THE ORIENTATION OF MAYAN CEREMONIAL CENTERS

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ABSTRACT. Numerous Maya ceremonial centers afford the geographer a rich opportunity to investigate man-land relationships in Meso-America. This study concerns the problem of site and building orientation. Most elements of the physical environment appear to play a minor role in site layout, and astronomical and cultural factors account for only some orientations. None of these reasons explains why the Maya shifted building alignments from time to time and often simultaneously at widely separated locations. The alternation of structural positioning through time indicates a moving reference point, and the tantalizing possibility that the Maya had a method for determining magnetic north is suggested.

AMONG the many cultural landscapes created by preindustrial man during the last two millennia, few surpass that wrought by the Indians of Mayaland.[1] At its cultural peak (ca. A. D. 750), Mayan civilization occupied 100,000 square miles of territory, ranging from tropical rainforest in the southern portions to the tropical steppe of northern Yucatán. More than 100 major ceremonial centers that were erected between A. D. 200–1200 have been located and studied; perhaps a significant number remain to be discovered (Fig. 1).[2]

Although archaeological and ethnological reports concerning the Maya are prolix, little has been done by the geographer. Not since the epic journey of Stephens and Catherwood (1839–1840) has anyone, save the anthropologist, attempted to really understand the character of Mayaland.[3]

THE CEREMONIAL CENTER

The ceremonial center was the Maya's greatest contribution to the cultural landscape. Whereas his agriculture was of a low order, and transitory, his achievements in stone have persisted. The humid tropical climate, with its accompanying vegetation, has erased the meager scars man made with his digging stick on the limestone plain and among the low clay hills. Even in the subhumid north the scrub forest has smothered all vestiges of aboriginal farming. Native dwellings, of wattle-daub construction, resisted the ravages of time and nature with no more success than did the fields. Even the people who built and supported the ceremonial centers have vanished from certain large areas.

But the ceremonial center remains. To a degree, its origins, functions, and diffusion have been made known to us by the anthropologists. The crafts, religion, social and political organization, and artistic and intellectual achievements associated with these centers have been analyzed. We know with reasonable accuracy when, where, and how the Maya lived, farmed, quarried stone, made mortar, mixed pigments, and worked in stucco. His calendar and mathematics are fully comprehensible, and many of his hieroglyphics have been deciphered. Still hidden in the mists of time is his cultural origin, and debates continue on the cause of the collapse of Classical Maya civilization (ca. A. D. 900).

Despite all of the knowledge we have assembled since Bishop Landa wrote his firsthand account, few have backed off far enough from the ceremonial centers to view each as an organic whole, or to compare one with the others.[4] Perhaps the scholar gets too close to

Accepted for publication September 3, 1968.

[1] The term *Mayaland* is used throughout this paper to refer to the territories occupied by the Maya. This encompasses those areas, identified in Fig. 1, where Maya ceremonial centers have hieroglyphic inscriptions and/or corbeled vaulting.

[2] J. E. S. Thompson, *The Rise and Fall of Maya Civilization* (Norman: University of Oklahoma Press, 1954), p. 18. Thompson identified 113 principal sites; however, the total number of major and minor ruins probably totals 5,000.

[3] J. L. Stephens, *Incidents of Travel in Central America, Chiapas, and Yucatán* (New York: Harper and Bros., 1841), and *Incidents of Travel in Yucatán* (Norman: University of Oklahoma Press, 1962).

[4] A. M. Tozzer, "Landa's Relación de las cosas de Yucatán," *Papers of the Peabody Museum*, Harvard University, Vol. 18 (1941).

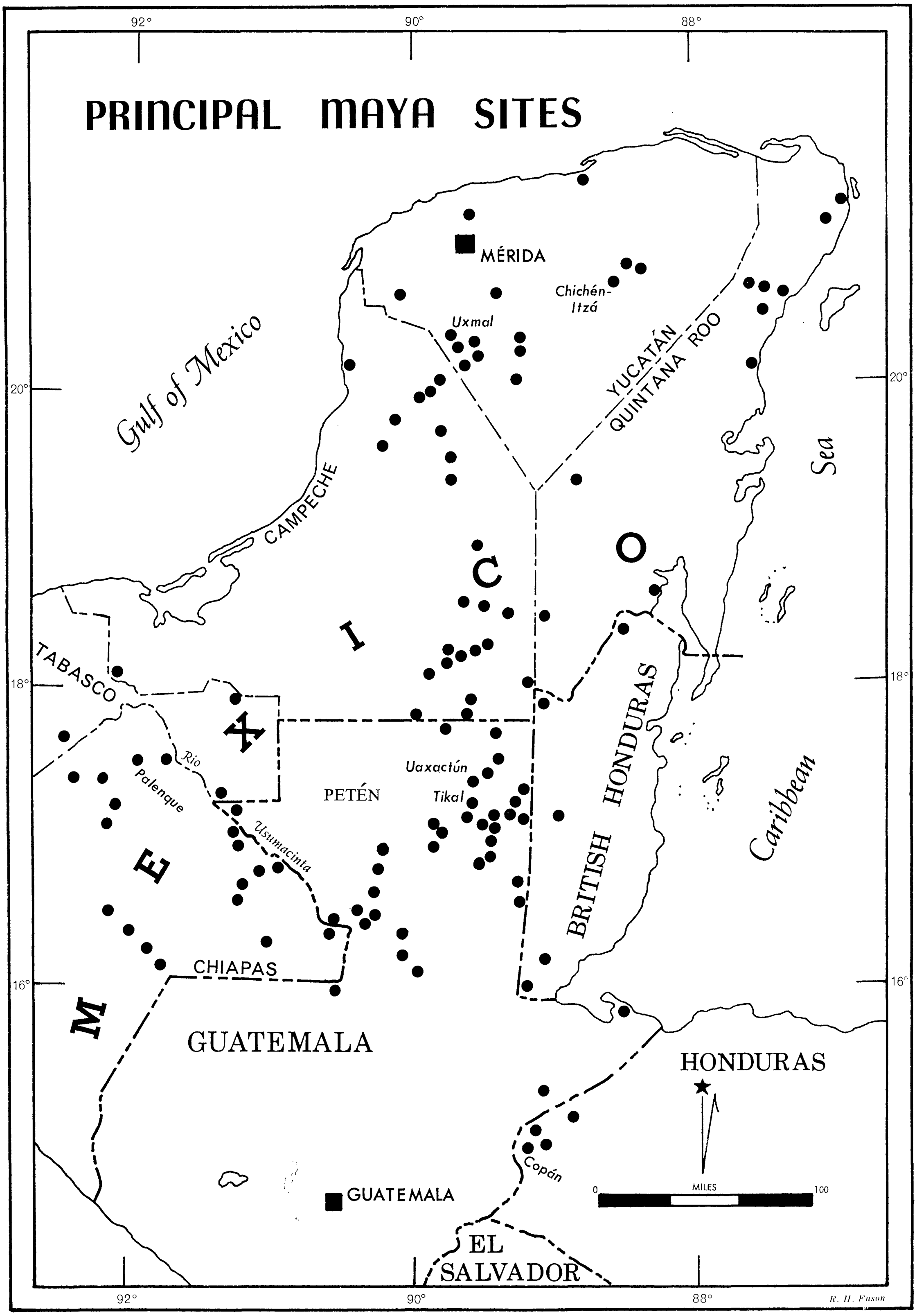

Fig. 1. Principal Maya ceremonial sites.

his work; in an age of specialization this is difficult to avoid. From a distance all Maya centers display a rather similar pattern of temples, monuments, and courtyards. Although never identical there is a pattern of likeness.[5]

When the mapped centers are examined and compared, one fact stands out; almost never are structures within a given ceremonial complex aligned with each other throughout the extent of that complex. The first impression is that there was no plan; that these were "spontaneous" arrangements, and that they grew like Topsy.[6] One building group does not "line up" with another. Often an annex to a building fails to be aligned with its parent structure. It would seem that the Maya architects were unable to build on a grid, though it is equally apparent that this seems to have been their intent. Stephens, while at Chichén-Itzá, was the first to suggest this.[7]

> It (the *Castillo*) does not face the cardinal points exactly, though probably so intended; and in all the buildings, from some cause not easily accounted for, while one varies ten degrees one way, that immediately adjoining varies twelve or thirteen degrees in another.

If variance from a true grid was accidental, then it was consistently accidental throughout Mayaland. When one considers the obsession the Maya had for mathematical precision, it is difficult to imagine why he failed to carry it forth in his ultimate creation, the ceremonial center. The Maya was preoccupied with mathematics, astronomy, and time.[8] Every aspect of his life, including the theology that subsumed everything and everyone, was permeated with mathematical precision. Each individual structure in the ceremonial center was planned and erected with a degree of technical sophistication that evokes envy even today among builders. Yet, the total effect of the centers is one of disarray.

Much has been written of the physical and cultural controls that govern the arrangement and alignment of buildings, whether they be in Mohenjo-Daro or Brasília. Controls such as topography, water bodies, roads, defense necessities, old land-use patterns, politico-economic considerations, astronomical factors, climatic elements, esthetic, and religious influences are among those often mentioned.[9] Operating with the premise that the Mayas were obsessed with a notion of preciseness in everything they did, and that each individual building reflects this quality, the conclusion is reached that the arrangement of each ceremonial center as a unit was governed by something greater than fancy, whim, or sloppy workmanship. Most of the items usually cited as affecting site plan can be discarded at the outset.

Topography had virtually no influence on the general plan; as topography varies the general center arrangement remains constant. This is not to say that topography had no influence on individual structures or on site location. Water bodies also affected the general location of the site (*cenotes* in northern Yucatán, rivers in southern Mayaland, but neither in between), but appear to have had no influence on a center's morphology. Maya sites, until very late and after the Toltec invasion (ca. A. D. 1000), were undefended. Warfare was probably not a part of the Classical Maya scheme of things. Land-use patterns forced no conformities, for property lines were neither private nor fixed, except immediately adjacent to the Maya house, which was located outside the center proper. Climate, with all of its variable elements, correlates in no way with orientation. In fact, there are several reasons (discussed later) why many Maya structures were poorly situated with regard to this factor. Politics and economics may be discounted; Mayaland was not a state in even the Aztec meaning of the word. The list of possible controls that exercised little or no influence on orientation may be extended, but only one remains that must be reckoned with: religion.

Theocratic Mayaland was "ruled" by a priest-astronomer class. These keepers-of-the-pantheon were also the masters of all higher knowledge: mathematics, astronomy, and writing. Without question they directed the planning of ceremonial center layouts. Al-

[5] Thompson, *op. cit.*, footnote 2, p. 61.

[6] A. E. Smailes, *The Geography of Towns* (London: Hutchinson & Co., 1960), p. 103.

[7] Stephens, *Incidents of Travel in Yucatán*, *op cit.*, footnote 3, p. 203.

[8] Thompson, *op. cit.*, footnote 2, pp. 137–59.

[9] J. W. Dow, "Astronomical Orientations at Téotihuacan, A Case Study in Astro-Archaeology," *American Antiquity*, Vol. 32 (1967), pp. 326–34. Dow considers only celestial, topographic, and chance as possible factors affecting Téotihuacan alignments.

though Classic Maya centers were generally autonomous and never formed a political unit, they must have comprised a cultural-theological union. We know that astronomical calculations made at Copán, Honduras, went out to other centers.[10] Other changes, such as stylistic alteration of ceremonial ceramics, were made apparently at the order of some supreme priest, perhaps from Tikal, Guatemala, or from Copán.[11] Ceramic changes can be effected much more easily than those involving architecture or the calendar, but the very fact that they were made at regular intervals opens up the whole question of ancient Maya political organization.

If any controls operated to regulate the arrangement of temples, stairways, platforms, ballcourts, and pyramids, they were religious in nature. The complexity of the typical ceremonial center, however, suggests that a variety of religious dogmas must have prevailed, not only during the 1000-year span of Maya civilization, but often at a given moment in time. It must also be remembered that Maya architecture, planning, astronomy, and mathematics cannot be separated from religion. These things were religion, and vice versa. We might refer to the whole system as one involving a complicated feed-back mechanism, cyclical in nature and having no beginning or ending.

RELIGIOUS CONTROLS ON ORIENTATION

Maya structures, either independently (rarely), throughout an entire ceremonial center (rarely), or in large groups within a given center (usually), are aligned to: 1) some other (perhaps superior?) ceremonial center; 2) astronomical positions (usually to true north or a sun position); or 3) a line that generally coincides with the present magnetic declination in the region (approximately 7° 30′ E). In a few cases there appear to have been two of the above-cited controls in operation at the same time and, in a very few instances, the orientation of a particular building or group cannot be explained by reference to any one of the three controls.

Orientation Toward Another Ceremonial Center

Uaxactún, Guatemala, dates from A. D. 278 (8.12.0.0.0 in the Maya Long Count) to A. D. 889 (10.3.0.0.0).[12] Construction at the site was probably begun before the first dated stela was erected (A. D. 278) and there is a radiocarbon date of A. D. 187 for the earliest group.[13] During the Early Classic Period, from A. D. 278 to 593 (9.8.0.0.0), all important buildings faced south, toward Tikal (twelve miles away).[14] Tikal may have been the parent center, from which Uaxactún was settled, and from the North Acropolis at Tikal we have a radiocarbon date of 439 B. C.[15] A "colony" might be oriented toward its founder, whose major temples were within eyesight of the offspring. Most of the structures in Group *E* (as it is designated by the archaeologists) were oriented to the cardinal directions (Fig. 2), and the more important of these were erected before A. D. 357 (8.16.0.0.0).[16] When Uaxactún's ceremonial emphasis shifted to another area (Group *A*), there was a corresponding shift in building orientation. A possible explanation for this is discussed later, and it may indicate that Uaxactún was by then following a course independent from that of Tikal.

It would be extremely tenuous to suggest that many other (or any other) centers were aligned toward some other center. It may be only coincidental that Uaxactún faced Tikal, but the circumstantial evidence indicates that it was intentional.

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[10] Thompson, *op. cit.*, footnote 2, pp. 79–80; and S. G. Morley, *The Ancient Maya* (Stanford: Stanford University Press, 1956), pp. 276–79.

[11] J. M. Longyear, III, *Copán Ceramics: A Study of Southeastern Maya Pottery* (Washington, D. C.: Carnegie Institution of Washington, Publication 597, 1952), pp. 69–70; and A. L. Smith, *Uaxactún, Guatemala: Excavations of 1931–1937* (Washington, D. C.: Carnegie Institution of Washington, Publication 588, 1950), p. 8.

[12] Smith, *op. cit.*, footnote 11, pp. vi, 67–68; and R. F. Flint and E. S. Deevey, "Uaxactún," *Radiocarbon*, Vol. 1 (1959), p. 165. The Maya Long Count dates are given here because positive correlation of Maya and Christian calendars has yet to be made. The Goodman-Martínez-Thompson system is used, with 3113 B. C. accepted as the beginning date for the Maya count. For a summary of the dating problem, and a bibliography of recent works pertaining to it, see E. K. Ralph, "Review of Radiocarbon Dates from Tikal and the Maya Calendar Correlation Problem," *American Antiquity*, Vol. 30 (1965), pp. 421–27.

[13] Flint and Deevey, *op. cit.*, footnote 12.

[14] Smith, *op. cit.*, footnote 11, p. 13.

[15] E. S. Deevey, R. F. Flint, and I. Rouse, "Tikal," *Radiocarbon*, Vol. 8 (1966), pp. 371–83.

[16] Smith, *op. cit.*, footnote 11, pp. 69, 86–87.

Orientation Toward An Astronomical Position

The alignment of structures and building complexes with astronomical positions is an ancient one.[17] Ancient man attributed supernatural powers to celestial bodies and certain temples were dedicated to these deities, even in societies with poorly developed mathematics and astronomy. It was probably because of an early religious need to follow the gods through the skies that led to a gradual accumulation of knowledge which appears to us to be more astronomical than theological. Nevertheless, religious considerations were the *raisons d'être* for all ancient astronomical development—even the highly sophisticated kind—and with the Maya this was especially true.

Polaris

Ursa Minor, which the Maya called the "guardian of the north," provided a positive reference to the pole star, *Xaman Ek*. Even though Polaris made a general determination of north relatively easy, during Classical Maya times it was further from the geographic north pole than at present. In fact, at the pinnacle of Classical Maya civilization (ca. A. D. 700), *Xaman Ek* described a circle 18° from the pole of the ecliptic (about 5° from the rotational pole). Precise orientation by this means would have been difficult, though not impossible.

Sun

Maya calculations pertaining to the sun were exceedingly accurate. By the sixth century A. D. the Maya solar calendar was more accurate than the Gregorian calendar now in use in the western world. The length of the year, as determined by the Maya priest-astronomers, was 365.2420 days.[18] Modern astronomy sets the solar year at 365.2422 days, whereas the present calendar yields a year of 365.2425 days. The old Julian year (used until 1582 in the Roman Catholic countries, and until 1752 in Great Britain and its colonies) set the year at 365.2500 days.[19]

Maya astronomical manipulations are too well known to repeat here, but it should be noted that they probably had a zodiac of thirteen units.[20] The Pleiades were *tzab ek* (rattlesnake-rattles star), Gemini were *ac ek* (turtle stars), and Scorpio were *zinaan ek* (which strangely enough meant "scorpion stars").[21]

Considering such a high order of solar astronomy, it is logical to assume that the Maya determined cardinal directions by means of the sun rather than by Polaris. The Observatory (*Caracól*) at Chichén-Itzá, Yucatán (Fig. 3), was clearly an astronomical observatory, with positions for viewing strategic sun positions and moon points.[22] The "round tower" at Mayapán, built in the late thirteenth century, was probably copied from the *Caracól*.[23]

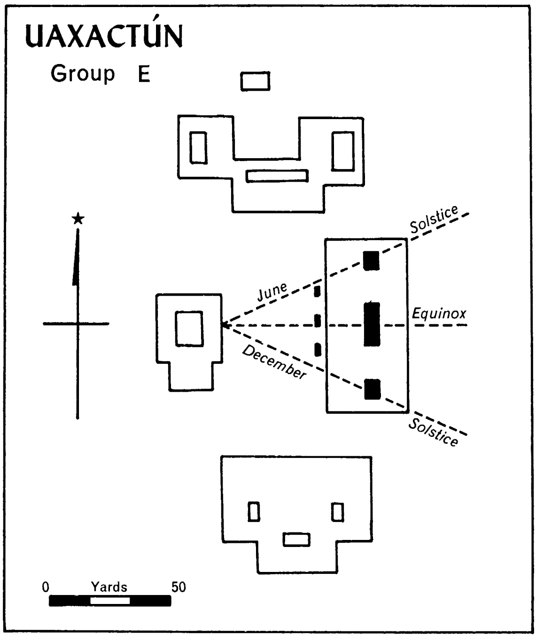

FIG. 2. Group *E*, Uaxactún, Petén, Guatemala. The building assemblage strongly suggests solar alignment.

[17] G. S. Hawkins, *Stonehenge Decoded* (New York: Doubleday & Co., 1965); Dow, *op. cit.*, footnote 9, pp. 326–34.

[18] Morley, *op. cit.*, footnote 10, p. 256.

[19] L. C. Harrison, *Sun, Earth, Time and Man* (Chicago: Rand McNally & Co., 1960), pp. 214–19.

[20] Morley, *op. cit.*, footnote 10, p. 260.

[21] Morley, *op. cit.*, footnote 10, pp. 260, 468; and *Codex Peresianus* (Paris: Bibliothèque Nationale de Paris, 1887).

[22] Morley, *op. cit.*, footnote 10, p. 287; and K. Ruppert, *The Caracól at Chichén Itzá, Yucatán, México* (Washington, D. C.: Carnegie Institution of Washington, Publication 454, 1935).

[23] H. E. D. Pollock, et al., *Mayapán, Yucatán, México* (Washington, D. C.: Carnegie Institution of Washington, Publication 619, 1962), pp. 7, 114.

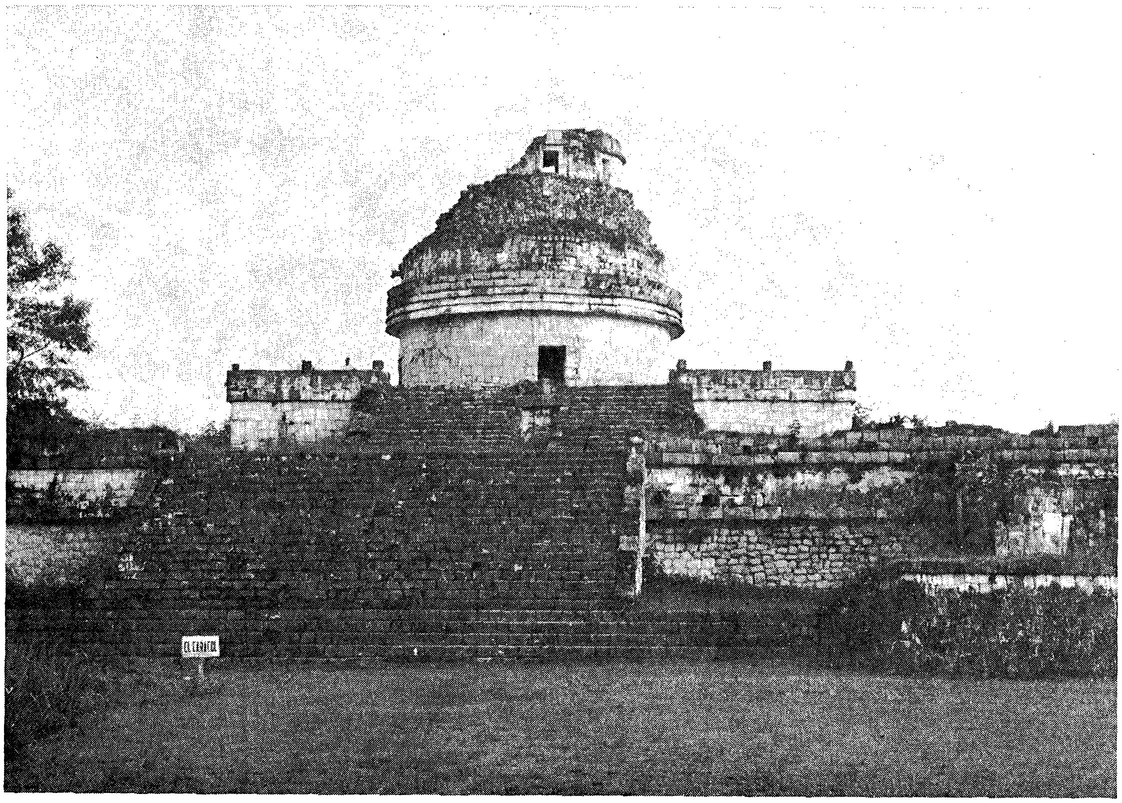

FIG. 3. The *Caracól* (Observatory), Chichén-Itzá, Yucatán, México. Constructed ca. A. D. 900, this edifice is oriented to principal sun and moon positions.

Morley believed that the first known solar observatory for the Classic period had been found at Uaxactún.[24] The arrangement of the Group-E complex at Uaxactún permits accurate determination of the solstices and equinoxes by means of a large east-facing observation pyramid and three lesser structures that face west (Fig. 2). This general plan was followed in at least eleven other ceremonial centers, and possibly in seven others.[25] No doubt other Uaxactún-style solar observatories will be found as mapping proceeds in the region.

Undoubtedly the Maya built observatories. The question is whether or not buildings were oriented to the sun irrespective of the fact that they were or were not observatories. A careful plotting of sunrise and sunset positions for the principal sites suggests that certain sun points did determine building orientation in many cases.

Most of the Maya ceremonial centers of the Classic period lie between 15° and 20° North Latitude. At 15° N, the sun rises 24°35′ north of east on the summer solstice, and sets 24° 35′ north of west.[26] These same headings, except that they are south of east and west, hold true for the winter solstice. At 20° N, the sun rises at 25°24′ north of east on the summer solstice, and sets 25°24′ north of west. Again, these positions work in reverse for the winter solstice. An average value of 25° north or south of east or west may be used for the solstice positions of the sun throughout Mayaland.

Plotting these sun positions for every viewing position within the more-than-a-hundred principal Maya ceremonial centers is not an easy task. The gathering of the raw data

[24] Morley, *op. cit.*, footnote 10, pp. 299–300.

[25] K. Ruppert and J. H. Denison, Jr., *Archaeological Reconnaissance in Campeche, Quintana Roo, and Petén* (Washington, D. C.: Carnegie Institution of Washington, Publication 543, 1943), pp. 5–6.

[26] Harrison, *op. cit.*, footnote 19, p. 73.

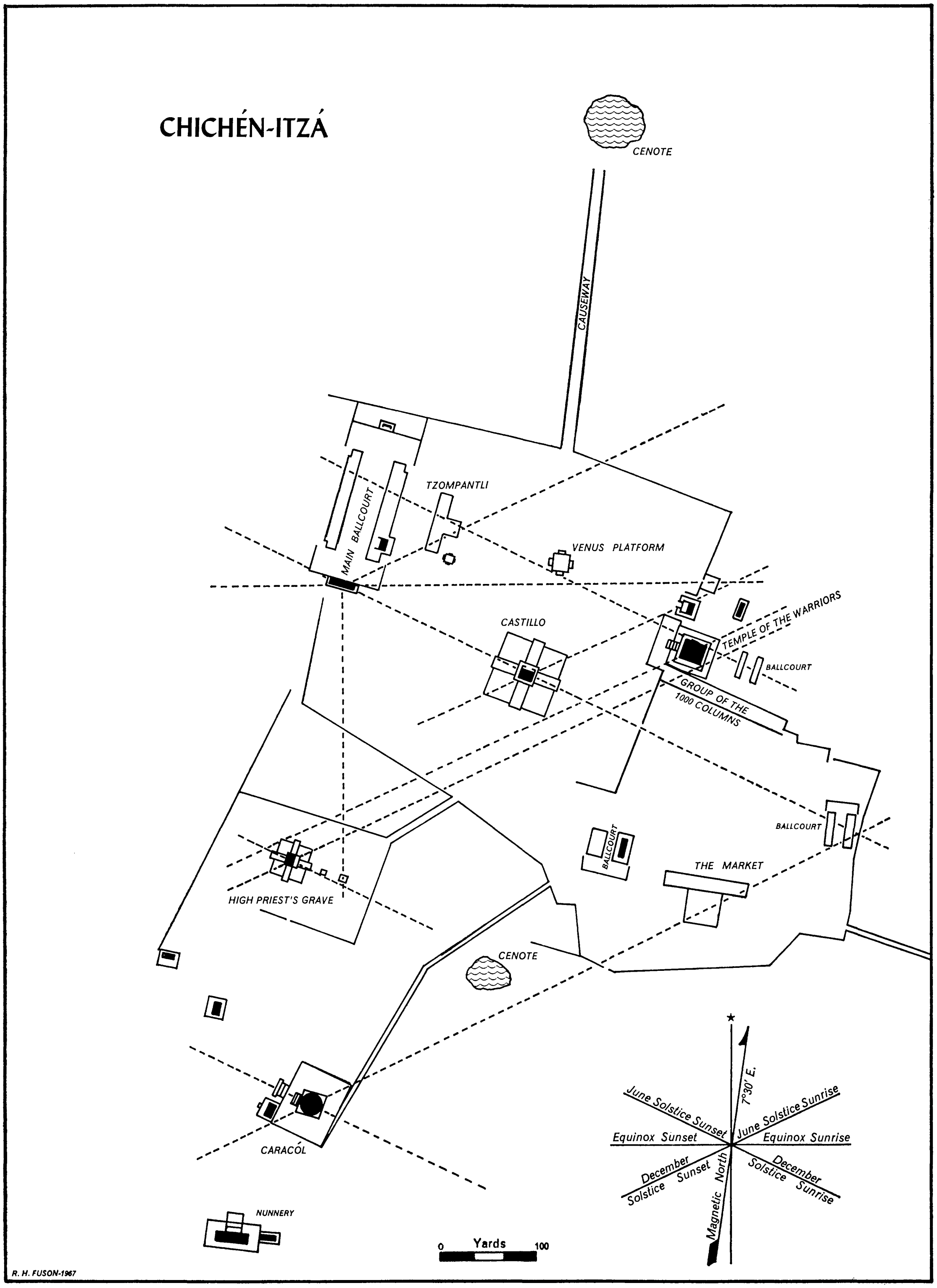

FIG. 4. Chichén-Itzá, Yucatán, México. The principal structures, erected between A. D. 850–1200, illustrate the typical easterly orientation of Maya sites.

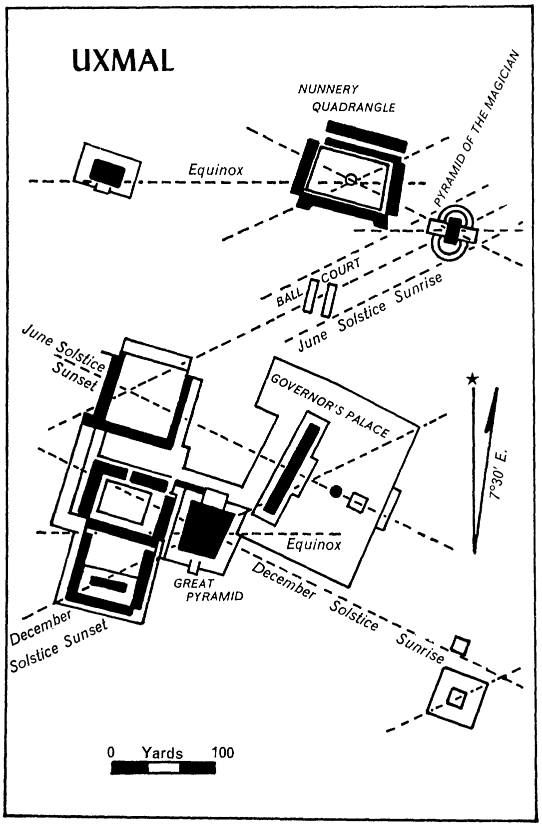

FIG. 5. Uxmal, Yucatán, México.

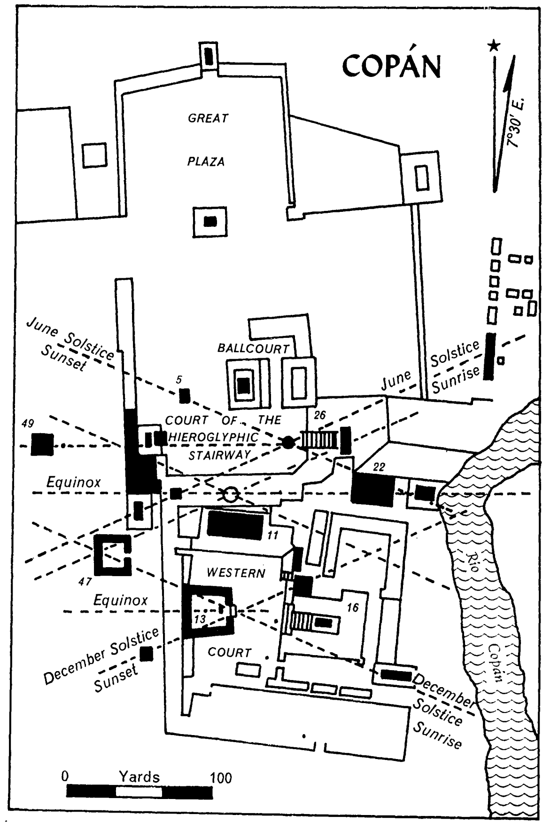

FIG. 6. Copán, Copán, Honduras.

from just one site is an exhausting operation. Nevertheless, with the aid of the best site maps available, an unusually large number of statistically significant correlations may be made.

Figures 4, 5, and 6 illustrate solstice and equinoctial sightlines for sunrises and sunsets at three selected Maya sites.[27] Certain logical viewing positions were determined in the field by considering the elevation of the observation point, prominence of objects along the viewing path, and the significance of the structures involved as determined by archaeological investigations.

From an analysis of the maps it is clear that many Maya structures could have been used to mark the solstice and equinox positions of the sun. Other than the round observatories at Chichén-Itzá (Fig. 3), and Mayapán (now fallen and disintegrated), and the Uaxactún Group-E assemblage (Fig. 2), none of the other structures are proven solar observatories. If others were not built with solar positions in mind, then the odds against such alignments being consistently accidental from one end of Mayaland to the other are staggering.

For the vast majority of ceremonial centers, the longitudinal axes extend generally north-northeast, south-southeast. A few, (such as Uaxactún) where attention was shifted from one grouping of buildings to another, maintain this general alignment within each complex. Only a few sites have any groups that are laid out north-south, and these invariably comprise a minor portion of the entire center.

[27] The maps presented here are based on maps contained in the publications of the Carnegie Institution of Washington, already cited, and on those found in: K. Ruppert, *Chichén Itzá: Architectural Notes and Plans* (Washington, D. C.: Carnegie Institution of Washington, Publication 595, 1952); A. Ruz, *Chichén-Itzá: Guía Oficial del Instituto Nacional de Antropología e Historia* (México: Talleres de Edimex, 1965); A. Ruz, *Uxmal: Guía Oficial del Instituto Nacional de Antropología e Historia* (México: Talleres de Edimex, 1965); and on field work by the author in 1966 and 1967 at the principal sites.

Of the major centers, Quiriguá, Guatemala, is the only one that has a significant portion of its structures oriented northwest-southeast.[28]

Site orientation and single-building orientation must not be confused. Although many principal structures have main entrances that are easy to discern, untold numbers lie in ruins. The orientation pattern of a site may be ascertained, especially as it relates to a longitudinal axis, but we tread on thin ice if we attempt to make positive statements about minor buildings in most centers. In a few cases, however, careful archaeology provides us with some information concerning the orientation of minor structures.

Almost all buildings that face west are temples or related structures of religious significance.[29] Unfortunately, little archaeological work has been done in the farming villages that lay some distance from, but were affiliated with, each ceremonial center. But at Mayapán, which was a post-Classic walled town of approximately 12,000 people and 2,000 dwellings, it has been shown that the Maya almost always avoided facing his house to the west.[30] Less than 100 Mayapán houses faced west, and it is possible that these were not dwellings of commoners. Though the Maya may have wished to avoid the afternoon heat and take advantage of the prevailing wind, he also exposed the open side of his house to driving rains not unlike those experienced by Stephens and Catherwood during their first night at Palenque.[31] Further, the author has found that tropical farmers in Panamá, living in houses possibly derived from the Maya, tend to present the solid side of their houses to the windward, thereby keeping out dust during the dry season and lessening the risk of their fires being extinguished or spreading to consume the *bohío*.[32]

It is of additional interest to note that the Maya associated the color black (*ek*) with the west (*chikin*), whereas red (*chac*) was associated with the east (*likin*). The significance of these color associations may be: black, where the sun sets, and red, whence it rises. The east gave light every day, and to the Maya each day was a god. The west taketh away. It is not difficult to imagine these devout folk so honoring the new day, and it is even possible that the common man was either forbidden to orient his house to the west or was afraid to do so. It appears that the religious motivations quite clearly overrode any others, especially environmental ones.

Moon

Morley has shown how the *Caracól* at Chichén-Itzá served to determine the greatest northern and southern declination of the setting moon.[33] Unquestionably, lunar observations were made at many centers, for the Maya could predict the moon's passage before the sun (solar eclipse) with great accuracy. The Dresden Codex gives eclipse tables for a period of 11,960 days (about thirty-three years), after which time the table could be reused.[34] There was no apparent attempt to align any structures with lunar positions, though every principal ceremonial complex must have had some location from which observations were made.

Venus

Noh Ek (great star), or *Xux Ek* (wasp star) —both Maya names for Venus—occupied a special place among celestial bodies. The intricate calculations pertaining to Venus, and a detailed explanation of these, may be found in Morley or Thompson.[35] Figured to within 0.08 day over a period of 481 years, Venus rated equal space with the moon on Maya stelae. The day 1 *Ahau* was another name for the Venus god, and *Yax* was the month of the deity.[36] Venus was also identified with *Kukulcan* (Quetzalcoatl), the feathered serpent and the God of Civilization and Knowledge.[37]

Such an important god probably influenced Maya architecture. Several centers have

[28] S. G. Morley, *Guide Book to the Ruins of Quiriguá* (Washington, D. C.: Carnegie Institution of Washington, Supplemental Publication 16, 1935), p. 8.

[29] Pollock, et al., *op. cit.*, footnote 23, p. 208.

[30] Pollock, et al., *op. cit.*, footnote 23.

[31] Stephens, *Incidents of Travel in Central America, Chiapas, and Yucatán, op. cit.*, footnote 3, pp. 300–03.

[32] R. H. Fuson, "House Types of Central Panamá," *Annals*, Association of American Geographers, Vol. 54 (1964), p. 192.

[33] Morley, *op. cit.*, footnote 10, p. 287.

[34] Thompson, *op. cit.*, footnote 2, p. 149.

[35] Thompson, *op. cit.*, footnote 2, pp. 144–49; and Morley, *op. cit.*, footnote 10, pp. 258–60.

[36] Thompson, *op. cit.*, footnote 2, pp. 145, 190.

[37] G. C. Vaillant, *The Aztecs of México* (London: Penguin Books Ltd., 1953), pp. 170–74.

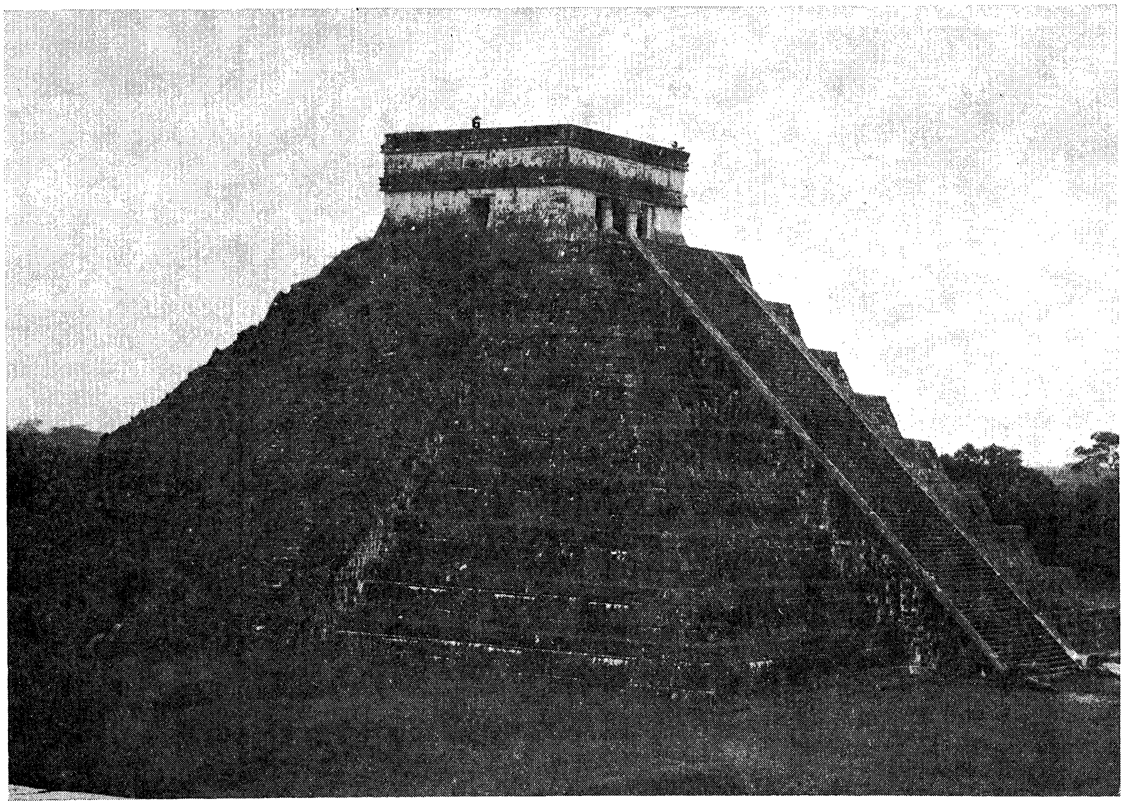

FIG. 7. The *Castillo* (Temple of Kukulcan), Chichén-Itzá, Yucatán, México. This pyramid closely articulates with Maya calendrics and astronomy.

temples and platforms that were dedicated to Venus. Whether or not Venus played any role in building alignment is another matter. A number of the structures oriented to sun positions might have been built to mark the heliacal risings and settings of the Morning and Evening stars. An example of one such possibility is the *Castillo,* or Temple of Kukulcan, at Chichén-Itzá (Fig. 7), which is described as the Temple of Venus by Thompson.[38]

Still to be determined is whether or not there is some relationship between Venus and the *Tzolkin,* or Maya sacred calendar of 260 days. In Maya astronomy, Venus was the Evening Star for 250 days (actually the value is closer to 240 days), and then out of sight for eight days (fourteen days is more nearly correct) during inferior conjunction. This total of 258 days from the time Venus rises as the Evening Star until it appears as the Morning Star is quite close to the 260-day sacred year. Inasmuch as the Maya were compelled to a large degree by their vigesimal system of mathematics to work around the number twenty, it is reasonable that they might add two days to this cycle to permit twenty thirteen-day periods. Because it is a fact that the solar calendar (*Haab*) of 365 days left its mark on structures, is it not logical to assume that the 260-day *Tzolkin* might have done the same?[39]

An extension of this line of thought could lead to the idea that, since the fifty-two-year "Calendar Round" marked a passage of time when both sacred and secular calendars each

[38] Thompson, *op. cit.,* footnote 2, pp. 189–97.

[39] The principal pyramid at Chichén-Itzá articulates well with the Maya solar calendar. There are four stairways of 91 steps each and an upper platform with one more step, for a total of 365. Each side of the structure has 52 panels (equal to the number of years in a Calendar-Round), rising in 9 terraced levels. The 9 levels are divided on each side by a stairway that produces 18 terrace sections on each side (equal to the 18 months of the Maya year).

returned to simultaneous starting positions, this concept be immortalized in stone. At the end of two Calendar Rounds (104 years) the beginning of four time counts coincided: the Venus year (synodical revolution of 584 days), the solar year (365 days), the sacred year (260 days), and the fifty-two-year Calendar Round. At the end of the fifty-two-year count, and especially after a double Calendar Round, there were ceremonies of great religious significance. Buildings were often remodeled, new structures added, and stelae dedicated. Certain principal buildings and complexes could represent the blending of all these elements. This would be an excellent time to reorient a group of buildings or to build a new complex with a new alignment.

Other Planets

For some unknown reason, the four other visible planets made little impact on the Classical Maya. It is difficult to imagine why the Maya neglected them. Mercury, Mars, Jupiter, and Saturn may be discounted as having an influence on either architecture or arrangement of structures.

Orientation Toward Magnetic North

Whether by some fortuitous coincidence, or whether by deliberate design, the Maya aligned many of their ceremonial centers (or portions of them) with a line that approximates the current magnetic declination in the region. For the present Epoch (1965.0), magnetic declination in Mayaland ranges from 6° to 8° easterly, with 7°30′ easterly declination being a good average value for the central area of Guatemala and Yucatán.[40] The rate of annual change averages 00°03′ westerly (*i.e.*, decreasing), but between Epoch 1912.5 to Epoch 1942.5, there was a general increase.[41] This secular change averaged 00°03′ 18″ easterly in Epoch 1912.5, and by Epoch 1942.5 had lessened to 00°01′06″ easterly. A similar trend may be noted during the same years for magnetic inclination (or "dip").

Secular magnetic change (averaged annual changes) cannot be predicted, and no law has been found that will describe it.[42] If secular variation were at a constant rate, and continued indefinitely, we could express it in mathematical terms and instantly establish whether or not certain Maya structures varied their orientation as the earth's magnetic field fluctuated.

Although established laws of geomagnetism are lacking where we need them most, this is not to say that we have reached an impasse. A significant amount of research is ongoing and the body of literature on the subject is expanding rapidly. It is now known that the "magnetic north pole," as a definite, determinable point, does not exist, even for a moment.[43] Yet, geographers continue to map this nonexistent point.[44] There is a North Magnetic Polar Area, which is not circular but elongated in the direction of north-northwest, south-southeast.[45] Within this area there are many "poles" and it is incorrect to say that the compass points to any one of them. The compass points in the direction of the horizontal component of the earth's magnetic field wherever the compass is located.

Some geophysicists have suggested that the geomagnetic "pole" moves around the geographic pole in a given period of years and that the axis of the geomagnetic dipole may coincide with the axis of rotation.[46] From this they hope to establish the relative positions of the geomagnetic and geographic poles through time. But when it is understood that the compass does not point toward a magnetic pole, it becomes clear that secular change could never be extrapolated from data concerning past locations of the magnetic "pole."

Nor do studies of secular change in other parts of the world aid us in our immediate search, for such change is a purely regional phenomenon.[47] At London, for instance, the

[40] U. S. Oceanographic Office, Chart H. O. 1706, *Magnetic Declination: Epoch 1960.0* (Washington, D. C.: 1959).

[41] E. H. Vestine, et al., *Description of the Earth's Main Magnetic Field and Its Secular Change, 1905–1945* (Washington, D. C.: Carnegie Institution of Washington, Publication 578, 1959), pp. 289–95, 329–35.

[42] H. H. Howe and L. Hurwitz, *Magnetic Surveys* (Washington, D. C.: U. S. Dept. of Commerce, Coast and Geodetic Survey, Serial No. 718, 1964), p. 6.

[43] H. H. Howe, *Magnetic Poles and the Compass* (Washington, D. C.: U. S. Dept. of Commerce, Coast and Geodetic Survey, Serial No. 726, 1962), p. 5.

[44] E. B. Espenshade, Jr. (Ed.), *Goode's World Atlas* (Chicago: Rand McNally & Co., 1964), 12th edition, pp. 48–49.

[45] H. H. Howe, *op. cit.*, footnote 43, p. 5.

[46] T. Nagata, *Rock Magnetism* (Tokyo: Maruzen Co., Ltd., 1961), p. 277.

[47] S. Chapman, *The Earth's Magnetism* (London: Methuen & Co., Ltd., 1951), p. 17.

declination shifted steadily westward from 11°20′ E in 1580, to 24°15′ W by 1819.[48] This marks a secular change of almost 36° in 239 years! When plotted on a graph it appears that there is a cyclic variation in about 500 years.[49] Although a graph for Paris for the same period resembles that of London, it is obvious that these closely spaced cities were exposed to different magnetic influences.[50]

In lieu of any present method by which we may derive mathematically the secular change for a locality, earth scientists have turned to the fledgling sciences of paleomagnetism and archaeomagnetism.[51] The secular magnetic declination for selected places during times past has been sought in a variety of ways. The magnetic inclination and intensity of old earthenware have been measured, and the direction and intensity of magnetism have been investigated in glacial varves, hearths, volcanic rocks, lava beds, and sediments under the sea. Very excellent sequences have been established for a number of areas, especially where volcanic material is present (Italy, Iceland, and Japan, for example). Careful measurement of old fire pits, which were dated by radiocarbon and dendrochronological methods, has yielded secular magnetic data for a 2,000-year period in the American southwest.[52]

Similar work for México has only just begun and there is not sufficient material to make comparisons with the Arizona-New Mexico samples.[53] When this has been done for Yucatán and Guatemala the author believes that a whole new arena for investigation will be opened. The results of such research may force us to reevaluate some of our present concepts about the ancient Maya, especially if the Mayas had a method for determining magnetic north. Did they orient some of their structures magnetically and alter the positions of later ones as the declination shifted?

Hints of Adjustment to Declination Change

As already stated, many centers have longitudinal alignments that approximate the present magnetic declination (approximately 7° 30′ E). Some buildings in these sites clearly face magnetic north, and many in a ruined state may be so oriented. The list of sites is exhaustive, but includes almost all structures at Tikal,[54] Balakbal, Okolhuitz, Xpuhil; and many building complexes at La Muñeca, Río Bec, Naachtun, Oxpemul, Becan, Uxul, Pechal, Peór es Nada, Chichén-Itzá, Uxmal, Palenque, Copán, Uaxactún, Mayapán, and Dzibilchaltún. In addition to the entire site of Tikal, some of the most famous Maya buildings are contained in the above list: at Uxmal, the Pyramid of the Magician; at Chichén-Itzá, the Market, Nunnery, Temple of Hieroglyphic Jambs, Venus Platform, and the Causeway to the Sacrificial Cenote; at Copán, the entire complex around Temple 16; at Palenque, the Palace and Temple of Inscriptions; and at Uaxactún, much of the Acropolis and the principal pyramid of the North Plaza.

No existing theory explains these alignments, but it is entirely possible that some of them resulted accidentally when a building was oriented to sun positions. The Temple of the Magician at Uxmal is perhaps the best example of this, for its long axis is 7°30′ E, and it serves admirably as an observatory for key sun positions (Fig. 8). For most structures, however, the relationship to known astronomical positions is highly suspect.

In a number of centers (and this applies to portions of some sites named above), orientation varies between 7°30′ E and 22°00′ E, with the majority of buildings not exceeding 12° E. Most buildings oriented between 18° and 22° E appear to be sun-oriented. Very few buildings lie between true north (00°) and 7°30′ E, and only Quiriquá, Guatemala, seems to line up west of north.

[48] J. A. Jacobs, *The Earth's Core and Geomagnetism* (London: Pergamon Press Ltd., 1963), p. 47.

[49] Chapman, *op. cit.,* footnote 47, p. 15.

[50] Jacobs, *op. cit.,* footnote 48, p. 50.

[51] Jacobs, *op. cit.,* footnote 48, pp. 92–112, presents an excellent summary of paleomagnetic investigations to date, and offers a lengthy bibliography. Also see Nagata, *op. cit.,* footnote 46, pp. 276–309, in which he discussed both paleomagnetism and archaeomagnetism; and E. Irving, *Paleomagnetism and Its Application to Geological and Geophysical Problems* (New York: John Wiley & Sons, 1964).

[52] K. F. Weaver, "Magnetic Clues Help Date the Past," *National Geographic Magazine,* Vol. 131 (1967), pp. 696–701.

[53] Personal communication from R. L. DuBois, School of Geology and Geophysics, University of Oklahoma, Norman, Oklahoma.

[54] R. F. Carr and J. E. Hazard, "Map of the Ruins of Tikal, El Petén, Guatemala," *Tikal Reports, Museum Monographs, University Museum,* No. 11 (Philadelphia, Pa., 1961).

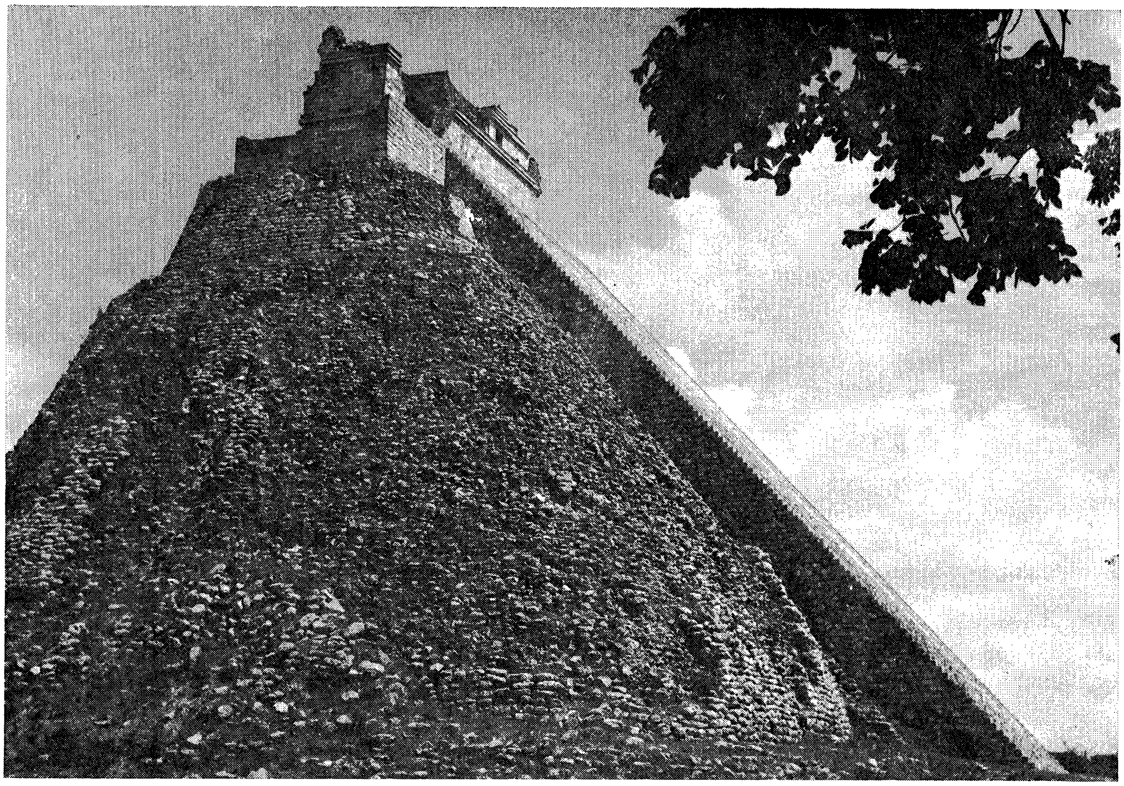

FIG. 8. The Pyramid of the Magician (House of the Dwarf), Uxmal, Yucatán, México. Six earlier temples lie buried beneath its mass.

Since the 1840's, few students of the Maya have concerned themselves with site orientation.[55] If all the references to alignment were put together they would probably not fill two pages of this size. Where alignment is treated, faulty generalizations (presumably made many years ago) live on in print. We read that, at Chichén-Itzá, "the majority of the buildings are oriented with a deviation of some 17 degrees toward the east on a north-south axis."[56] The same thing is said for Uxmal.[57] Even such a well-studied site as Téotihuacan (non-Mayan, in the Valley of México) offers proof of this neglect. Commenting on the progress of the current Téotihuacan mapping project, Millon stated: "The Street of the Dead appears to have an orientation of 15°30′ east of north (astronomic) rather than the frequently cited figure of 17° east of north."[58] It is incredible that erroneous orientation figures have gone unchallenged for so long.

The problem of dating is another factor of prime importance in any analysis of orientation. In areas of the world where past secular magnetic declinations have been derived, there had to be some independent means of precise dating. In Mayaland dates are based primarily on either stelae erected and dated by the Maya themselves, or on radiocarbon analysis, or both. The stelae must, of course, be correlated with stratigraphy (especially floor levels and construction stages) and the problem is exceedingly complex. In the case of stelae the controversy still rages around how the Maya and Christian calendars are to be correlated.[59] The Goodman-Martínez-Thompson correlation is generally used (and it is used in this paper), with the Maya Long

[55] Stephens, *Incidents of Travel in Yucatán, op. cit.,* footnote 3, p. 203.

[56] Ruz, *Chichén-Itzá, op. cit.,* footnote 27, p. 11.

[57] Ruz, *Uxmal, op. cit.,* footnote 27, p. 7.

[58] R. Millon, "The Téotihuacan Mapping Project," *American Antiquity,* Vol. 29 (1964), p. 346.

[59] Ralph, *op. cit.,* footnote 12.

Count numbering elapsed days since a mythical creation in 3113 B.C. If the Spinden correlation is used the base date becomes 3373 B.C. A difference of 260 years becomes highly significant if dated objects are to be equated with magnetic declination for a given year. It should be recalled that there was a proven 36° shift at London in less time than that.

The problems posed by radiocarbon dates are also significant.[60] Radiocarbon dates have tended to favor the Spinden correlation, but great effort has been expended to support the popular GMT system.[61] There seem to be occasions when radiocarbon dates are accepted or discarded according to which preconceived conclusion requires validity. Until reliable dating is established for structures, any work done with secular magnetism during the Classical Period will be speculative.

When valid dates can be determined for principal structures in Mayaland, and fossil magnetism can be ascertained from fire pits that are contemporary with those structures, then the secular changes can be plotted. If there is a correlation of building alignment and archaeomagnetic declination, then it might be possible to date scores of other buildings by comparing declination with building orientation. This would be a radically new tool for establishing Maya chronology.

Certain shifts in orientation did occur at approximately the same time at widely separated sites. For some of these we can be sure they happened at the same time because of the dated stelae, though we may still be unsure of the actual Christian date. Also, the only sites suited to an analysis of this sort would be those that have had intensive archaeological study and offer numerous examples of date glyphs. Uaxactún and Copán are two ceremonial centers that possess these characteristics.

The earliest Uaxactún date (Stela 9) is A.D. 327 (8.14.10.13.15), and the last date (Stela 12) is A.D. 889 (10.3.0.0.0).[62] Copán was in its prime between A.D. 515 (9.4.0.0.0) and A.D. 802 (9.18.10.0.0).[63] Unquestionably, both ceremonial centers were in existence before they erected monuments dedicating the completion of major structures, and both must have continued for a time after the last date glyph was carved.

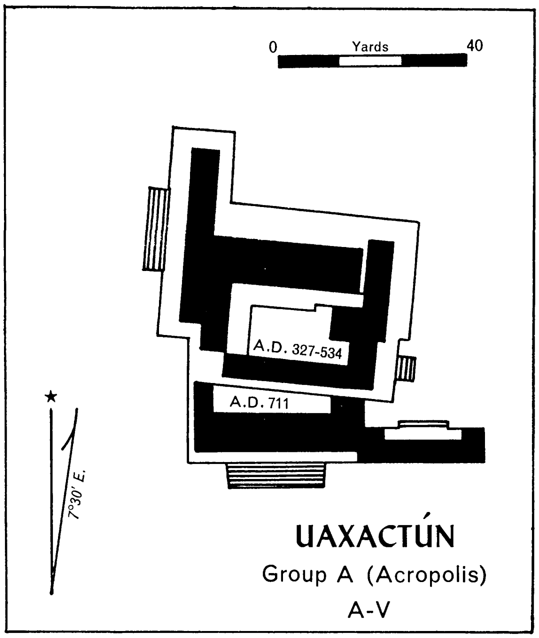

FIG. 9. Group A-V, Uaxactún, Petén, Guatemala. A deliberate shift in alignment was made during later phases of construction.

Uaxactún. Group *A* contains thirty-four buildings and is the largest at Uaxactún. Of this number, the complex known as the *Acropolis* (complex A-V) is the best documented (Fig. 9). The original A-V group was constructed between A.D. 327 (8.14.10.13.15) and A.D. 534 (9.5.0.0.0). This structure, though with some architectural modification during those years, maintained its general outward orientation of 3° E. There was, however, a so-called "astronomical circle" on the temple floor that was divided into quadrants, and oriented about 8° E. The early Group *E*, built before A.D. 357 (8.16.0.0.0) was generally north-south. Structure B-VIII, built by A.D. 366 (8.16.10.0.0), was aligned as A-V.

Around A.D. 711 (9.14.0.0.0) an annex of major proportions was constructed on the south side of A-V. It was not squared with the earlier structure, but rather moved slightly westward to a true north-south axis.

Copán. The West Court reached its present dimensions by A.D. 625 (9.9.10.0.0), and had

[60] R. H. Fuson, "Radiocarbon Dating," *The Professional Geographer*, Vol. 11 (1959), pp. 5–7. Also see Ralph, *op. cit.*, footnote 12.

[61] For an exception, see R. Girard, *Los Mayas* (Mexico City: Libra Mex, 1966).

[62] Smith, *op. cit.*, footnote 11, pp. 67–68.

[63] Longyear, *op. cit.*, footnote 11, p. 5.

an alignment of 7°30′ E (Fig. 6). A ballcourt existed from an early date and was rebuilt in A. D. 704 (9.13.10.0.0), with its axis slightly east of north. A smaller version of Temple 11, oriented 7°30′ E, probably faced the West Court at about the same time.

After A. D. 704 there was a shift in all new construction to a north-south axis. In at least one instance an old structure, the ballcourt, was rebuilt (for the third time) and its axis shifted. This occurred in A. D. 776 (9.17.4.0.0). The Hieroglyphic Stairway and Temple 26, aligned north-south, were dedicated in A. D. 758 (9.16.5.0.0).[64] Temple 11 was enlarged (if it already existed) during this same period, and Temple 22 (dedicated to Venus) was finished in A. D. 771 (9.17.0.0.0). This last structure was oriented to the east by 7°30′, and may be over an earlier structure with the same orientation. The massive stairway on the south side of the Court of the Hieroglyphic Stairway probably dates from the same period, and it is on a north-south line.

The reason for the Copán building boom around A. D. 700 may be attributed to new discoveries. The exact length between lunar eclipses was computed and the length of the solar year was brought up-to-date. The shift in orientation, however, *that parallels that of Uaxactún in time and direction,* is difficult to explain. The only thing one can be reasonably sure of is that the axial shifts were deliberate: Maya precision would not have tolerated what to them would have been blasphemous.

The Case for a Maya Compass

M. D. Coe may have discovered part of a pre-Maya compass at San Lorenzo, in southern Veracruz.[65] There, as in other Olmec sites, magnetite objects (usually small polished mirrors and mirror fragments) occur in some quantity. At San Lorenzo they occur at the end of the San Lorenzo Phase and in the Nacaste Phase, and are dated between 1000–800 B. C. Coe reports that one of these magnetite objects is not a mirror, but a flattened, oblong piece that is perfectly squared on all faces, and with a longitudinal groove extending along one surface. The object was made with such great care that it appears to be machined.

The general appearance immediately suggested to Coe that it might be part of a compass. To test the possibility, he cut a piece from a cork mat, placed the object on it, and floated it in a plastic bowl full of water. It consistently oriented itself to the same direction, which was slightly west of magnetic north. Turned over, the "pointer" always aligned itself to a consistent orientation slightly east of magnetic north. Coe feels that this variation may be attributed to the way the pointer was cut from the original piece of magnetite. He further suggests that the Olmec (or later the Maya) may have floated the "pointer" on a piece of balsa wood in a calabash bowl. Also, Coe believes that many of the magnetite mirrors, if suspended by thread, will line up with north, and may have been used for this purpose.

Although the suggestion that the Olmecs, and later the Mayas, possessed a compass may seem highly speculative, it must be remembered that the history of the compass in Europe and Asia before the 11th century A. D. is just as vague.

There is a Chinese reference to use of a compass between A. D. 1030–1093,[66] and the first European notice of the instrument was given by Alexander Neckam in 1187.[67] Magnetite, or lodestone (Fe_30_4), was discussed by Thales of Miletus (ca. 500 B. C.),[68] and after that time a number of Greek and Roman sources make reference to the magnetic mineral. Legend has it that the Chinese won a battle in 2634 B. C. because they had a compass mounted on a chariot.[69] As Greek and Roman sources fail to mention that the lodestone gave direction, we must assume, from the evidence, that it took mankind 1,500 years to make that rather obvious discovery. Though declination has been recognized since the fourteenth century, it was not mapped until

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[64] Longyear, *op. cit.,* footnote 11, p. 52. Stela *M,* erected in front of the Hieroglyphic Stairway, yields a date of A. D. 758 (9.16.5.0.0). Morley, *op. cit.,* footnote 10, p. 276, prefers A. D. 756. Thompson, *op. cit.,* footnote 2, p. 79, believed these dates should be about 35–50 years earlier.

[65] Personal communication from M. D. Coe, Department of Anthropology, Yale University, New Haven, Connecticut.

[66] "Magnetism," *Encyclopaedia Britannica,* Vol. 14 (1965), p. 585.

[67] Jacobs, *op. cit.,* footnote 48, p. 44.

[68] "Magnetism," *op. cit.,* footnote 66.

[69] "Compass," *op. cit.,* footnote 66, Vol. 6 (1965), p. 225.

the sixteenth century.[70] Not until 1635 did anyone note that secular change occurs.[71]

The Maya could have discovered lodestone, for magnetic iron ores are present in Central America and México. They could have received a knowledge of the mineral (or the mineral itself) by diffusion from southeast Asia, as perhaps they acquired the jade complex with all of its oriental detail. Or, they might have made a more fortuitous discovery that gave them something very close to a modern compass.

Mercuric sulfide (HgS), or cinnabar, was well known to the Maya from at least the Early Classic Period. From it was obtained the brilliant red powder, called vermilion, which they used as a red pigment. Monuments and buildings as far away as the Valley of México were recipients of this vivid color, and its quality is attested to by the fact that many of these colors remain, even after centuries of exposure. Jade, perhaps the most highly prized item in the Maya inventory, was carved with the lotus motif, colored with cinnabar paint, and placed in the mouths of important deceased personages before burial (precisely as was done in southeast Asia). From the long-term and widespread use of pigments derived from mercuric sulfide, the Mayas probably discovered liquid mercury.

It would have been almost impossible for the Maya not to discover mercury, considering the way he prepared the ore.[72] For one thing, mercury is extremely easy to recover from cinnabar. It may be roasted in air ($HgS + O_2 \rightarrow Hg + SO_2$) or roasted with lime ($4HgS + 4CaO \rightarrow 4Hg + 3CaS + CaSO_4$), and in a confined space (such as a kiln) the mercury vapor would condense and be deposited on the furnace walls. Or, pottery painted with mercuric sulfide pigments would yield droplets of mercury on firing. If crushed cinnabar is mixed with water the pigment will not remain in suspension, but if lime is added (perhaps to lighten the very bright red?) the pigment will remain in suspension for use. Here we have $HgS + CaO$; upon firing the process is complete, and the mercury is separated from its ore.

Assuming for a moment that the discovery of mercury is inevitable if constant use is made of HgS, lime, and fire, how would its discovery be greeted by a Maya priest-astronomer? Surely, in even a small quantity, it would have been a gift from the gods. Would he have regarded it as a form of water? It is possible that such an association explains the curious habit of painting jade (also associated with water in America and Eurasia) with cinnabar pigments. Also, the Maya word for red, *chac*, was the name assigned to the rain god. Again, the association of red and water.

Would the priest-astronomer attempt to float something in a pool of mercury? Since it is 13.6 times as heavy as water he would discover that almost anything will float in it. In fact, the density of mercury is so great that, had the Maya a knowledge of iron, copper, zinc, tin, or lead, he could have floated hunks of any of them as easily as wood floats on water. He could have floated a rock, and if it happened to contain magnetite, the priest would have joined the ranks of the world's great inventors, for his would have been a highly functional compass. Direct flotation on mercury is not as cumbersome as placing magnetite on balsa and floating the combination on water, as Coe suggests might have happened.

If such a compass ever existed there would be virtually no chance of recovering one intact. However, the components might survive. Coe's pointer (or "floater") may be such an example. Liquid mercury has also been recovered from Maya sites, though only four such finds are known to the author.[73] Maudslay reported finding several liquid ounces of quicksilver in Mound IV at the Great Plaza of Copán.[74] The mercury was sealed in a vessel that contained various jade items and

[70] The author is indebted to Mr. K. L. Svendsen, Chief, Analysis Branch, Geomagnetism Division, Coast and Geodetic Survey, for providing him with copies of declination maps for the years 1500–1700, published by W. Van Bemmelen, "Die Abweichung der Magnetnadel," *Observations made at the Royal Magnetical and Meteorological Observatory at Batavia*, Vol. 21 (1899), map supplement.

[71] S. Chapman, *Solar Plasma, Geomagnetism, and Aurora* (New York: Gordon & Breach Co., 1964), p. 3.

[72] The author is especially grateful to Dr. T. C. Owen, Department of Chemistry, University of South Florida.

[73] The author is indebted to Mrs. Kathleen Fisher and the Carnegie Institution of Washington for facilitating research among their private collections.

[74] A. Maudslay, "Archaeology," *Biologia Centrali-Americana* (London: 1899–1902), p. 20.

some cinnabar. Numerous additional containers of cinnabar were recovered from Copán, and though some held jade there were no others with mercury.[75] Maudslay also assured Thompson that additional quicksilver was found at Quiriquá.[76] Gann reports that Frans Blom wrote to him concerning a discovery of six liquid ounces of mercury at Paraíso, near Copán.[77] Kidder made the most recent discovery of mercury in a burial at Kaminaljuyú, where he found 25 cc. of the liquid.[78]

That mercury was possessed by the Maya there can be no doubt. It is used today in Guatemala to shine low-grade silver objects, with the polish lasting just long enough for the unsuspecting purchaser to be on his way before the discovery is made. When questioned about the use of mercury the villagers become secretive; they simply will not talk about it.

There is corroboration of the Guatemalan mercury mystery:[79]

> Persistent reports that quicksilver deposits are to be found in Guatemala have been heard from many sources. From time to time Indians come to Guatemala City with small quantities of mercury whose source they have refused to reveal, but as the Indians are generally from the volcanic area between Lago de Atitlán and Quetzaltenango, the source has been presumed to lie in that area. . . . The source of the Indians' mercury is . . . still unknown.

Mercury is produced in commercial quantities in neighboring Honduras and in at least five Mexican states. The Honduran deposits are intriguing, because a number of the workings take place in natural limestone caves, where discontinuous veinlets of cinnabar and native quicksilver are found in the walls.[80] Since the Mayas explored virtually every cave in their area, as proven by their carvings, ritualistic, and quarrying activities, the implications are obvious. Though many archaeologists favor Guatemala as the source region for Maya cinnabar the author suggests Chiapas as a strong contender.[81]

Magnetite, like cinnabar, could have reached the Maya from a variety of sources. It was known to the Olmecs, México's most ancient civilization.[82] Large magnetite formations occur in Honduras, with smaller ones in Guatemala, and the magnetic variety of magnetite (lodestone) is present.[83] The largest iron deposit in Guatemala lies just south of the Motagua River, near Copán and in the heart of the ancient Maya territory. Just north of this river is located a primary source of Maya jade. Regardless of the source or sources relied upon by the Maya for cinnabar, magnetite, and jade, they occur near each other and within easy reach.

Not only were these substances available within the limits of the territory occupied, but the Maya often received items from central México and as far away as Panamá. Copper objects, found at Mayapán, are almost certainly from Oaxaca, and some possibly came as trade pieces from Perú.[84] Gold and *tumbaga* (gold-copper alloy) probably came to Yucatán from Panamá.[85] Obsidian may have come from highland México, Guatemala, or Honduras.[86] Chiapas could have contributed some (or all) of these artifacts, but virtually nothing is known of Chiapas' resources.[87] It is evident from these few examples that the Maya did import items, especially those of value to him. Magnetite could have come in just as easily, if a local source is denied.

CONCLUSION

There was order, precision, high esthetic quality, and extreme dedication in everything the Classical Maya set about to do. The ceremonial center, as a cultural expression of

[75] G. B. Gordon, "Prehistoric Ruins of Copán, Honduras," *Memoirs of the Peabody Museum of American Archaeology and Ethnology,* Vol. 1, No. 1 (1896), p. 24.

[76] E. H. Thompson, "Cave of Loltun, Yucatán, *Memoirs of the Peabody Museum of American Archaeology and Ethnology,* Vol. 1, No. 2 (1897), p. 14.

[77] T. W. F. Gann, "Maya Jades," *Proceedings of the 21st International Congress of Americanists* (Göteborg: 1925), p. 279.

[78] A. V. Kidder, et al., *Excavations at Kaminaljuyú, Guatemala* (Washington, D. C.: Carnegie Institution of Washington, Publication 561, 1946), pp. 144–45.

[79] R. J. Roberts and E. M. Irving, *Mineral Deposits of Central America* (Washington, D. C.: U. S. Geological Survey Bulletin 1034, 1957), p. 174.

[80] Roberts and Irving, *op. cit.,* footnote 79, pp. 169–74.

[81] Smith, *op. cit.,* footnote 11, p. 12, believed that cinnabar may have come to Uaxactún from the Guatemalan highlands.

[82] M. D. Coe, *México* (New York: Frederick A. Praeger, 1966), p. 89.

[83] Roberts and Irving, *op. cit.,* footnote 79, p. 66.

[84] Pollock, et al., *op. cit.,* footnote 23, pp. 398–99.

[85] Pollock, et al., *op. cit.,* footnote 23, p. 391.

[86] Pollock, et al., *op. cit.,* footnote 23, p. 431.

[87] Pollock, et al., *op. cit.,* footnote 23, pp. 392–93.

the integration of architecture, sculpture, painting, hieroglyphics, mathematics, astronomy, and religion, is a dramatic manifestation of this. And the ceremonial center is one vehicle by which the geographer may involve himself in a study of this remarkable civilization.

The orientation of Maya sites cannot be understood without first coming to terms with the cultural system. To fathom the multiple reasons that underlie the planning requires a comprehension of how human notions and ideas are translated into physical terms. In attempting to show how this was done, the author readily admits speculation at many junctures. Although logic and statistical probability are helpful, it is difficult to substitute them for missing data. Part of the problem rests on the fact that geographers, who by definition are trained to interrelate culture and nature, have shied away from the general subject that we may call the historical (or urban?) geography of pre-Columbian America.

Maya ceremonial centers were carefully planned and well-engineered. They are situated in environments that are often thought of as unfavorable, yet, to the Maya, this must have been otherwise, and it would behoove us not to transfer our values to them. The structures were wrought from the wood and limestone of this environment and the technological sophistication that made all of this possible was mostly indigenous. The theology that often dictated the building plan was as closely related to nature as the buildings themselves. Gods were made from animals, and plants, and celestial bodies, and from the elements of weather and climate. The sterile subject that we teach college freshmen as earth-sun relationships came alive for the Maya. The days and their dates were more than numerical expressions of earth rotations and revolution, for their intricate calendar marked that time when two different gods transferred their burdens to their successors. All of these things governed the layout of the sites.

As the Classical Period waned (ca. A. D. 900) so did the ceremonial centers, and most were abandoned to the elements. In some areas, such as in northern Guatemala and Quintana Roo, even the population vanished. A few sites were revived by the invading Toltecs, (ca. 1000), such as Chichén-Itzá, and others (as Mayapán) were built later. As the span of time from the end of the Classical Period increased, there was a cultural degradation that set in. The 700-year tranquility of the earlier period gave way to military orders, conflict, and human sacrifice. Although the basic form of the ceremonial center persisted into the Spanish era, many became fortified towns with the population clustered behind protecting walls. Eventually, what nature failed to eradicate, invaders accomplished.

We have asked more questions than we have answered; perhaps that is a legitimate procedure. If the cultural landscape of the Maya is ever to be reconstructed, geographers must join the effort. The ceremonial center seems a logical place from which to commence the undertaking.