The Importance of Zenith Passage at Angkor, Cambodia

By Edwin Barnhart and Christopher Powell

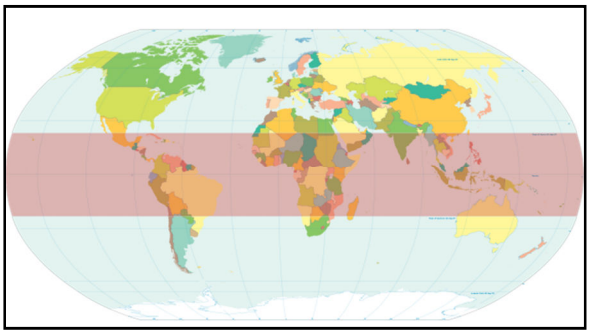
In August of 2010 and 2011, we led University of Texas at Austin Chautauqua Program courses to the ancient city of Angkor, Cambodia to investigate a question: was the zenith passage of the Sun important to ancient Khmer culture? What we found was a resounding "yes!" From architectural features and orientations to art panels and monuments, the evidence that zenith passage was recognized permeates the entire city.

The idea to search for evidence of zenith passage at Angkor was inspired by our prior research in Mesoamerica. There, I and other scholars have recognized the presence of gnomons, zenith sighting tubes, and zenith sunrise oriented architecture from Northern Mexico down through Honduras (Nuttall 1928, Friedel and Schele 1993, Milbrath 1999, Aveni 2001, Broda 2006, Mendez et al. 2005). There is also strong evidence that the Maya calendar was developed along the 14.8° line of latitude, where the zenith passage date neatly divides their sacred 260-day cycle from the solar year's cycle of 365 days (Malstrom 1997).

This paper will explain our discoveries at Angkor, other areas of Indochina which further support our hypothesis, and the Hindu cultural foundation from which their knowledge of zenith passage may have been inspired. In the conclusion we will suggest that as in Mesoamerica, the Khmer reasons for recognizing zenith passage may be related to the spiritual importance of an axis between the center of the world and the center of the universe. To begin, an explanation of what zenith passage is and how it functions is in order.

What is the Solar Zenith Passage?

Zenith is the highest point in the sky, directly overhead no matter where one stands. Solar zenith passage is the moment when the Sun passes through that very highest point in the sky. Shadows cast directly down at that moment and a perfectly straight stick planted in the ground, referred to as a gnomon, will cast no shadow at all. Conceptually zenith passage happens at noon, when the Sun crosses from the eastern to the western half of the sky, but the actual moment varies slightly by how far off a time zone line one stands and by daylight savings hour changes. Take away the western notion of a clock, and zenith passage occurs during the noon-day sun.



Map 1. World map with the Tropics highlighted in pink

Zenith passage does not occur everywhere on Earth. In fact, it can only happen in the tropics. The tropics are defined by the longitudinal lines of the Tropics of Cancer and Capricorn, 23.5° N and 23.5° S respectively (Map 1). Above or below the tropics, the sun's east to west daily passage occurs at such a steep angle that it can never cross directly overhead. Thus, only those who live in the tropics can experience a zenith passage.

The important moments of the Sun's annual passage through the sky are commonly recognized as summer solstice, winter solstice, and the two equinoxes, spring and fall. Everywhere on Earth, these events take place on the same four days of the year (give or take a day depending on the leap year cycle) - March 21, June 21, September 21, and December 21. Winter solstice is the shortest day of the year, when the Sun makes its shortest trip through the sky. Summer solstice is the longest day of the year. The equinoxes are days when day and night are equal lengths of time and during which the Sun rises up from due east and sets due west. Though the angular path of the Sun through the sky differs with latitude, becoming more reclined in angle in proportion to one's distance from the Earth's equator, the dates of these four solar stations are always the same everywhere on the planet (Figure 1).

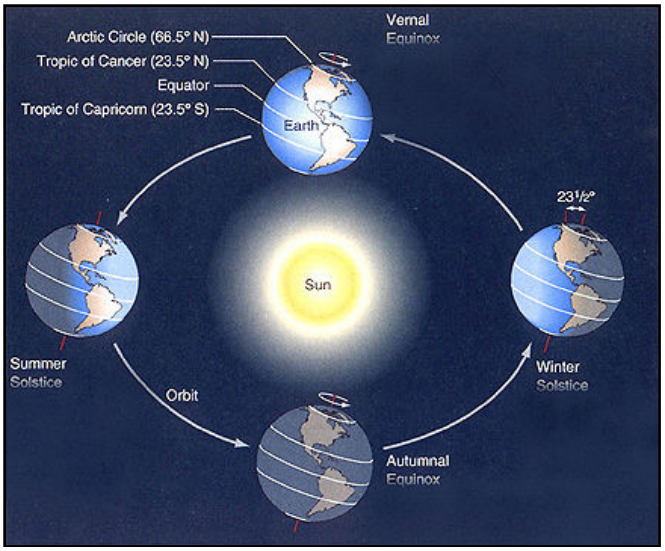
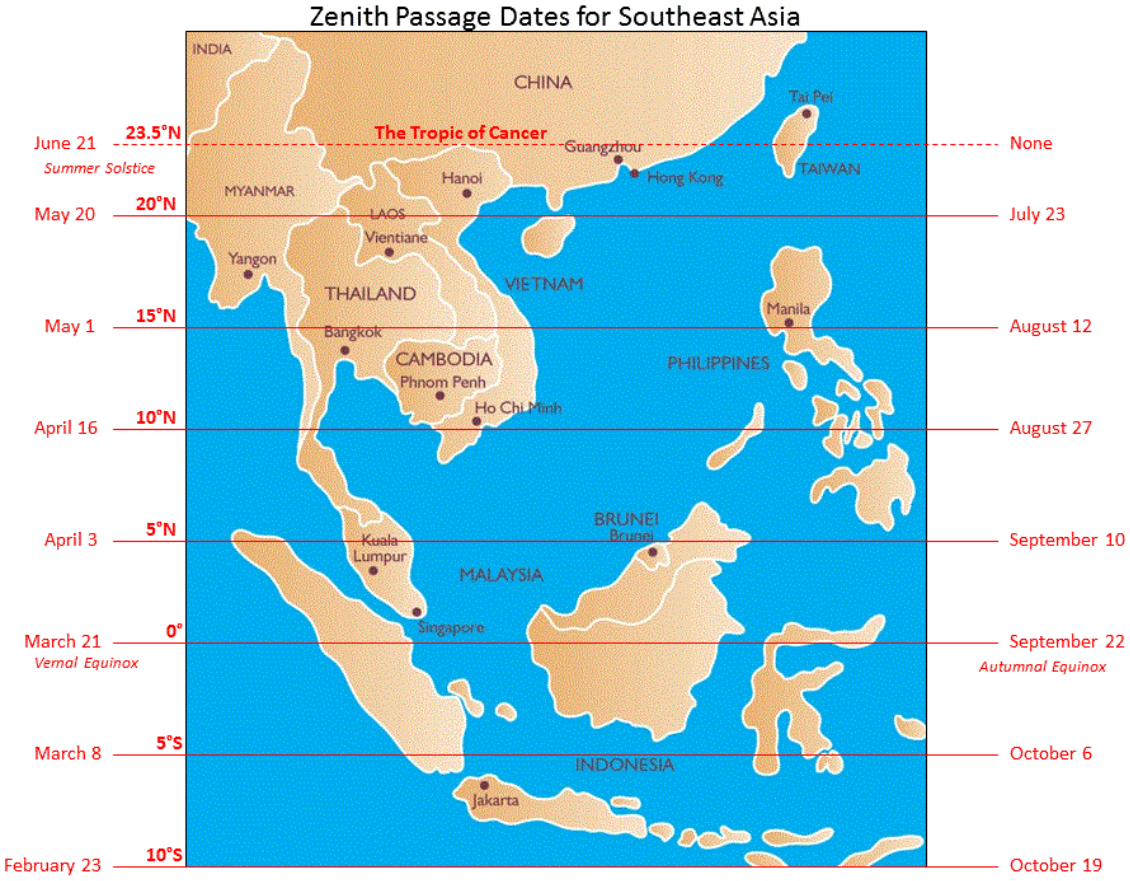


Figure 1. Diagram of the four common solar stations

The days of zenith passage do not follow the same rules. Instead, the specific days of zenith passage change depending on the latitude. There are two days of zenith passage in the tropics, stretching farther apart as one travels south or north from one of the tropics lines at 23.5° N and S. At the equator, zenith passage occurs on the same days as equinox, March 21 and September 21, a full 182 days apart. If one were to move north to 15° N latitude, the passages would occur on August 13 and April 30, only 105 days apart. At 20° zenith passage occurs on May 20 and July 23, only 64 days apart. Ultimately, on the Tropic of Cancer line at 23.5°, there is only one day of zenith passage - summer solstice on June 21. Any farther north and the Sun's angular path through the sky is reclined at such a degree that there is no zenith passage at all.

Most of the world's major ancient cultures developed outside of the tropics - Greece, Rome, Mesopotamia, China, even all but the southern edge of Egypt. Thus, these cultures had no zenith passages. The ancient Maya, whose region spans almost 10 full degrees of the tropics were not only recognizing zenith passage, but clearly communicated between latitudes about the differences of zenith passage dates (Aveni and Hartung 1981, Malstrom 1997, Green (in press)).

Looking across the globe for other major ancient civilizations within the tropics, the list is short. The cultures in the Andes of Peru are in the tropics, and indeed they are known to have recognized zenith passage and incorporated it into their cosmology (Urton 1981, Bauer and Dearborn 1995). Southern India is also in the tropics and their ancient culture's understanding of zenith passage will be discussed later in this paper. The only other place within the tropics with major ancient civilizations is Southeast Asia, also called Indochina. The zenith passage dates for Indochina are shown on Map 2. Virtually no published studies have investigated these cultures for knowledge of zenith passage and this is why we went to Angkor in August of 2010.



Map 2. Zenith passage dates by latitude for Southeast Asia

The Research Plan

Zenith passages at Angkor occur on August 17 and April 26. Thus, we planned our exploration of Angkor for August 10-20. This gave us a chance to search the ruins for possible zenith passage related features for a week before the actual event. There were five general categories of evidence we sought.

1. Gnomons are the most basic tools one can build to observe a zenith passage. A straight, plumb stick or post in the ground can be watched for the day during which it casts no shadow at noon. Looking at photos of Angkor prior to our visit, lingas and perhaps temple tops seemed possible gnomon candidates.

2. Zenith sighting tubes are the most exacting and accurate way to determine the days of zenith passage. While the absence of shadows off a gnomon can be hard to observe at just the right day and moment, a straight vertical tube leading from the open sky into a dark chamber will produce an unmistakably powerful beam of light only on the day of zenith passage. The best, most accurate tubes are long and narrow. In Mesoamerica zenith sighting tubes have been found at Monte Alban, Xochicalco, and Teotihuacan. Could such tubes exist at Angkor? A picture looking up at a hole in the roof of the library south-east of Prasat Pram gave us hope (Figure 2).

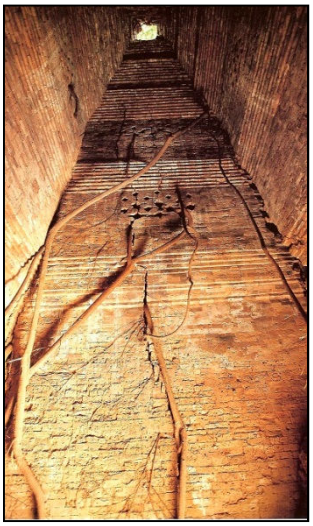


Figure 2. Prasat Pram Library (photo by Philippe Lafond)

3. Architectural orientations and arrangements can be designed in ways that indicate the place along the horizon where the zenith passage Sun will rise or set. Though zenith passage is the moment when the Sun passes through the pinnacle of the sky, the approach of that day can be tracked by watching the sunrise position move along the horizon. That can be either the orientation azimuth of a structure looking directly at a point along the flat horizon, or a view over an architectural viewing point of reference. Since Angkor is almost exclusively cardinal direction oriented, we would be looking for the latter. The angle we would look for is 76°, the azimuth for zenith passage sunrise at Angkor.

4. Art or carved texts can contain clues about astronomical observations. References to the Sun, Moon, and planets are traditionally the strongest windows into ancient astronomy. In Mesoamerica, astronomical deities cover the walls of temples and hieroglyphic distance dates often denote astronomical cycles. Angkor is covered in art panels and Sanskrit texts which would be definite possibilities.

5. Numerology can sometimes indicate recognition of specific celestial cycles. As a collection of 365 objects or architectural features would symbolize the days of a solar year, zenith passages at specific latitudes could be indicated by the number of days in between them. In the case of Angkor, that number would be 114.

Discoveries at Angkor

Though it is not apparent from the outside, each one of the beehive shaped temples of Angkor are hollow on the inside. Walking in and looking straight up, the roof is open all the way up to the top and that top has a hole where the sun shines in. We were told by the temple attendants that the holes on top of the roofs were there because the capstones had all been knocked off by erosion or more commonly by looters searching for jewels. Finding these fallen capstones among the rubble around the temples was our first surprising clue. Most capstones were beautifully carved as lotus flowers and all had a hollow tube running down their axes. Each had a very straight, long tube that would have let only true zenith passage sun light down into the temples (Figures 3a-l). Whether or not this was their intention, functionally this makes every single temple of this kind at Angkor a zenith tube.

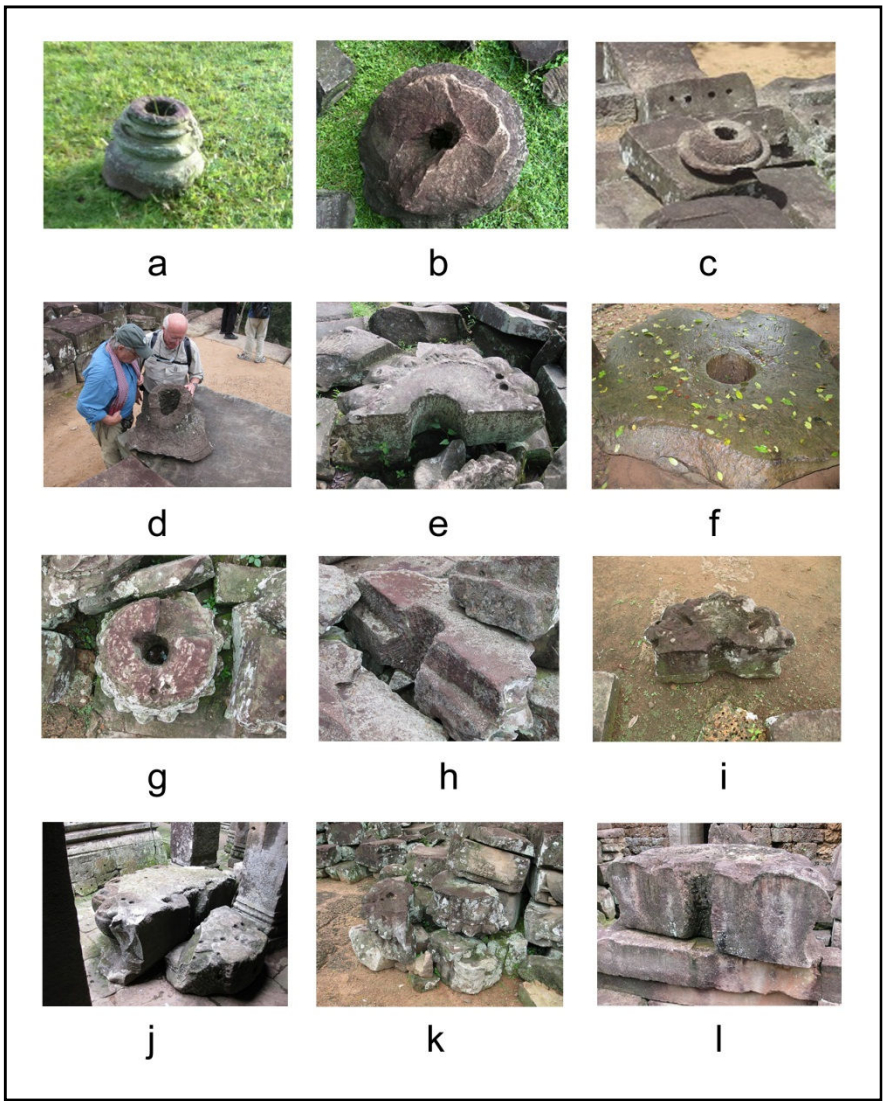


Figure 3a-l. Fallen capstone pieces from around Angkor. *a and b. Angkor Wat, west outer courtyard; c. Pre Rup terrace; d. Pre Rup terrace with Hal Green and Wally Smith; e. Preah Khan rubble pile; f. Beng Melea, east side; g-l. Various locations within the Bayon.*(photos by Ed Barnhart)

Lowering our eyes once again to the floors of these temples, we see what this zenith passage light would hit. The most common object found there was a carved stone linga. Lined up exactly in the center of the chamber, these lingas, as hypothesized before our journey, would indeed function as gnomons, albeit surprising inside a temple! These lingas stand erect because they are inserted into an altar-like, square pedestal (Figure 4). A grooved channel is carved around the top-face edges of these pedestals, wrapping around to gather into a pouring spout always pointing north. This pedestal feature is called a yoni, the female counterpart to the male, phallic symbol of the linga (Figure 5). As the roofs of these temples have tubular holes in their tops and that Angkor has a high annual rain fall, rain frequently drips down on to the linga, drains into the grooves of the yoni and spills out onto the temple floor (or perhaps in ancient times into a catchment vessel of some sort). Because the overall monument functions so well to gather this water, obviously intentional in design, it has been assumed by both local people and archaeologists that the purpose of the holes in the temples' roofs was to let in the rain water. French archaeologists charged with the task of reconstructing the temples of Angkor Wat decided the rain coming through was damaging and made the decision to seal the roof holes with cement.

Figure 4. A linga in the Bayon during zenith passage (photo by Ed Barnhart)

Figure 5. A yoni in the West Mebon during zenith passage (photo by Ed Barnhart)

In our view these roofs were open to function as zenith tubes and the linga-yoni features were both part of zenith ritual complexes and practical in their ability to protect the temple floors during frequent rainstorms. Unfortunately, the majority of these linga-yoni pedestals have been knocked over, smashed, or otherwise removed by looters who sought the jewel boxes buried underneath them. Some have been put back in place by restorers, but many remain off to the side of looters' pits where they once stood (Figure 6).

Figure 6. Looter's hole in Bakong's central temple at zenith passage (photo by Ed Barnhart)

In their current state of partial ruin, the temple roofs let in zenith passage sunlight in beams of jagged shapes that swept across the temple floor from west to east over a period of some 20 minutes. However, architectural features indicate that two levels of wooden ceilings spanned the interior roof cavity and logic would dictate that they had holes in their middles, creating a very controlled path for sunlight to enter

the room below. Figure 7's cross diagram shows a temple in profile cross section. Zenith passage sunlight went first through the tube inside the capstone, then next to a wooden ceiling containing a jewel-studded box around a hole in its center. It was these jewels that drove looters to knock the capstones from the temple tops. Sunlight would be constricted sufficiently by these first two features, yet a third hole in a lower wooden ceiling situated atop the temple room's spring line would assure that only sunlight of exactly zenith passage could shine down into the usually dark inner chamber, illuminating the linga with absolutely no shadow and reflecting off of any water in the yoni. The effect in its pristine state would have been blindingly bright and have lasted only 3-5 minutes on the exact day of zenith passage.

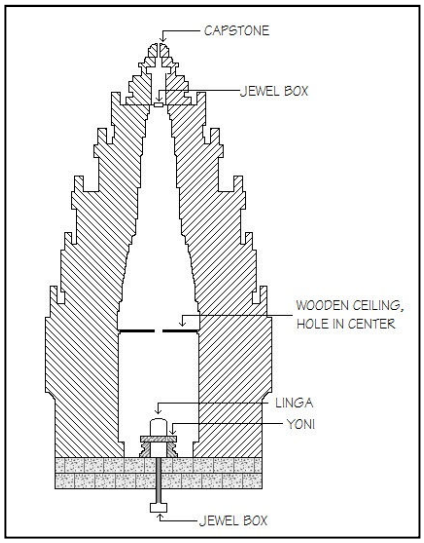


Figure 7. Cross section diagram of a typical temple in Angkor (drawing by Linda Hand)

Figure 8. Gilding attachment holes in a Ta Prohm temple (photo by Ed Barnhart)

In many of Angkor's temple complexes, including the major complexes of Ta Prohm, Ta Keo, Angkor Wat, and Preah Khan, there was gold gilding all around the walls of the temple rooms, no doubt reflecting brilliantly when zenith passage light entered the room. The gilding was ripped out by the Thais who invaded from their new capital in Ayutthaya in the mid-14th century (Coe 2003), but the places where it attached to the walls are still visible (Figure 8). Between the golden walls, the jewels, and the water in the yoni all reflecting, the light effect must have been spectacular.

Photographic Evidence

From August 16th through 19th, in 2010 and again in 2011, we went to various temple complexes at noon to take photographs. Since destruction and dilapidation has exaggerated the temples' roof holes, the zenith passage sun light effect also happens at least a day before and after in most temples. Knowing that zenith passage heads south day by day in August, we started at northern locations in the city and headed south from there as our window of opportunity opened and closed. On August 16th, 2010, we were at Pre-Rup and East Mebon. On August 17th, 2010, actual zenith passage, we sat in the Bayon and watched the rain clouds completely block the noon day sun. On August 18th, 2010 we returned to the Bayon and took our best photos of the zenith passage effect that year. Luckily the next year August 17th, 2011 was a sunny and perfect day for documenting zenith passage. Finally, on August 19th, 2011, we went to Bakong, the southernmost temple complex at Angkor, where the primary temple's intact capstone

provided an astounding lightshow. We attempted the same photos on August 18th, 2011, but alas the sky was completely cloudy at noon. The next section presents the photos we captured on those days.

Zenith Passage at Bayon

In 2010, our team of ten observers arrived at the Bayon (Figure 9) at 11:30 am on August 18th after a disappointingly cloudy day the day before. Given the longitude and latitude of the Bayon, the actual moment of zenith passage was calculated to be 12:09 pm. A review of potential observation points had been done two days before, based on the extent to which tower roofs were intact. With 54 total towers in the Bayon, this was an ideal place to find intact examples. A few interior towers on the first level and a few more on the top level were in good shape, but the best was the central, tallest tower in the complex. None of Bayon's towers had their uppermost capstones on top, which would have caused the zenith passage light to enter the temples for only one or two minutes. Instead, most light beams began entering at an angle starting about noon and swept slowly across the temple floor east to west, fading away about 12:20 pm. Figures 10 a-f show some photos when the first light entered the temples, Figures 11a-i show photos of the exact moment of zenith passage, and Figures 12 a-c show some of the last moments of light in the Bayon's towers.

Figure 9. The Bayon from the east (photo by Ed Barnhart)

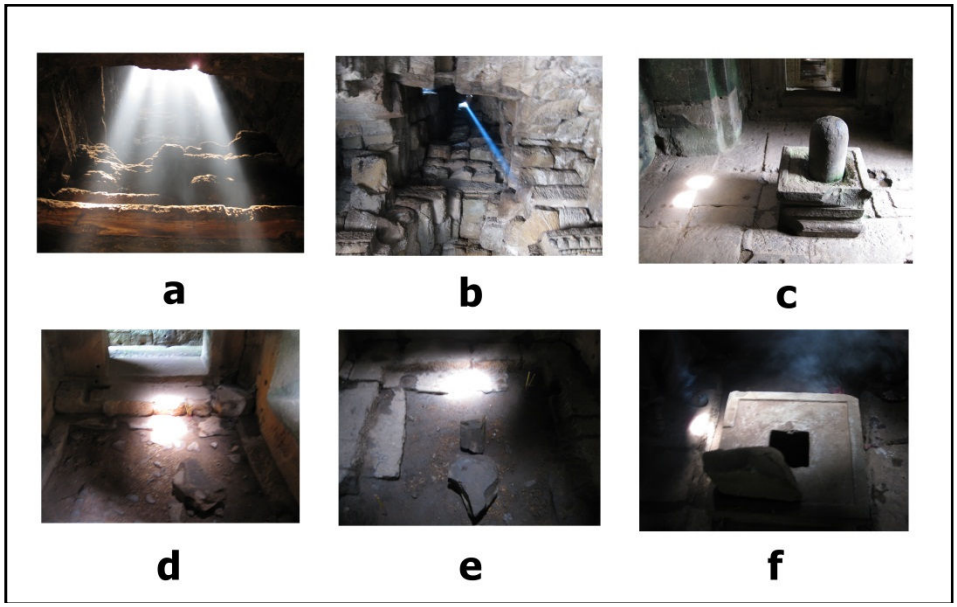


Figure 10 a-f. The first beams of light of zenith passage in the Bayon in 2010. *a. The tower chamber just east of the central tower, b. light from above in a north side tower chamber, c. light on the floor of an upper central tower, d. light on the floor of a central lower level tower, e. light on the floor of another central lower level tower, and f. light just west of a yoni in a north side lower level tower.* (photos by Ed Barnhart)

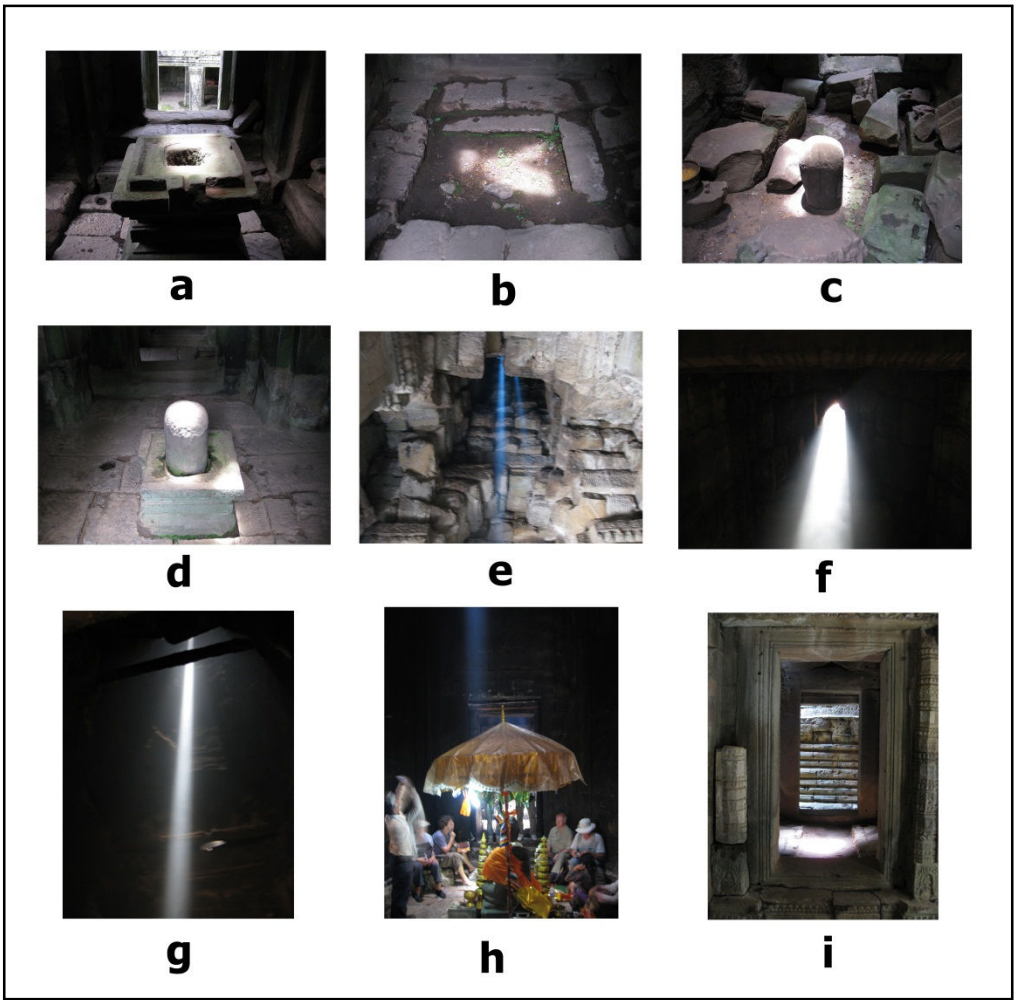


Figure 11 a-i. The moment of true zenith passage in the Bayon in 2010. *a. light in the center of a yoni in an upper tower south of the central tower, b. light in the center of a tower in the central lower level, c. light striking the top of a linga in the center of a lower level tower, d. light striking the top of a linga in a south side corridor below a tower, e. light coming from above in a tower in the east side of the Bayon, f. close up of the light coming in the top of the central tower, g. Longer view of the light coming into the central tower, floor view of the light coming down on to the shrine in the central tower, and i. light hitting the floor in an upper tower south of the central tower.* (photos by Ed Barnhart)

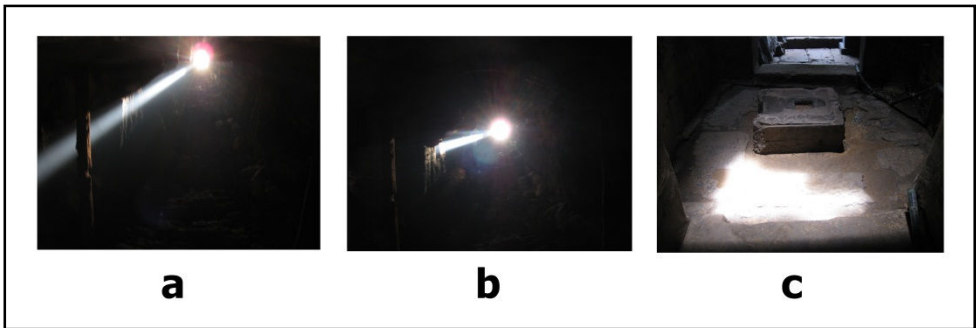


Figure 12 a-c. The last moments of zenith passage in the Bayon, 2010. *a. light in the central tower moving east, b. central tower last light, and c. lower tower, last light.* (photos by Ed Barnhart)

In 2011, a smaller group of observers focused their attention on the Bayon's central temple. The sun was shining brightly on August 17, 2011 and the effect brilliantly illuminated the temple's interior. The nuns and monks who tend the central shrine recognized Dr. Barnhart, remembering his visit from the year before. So did the temple guards, who kindly removed a parasol over the tower's altar. Photos of the moment of zenith passage are shown in Figures 13a-c. The altar had been replaced by archaeologists slightly off center, as noted in the photo.

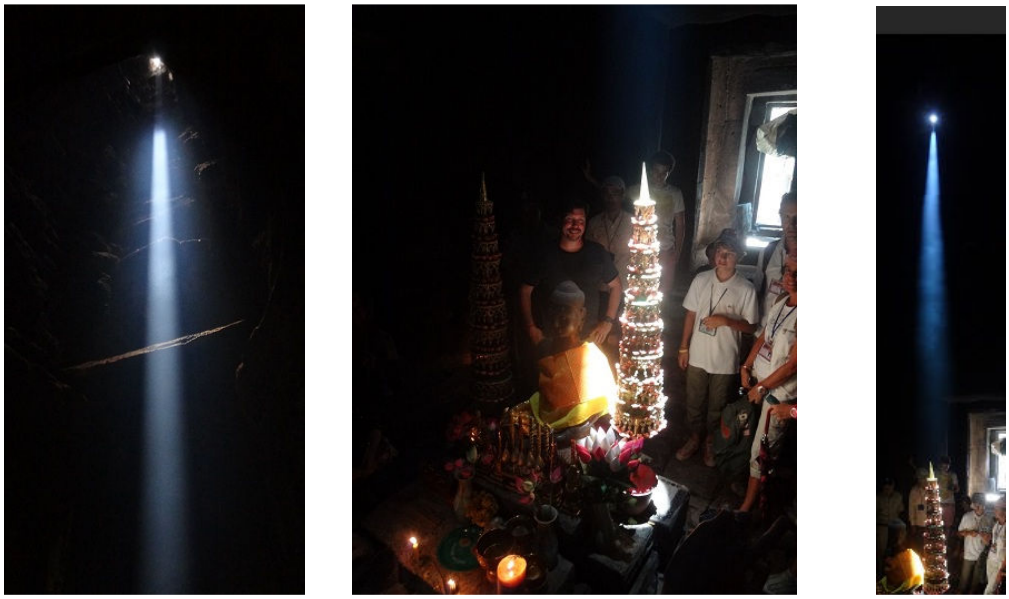


Figure 13 a-c. The moment of zenith passage in the Bayon's central tower in August 2011. *a. light coming in from above, b. light as it hits the tower's shrine, and c. a long view of the entire zenith passage light event* (photos by Brent Williamson)

Zenith Passage at Bakong

Bakong (Figure 14) is located in the Rolous Group, the southernmost group of temples at Angkor. It is also one of the oldest temples at Angkor, built in the early 800's AD. Due to its southernmost location, observations inside its central temple could be made on August 18th at noon. By good fortune, Bakong's central tower retains most of its uppermost capstone, making the zenith passage beam of light tight and circular as it hits the floor. Equally as unfortunate, looters seeking jewels destroyed the central altar, leaving a large hole in the temple's floor. Figures 15 a-f show photos of inside Bakong's tower at the moment of zenith passage.

Figure 14. Bakong's single tower atop of a pyramidal base (photo by Ed Barnhart)

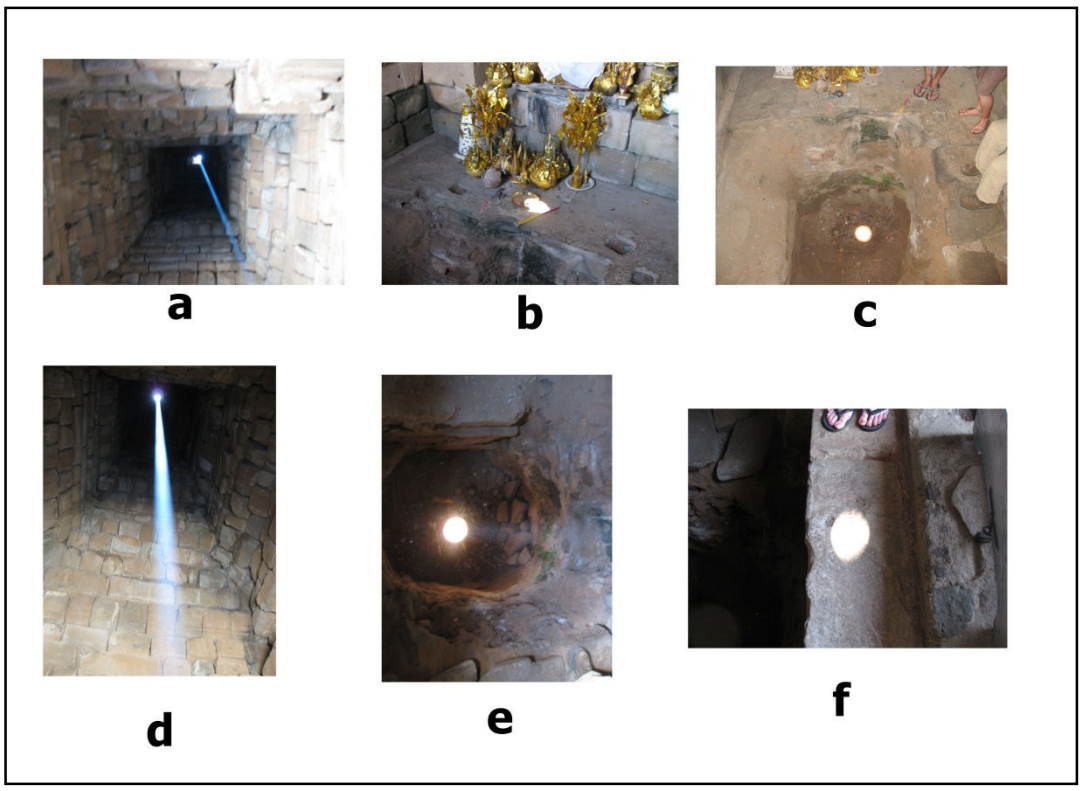


Figure 15 a-f. Zenith Passage light inside Bakong's central tower on August 18, 2010. *a. the first rays of light entering at an angle due to an incomplete capstone, b. first light hitting the floor to the west of center, c. light hitting the floor just off center in the looter's hole, d. light from above at the moment of zenith passage, e. light hitting the dead center of the looter's hole at the moment of zenith passage, and f. light hitting the floor of the tower to the east of center just as the final rays of light are disappearing.* (photos by Ed Barnhart)

Other Zenith Passage Related Observations at Angkor

Architectural Alignments

The idea that architecturally created horizon orientation alignments could mark zenith passage at Angkor Wat was investigated during three dawn visits to its front entrance and two dusk visits to its back gate in 2010. Both visits to the back gate were cloudy days, but one of the dawn visits allowed some potentially important observations. As the sun rising over its uppermost, central tower during equinox from the main causeway has become a famous photo, we decided to focus on the tower to the north of center. Trying a number of different viewing locations, we quickly learned that at the distance of Angkor Wat's exterior-most gateway zenith passage sunrise was visually far off to the north of the central precinct. As we approached along the causeway, the Sun slowly moved into place behind the towers. Just as we stepped up on the cruciform platform leading into the innermost courtyards of Angkor Wat, zenith passage sun rise was hanging directly over the north tower (Figure 16a). It was almost perfectly aligned while viewing from dead center of the cruciform platform. At sunset, from Angkor Wat's back gate, a similar alignment over the north tower was noted (Figure 16b).

Figure 16 a-b. Sunrise and sunset at Angkor Wat on the day of zenith passage, August 17, 2010. *a. the rising sun at 7:10 am from the center of the cruciform platform on the west site of the complex (photo by Ed Barnhart) and b. the setting sun at 5:10 pm from the exterior gate on Angkor Wat's east side (photo by Wally Smith).*

While this evidence is tentative and needs both better documentation and supporting examples to move it from enigma to pattern, the cruciform platform's center is certainly a prime candidate for a proper horizon viewing station. Future studies will focus more on the hypothesis that certain architectural complexes at Angkor serve as solar station markers.

Numerology

On the back (east) side of Angkor Wat's main enclosure the wall is carved with a long scene of the mythic churning of the sea of milk. Pulling the giant body of the snake king Naga back and forth, devas and asuras (gods and demons) play a tug of war that churns the sea into a froth that will release the elixir of immortality. While this scene is all over Angkor, this portrayal is unique in that it has 89 devas and 91 asuras doing the pulling. Eleanor Mannika (1996) recognized this as the number of days between equinoxes and solstices. Another unique feature of this churning depiction is that notably larger devas (Figure 17). At number 29 on the deva side and 30 on the asura side are the first two larger figures. If the total number of pullers represents a count of days between solar stations, it's possible these two positions represent one moon phase to either side of the central figure, Vishnu. Then at 57 and 59 respectively to either side are the other two larger figures. Adding these two numbers up, we get a total of 116, just off the 114 days between Angkor's two zenith passage dates.

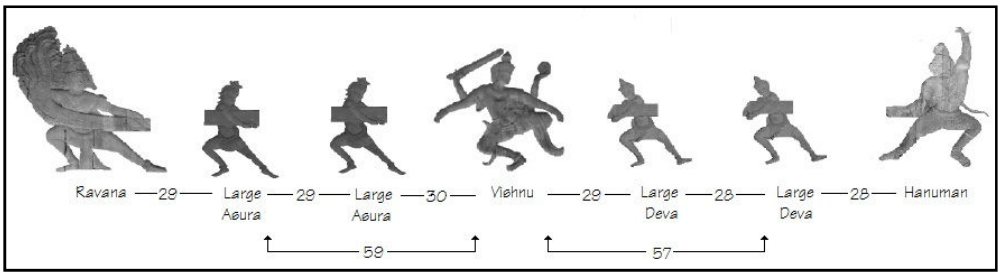


Figure 17. Counts of pullers on either side between larger figures on Angkor Wat's eastern gallery churning of the sea of milk scene (graphic by Linda Hand)

If Mannika's identification of equinox and solstice numerology here is correct, then these two figures positions are most logically explained as the zenith passage days of August 17 and April 25. However, this hypothesis would call for a change to Mannika's theory that the central figure of Vishnu sits at equinox. Instead, the date would be the June 21 summer solstice, with 57 days before being Angkor's first zenith passage on April 25th and 59 days later being August 19th, just two days off Angkor's second annual zenith passage. Though Mannika prefers to interpret Vishnu as sitting in the position of equinox, her photos of dawn at summer solstice better support our hypothesis. Figure 18 shows Mannika's photo of the churning scene's pivot point at one hour after actual sun rise. She explains that trees block the sun until this time and then the light drifts slowly to the left and down the wall as the sun continues to rise. As can be noted from her photo, a knife of light is directly below Vishnu, pointing to him on the day of summer solstice. If the light had contacted the panel an hour earlier, it would have been an even thinning ray of light touching Vishnu himself right in the center of his chest.

Figure 18. Mannika's photo of the churning scene's pivot point at dawn on summer

One other interesting element to notice about Angkor Wat's churning the ocean of milk scene is the fact that the large figures on either end are not Bali and Indra, the leaders of the demons and gods, but rather Ravana and Hanuman, the antagonists from another famous Hindu story called the Ramayana. Later in this paper we will discuss the Ramayana and its connection to solar astronomy. Why would the artists transpose these two figures into the lines of pullers? We believe it's yet a further validation that the numerology of the scene is counts between solstices, equinoxes, and zenith passages.

This would not be the only example of zenith passage numerology in Angkor. Mark Long of Borobudur TV and Caesar Voite have suggested another possible numerological reference to zenith passage at the gates of Angkor Thom. Quoting the account of Chinese trader Zhou Daguan, Long states that a fifth, golden head once stood atop the four faced head above each of Angkor Thom's five gates. Each gate was reached by a bridge over the moat surrounding the city. Each bridge was lined with 108 supernaturals pulling the body of the snake (Figure 19), 54 devas on one side and 54 asuras on the other. Long suggested that 54 + 5 + 54 = 113, the number of days between Angkor's two zenith passages. Further, they hypothesize that the five heads all on the gate tower represent how the Sun hangs at a single horizon position at summer solstice, the mid-way point between zenith passages.

Figure 19. The south gate of Angkor Thom with 108 figures pulling the body of the snake as the bridge balustrades (photo by Ed Barnhart)

Hindu influenced Indochina contains other examples of zenith passage numerology, as will be explained in the next section on Borobudur and the other ideas of Mark Long.

Zenith Passage in Hindu Influenced Indo-China

Perhaps due to the violent events on Southeast Asia's mainland over the last few decades, a literature search turned up virtually no studies of ancient Khmer astronomy. However, Mark Long and Ceasar Voite have discovered some compelling evidence in ancient Java (Long 2002). First, Long has presented convincing evidence of zenith passage numerology encoded in the Loro Jonggrang temple complex at Prambanan, located in central Java just east of the modern city of Yogyakarta (7°45'21"S, 110°29'21"E). The complex is clearly Hindu inspired, with three tall shrines at its center dedicated to Brahma (south), Shiva (center), and Vishnu (north). Around that central yard is Yard II, containing 224 perwara temples (Figure 20). As the two zenith passages for this latitude (7°45'S) occur on February 26th and October 9th, the distance between these two events, with June solstice right in between, is 224 days. Long suggests that these 224 temples denote a recognition of zenith passage and the authors of this paper agree.

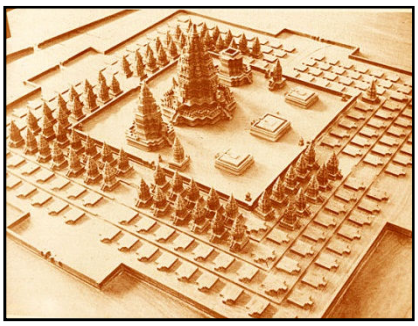


Figure 20. A model of Prambanan showing the 224 smaller temples around the main complex (Mark Long)

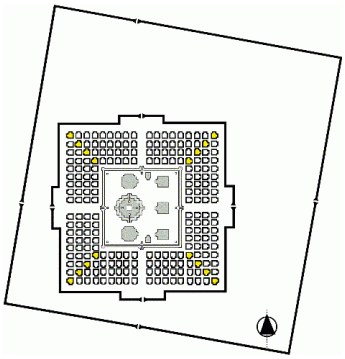
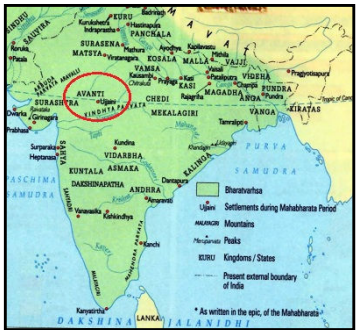


Figure 21. Plan view of Loro Jonggrang's outer wall facing its zenith passage sunrise (drawing by Mark Long)

What Long did not recognize (at least in print) was another element of the Loro Jonggrang complex that strengthens his hypothesis. The outermost walls of the complex, enclosing Yard I, are at an odd angle as compared to the inner yards which follow the standard Hindu inspired pattern of cardinal direction alignment. Measuring the angle of that outer compound, we find an angle of 8° south of east, the very same azimuth as zenith passage sunrise at Prambanan (Figure 21).

The Myth of Lanka and the Hindu "Prime Meridian"

The first written mention of zenith passage in Indian comes from Varahamihira in the 6th century (Sastry 1993). He noted that in the kingdom of Avanti the day of summer solstice and zenith passage were the same. He further qualified that north of Avanti, no zenith passage occurs. The ancient city of Ujjain is where Varahamihira wrote those observations and is commonly known as the birth



Map 3. Location of Ujjain and the kingdom of Avanti at 23.5° N.

place of Hindu astronomy. Many ancient studies and discoveries were made there. Ujjain itself was located at 23.5° latitude (Map 3). Centuries before Greenwich and the world's modern coordinate system, India established their own "prime meridian", a north-south "zero" line of latitude starting at Ujjain and running straight down to the island of Lanka, said to be at the equator. Lanka is a location out of the mythical story the Ramayana, as yet unidentified as an actual location. Some scholars believe it to be the island nation of Sri Lanka, but others argue Sri Lanka's location at 8° N latitude and 6° off to the east of directly below Ujjain invalidate it as a viable candidate. Mark Long suggests Lanka is a celestial location and that seeking a terrestrial candidate is unnecessary. However, looking at a map of India and following what the story of the Ramayana says about Lanka, your authors contend that there is a viable candidate for a real location.

Map 4. The underwater ridge extending to the Maldives and a line from Ujjain to their southern end.

Ujjain is at 23°09'N and 75°43'E. If a line is drawn straight south from Ujjain, following the ancient Indian prime meridian to zero degrees latitude, it falls within two degrees of the southernmost islands of the Maldives. This is significantly closer to the stated location than Sri Lanka. In addition, the Ramayana tells of a bridge built for Rama by an army of monkeys, extending from mainland India out into the ocean so he could reach Lanka. Looking at a map of the ocean floor in the India Ocean, a clear ridge extends from the mainland down to the Maldives chain (Map 4). The Maldive Islands leading down to their southernmost ones at the equator even run in parallel groups, like the banisters of a bridge! Thus, geographically speaking, land forms closely matching Rama's bridge down to the island of Lanka at the equator do indeed exist.

Map 5. The line between Ujjain and the bottom of the Maldives.

This is not a new idea, but one that has been hinted to in literature for at least 200 years (Moor 1810, Pillai 1928, Mahalingam 1983). However, most of the references are in passing and more about the improbability that Sri Lanka (also called Ceylon) then the viability of the Maldives as a candidate. Edward Moor's book *The Hindu Pantheon* written in 1810 suggests the Maldives as Lanka and notes that one of the islands at about 7° latitude was named Hunnamandow after Hanuman, the monkey king from the Lanka

myth. Neither Moor nor any other author that suggest the possibility of the Maldives as Lanka have noted the underwater ridges that mirror the description of Hanuman's bridge.

Taking this argument one step further, the bridge was built for Rama, an incarnation of the solar deity Vishnu. As Long and other scholars before him suggest, the Ramayana symbolizes the passage of the sun through its annual stations. If the bridge followed the prime meridian line straight south to equatorial Lanka, this means that two key zenith passage related locations were marked - at the equator where zenith passage occurs on the equinoxes and at Ujjain, where it occurs only once a year, on the June solstice (Map 5).

Zenith Passage Observations of the Chinese Pilgrim I Tsing

In the late 7th century AD a Chinese traveler named I Tsing visited the Buddhist Kingdom of Srivijaya on the island of Sumatra and recorded what he witnessed. He noted that local people were recognizing two days of the year when a man casts no shadow at horse-hour (local noon). He relates those two days in terms of their lunar calendar, but they can be matched up to September 29, 687 AD and March 8, 688 AD, exactly the two zenith passages days for that latitude.

I Tsing also noted a community wide activity that indicates every monk in ancient Srivijaya aware of zenith passage. According to monastic rules, all monks and nuns had to complete their daily meals before local noon. To determine when noon occurred, I Tsing wrote the following passage:

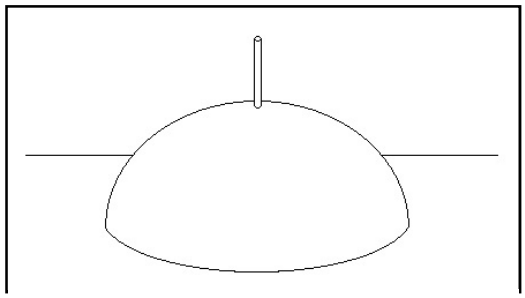


Figure 22. A reconstruction drawing of a monk's gnomon in 7th century Sumatra. (drawing by Linda Hand)

"If a person who guards himself against the fault (of missing the time) wants to get the exact cardinal points, he has to calculate the north star at night, and at once to observe (the quarter of) the south pole; and (doing this), he is enabled to determine the exact (north-south) line. Again he has to form a small earthen elevation at a suitable place. This mound is to be made round, of one foot diameter, and five inches high, at the center of which a slender stick is to be fixed. Or, on a stone stand, a nail is to be fixed, as slender as a bamboo chop-stick, and its height should be four fingers width long. At the exact moment of the horse-hour (local noon) a mark is to be drawn along the shadow (that the stick casts onto the stand). If the shadow has passed that mark, one should not eat.... The way of measuring the shadow is to observe the shadow of the stick, when it is shortest. This is exact mid-day." (I-Tsing, Muller, and Takakusu 1893).

Figure 23. A linga in a bayon tower at zenith passage. (photo by Ed Barnhart)

Thus, if every monk in Shirijava created one of these gnomons to judge noon daily, they certainly were aware of the days in which it cast no shadow at noon. Figure 22 is a simple reconstruction drawing of how such a gnomon may have looked.

As an observation for the readers of this paper to consider - the dimensions of the gnomons made by the 7th century monks on Sumatra are quite similar to those of the larger, though visually identical linga-yoni statues found in temple towers everywhere in Angkor. Those towers have holes in their roofs which allow only zenith passage sun to shine directly down upon the lingas, as shown in Figure 23. Perhaps it was just a coincidence, but reading the account of I Tsing inspired the authors of this paper to observe the eating habits of the monks and nuns who tended the lingas and other statues in Angkor's temples. On at least five occasions during our 10 days in Angkor we witnessed Buddhist monks, nuns, and their children take out their lunches at around 11:30 am and they were always finished eating before noon. Intentional? Tradition? For now, we will call it an observation.

Angkor Wat. Zenith Passage, and the Tomb of Suryavarman II

The uppermost temple at Angkor Wat, the heart of the entire complex, once contained a massive statue of the solar deity Vishnu. Restorers have moved that statue into one of the temples off to the side of Angkor Wat's entrance gate (Figure 24). Directly underneath that statue's original position, in the very center of the temple's floor, French archaeologists discovered a shaft some six inches in diameter which led 89 feet down to a sarcophagus. This is commonly believed to be the tomb of Suryavarman II, the Angkor ruler for whom Angkor Wat was built.

Figure 24. Statue of Vishnu at Angkor Wat (photo by Brent Williamson)

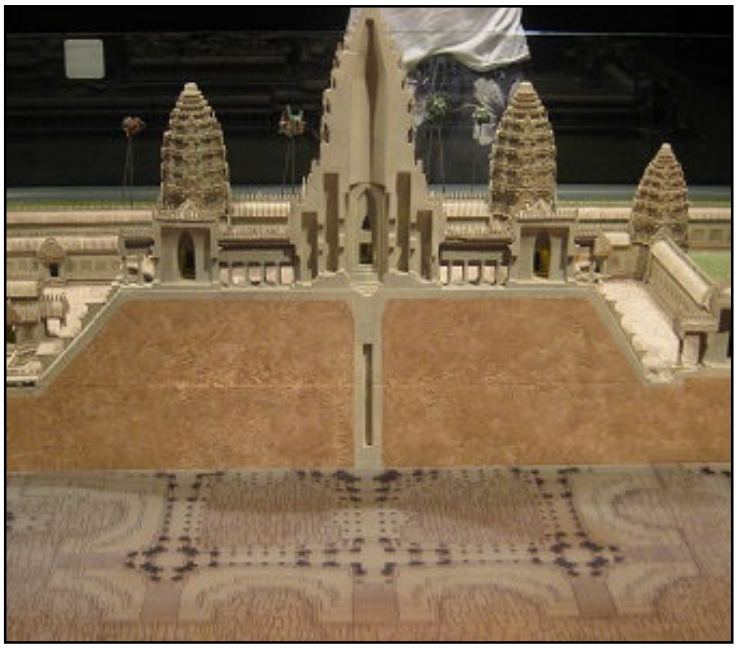


Figure 25. A model of Angkor Wat in Siem Reap's Angkor Museum showing the shaft leading to Suryavarman II's tomb.

Though restorers have recently sealed the roof of this temple, it originally had an open topped capstone like all of

Angkor's temples. Thus, the only light that could possibly shine down on the statue of Vishnu, the solar deity, was the twice a year zenith passage sunlight. That zenith passage light could also shine all the way down the shaft in the floor to the sarcophagus below. Though the sarcophagus was extracted during excavations and subsequently moved to Phnom Penh, it is known to have an odd hole carved through its lid. If that hole lined up with the shaft from above, then the zenith passage light could have actually reached into the sarcophagus itself.

Burying sarcophagi underneath the temples at Angkor was a tradition, as verified by the six other sarcophagi found thrown to the side of lamentable looting holes. One, in Banteay Samre, actually retained its lid and it does indeed have the same odd hole in the center (Figure 26a). Another example of this kind of coffin can be found lying amongst the rubble of Beng Melea, the complex thought to be Suryavarman II's model for the later Angkor Wat (Figure 26b). Since such a hole would have surely exposed the body to the humidity, insects, and other intrusions, it is suggested here that its design indicates that allowing sunlight from above to reach it was of greater importance that protecting its contents from the elements. The only sunlight that could make it all the way down a tomb shaft of small diameter would have to come from directly above, though the temple roof hole at zenith passage.

a b

Figure 26a-b. Angkor Sarcophagi with holes in their lids. *a. Banteay Samre, and b. Beng Melea (photos by Ed Barnhart)*

Conclusion

As was noted at the beginning of this paper, our studies of the importance of zenith passage among the ancient Maya of Central America were the inspiration for our expedition to Angkor. Not only have we found that the Maya recognize zenith passage, but that it was connected to rituals which "center the world" at the locations of sacred temples and cities. We believe this same practice may have been in play at Angkor.

For the Maya, and also the larger cultural area called Mesoamerica, everywhere was the symbolic center of the world simultaneously. The four cardinal directions meet at the

center, marking the center of the world. That center could be and was anywhere and everywhere at once. Mesoamerican cities were conceived as *Tollan*, the origin place of life and the center. From that point, a central axis continued up and down to the zenith of the heavens and the nadir in Xibalba, the mythic underworld. The moments when the sun passed through those points were calculated, recognized and honored by the Maya (Mendez and Karasik, in press).

Ancient Mesoamerica was not the only place in the world that believed in an omni-present center of the world. In fact, the concept was virtually global. Anthropologists and theologians call it the "Axis Mundi". It's the recognition of the four directions intersecting at a center point, symbolized as crosses in many cultures. It is also the concept of "the World Tree", connecting the heavens, the earth, and the below. The famous scholar of world religions and shamanism Mircea Eliade recognized this concept as global and described its function as, "The Axis Mundi is the conduit through which travel and correspondence is made between the higher and lower realms (Eliade 1991). He also notes the concept of the center existing everywhere writing, "Every temple or palace – and by extension every sacred city or royal residence – is a Sacred Mountain, thus becoming the center (Eliade 1971). The mountain of which Eliade speaks is especially represented in the ancient temples and pyramids around the world, be it a Maya pyramid at Tikal, Cuzco as the navel of the Inca Empire, the Hindu temples in India, or the Khmer temples in Cambodia.

George Cœdes, a renowned Khmer culture scholar from France, concluded that the temples of Angkor were symbolic recreations of Mount Meru (Cœdes 1963). Mount Meru for both Hindus and Buddhists across the ancient world was considered the center of the universe, surrounded by an ocean and standing 84,000 yojanas, or 1.082 million kilometers high. If, as most scholars agree, Cœdes's interpretation is correct, then Angkor's temples are functionally Axis Mundi, connecting the center of the earth to the center of the heavens, or zenith point. The sunlight from that zenith point comes down through the holes in these Mount Meru inspired temples to illuminate the center of the earth, which Hindu cosmology views as both male and female. Most of Angkor's towers have the linga-yoni altars standing in the center of their floors, identifying their center points as male-female, just like the center of the earth.

In summation, we have discovered that all of Angkor's temple towers function as zenith passage tubes. Both we and Mark Long have found the number 114, the days between zenith passages at Angkor's latitude, numerologically imbedded in Angkor's Churning of the Ocean of Milk scenes. Long has also found zenith passage numerology in Java, making the examples at Angkor not enigmatic. We have also proposed that the myth of the Battle for Lanka, depicted prominently on the walls of Angkor Wat, is referencing 0° and 23.5° latitude, the places in which zenith passage shares its days with equinox and summer solstice. From 7th century Java we have monks referencing small gnomons on a daily basis to know when the sun is at its highest point in the sky.

We know that the temples in both Java and Angkor are influenced by Hindu ideas from India, but also indigenous Khmer ideas dating back to the 1st century establishment of the

Funan kingdom in modern day Vietnam. The temple tower forms in Java and Angkor are clearly modeled after earlier versions in India, but their Indian counterparts lack the hole in their roofs (Mitchell 1977). Thus, it would stand to reason that the addition of this architectural feature was rooted in Khmer ideas dating back to the 1st century or earlier. Our future studies will focus on Javanese temples of the 8th century, which likely influenced Angkor, and on the earlier Funan kingdom from which the Javanese elite were said to have inherited their rights to rulership. Textual evidence from Sanskrit tablets in these areas will also be sought. For now, we can conclude by asserting that the objectives of our expeditions to Angkor have been met and that we have demonstrated the importance of zenith passage in ancient Angkor.

Acknowledgements

We would like to thank all the participants of our 2010 and 2011 Chautauqua course, namely Cassandra Barnhart, Marge Friar, Jeffery Wimer, Harold Green, Wally Smith, Satish Batnagar, Linda Hand, Bill Linderman, Ron Pratt, Scott Dorman, Guru Khlasa, Glenna Parkinson, and Brent Williamson. Special thanks goes to Harold Green and Wally Smith for the extra efforts they made to assist us in collecting architectural dimensions for a separate study of Angkor's geometry, to Brent Williamson for his excellent photos, and to Linda Hand for the drawings she rendered for this paper. We would also like to thank the University of Texas at Austin's STEM Center's Chautauqua Program and its Director James Barufaldi. This study would have never been conducted without their support. Finally, we would like to thank our expert guides during the two years, Kin Po Thai and Ken Ya who introduced us to the wonderful world of Angkor and patiently answered all of our strange questions.

Bibliographic References

Aveni, Anthony
2001 *Skywatchers of Ancient Mexico*, 2nd Edition. University of Texas Press.

Aveni, Anthony F. and Horst Hartung
1981 The observation of the sun at the times of passage through the zenith in Mesoamerica. *Archaeoastronomy* (Supplement to the Journal for the History of Astronomy 12) 3:S51-S70.

Bauer, Brian and David Dearborn
1995 *Astronomy and Empire in the Ancient Andes*, University of Texas Press.

Broda, Johanna
2006 "Zenith Observations and the Conceptualization of Geographical Latitude in Ancient Mesoamerica: A Historical and Interdisciplinary Approach" in *Proceedings of the Oxford Seven Conference in Archaeoastronomy*, edited by Todd Bostwick and Bryan Bates.

Coe, Michael D.
2003 Angkor and the Khmer Civilization. Thames and Hudson.

Cœdès, George
1963 Angkor, An Introduction, translated and edited by Emily Floyd Gardiner, Oxford University Press.

1968 *The Indianized States of Southeast Asia*, edited by Walter F. Vella and translated By Sue Brown Cowing. University of Hawaii Press.

Eliade, Mircea
1971 "Archetypes and Repetition", in *The Myth of the Eternal Return*. Princeton University Press.

1991 "Symbolism of the Centre", in *Images and Symbols* (English translation). University of Princeton Press.

Freidel, David, Linda Schele and Joy Parker
1993 *Maya Cosmos: Three Thousand Years on the Shaman's Path.* William Morrow.

Green, Harold H.
In Press "Cosmic Order at Chocola: Implications of Solar Observations on the Eastern Horizon of Chocola, Suchitepequez, Guatemala"

Higham, Charles
2001 *The Civilization of Angkor*. University of California Press.

I-Tsing, Friedrich Max Muller, and Junjiro Takakuso
1896 *"A Record of the Buddhist Religion as Practised in India and the Malay Archipelago (A. D. 671-695)"*, Clarendon Press

Jacques, Claude and Philippe Lafond
2007 *The Khmer Empire – Cities and Sanctuaries, Fifth to the Thirteenth Centuries*, River Books. Translated from the French by Tom White.

Long, Mark
2002 "Exploring Prambanan", posted on www.borobudur.tv/temple_index.htm

Mahalingam, N.
1983 *Three Gems of the Ancient Past: The Riddle, the Discourse, and the Lanka*, International Society for the Investigation of Ancient Civilizations, Madras.

Malmström, Vincent
1997 *Cycles of the Sun, Mysteries of the Moon: The Calendar in Mesoamerican Civilization.* University of Texas Press.

Mannikka, Eleanor
1996 *Angkor Wat - Time, Space, and Kingship*, University of Hawai'i Press

Mendez, Alonso and Carol Karasik
In press "Centering the World: Zenith and Nadir Passages at Palenque", in *New Perspectives on Ancient Maya Astronomy*, edited by Edwin Barnhart And Gerardo Aldana. University of Colorado Press.

Mendez, Alonso, Edwin L. Barnhart, Christopher Powell, and Carol Karasik
2005 "Astronomical Observations from the Temple of the Sun." *Archaeoastronomy,* Vol. XIX, pp. 44-73. University of Texas Press.

Michell, George
1977 *The Hindu Temple – An Introduction to Its Meaning and Forms*, University of Chicago Press.

Milbrath, Susan
1999 *Star Gods of the Maya: Astronomy in Art, Folklore, and Calendars.* University of Texas Press.

Moor, Edward
1999(1810) *The Hindu Pantheon*, first published in London in 1810, reprinted by Asian Educational Services in 1999 (2nd edition).

Pillai, M.S. Purnalingam
2003 (1928) *Ravana – The Great King of Lanka*, first published in Tinnevelly in 1928, Reprinted by Asian Educational Services in 2003 (3rd edition).

Nuttall, Zelia
1928 "The New Year of Tropical American Indigenes", in *the Bulletin of Pan American Union* 62"67-73.
Sastry, T.S. Kuppanna
1993 *Pañcasiddhántiká of Varahamihira, with Translations and Notes*, P.P.S.T. Foundation, Adyar, Madars.

Urton, Gary
1981 *At the Crossroads of the Earth and the Sky*, University of Texas Press.

Voute, Ceasar and Mark Long
2008 Borobudur: Pyramid of the Cosmic Buddha, DK Print World.