10 July 1981, Volume 213, Number 4504

SCIENCE

Tropical Archeoastronomy

A. F. Aveni

There is yet something else. Those people live like wild beasts on either side of the equator and between the poles men live like wild beasts, as Ptolemy says in his Quadripartite. And now this has been discovered by experience. . . .

This statement, made by the Scottish theologian John Major (*1*) five centuries ago, expresses a total lack of understanding of another race's view of its existence. Often in our age we tend to view and judge the cosmologies of other civilizations through our own eyes. The comparative study of astronomical systems demonstrates that ancient man's view of the universe is best considered in the context of his cultural values and environmental background.

Summary. Too often, judged by the Western cultural yardstick, astronomical systems developed by indigenous civilizations of the tropical latitudes are found to be both complex and fundamentally different from those originating in civilizations of the temperate latitudes. One explanation for this difference is the radically contrasting sky orientations that are viewed from different parts of the globe, a determinative environmental factor in the development of cosmological systems that should not be neglected by the anthropologist and cultural historian.

In this article I shall use recent archeoastronomical evidence to define certain common denominators with respect to cosmology that appear among cultures spanning the region between the Tropic of Cancer and the Tropic of Capricorn (Fig. 1). I will attempt to demonstrate that, because of the remarkable differences in the arrangement and motion of celestial bodies as viewed from the tropical and temperate zones, we may expect that different systems of astronomy might develop in these zones. This idea was alluded to but never fully developed by Nuttall (*2*) and more recently has been mentioned by Brecher and Morrison (*3*).

Specifically, I will show, through a wide selection of examples, that nearly all tropical cultures that developed indigenous astronomical systems, regardless of whether the motive was largely practical or religious, gravitated toward a reference system consisting of zenith and nadir as poles and the horizon as a fundamental reference circle. Such an arrangement stands in remarkable contrast to the celestial pole-equator (or ecliptic) systems developed by ancient civilizations of the temperate zone.

In all ancient societies, the sky and its contents lay at the very base of human cognition. Early hunter-gatherers and later sedentary societies were profoundly influenced by the dependable precision of cyclic recurrence unfolding in the celestial canopy. To appreciate the difference between tropical and temperate celestial environments, let us imagine the earth's geographic coordinates to be reflected upon a hemispherical bowl that represents the sky (Fig. 2). For an observer stationed at the equator, the poles of the earth's axis of rotation appear at the horizon while lines of geographic latitude projected onto the sky pass vertically from the eastern to the western horizon (Fig. 2a). This equatorial observer finds the rotation of the earth mirrored in the movement of the stars around him, the motion taking place along the direction of these vertical diurnal circles. When a star rises, it remains at a relatively fixed azimuth and can provide a stable horizontal direction in the landscape for a considerable length of time. The symmetry of celestial motion is emphasized; sky activity to the north behaves the same as that to the south, the observer assuming the central place. Away from the tropics the situation is quite different (Fig. 2b). There, star motion is a combination of both vertical and horizontal. All celestial objects rise and set along oblique tracks, with the angle that the star path makes with the horizon becoming smaller as one travels farther from the equator.

As one approaches the higher middle latitudes, the pivotal motion becomes dominant and the asymmetry of celestial motions in a framework centered on the observer begins to increase. The pivot, the celestial pole, today marked by its attendant luminary, Polaris, is a point far removed from the earthly observer. Certain other differences in celestial aspect, perhaps more subtle, are also evident. For example, the amplitude of the lunar and solar oscillations along the horizon become larger at higher latitudes. Moreover, since it remains in the same half of the celestial hemisphere, the ecliptic, or path of the sun, moon, and planets among the stars, behaves less erratically in temperate latitudes.

Elementary modern astronomy texts teach us that the horizon system of coordinates is a local frame of reference convenient for navigators but possessing disadvantages in the study of true scientific astronomy. Pedagogically, we replace it with the equatorial system of coordinates which we consider better because its component parts, projections of parallels of terrestrial longitude and latitude into the celestial sphere, remain fixed relative to the stars. Therefore, neglecting precession of the equinoxes, all astronomers are able to use an objective external reference frame when de-

The author is professor of astronomy and anthropology at Colgate University, Hamilton, New York 13346.

 0036-8075/81/0710-0161$02.00/0

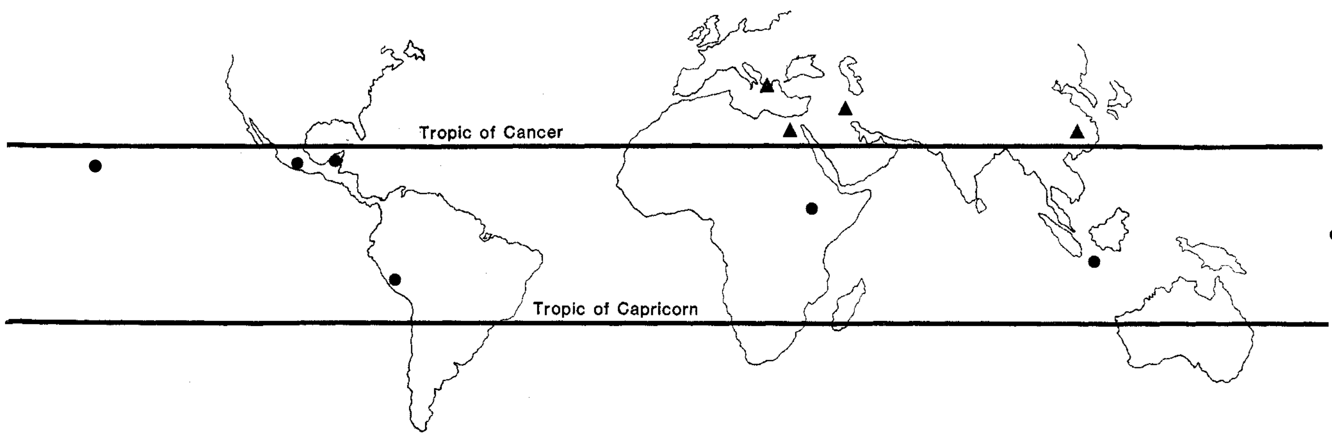

Fig. 1. The tropical region, the zone between the parallel lines, is inhabited by cultures (dots) possessing a view of the heavens different from that of the well-known early civilizations of the temperate zone (triangles).

scribing celestial phenomena. Such a course is the only desirable one in accord with our scheme for viewing the natural world. But our cultural bias, like John Major's, can stand in the way of our comprehension of the way another culture might order the world, should we discard that view as uninteresting because it lacks certain elements present in our own cosmic outlook.

Zenith-Horizon System in Oceania

Among the seafaring people of Oceania, straddling the earth's equator, the zenith-horizon system was put to remarkably good use. It served as the basis of a complex system of navigation.

Arorae is a small Pacific atoll in the Gilbert Islands. Its northern shore is dotted with half a dozen pairs of parallel rough-cut slabs, each about the size of a man, arranged horizontally and cemented into the ground. One pair points to the neighboring island of Tamana 80 kilometers distant, another to Beru Island 140 km away, and a third to distant Banaba, 700 km over the horizon. Islanders call them "Stone-canoes" or "the Stones for Voyaging." They say that the slabs were used to set directions for inter-island navigation and also served as instructional models. Each pair of stones also aligns with the place where certain stars will appear or disappear on the sea horizon at different times of the night (see cover). For example, at sunset in August the bright star Regulus aligns with the Tamana stone, whereas at midnight Arcturus gives the same bearing. The navigator simply memorizes a "constellation" consisting of a long chain of stars associated with the island he wishes to visit, then steers his canoe toward them. In effect, the star rise positions become the points on a compass developed as a mnemonic device through oral tradition and trial and error.

Such correlations for accurate long-distance sailing must have required generations of experience to develop. Indeed, the system still functions today (*4–6*). To solve the problem of navigation, maritime astronomers of Oceania, both illiterate and unskilled in numbers, developed two concepts that possess no analog in the cosmology and astronomy of the civilizations of the classical world: linear constellations and a sidereal compass (Fig. 3). Both these indigenous creations of the mind seem to have been prompted by the environment. The orientation of the sky in the tropics made accurate navigation possible by this method, a technique that circumvents the conventional magnetic compass and other astronomical contrivances of our own culture. Consider the problem that might develop for a North Pacific or South Atlantic sailor who adopted the system used at Arorae. As soon as his guide star appears, it begins to move laterally relative to its place of initial appearance. Unless a substitute star is immediately available, the navigator's course deviates radically from a straight line. For example, if he is sailing from New England to Great Britain, within an hour he will be thrown off 10°, or 20 km along a 100-km segment of his course.

Practical-minded Oceanic peoples took a fact of geography and turned it to their advantage. They used astronomy based on the horizon and zenith because at equatorial latitudes this system possessed obvious advantages when dealing with celestial motion.

According to Makemson (*7*), Hawaiian sky-watchers (latitude 20°N) made practically no reference to the ecliptic and equator, but, like most tropical people, they gave great importance to the cardinal points of the horizon. Like the Maya, they conceived of pillars supporting the sky in each of the four directions. They named these pillars as if referred to an object (the sun?) situated at the east point of the horizon (*alihilani*) facing along an east-to-west axis. North (*kukulu akau*) was the right-hand pillar (also meaning the direction "up"), and south (*kukulu hema*) was the left-hand pillar or "down." The observer's position (*piko*) lies under the zenith point (*hikialoalo*), and the rising and setting points of celestial objects are called *hiki* and *kau*, respectively (*8*).

For the people of the Gilbert Islands (latitude 3°S), the sky was segmented into named zones formed by slicing the celestial sphere several times in the vertical direction (parallel to the east-west line) and by cutting it with another set of lines running parallel to the horizon (Fig. 4). The vertical lines were ridge poles (the great circle of the meridian) and rafters (small circles), and the horizontal arcs of the celestial sphere signified crossbeams or purlins. Thus the location of a star could be described in terms of its position in one of a collection of imaginary boxes dividing the celestial sphere.

Mesoamerican Astronomical Concepts

The ancient Maya are noted for their sophisticated systems of writing, astronomy, and mathematics. Yet these people, inhabitants of tropical Mesoamerica (latitude 14° to 21°N), and their descendants also used the horizon system to monitor celestial events and to mark time:

> Stone markers extending from behind Campo Santo up to top of high hill west of town. From Campo Santo to top approximately 1½ km. Sun rises on lines PS & OS observed

from stones O & P on March 19, 1940, two days before the equinox. Sun rises this day at 6 degs 31½ ms. Direction observed with simple adjustable compass. Observations of the sun are made at the stone today by zahorins {shamans} for planting and harvesting.

Long's (*9*) transcript of field notes taken by anthropologist J. Steward Lincoln concerns the astronomical practice of the contemporary Ixil Maya of the highland Guatemalan village of Nebaj (latitude 15°N). Using Lincoln's notes, we can reconstruct a horizon scheme used by the descendants of the great Maya astronomers of the Yucatan Peninsula. It is a pity that Lincoln's premature death prevented him from studying this fascinating system in detail; however, his notes leave little doubt that these people had established a method for precisely specifying the location of the sun at the horizon as seen from two different vantage points in order to mark the important planting dates in the tropical year. There are certain days, we are told, which are the only ones suitable for tilling the soil, and sometimes the people work very fast on those days so that the planting does not extend to an unfavorable day.

The ancient Mesoamerican counterparts of these contemporary horizon observatories still remain in the monumental architecture and rock petroglyphs of Mexico and Central America, although the detailed motives underlying many of the structural alignments still elude us. At the wasteland along the Tropic of Cancer near Zacatecas, Mexico, we find what appears to be an ingenious horizon sun-watching scheme still intact in the archeological record of the Chalchihuites culture (Fig. 5) (*10*). It consists of a double solar alignment, with the sun-watchers stationed 7 km apart in a generally north-south direction. One observer, standing in the Temple of the Sun at the ruins of Alta Vista (built about A.D. 400), sees the sun rise at the spring and autumn equinoxes over Picacho Peak, a pinnacle located due east of the ruins at a range of 15 km. On the summer solstice an observer situated on Cerro El Chapin, a high plateau 10 km to the south, watches the sun rise over the same peak. Moreover, an unusual rock carving marks the latter spot. It consists of a double circle, quartered by a pair of intersecting lines pecked into a flat rock on the edge of the summit of the hill. The design is identical to a family of petroglyphs found carved on rocks and in the floors of buildings at the ceremonial center of Teotihuacan, 650 km to the south. Furthermore, a similar marker appears in the floor of structure A-V at the Maya ruins of Uaxactun, situated 2000 km away from the Tropic site.

These pecked cross circles, which Aveni and Horst Hartung, an architect at the University of Guadalajara, have mapped and measured in detail, are found to exhibit calendric as well as orientational properties (*11*). In many cases the Mesoamerican 260-day calendar (a cycle consisting of the alternation of a series of numbers, from 1 to 13, with a sequence of 20 named days) is exhibited in the tally of the peck marks. The cross circles appear to have been devised by astronomers of the Teotihuacan empire, an advanced civilization that made its presence felt throughout Mesoamerica during the millennium of its existence around the beginning of the Christian era. Fifteen pecked cross markers are found in the valley of Teotihuacan, northeast of modern Mexico City. A pair of them are so situated that they could have been used to orient the rectangular grid plan of the ancient city by astronomical alignment, most probably with the setting point of the Pleiades star group.

The inhabitants of Alta Vista seem to have been seeking the actual location of the Tropic of Cancer, the place where the sun turns around on its northern

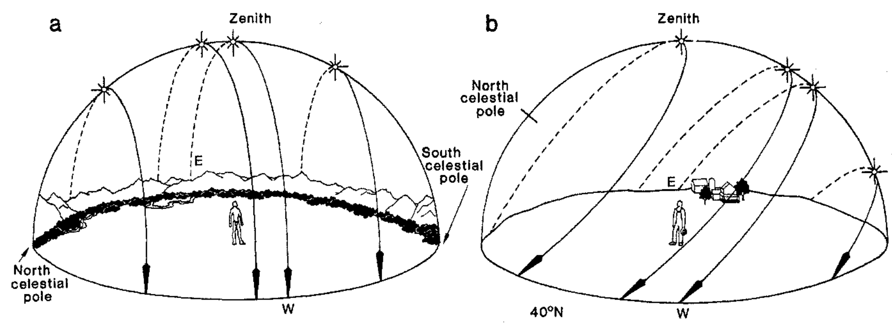

Fig. 2. Basic sky geometries of tropical- and temperate-zone astronomy. For observers in the region of the earth's equator (a), the horizon usually functions as a fundamental reference circle. Ideally, it is a great circle situated 90° from the "up-down" axis connecting the observer with the zenith (the point overhead) and nadir (the point directly underfoot). Here daily celestial motion is vertical. The observer in middle northern or southern latitudes (b) views essentially circulatory motion, the celestial pole serving as pivot and either the celestial equator or the ecliptic (a great circle tilted 23.5° with respect to the equator, not shown) as the fundamental reference plane.

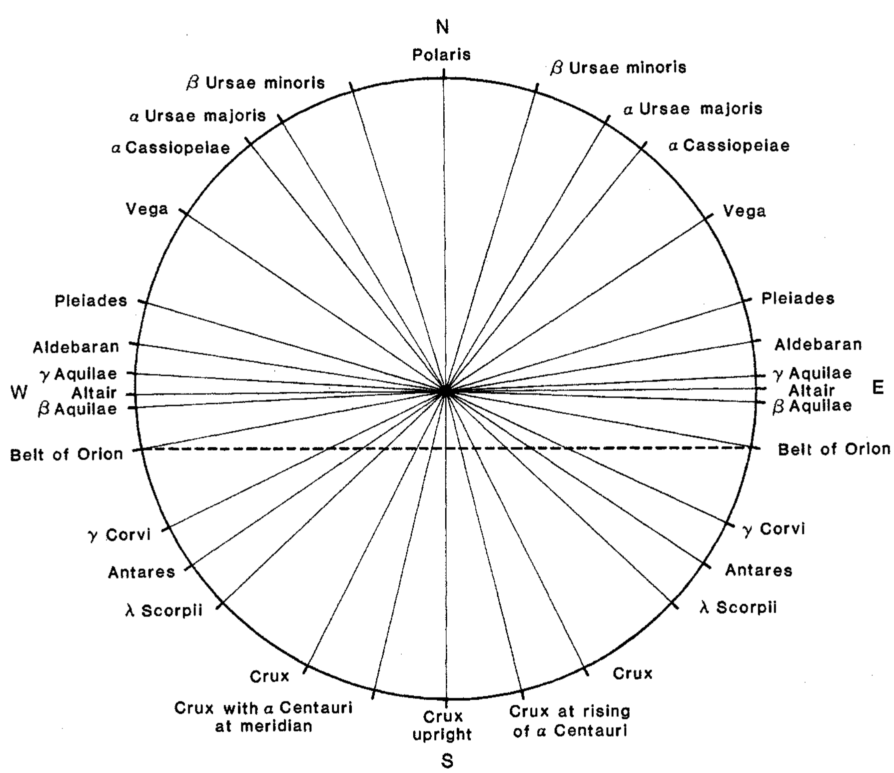

Fig. 3. "Star compass" used by navigators of the Caroline Islands. It consists of 16 pairs of rise-set positions of stars correlated with island directions. [After Goodenough (*49*)]

migration. At the latitude of the Tropic, the sun will stand in the zenith at noon on the longest day, the first day of summer. A shadowless moment occurs as the sun arcs over the zenith and returns to the southern part of the celestial sphere. Our alignment studies suggest that the people of Alta Vista used their landscape to demarcate the year by the equinoxes and the summer solstice. Although we have yet to find one, an observing station for the winter solstice may well lie to the north of Alta Vista. From there an observer could watch the sunrise over Picacho Peak at its winter standstill.

One of the most secure examples of the incorporation of a horizon-based astronomy in architecture exists at Chichen Itza (latitude 21°N) in the north of the Yucatan Peninsula. The example, called the Caracol, consists of a cylindrical tower on an asymmetric quadrangular base, erected about A.D. 1000 (Fig. 6). Particularly impressive are those sight lines achieved through a set of horizontal shafts that feed into a sealed rectangular chamber at the top of the tower. The extreme northerly and southerly disappearance points of Venus over the western horizon give a nearly perfect match to the measured directions of the azimuth of the shafts (*12*).

But how can we be sure that the builders of the Caracol intended the Venus alignments we find? The Maya codices, the only written legacy to survive the Spanish Conquest, provide relevant evidence. Studies of the hieroglyphic writing in these ancient texts indicate that a Venus ephemeris was one of the prominent features of Maya chronology. In the Dresden Codex, originally from North Yucatan, the Maya tabulated their observations of this planet.

A closer look at the format of the Dresden Venus table (Fig. 7) (*13*) helps us to appreciate both the importance of the horizon in the Maya observing scheme and the connection between their written calendar and building orientations. The tabulated cycle of Venus begins when the planet first appears over the eastern horizon as the morning star, then continues through its appearance as the evening star, and finally returns to the morning star apparition, punctuated by periods of disappearance. The reappearance of Venus at the horizon after the 8-day disappearance interval is by far the most important event in the table. The pictures that occupy the right half of each page record this particular aspect of the Venus god (center picture), who holds the spear that represent the dazzling rays of the image of Venus at first appearance. He hurls them at victims (bottom picture) whose symbolic spearing denotes some sort of omen described in the text. In the top picture a ritual procedure, such as the offering of incense, takes place to commemorate the event.

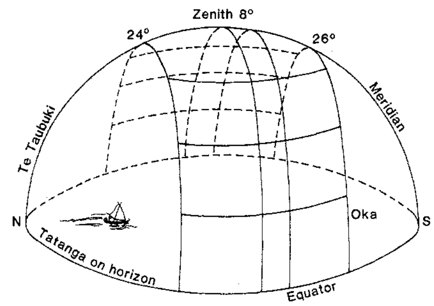

Fig. 4. The horizon system dominates the Gilbertese concept of the heavens. Ridge poles and crossbeams "hold up" the sky; crossing points delineate the boundaries of a series of altitude-azimuth boxes that served to specify star positions at different times of the night. [After Makemson (*7*)]

Viewed with the naked eye, Venus always seems to follow the sun rather closely, as if attached to it by an elastic extension. In fact, in Aztec legend the Venus god Quetzalcoatl (the same as the Maya god Kukulcan, who appears on the pages of the Dresden document and is symbolically revered by the erection of round temples dedicated to him) is said to rise out of the sun's ashes after he dies or disappears in the west. The point of disappearance in the west is, in fact, an accurate determinant of the length of time Venus will be lost in the glare of the sun before it returns to the morning sky and undergoes its heliacal rising, a period which can vary from a few days to 2 weeks. The building alignments incorporated into the Caracol of Chichen Itza—the Venus standstills—are precisely those we might expect from a people interested in predicting the malevolent predawn appearance of the planet Venus at the horizon.

By contrast, an examination of the astronomical written record of the Babylonian culture, which flourished at latitude 32.5°N, reveals a very different celestial outlook (*14*). In the so-called Astronomical Diaries excavated at Babylon, one usually finds recorded the year, month, and date of an observation and the zodiacal position of a wandering planet (for example, "Venus in Gemini"). Often the sun's place is specified by proximity to the nearest representative star of a zodiacal constellation, for example, "sun 3° east of β Scorpii." Nearly all of these observational relations, planet to star, sun to star, moon to star, are totally detached from the locale of the observer. They are not viewed in a local frame of reference but, rather, they are abstracted to a universal one (*15*). The same can be said of temperate-zone Chinese astronomy, which Needham (*16*) has described as "polar and equatorial" with a zodiac consisting of constellations referred to the celestial equator. Space does not allow a detailed comparison of every aspect of these temperate-latitude systems with those developed in the tropics and described in this article. It is my hope that this research on tropical systems will stimulate such comparative studies.

Inca Astronomy and the Ceque System

In the 16th century folio (*17*) of Felipe Guaman Poma, the Inca chronicler, we find a thorough description, in both words and pictures, of the environment of Cuzco, the ancient Inca capital in the high Andes of Peru (latitude 13°S). The historian, himself part Quechua and part Spanish, tells us that before the Spanish Conquest the Inca had built observatories with windows through which they looked at points on the horizon early in the morning to see the sun's first rays. He also states that the sun was viewed from a similar observatory when it set. The solar events were observed in order to determine when to sow and harvest and to shear the llamas and alpacas, events that occurred at different times in the tropical year. When Guaman Poma described the function of the court astrologer, he referred specifically to the sun at horizon "sitting in various chairs" as he progresses on his rounds (*17*, folios 883–884):

> The sun sits in his chair one day and he rules from that principal degree—then the sun sits in another chair from the first and in this chair he does not move in his principal day and he rests and rules and governs from that degree. And the third day he moves and prepares his trip—and from that degree he goes walking each day without resting.

Is Guaman Poma discussing the arrival of the sun at one of its standstills? He refers to the "ruedo del sol" or "round of the sun," but the entire scheme is not explained. It does seem likely that the primary pathway of the sun, as the Inca conceived it, lay along the horizon. But how was the solar course marked? What were the signposts along the solar highway?

There is good evidence from the Spanish Chronicles that the Inca of Cuzco erected sets of vertical pillars to mark important times in the solar and lunar calendar and that these structures were a part of the ceque system of Cuzco. This system was an expression of the organization of sociopolitical, religious, and familial space; I know of no analog outside the Inca domain, and the system is still evident in many Andean communities. The city was divided by a network of 41 radial lines (*ceque*, Quechua; *raya*, Spanish) emanating from the Temple of the Sun (Coricancha) which was located in the middle of the valley of Cuzco at the juncture of its two principal rivers. The Spanish chroniclers Cristobal de Albornoz (*18*) and Bernabe Cobo (*19*), writing only a few generations after Pizarro's penetration into Peru, provided a detailed description of the directions of these ceque lines (*20*, *21*). Cobo described and specified the locations of 328 huacas or sacred places that lie along the ceques and he called them "stations of pious places, whose veneration was general to all" (*19*, p. 169) (author's translation).

Based on the study of the chronicles pertaining to place names, Zuidema and Aveni have located and mapped approximately one-quarter of the ceque lines. One of the problems associated with undertaking such work is that the huacas are often described in a vague way, and some appear to have been only general areas. Nevertheless, there is enough specific information in Cobo's 17-page description of the system to enable us to set reasonable limits on the astronomical places surfacing in his discussion.

Three ceque lines are of particular interest to those of us studying horizon-system astronomy (Fig. 8, a and b). Cobo explicitly stated that observation towers or pillars were huacas of these ceques. Naming the ceques and huacas by number within their respective quadrants of the city, he said with reference to Chinchaysuyu quadrant (northwest), ceque 6, huaca 9 (counting from the west to the north and radially outward from the Coricancha) (*19*, p. 172) (author's translation):

> A hill called Quiangalla that is on the road to Yucay where there were two monuments or pillars that they had for signs and when the sun arrived there it was the beginning of summer.

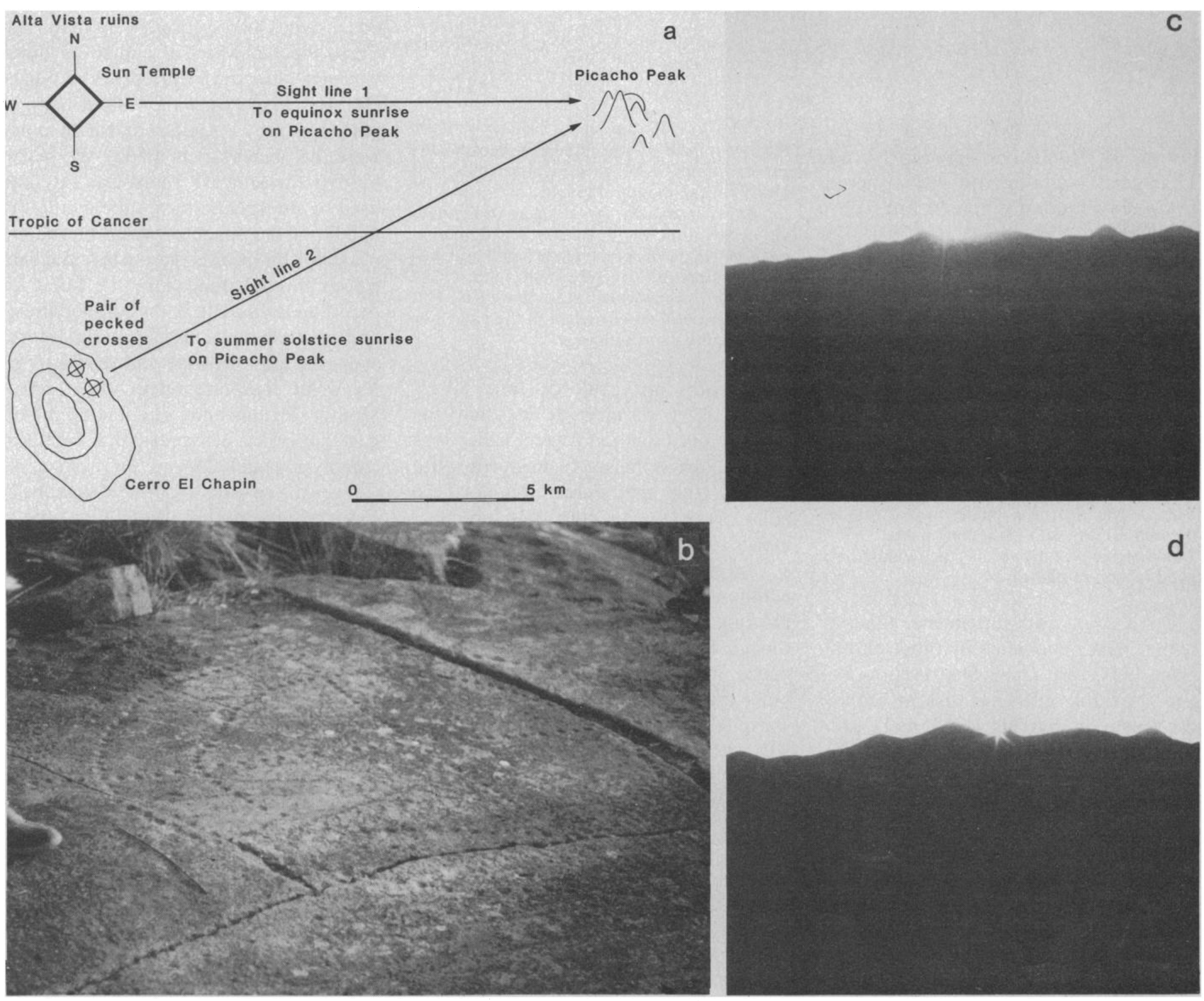

Fig. 5. (a) A double solar alignment at the Tropic of Cancer. Sight line 1 from the Alta Vista ruins near Zacatecas, Mexico, catches the sunrise over Picacho Peak on the first day of spring or autumn; sight line 2 is directed from an astronomical marker (b) over the same peak on 21 June, the summer solstice. The solstice and equinox events are documented photographically in (c) and (d) where we note the similar Loujons viewed from the two observation posts. [(a) Courtesy of E. C. Krupp, Griffith Observatory]

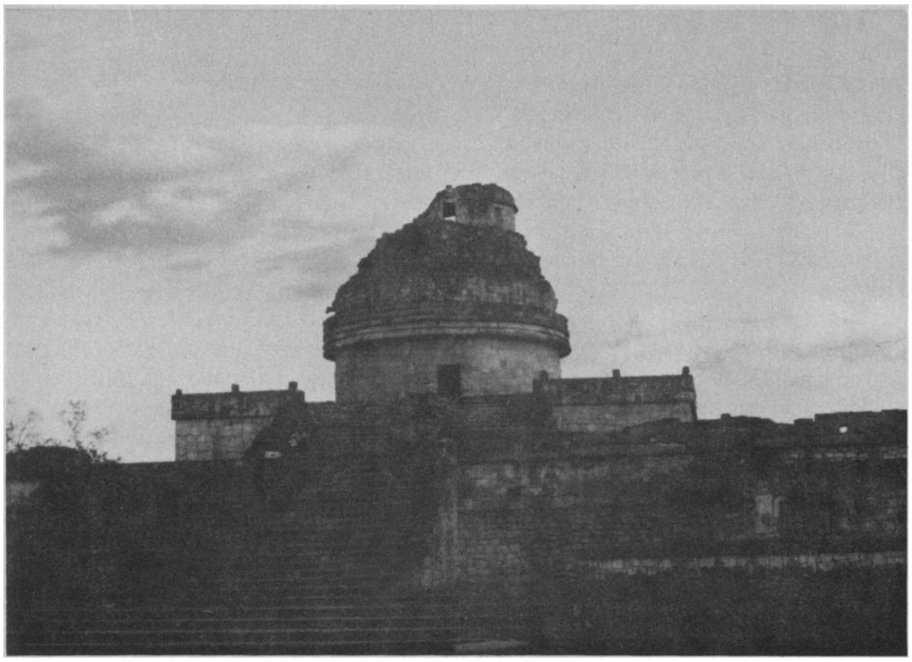

Fig. 6. The Caracol of Chichen Itza. The horizontal shafts at the top of the building are directed toward the horizon to delineate specific astronomical events of importance, for example, the sunset at the vernal and autumnal equinoxes, and the extreme setting points of the planet Venus that were used to establish the 584-day cycle tabulated in the codices.

Cobo's chronicle also includes the following for Cuntisuyu quadrant, ceque 13, huaca 3 (counting from west to south) (*19*, p. 185) (author's translation):

> Chinchincalla is a large hill where there were two monuments at which, when the sun arrived, it was time to sow.

and the information for Cuntisuyu quadrant, ceque 8, huaca 7 (*19*, pp. 173–174) (author's translation):

> Sucanca was a hill where the irrigation canal of Chinchero passes. On it were two pillars or monuments to signal that when the sun arrived there it was time to begin to plant maize. The sacrifice made there was addressed to the sun and they asked that it would arrive on time so that they would have good reason to plant. . . .

Cobo's first two statements, together with similar statements by other chroniclers, imply that a pair of structures was used to frame the solar disk at each of the solstices, but his last remark indicates that another critical series of sunsets at a different time of the year was being reckoned. A more detailed description of the sucanca (pillar) system by an anonymous chronicler of Inca history suggests that multiple pillars were involved (*22, 23*). He gave their dimensions and spacing and told how the Inca used them (*22*, p. 151):

> High on a hill overlooking Cuzco from the west lay a grouping of pillars and when the sun passed the first pillar they prepared themselves for planting in the higher altitudes, as ripening takes longer there.
>
> When the sun entered the space between the two pillars in the middle it became the general time to plant in Cuzco; this was always in the month of August.
>
> And when the sun stood fitting in the middle between the two pillars they had another pillar in the middle of the plaza, a pillar of well worked stone about one estado high, called the Ushnu, from which they viewed it. This was the general time to plant in the valleys of Cuzco and its surroundings.

Evidently an array of four pillars served as a warning device that the planting season in the Cuzco Valley was nearing, just as the sun on its north-south horizon trek approached the northern pillar. People who cultivated crops at higher altitudes, where growth occurs at a slower pace, would have sufficient additional time to sow their seeds before planting commenced in the valley. Although the chroniclers provide no evidence, we speculate that the southern pillar may have been used as a similar warning device during the harvest season when the sun, moving from left to right or south to north, passed it in April. Using the chroniclers' estimates of the distance separating the pillars, we find that the spacing corresponds to a month of sunsets. With the sun centered in the space between the inner pillars about mid-August, we found that it would arrive at the northern pillar 14 days (one-half lunar month) before, and at the southern pillar one-half month after, mid-passage. This raises the interesting possibility that observations of the moon might have been correlated with the solar sightings. As corroborating evidence, Cobo also said that there were pillars to signal the months of the year (*19*, p. 186). Apparently, when the sun arrived at successive pillars in its annual course, these were taken to mark the lunar stations. We cannot yet seek the archeological evidence to locate these lunar pillars because the method of laying them out is barely outlined by the chroniclers; we have particular difficulty interpreting their confused statements about the moon. Sadly, the old Spanish historians paid too little attention to the sophisticated calendar system that was written in the landscape under their feet. At least for the time being, we must content ourselves with the task, in itself complicated and not yet complete, of locating all the solar pillars.

Some detail on the proposed location of the solar pillars can be filled in. On the August date mentioned by the anonymous chronicler, sunsets do, in fact, occur over Cuzco's prominent mountain Cerro Picchu, which is named by other chroniclers as the location of the pillars (*24*). But where were these time markers placed exactly? And from which point were the observations made? We began by hypothesizing 18 August as the date used by the Inca to locate the sun in the middle of the space between the pillars because this is the date when the sun passes through the nadir, the point directly underfoot. It is the antipodal calendar date to the zenithal passage. Moreover, the ethnohistoric and modern ethnographic literature refers to the Earth Mother (Pachamama) opening up in August (antizenith passage) and in February (zenith passage) (*25*).

Over the course of four field seasons in Cuzco, Zuidema and Aveni were able to pinpoint the original locations of three other huacas on the ceque line passing through the pillars (Fig. 8b). We traced this ceque line from its outermost huaca toward the direction of Coricancha and defined the location of the middle pillar as that place where the ceque line crosses Cerro Picchu and the plaza first becomes visible. Then we sought the place in the plaza from which sunset on 18 August would be seen to occur at the location of the pillar at the horizon thus defined. This location turned out to correspond to the exact midpoint of the plaza as it was delineated in Inca times. Furthermore, the plaza center was marked shortly after the Spanish Conquest by a "picote" or pillar surmounted by a Christian cross that was said to have been put in place by Pizarro precisely on the site of the Ushnu (*26*), the place from which the anonymous chronicler says the Inca made their solar observations.

Indeed, the simultaneous use of the zenith-nadir axis and the horizon to mark the antizenith solar event was a brilliant stroke on the part of the Inca. It is in accord with the vertical dualism embodied in many contemporary Andean social concepts (*27*). Unfortunately, nothing remains of any of the tower sites now, for the Spanish conquerors, ignorant of the Inca cosmic view, had dismantled the structures before 1600 in order to use the stones as building material for their system of aqueducts (*28*). Nevertheless, it would be worthwhile for archeologists to perform excavations at the locations we predict to see if any substructures relating to these important calendric indicators remain.

When we followed the astronomical directions back into Cuzco from the solstitial pairs of pillars where the sun was observed to set, we were surprised that only one of them led to the Temple of the Sun, the other terminating at a mountaintop station 2 km to the north of the plaza. We are forced to conclude that the horizon-based astronomical system of Cuzco consists of at least three different observing stations overlooking three sets of pillars on the western horizon, hardly the simple scheme the chroniclers had suggested.

Observing the Sun at the Zenith

If there are alignments to the sun at the horizon in the tropics, might we also expect observations of the sun when it is at the zenith, the fundamental reference pole? Here the evidence is quite clear, not only in Cuzco but also in Mesoamerica, Malaysia, and Oceania.

Evidence of the significance of the zenith sun among the people of ancient Java (latitude 7°S) exists in the gnomon or shadow-casting device they used to partition the year in a unique way. The cruciform plate of the device (Fig. 9a) is fashioned to reckon the start of the year from the June solstice, the first day of winter in the Southern Hemisphere. The so-called rustic year is segmented into 12 months of unequal duration, ranging from 43 days (the first, sixth, seventh, and twelfth months) to 23 days for certain months in between. Maass (*29*) has demonstrated that these unequal time intervals are precisely obtainable if one uses as the guiding principle equal units of length traveled by the shadow cast by the tip of the gnomon at noon. The passage of the sun through the zenith serves as the pivotal point for dividing up the year.

In the latitude of central Java, a very special condition occurs in gnomonic geometry. As Fig. 9a demonstrates, when the sun stands on the meridian at noon north of the zenith on the June solstice, the shadow length, measured to the south of the base of the vertical pole, is exactly double the length that obtains when the sun at noon lies at the December solstice south of the zenith, then projecting the shadow to the north. Javanese chronologists halved the shorter segment and quartered the longer, thereby producing a 12-month calendar. As it occurs in most cultures, the number 12 probably was chosen to integrate full moons into the yearly scheme. Because the sun moves more slowly at the solstices, we should expect the first and last months along with the sixth and seventh months, when the shadow approaches the southerly and northerly extensions, respectively, to be those of greatest duration, whereas months defined by equal shadow lengths when the sun is near the equinox ought to be rather brief. This is precisely what occurs. The Javanese time scheme yields a calendar consisting of 12 months of variable length, ranging from 23 to 43 days. Calendar keepers later altered particular intervals by 1 or 2 days either way in order to force them to correspond more precisely to agricultural practices.

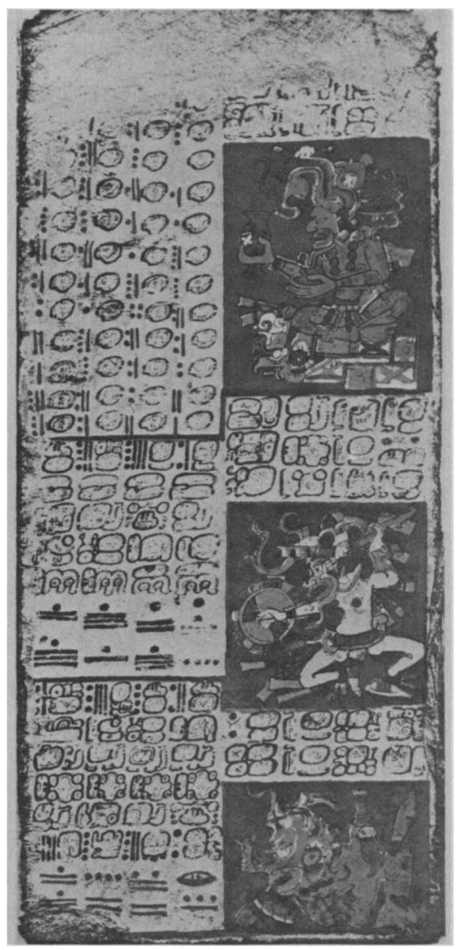

Fig. 7. A page from the Venus ephemeris in the Dresden Codex (*13*). Light-colored dots and bars at the bottom denote the four stations of Venus; the top half of the diagram lists the ritual dates of arrival of Venus at each station. Pictures at the right celebrate the heliacal rising of the planet, its first appearance at the horizon following obscuration by the light of the sun. [Courtesy of the American Philosophical Society, Philadelphia]

The architects of this curious calendar took a spatial unit and transformed it into a temporal one. But the Malaysian attempt to fuse space and time is not unique to that culture. This notion also appears in the calendars of ancient Mexico where the day names of the 260-day calendar are assigned positions around the horizon, and the year-bearers or names of New Year's Day in succeeding tropical years are associated with different cardinal points. Does this habit also appear in our contemporary outlook on nature in the form of the theory of general relativity?

In Mexico there is little evidence for shadow casting, but we know that the sun was observed at the zenith and so were the Pleiades. Next to a diagram of certain Aztec constellations drawn by a native informant, Padre Bernardino de Sahagun, a historian of early Mexico City (Tenochtitlan), tells us (*30*, pp. 143–144):

> These are representations of the Pleiades which mark the 5th cardinal point. At the beginning of a period of 52 years, fire was newly kindled when the Pleiades were in the zenith at midnight. The flaming up of this fire was a sign to the anxious waiting multitude that the world was not, as they had feared, to be swallowed up in darkness, but that a new era would be granted to mankind.

The fifth cardinal point referred to by the historian was the zenith, and the other four lay in the horizon plane.

Juan Pio Perez, a 19th-century chronicler and political chief of the town of Peto, writes that in Yucatan the year began at zenith passage (*31*, p. 280):

> To this day the Indians call the year *Jaab* or *Haab* and while heathens, they commenced it on the 16th day of July. It is worthy of notice that their progenitors, having sought to make it begin from the precise day on which the sun returns to the zenith of this peninsula on his way to the southern regions, but being destitute of instruments for their astronomical observations, and guided only by the naked eye, erred only forty-eight hours in advance. That small difference proves that they endeavored to determine, with the utmost attainable correctness, the day on which the luminary passed the most culminating point of our sphere and that they were not ignorant of the use of the gnomon in the most tempestuous days of the rainy season.

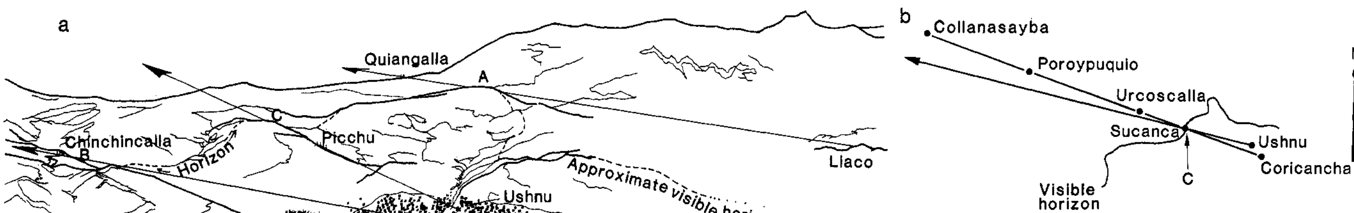

Fig. 8. Horizon astronomy in the high Andes. (a) View of the valley of Cuzco from the south showing the three horizon alignments constructed in the landscape. Two sets of pillars (*A* and *B*), viewed from separate stations in the city, marked the sun at its June and December limits. Four pillars at *C* marked the sunset point on the day it passed the nadir (antizenith). (b) The ceque line (connecting dots which represent known huacas) containing the four pillars (*sucanca*) on Cerro Picchu and the astronomical line (with arrow at tip) directed from the *ushnu* that was once situated in the present-day Plaza de Armas to the central pair of pillars where the sun set on the day of passage through the antizenith. [(b) Courtesy of E. C. Krupp, Griffith Observatory]

Don Juan's Spanish cultural bias seeps into his statement when he "proves" that the Maya used a gnomon or vertical stick to mark the time. Although there is no direct evidence that such a technique was used, there is some rather good evidence to illustrate how the shadowless moment was determined in ancient Mesoamerica. Linsley, Hartung, and Aveni have identified two peculiar architectural structures in Mexico as "zenith tubes," one at Monte Alban (*32*) (in the Zapotec highlands near Oaxaca, latitude 17°N) and the other at Xochicalco (south of Mexico City at latitude 19°N) (*33*). These tubes seem to have functioned to admit the sun's image directly and to pass it vertically into a darkened chamber.

Fashioned out of the existing stairway of building P [constructed during the period Monte Alban II (about 275 B.C.) on the east side of the main plaza] a square tube 15 centimeters on a side and 210 cm long feeds into a darkened rectangular chamber large enough to comfortably accommodate one or two persons. An access port and chamber leading to the tube are built into the stairway of the building (Fig. 9b).

But astronomical functionalism in the architecture can be argued even further in this case. Several years ago we discovered a possible motivation for the precise location of the tube. It was associated with the skewed and misshapen building J, located 200 meters to the southwest. (The axis of building J deviates by 40° from the other buildings there.) When we measured the perpendicular to the doorway of building J with a surveyor's transit, we found that it passed close to the mouth of the tube in building P. Moreover, the perpendicular to the stairway of building J could be extended precisely through the doorway of building P and then projected onto the distant horizon at the position where Capella, sixth brightest star in the sky, rose. Now Capella had a unique celestial distinction at Monte Alban at this time because it underwent heliacal rise on the same day as one of the solar passages of zenith. We proposed that the priests observed Capella make its first apparition on the horizon over building P from the doorway of building J. The stellar event signaled that the sun would transit the zenith on that day, and the priest-astronomers could decend into the chamber in building P and receive its light through the tube.

We carried out detailed measurements and calculations on the zenith tube to see just how well it functioned. We found, possibly because the structure had settled, that its vertical axis leans 1.7° out of plumb to the west. The tube gives a 4.1° by 4.9° rectangular view of the overhead region. Plotting solar passages on different dates as viewed through the tube opening from the bottom end by an observer standing with his head centered in the opening, we found that the sun's image was directly visible through the hole at about noon over a period of a few weeks, but on the day of zenith passage (± 1 day) the sun made its longest stand in the shaft.

At the ruins of Xochicalco, Mexico, there is another such vertical shaft (Fig. 9c). It is 8 m long, perfectly straight, and opens into a roundish chamber 10 m in diameter. The tube had been carefully inlaid with stone blocks, the cross section forming a hexagon. Early explorers thought the shaft might have served to vent smoke from fires out of the chamber. But both the careful structural engineering of the tube design and the absence of char in the chamber rule out that possibility. It is far more likely that the hole was meant to enable an observer to view celestial events in the patch of sky overhead. In fact, a building adorned with astronomical relief (calendric dates and eclipse symbols) is situated only 100 m to the west. The Xochicalco zenith tube leans only slightly out of plumb, about 0.5° to the north. We found the width of field to be 2.5°, thus the size of the sun's disk relative to the area of the aperture is somewhat larger than at building P, Monte Alban; however, on zenith day the sun does not pass through the center of the tube. Actually, its full disk is visible at the southern extremity of the opening 3 days before or after zenith passage and passes the northern limit 8 days before or after zenith passage. Were the people who lived at this site being sloppy, or did they have a reason to mark solar dates close to but not precisely in coincidence with zenith passage? At this point, we cannot say. A second tube of slightly larger relative dimensions, now plugged with rubble and not yet studied, can be found nearer the entrance to the same cave. Perhaps archeological excavation and further astronomical study will reveal the answer to this question.

Although we have found only two examples thus far in Mexico, we can draw some preliminary conclusions about zenith sun-watching. In view of the overwhelming evidence that the zenith sun and the Mesoamerican calendar were connected, zenith tubes, rather than the gnomons more familiar to our culture, constitute the most recognizable method for watching the sun traverse the fifth cardinal direction. Furthermore, we find no better hypothesis to account for the existence of the vertical tubes so carefully engineered into the architecture at Xochicalco and Monte Alban. Archeologists should search for other examples of this type of device in the remains of the civilizations of the tropical Americas.

Garcilaso de la Vega, the Renaissance historian of the Inca, leaves no doubt that Cuzqueños of 15th-century Peru used the gnomon to observe the sun at zenith (*25*, p. 117):

> When the priests felt that the equinox was approaching, they took careful daily observations of the shadows cast by columns. The columns stood in the middle of a great circle filling the whole extent of the mesa or courtyard. Across the middle of a circle a line was drawn from east to west by a cord, the two ends being established by long experience. They could follow the approach of the equinox by the shadow the column cast on this line, and when the shadow fell exactly along the line from sunrise and at midday the sun bathed all sides of the column and cast no shadow at all, they knew that that day was the equinox. They then decked the columns with all the flowers and aromatic herbs they could find, and placed the throne of the Sun on it, saying that on that day the Sun was seated on the column in all his full light.

Although Garcilaso has confused the equinoxes with the zenith passages in his narrative, he gives us the impression that the Inca had developed a sophisticated scheme for timing the solar year by means of the zenith-horizon system. In addition to horizon pillars, shadow-casting columns were found throughout the Inca empire, which stretched over 30° of latitude in a narrow north-south strip.

A set of columns near Quito (latitude 0°17′S) was held in special veneration, says Garcilaso, for there the sun is "in plumb line" at the equinoxes; "they afforded the sun the seat he liked best, since there he sat straight up and elsewhere on one side" (*28*, p. 117). But archeological evidence bearing on the pillars is difficult to establish, for, as Garcilaso also tells us, "like the horizon pillars of ancient Cuzco they were very properly pulled down and broken to pieces by the Governor Sebastian de Balalcazar, because the Indians worshipped them idolatrously. The others throughout the empire were demolished by the Spanish captains as they came across them" (*28*, p. 118; *34*).

Zenith stars rather than the zenith sun were recognized in Polynesia, and again the motivation was navigation (*4*). We know that, because the declination (the angular distance north or south of the celestial equator) of a star that passes the zenith is the same as the latitude of the observer, every island could be associated with its own zenithal guide stars. In our terms, the navigator would have reached the parallel of geographic latitude of his destination when the arc of a guide star's course crossed the overhead position. Thus Sirius became the guide star for the Fiji Islands (latitude 17°S), Rigel, in the constellation of Orion, that of the Solomon Islands (latitude 7°S), and Altair that of the Caroline Islands (latitude 9°N) (Fig. 10). Longitudinal navigation was not conceptualized by these navigators, there being no indigenous method known or even a desire for the islanders to deal with this task by celestial observations. Although Old World navigators used time-keeping mechanisms for sailing in the east-west direction, the people of Oceania used a knowledge of wind and oceanic currents combined with astronomical observation, that is, purely natural forces, to circumvent the problem successfully. Thus we must not infer that longitude and latitude are necessary concepts for all successful navigators.

Other Cultures of the Tropics

To date, the interdiscipline of archeoastronomy has been applied only to a few ancient civilizations of the tropical latitudes. The basic ideas in this article can well afford to be subjected to more stringent testing. A good place to start would be the region of central Africa where a rich cosmological tradition is known to have existed (*35*).

One ethnographic study from southwestern Ethiopia (latitude 5°N) by British anthropologist D. Turton and astronomer C. Ruggles (*36*) holds promise. Today the Mursi are as interested in time reckoning as their ancestors were, and they confine themselves strictly to earth-based horizon references. The topography there permits a view of a distant horizon abundant in peaks and notches; thus the days are conveniently marked by the arrival of the rising sun at well-defined places. Most noteworthy are the solstice points. But the Mursi also correlate the seasonal cycle with the appearance and disappearance of the Pleiades, the stars we know as Orion's Belt, Sirius, Canopus, β and δ Crucis of the

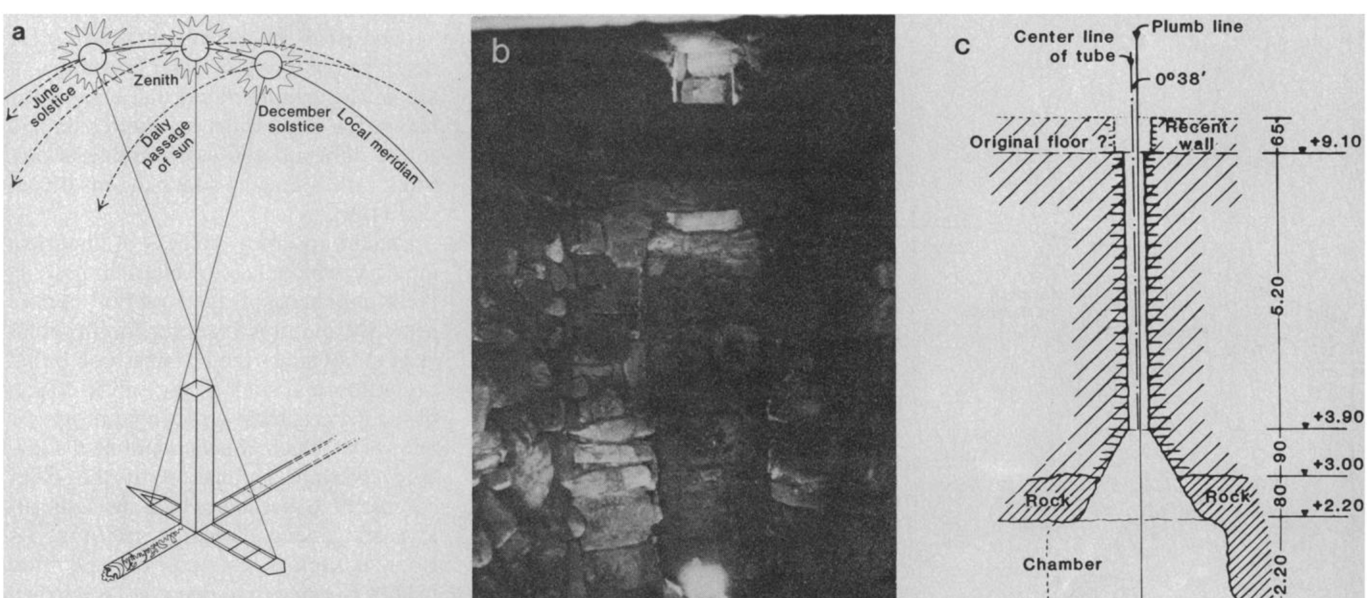

Fig. 9. Variations on the theme of zenith sun-watching from Malaysia and Mexico. (a) The Javanese sundial used to segment the year by following the noontime shadow of the gnomon or vertical stick over equal intervals of length on the base plate. (b) In Mexico, a hollow tube rather than a vertical stick was used. It was built into the stairway of a building at Monte Alban, where it is shown in operation on one of the zenith passage dates in that latitude. (c) Schematic view of a zenith tube 8 m long, hollowed out of a cave at Xochicalco, Mexico. [(c) Courtesy of H. Hartung]

Southern Cross, and α and β Centauri. The stars α and β Centauri regulate the flood season, the planting of cowpeas, and the flowering of the *sholbi* (acacia) tree. β Centauri is named after the *sholbi* tree because it disappears at the same time that the tree blossoms. δ Crucis is called *imai* because, plunging vertically downward, it disappears from view at sunset when the flooded Omo River rises enough to flatten the tall grass, also called *imai*. Turton and Ruggles, who have studied Mursi astronomy and timekeeping in detail and from whom I acquired this information, explain that, although the system today is not "scientifically" accurate, it must have developed from a correlation arrived at through careful observation of earth and sky phenomena. We can admire the Mursi for attaching the names of celestial bodies to ground features with which their courses may be practically and lastingly associated.

Ethnologist G. Urton (*37*), who has studied the astronomical system of the Quechua-speaking community of Misminay near Cuzco (latitude 12°S), tells us the natives there behave in a similar manner. They correlate the appearance at the horizon of each of their constellations, dark clouds of the southern Milky Way resembling animals, with important periods in the life cycles of those animals. Here the moving point of intersection of the Milky Way with the horizon takes on calendric significance. Both the Mursi and Quechua use complex, internally based reference systems.

Among the Sudanese Bambara (latitude 15°N) (*38*), cylindrical granaries serve the function of gnomon in an elaborate system wherein their structure is dictated by exact measurement, but it is not clear from the purely ethnographic studies, conducted 30 years ago, whether zenith or horizon phenomena were important. These ethnographies, as well as every reference to tropically based archeoastronomy listed in the Baity bibliography (*39*), would be worth reexamination.

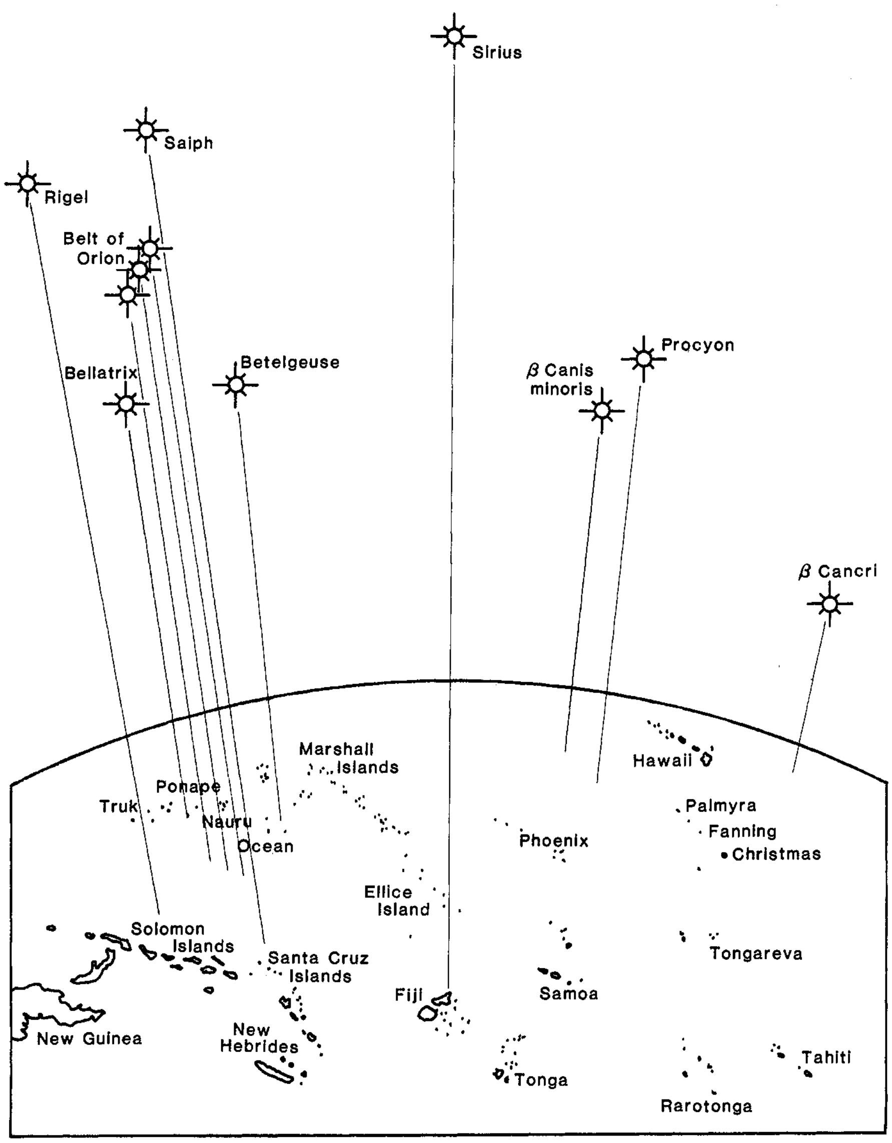

Fig. 10. Zenith stars used by navigators of Oceania to assist in the location of particular islands. [After Gatty (*50*)]

Conclusions

A hidden similarity has emerged from this brief examination of astronomical systems among indigenous tropical cultures. I contend that the circle of the horizon and the zenith-nadir axis constitute the underlying organizational basis of the observational end of every tropical system we have discussed. In the well-studied civilizations of the higher latitudes (China, Babylonia, Greece), this seems less the case (*40*). The geographic latitude in which these cultures developed may have played a profound role in determining what kind of system would develop. The debate about the degree to which environment affects the culture of man has deep and widespread roots in the 19th- and 20th-century history of anthropology. The old notion of the uniform evolution of all people through successive stages of sophistication from savagery through barbarism to civilization was discredited at the turn of the century by anthropologist Franz Boas and others who showed that people most diverse in culture and language often are found living under the same geographic conditions. Field anthropologists who applied Boas' historical method in great depth to the study of diverse peoples of the world demonstrated that any explanation for similarities had better be laid to the diffusion and slow mixing of cultures rather than to independent invention (*41*).

Caught up in the success of historical inquiry, which has resulted in putting great numbers of facts about certain primitive cultures in order, anthropologists today might tend to overlook broad general forms, such as the subtle effects of the geographical environment on cosmic views. Such effects might be discovered through application of the older comparative method of looking at specific traits among disparate cultures. As Boas himself suggested, once culture history had begun to become established as a valid discipline, as it has now for more than half a century, the comparative method might once again reach fulfillment because it would then rest upon a broader and sounder basis in fact (*42*).

Has the time to contrast the cosmological systems of ancient civilizations now arrived?

Still, there is a danger in expressing too rigidly generalizations about the influence of geography on developing astronomies. The vagaries and complexities of cultural development serve as ample warning in the present case. Of course, we can find cultures in the higher latitudes that use horizon references in their practice of astronomy. We need look no farther than Stonehenge, where the evidence on Bronze Age Megalithic astronomy *(43)* (latitude 50°N to 60°N), if taken as convincing, affords an excellent counterexample to my thesis. Certain examples from the study of North American archeoastronomy also demonstrate that it would be erroneous to conclude that all nontropical cultures will shun a horizon reference frame *(44)*. The Maori of New Zealand, also located well out of the tropics at latitude 40°S, used a navigational system like the Polynesians *(45)*, although this scheme probably diffused from the tropics. Conversely, the ecliptic and celestial equator are found to surface as astronomical concepts utilized among tropical people. Indeed, pages 23 and 24 of the Paris Codex, a book of ancient Maya writing, have been interpreted as a zodiac consisting of 13 constellations *(46)*. The Kogi tribesmen of northern Colombia *(47)* and the Dogon of central Africa *(48)* also pay attention to the movement of the sun among the stars. Rather than searching out similarities between tropical and temperate-zone astronomies, I have chosen to emphasize simple differences that appear to me to be rather profound. If the modern western scientist shares any common ground with the ancient astronomers of the tropics, it is perhaps that both seek the simplest formalism dictated by the observations.

References and Notes

1. J. Major, *Commentaries on the Second Book of Sentences (1510)*, as quoted in L. Hanke, *All Mankind Is One* (Northern Illinois Univ. Press, DeKalb, 1974), p. 101.
2. Z. Nuttall, *Pan Am. Union Bull.* **61**, 667 (1927); *Publ. Sec. Educ. Publica (Mexico City)* **17** (No. 20) (1928).
3. K. Brecher and P. Morrison, paper read at the American Astronomical Society meeting, Mexico City, January 1977.
4. D. Lewis [*We, the Navigators* (Univ. of Hawaii Press, Honolulu, 1972)] gives a complete bibliography.
5. For a discussion of this topic in the context of the comparison of astronomical systems among developing cultures, see D. Lewis, in *The Place of Astronomy in the Ancient World*, F. R. Hodson, Ed. [*Philos. Trans. R. Soc. London* **276**, 133 (1974)].
6. For a discussion of linear constellations, see E. Beaglehole and P. Beaglehole, *Bull. Bernice P. Bishop Mus., No. 150* (1938); J. Williams, *A Narrative of Missionary Enterprises in the South Seas* (J. Snow, London, 1837); and C. Kursh, paper read at the American Anthropology Association meeting (section on archeoastronomy), Houston, 1977.
7. M. Makemson, *Am. Anthropol. New Ser.* **40**, 370 (1938); *ibid.* **41**, 589 (1939).
8. M. daSilva, personal communication.
9. R. C. E. Long, *Carnegie Inst. Washington Notes Middle Am. Archaeol. Ethnol. No. 87* (1948), p. 214.
10. For details, see A. Aveni, H. Hartung, J. C. Kelley, *Interciencia*, in press.
11. Their properties are reviewed in detail and several hypotheses proposed for their function by A. F. Aveni, H. Hartung, and B. Buckingham [*Science* **202**, 267 (1978)].
12. A. F. Aveni, S. L. Gibbs, H. Hartung, *Science* **188**, 977 (1975).
13. J. E. S. Thompson, *A Commentary on the Dresden Codex, a Maya Hieroglyphic Book* (American Philosophical Society, Philadelphia, 1972).
14. For example, see A. Aaboe, in *The Place of Astronomy in the Ancient World*, F. R. Hodson Ed. [*Philos. Trans. R. Soc. London* **276**, 21 (1974)].
15. Many treatments of ancient calendars imply that an evolutionary process occurs which leads to greater abstraction with increasing complexity, but, as A. Leach [*Oceania* **20**, 246 (1950)] has argued, such beliefs are "often colored by one's own preconceptions about the nature of time and in the assumptions he makes about the objectives of primitive 'calendar-makers.' "
16. J. Needham, in *The Place of Astronomy in the Ancient World*, F. R. Hodson, Ed. (*Philos. Trans. R. Soc. London* **276**, 67 (1974).
17. F. Guaman Poma de Ayala, *El Primer Neuva Coronica y Buen Gobierno* (between 1584 and 1614) (Institut d'Ethnologie, Paris, 1936) (author's translation).
18. For the Albornoz chronicle, see P. Duviols, *J. Soc. Am. New Ser.* **56**, 17 (1968).
19. B. Cobo, *Historia del Nuevo Mundo* (1653) (*Bibliotica Autores Españoles*, Madrid, 1956), vols. 91 and 92.
20. For a full discussion of the ceque system, see R. T. Zuidema, *The Ceque System of Cuzco: The Social Organization of the Capital of the Inca* (Brill, Leiden, 1964).
21. For a discussion of the ceques in an astronomical context, see R. T. Zuidema, in *Native American Astronomy*, A. F. Aveni, Ed. (Univ. of Texas Press, Austin, 1977), pp. 219–259.
22. Anonymous, in *Juicio de Limites entre el Peru y Bolivia*, V. Maurtua, Ed. (Chunchos, Madrid, 1906), vol. 8 (author's translation).
23. See *(21)*, chapter 15, for a full discussion of the chroniclers' reference to sucanca pillars, their dimensions, separation, and use. Apparently there were four of them, the inner pair being closely spaced enough to capture the sun's disk.
24. P. Cieza de Leon, *La Cronica del Peru* (Biblioteca Peruana, Lima, 1973), p. 214. See *(21)* for a list of chroniclers who discuss the location of the towers.
25. R. T. Zuidema, in *Archaeoastronomy in the Americas*, R. Williamson, Ed. (Ballena, Santa Barbara, Calif., in press).
26. J. de Betanzos, "Suma y narración de los Incas" (1551) (*Biblioteca Autores Españoles*, Madrid, 1968), vol. 209, p. 38.
27. See B. J. Isbell, *To Defend Ourselves* (Univ. of Texas Institute of Latin American Studies Series, Austin, 1978), chap. 9.
28. Garcilaso de la Vega [*Royal Commentaries of the Incas*, H. Livermore, Transl. (Univ. of Texas Press, Austin, 1969), vol. 1, p. 116], writing in 1616 says, "I saw these towers standing in 1560, and unless they have since been pulled down, the point from which the Inca observed the solstices can be verified. I cannot say whether it was a tower in the house of the sun or another place."
29. A. Maass, *Tydschr. Indische Taal-, Land Volkenkunde* **61** (No. 1), 103 (1924). See also A. Cohen-Stuart, in *Regeeringsalmanak voor Nederlandsch-Indie* (Landsdrukkerij-Batavia, 1898), pp. 21–30.
30. B. de Sahagun, *Florentine Codex*, C. E. Dibble and A. J. O. Anderson, Transls. (School of American Research, Santa Fe, N.M., 1957), book 7.
31. J. P. Perez, in J. L. Stephens, *Incidents of Travel in Yucatan* (Harper, New York, 1843), vol. 1.
32. A. Aveni and R. Linsley, *Am. Antiq.* **37**, 528 (1972).
33. A. Aveni and H. Hartung, *Archaeoastron. Suppl. J. Hist. Astron.*, in press. This paper discusses both tubes and assembles the evidence on zenith sun-watching in Mesoamerica.
34. E. Ferdon (personal communication) has suggested the ruins of Rumicueho, 20 km north-northeast of Quito (latitude 0°1'N) as a possible site for these markers. On a recent visit to the site I noted some structures with circular foundations there.
35. C. D. Forde, Ed., *International African Institute, African Worlds: Studies in the Cosmological Ideas and Social Values in African Peoples* (Oxford, London, 1963).
36. D. Turton and C. Ruggles, *Curr. Anthropol.* **19**, 585 (1978).
37. G. Urton, *At the Crossroads of the Earth and Sky: An Andean Cosmology* (Univ. of Texas Institute of American Studies Series, Austin, 1981).
38. D. Zahan, *Africa* **20**, 126 (1950).
39. E. C. Baity, *Curr. Anthropol.* **14**, 389 (1973).
40. Egyptian astronomy, developing between latitudes 23° and 30°N, may be an interesting marginal case. The principal interest of the Egyptian astronomer seems to have been in segmenting the hours of the day by watching the movement of objects across the sky. He kept the hour by the *merkhet*, a device consisting of a plumb bob and notched stick, the principal reference line for the observations being the celestial meridian or the north-south line passing overhead. A zodiac was favored over horizon referencing, and the movement of planets among the stars was duly recorded. On the other hand, the heliacal rising of Sirius was observed and horizon references may have been used to orient the pyramids cardinally. Of course, the diffusion of astronomical concepts among the Middle Eastern civilizations is a problem.
41. The impact of Boas on 20th-century anthropology is treated by G. Stocking, *Race, Culture and Evolution* (Macmillan, New York, 1968).
42. See especially the introduction to chapter 6 of *(41)*, where the resurgence of the evolutionary approach is discussed.
43. A. Thom, *Megalithic Remains in Britain and Brittany* (Clarendon, Oxford, 1978), and earlier works cited therein.
44. J. Eddy, in *Native American Astronomy*, A. F. Aveni, Ed. (Univ. of Texas Press, Austin, 1977), pp. 147–170.
45. E. Best, *Dom. Mus. Monogr. No. 3* (1972).
46. H. Spinden, *Am. Antiq.* **18**, 53 (1915).
47. G. Reichel-Dolmatoff, *Rev. Colomb. Antropol.* **19**, 199 (1975).
48. M. Griaule, *Conversations with Ogotemmeli* (Oxford, London, 1965), pp. 209–220.
49. W. Goodenough, *Native Astronomy in the Central Carolines* (Museum Monographs, University of Pennsylvania, Philadelphia, 1953).
50. H. Gatty, *The Raft Book* (Grady, New York, 1943).

51. I am grateful for the criticism of this manuscript offered by G. Urton, S. Gibbs, and B. J. Isbell and for the illustrations provided by E. C. Krupp and the Griffith Observatory (Figs. 5a and 8b), H. Hartung (Fig. 9c), and J. Meyerson (all others). This article is a resumé of an invited lecture delivered at the section on "Archaeoastronomy and the Roots of Science" at the AAAS meeting in San Francisco, January 1980.