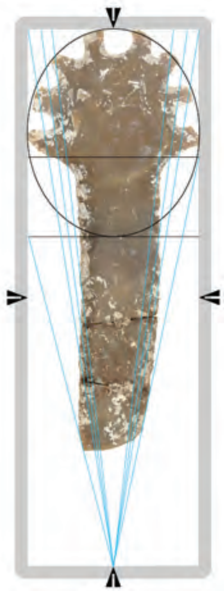
F3 C-1

F4--C-2

F5&F6--C-29

F8- C-9

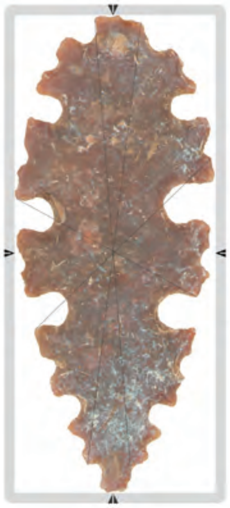
C-33



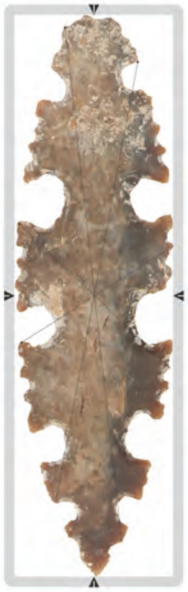
Family 13 - Exemplars

C-15

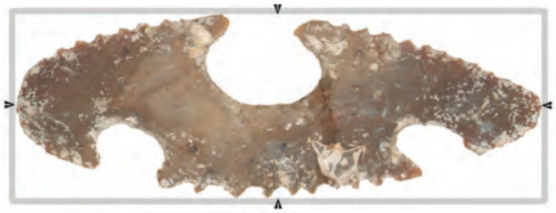
C-17



C-18



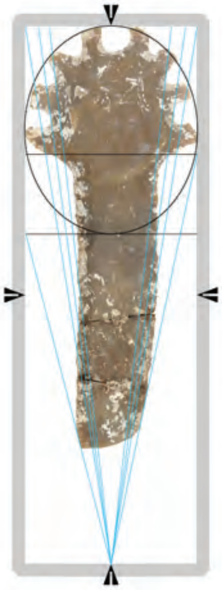
C-25



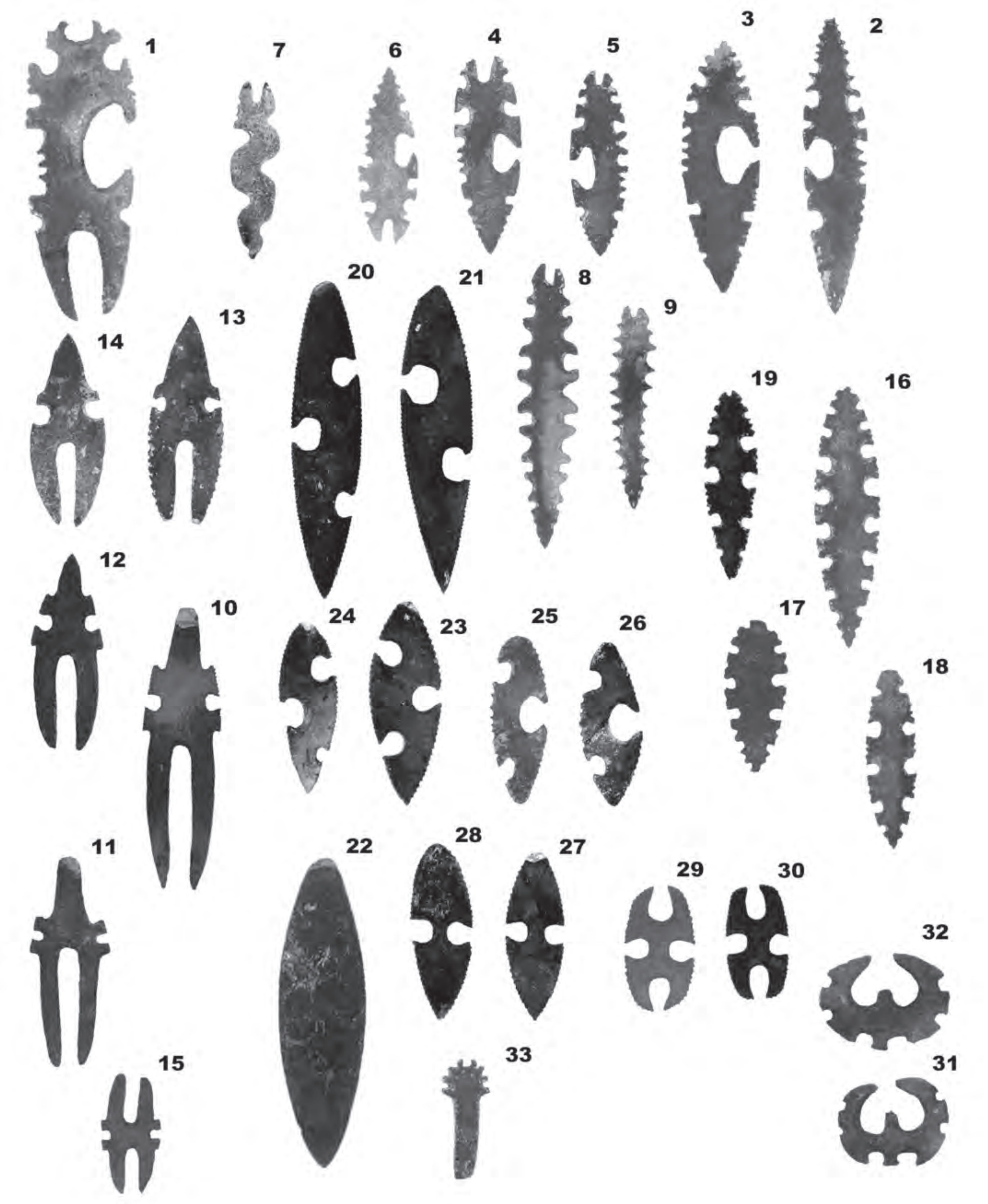
C-28

C-30

{C-33}



Entire cache at same relative scale



Glossary

Altitude: Angular measure of a star’s vertical position above the horizon.
Analemma: Elongated figure eight figure representing the position of the sun in the sky at the same time of day throughout the year.
Anomolistic month: Interval between successive passages of the moon by the perigree point (nearest to earth); 27.55455 days.
Asterism: An easily recognized group of stars, part of a constellation.
Astronomical horizon: A great circle centered on the observer and tangent to the surface of the Earth.
Axial tilt: Angle between an objects rotational axis and a line perpendicular to its orbital plane. (Also called obliquity.)
Azimuth: Angular measure in an easterly direction from true north to a star’s vertical position.

B’ak’tun (baktun): 260 *k’atuns*.
Bacob gods: Sky bearers
Bearing: The direction to a point stated as the number of degrees east or west of north or south.

Cardinal directions: Points of the compass: north, south, east, and west.
Celestial equator: Projection of the Earth’s equator onto the celestial sphere, 90 degrees for the celestial poles.
Celestial meridian: Great circle through the celestial poles and the zenith of the observer.
Celestial sphere: A projection of observed celestial bodies on an imaginary sphere with the Earth at its center.
Clock arithmetic: A system of integer arithmetic, where numbers “wrap around” after they reach a certain value — the modulus.
Conjunction: Apparent near-superimposition of positions of celestial bodies.
Commensurable: Quantities can be related to each other by an integer ratio.
Culmination: Passage of celestial body across an observers meridian, reaching greatest or least altitude from the observers horizon.
Celestial sphere: An astronomical reference system based on an imaginary sphere centered about the Earth.

Declination: Angular measure from the plane of the equator to a star.
Distance number: Number of days between two dates.
Draconic month: Time for one revolution of the Moon around the Earth relative to its ascending nodes, 27.21222 days.

Eclipse: Occurs when the Moon orbit intersects that of Earth's around the sun.
Ecliptic: The apparent yearly path of the sun against the background stars, inclined 23.5 degrees to celestial equator.
Ecliptic limit (lunar or solar): Zone near the nodes of the Moon's orbit, in which a lunar or solar eclipse may occur.
Ellipse: A conic section, for which the sum of distances to any point on it from two foci of the ellipse is constant.
Equinox: When the Sun crosses the celestial equator, it rises due east and sets due west. The vernal equinox occurs near March 21 when the Sun crosses from south to north and the autumnal equinox occurs near September 22 when the Sun crosses north to south.

Eccentricity: Measure of how much an elliptical orbit departs from a circle.

Factorization: The decomposition of a number into a product of other factors that, when multiplied together, give the original.
Fibonacci number: A sequence of numbers where each number is the sum of the previous two numbers.

Galactic equator: Plane of the Milky Way.
Gnomon: An object, such as the style of a sundial, that projects a shadow used as an indicator.
Grid north: The direction northwards along the grid lines of a map projection.

Haab': 365 days.
Heavenly rectangle: A rectangle in the proportion of 13 by 21 units.
Hierophany: Revelation of the sacred in an object or event of the otherwise profane world.

Inflection: A turning or bending away from a course or position of alignment.
Intercalation: Insertion of a portion of time into a calendar.

Ka'tun (katun): 260 *tuns* or 93,360 days.
K'awiil: Maya Lightning deity, often personified as a royal scepter.
K'in (kin): A day.

Long count: Number of days elapsed from the start of the calendar.
Longitude: E-W celestial longitude position, usually referenced by the angle from equinox.
Lunar node: The point where the orbit of the moon crosses the ecliptic, determined by occultation of stars on the ecliptic.
Lunar standstill: Point of maximum inclination of lunar orbit to the ecliptic, that defines a 6,798-day cycle of the precession of lunar nodes.
Lunation: A synodic month.

Magnetic north: Direction indicated by a magnetized needle.
Metonic cycle: A period of 235 lunar months, or about 19 years in the Julian calendar, at the end of which the phases of the Moon recur in the same order and on the same days as in the preceding cycle.
Mnemonic: A memory or learning aid.
Modulus: The value at which numbers "wrap around" in clock or modulo arithmetic.

Modulo math: Integer arithmetic that reduces all numbers to one of a fixed set [0...N-1] by effectively repeatedly adding or subtracting N (the “modulus”) until the result is within this range.

Nadir: The point directly below a plumb line, opposite the zenith.
Node: Point at which two orbits intersect. Intersection of grid lines.
N-point line: A straight line that can be defined by n-number of points.

Obliquity of the ecliptic: Inclination of the plane of the ecliptic to the plane of the celestial equator.
Occultation: Blocking one stellar object from view by another, as in an eclipse.

Parallax: Apparent displacement of an object’s position caused by changing the viewing position.
Payab: 94,900-unit measure of land.
phi: Irrational number, (1+sqrt5):2 = 1.61803...
Phi: Reciprocal of *phi*, 0.61803...
pi: Irrational ratio between the circumference of a circle and its diameter.
Precession: Slow migration of the earth’s axis of rotation, taking approximately 26,000 years to move apparent North in a complete circle opposite of Earth’s rotation.

Regression of nodes: Westward progression of nodes of the lunar orbit along the ecliptic, taking 18.61 years to complete one cycle.
Remainder: The non-integer amount left over from dividing integer quantities.
Residual: The quantity left over at the end of a process; a remainder.

Saros cycle: A period of 18 years, 11 days, 8 hours. After one Saros cycle, the moon will have completed roughly an integer number of synodic, draconic, and anomalistic months, and the Earth-Sun-Moon geometry will be nearly identical: the moon will have the same phase and be at the same node.
Seasonal year: Tropical year, tracked in regard to the seasons.
Semiotics: Study of how meaning is created by signs.
Scaling factor: A number that can be multiplied to maintain proportionality.
Sidereal period: Interval between successive passages of a body by a given star.
Synodic month: Lunation, or period between two identical phases of the Moon.
Synodic period: Interval between successive configurations of a body relative to the Sun.
Solstice: When the ecliptic is 23.5 degrees north of the celestial equator, approximately June 21.
Solar transit: When anything passes between the Sun and the Earth.

Tangent: A point in common between a straight line and a curve without them crossing.
Tangible point: Location that is permanently occupied by a physical object.
Trecena: Thirteen-day interval.
Trigonometric identity: Equalities that involve trigonometric functions that are true for every single value of the occurring variables.
Tropic of Cancer: Parallel of latitude 23.5 degrees north. Most northerly latitude where the sun can cast a shadow directly to the nadir.
Tropical year: Period of revolution of the earth around the sun (365.2422 days), commonly known as the seasonal year.
True north: Direction to the celestial pole, presently near Polaris.

Tun: 360 days.
Tzolk'in (tzolk'in): 13 *winals* or 260 days. (modern term)

Wayeb: Five nameless days closing out a *haab'* of 365 days.
Winal (uinal): 20-day interval.

Variance: A measure of the dispersion of a set of data points around their mean value.
Vector: A line formally described by coordinates.
Vesica: Shape enclosed by intersecting compass arcs of equal radius.
Virtual point: Location that can be referenced by the intersection of two or more lines, but has no physical presence.

Zapal: 1,300-unit arm span.
Zenith: The point directly overhead, opposite the nadir.
Zodiac: Named constellations in a belt about 8 degrees either side of the ecliptic.

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Index

Decrypting the Sacred

An intuitive insight into intricate, Maya chipped stone eccentrics— once thought merely decorative— may have revealed something far more profound: a sophisticated system for encoding explicit meaning through linear measurement. This discovery could lead to the recognition of a previously unknown method of communicating numeric information, embedded within ancient works.

Tracing this system backward through time connects it to the Olmec civilization and even further to Archaic-period mound sites in Louisiana dating back as far as 7,000 years. Continued exploration of these mound geometries shows that the numbers used to measure time in Mesoamerica correspond to cardinal positions of the 18.6-year lunar cycle at that latitude— suggesting a geographic origin for Mesoamerican calendric science.

The implications of these findings are profound.

They extend the known duration of the Mesoamerican calendric system by a factor of two and suggest an origin as early as 10,250 years ago. As the geometric conventions underlying this system of linear measurement are examined, they reveal how and what people were thinking (long before the advent of writing) while also providing a traceable path for how this knowledge may have moved from one culture to another. The apparent persistence of societal and cultural continuity is unprecedented.

You are invited to join the author on this journey of discovery... and perhaps to contribute your own insight to what may be one of the most exciting opportunities of our time: uncovering the workings of the ancient human mind.

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