ZENITH PASSAGE ALIGNMENTS AT KOH KER, CAMBODIA

Edwin Barnhart
Maya Exploration Center

Abstract:
Koh Ker is an ancient Khmer city built in Cambodia in the 10th century CE. While most Khmer temple complexes were built with cardinal or near cardinal direction orientations, Koh Ker has a section that is instead oriented to sunrise on the day of zenith passage.

The Koh Ker complex of Prasat Thom is linear and oriented to 14 degrees north of east. The Prang Pyramid at Prasat Thom's western end overlooks the entire alignment to a flat horizon where the zenith passage sun rises. Along that same 14-degree axis are zenith passage tubes in roofs and linga statues acting as gnomons to capture the exact moment of zenith passage at noon. This report presents the results of a project to photo document the zenith passage sunrise alignment from the top of the Prang Pyramid. It ends by providing evidence that Koh Ker's alignments are not an enigma by citing zenith passage related architectural features in Java, Sri Lanka, and the nearby Khmer city of Angkor.

Keywords: Koh Ker, archaeology, archaeoastronomy, Khmer history, Angkor, zenith passage

This report documents the success of two expeditions to document the zenith passage alignment of the ancient Khmer city of Koh Ker, in Cambodia. The vast majority of ancient Khmer architecture was built in with cardinal or near cardinal direction alignments, but a temple complex within Koh Ker named Prasat Thom is oriented notably off that usual alignment. The azimuth of the Prasat Thom complex, including a pyramid and a state temple complex, is 76°, which is 14° north of east. The complexes' alignment extends through a pair of smaller temples and out over a large, 3m tall meter linga pedestal (Shimoda & Sato, 2014). The latitude of the site is 13° 45', a near match to Prasat Thom's alignment. As this report will explain, that means the complex is

aligned to sun rise on the exact day of Koh Ker's zenith passage – the day the sun will pass directly through the zenith point of the sky at noon. Highlighting the intentionality of this alignment is the fact that the southern sections of Koh Ker are oriented to the usual cardinal or near cardinal directions (Figure 1).

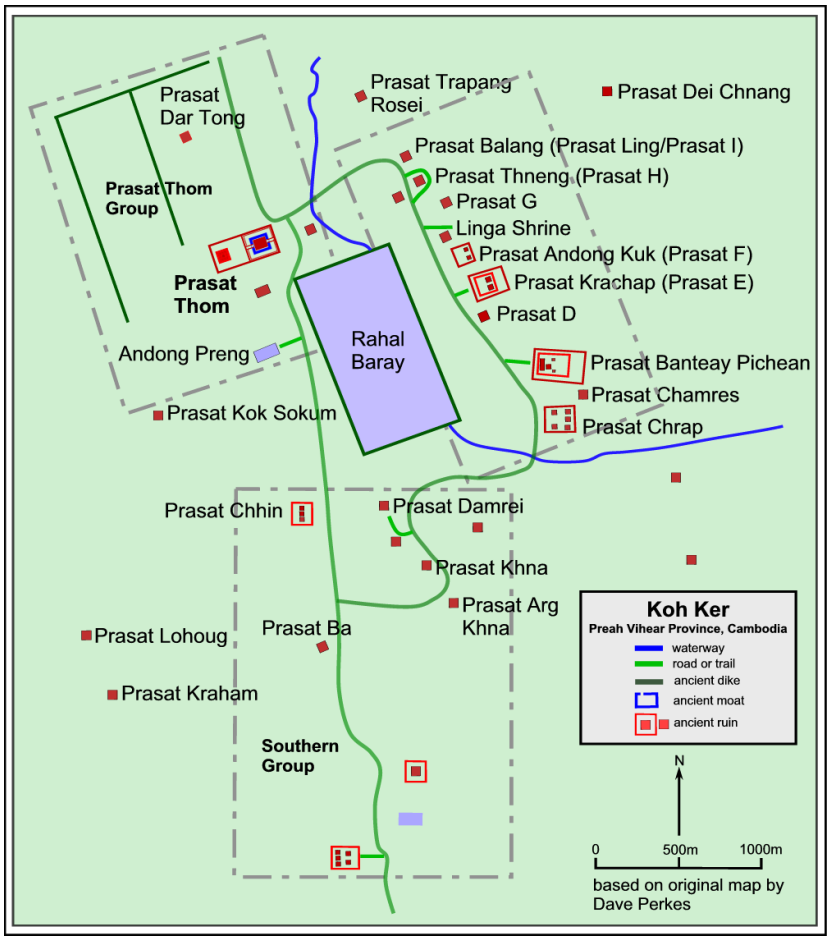


Figure 1. Map of Koh Ker showing the different orientations of Prasat Thom, the Rahal Baray, and other temples. Map by William F. Romain after original map by Dave Perkes, Koh Ker Map: Main Temple Area.

Seeing these things on an archaeological map from the opposite side of the planet isn't bad, but the actual ground conditions could have been affecting the alignment's unobstructed view of the horizon at dawn. Therefore, an expedition to photograph and verify the alignment was planned. This report documents the planning and execution of that expedition.

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.

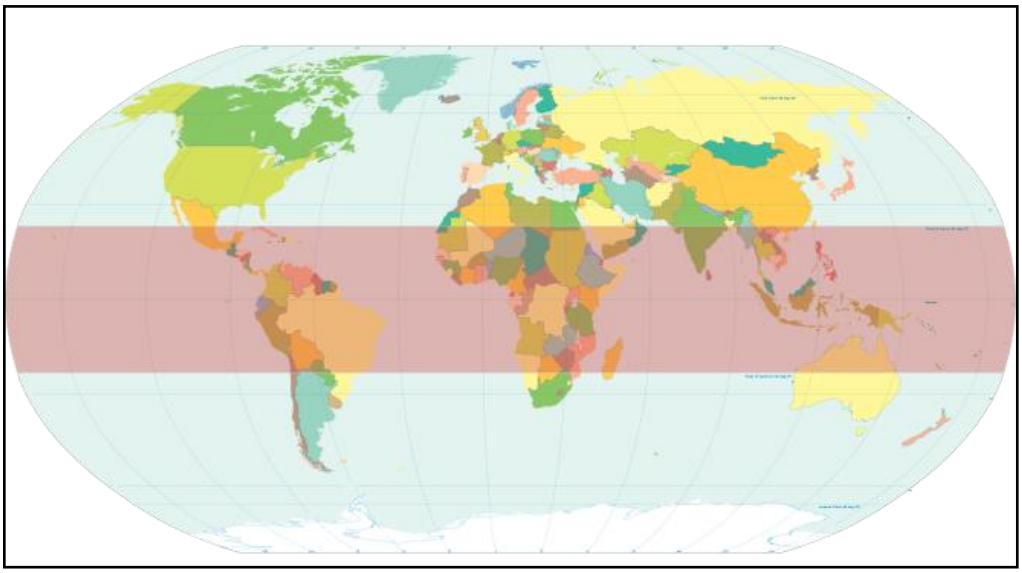


Figure 2. World map with the Tropics highlighted in pink. From: Genetics4Good, 2013. CC BY-SA 3.0 via Wikimedia Commons.

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 (Figure 2). 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 3).

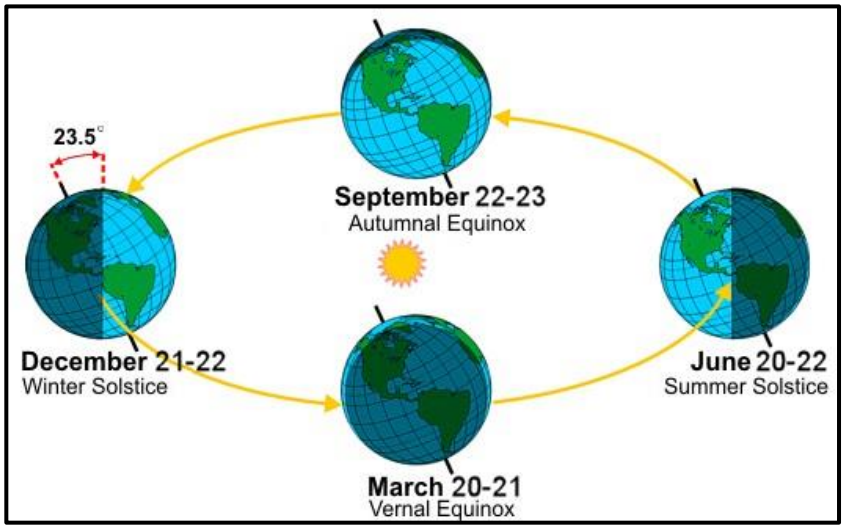


Figure 3. Diagram of the four common solar stations. From: National Oceanic and Atmospheric Administration [NOAA], www.weather.gov/cle/seasons

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 they travel 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 & Hartung, 1981; Malstrom, 1997).

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 & 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 Figure 4. Virtually no published studies had investigated these cultures for knowledge of zenith passage, and this is why we went to Angkor in August of 2010.

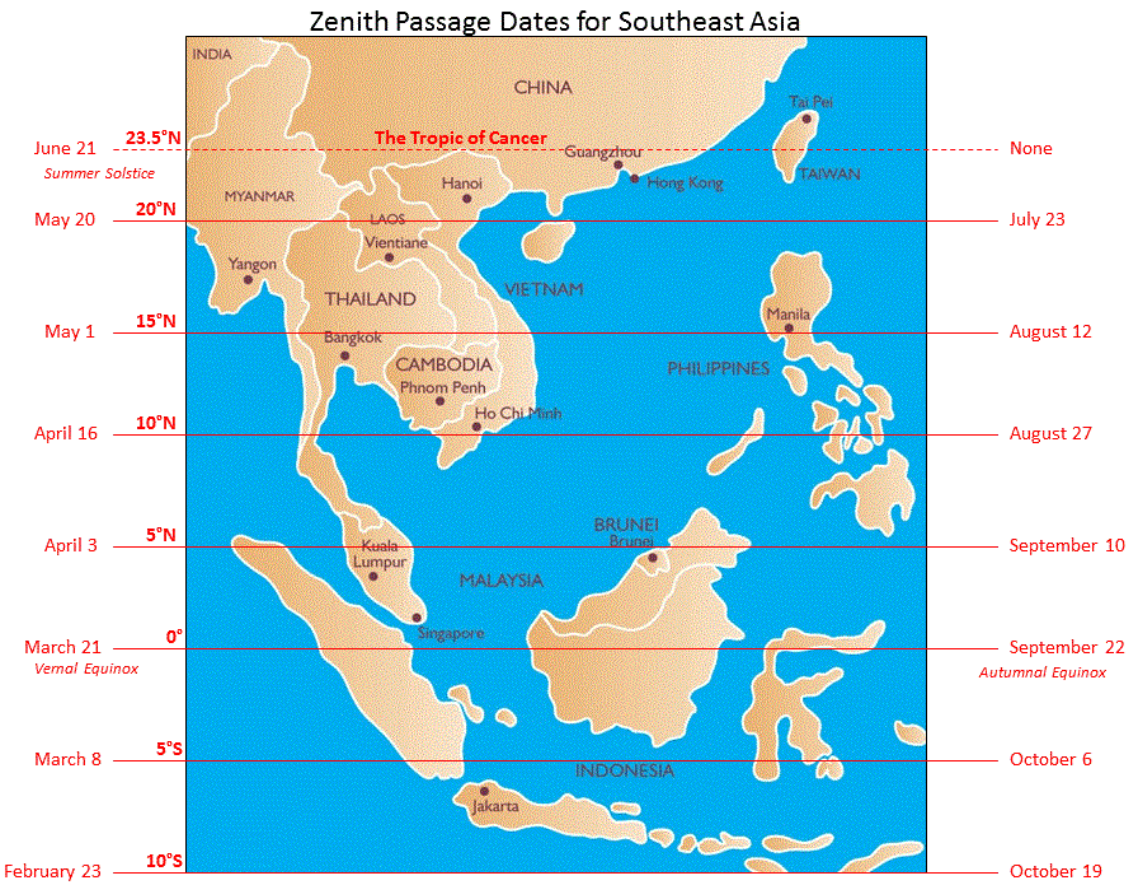


Figure 4. Zenith passage dates by latitude for Southeast Asia. Drawing by Barnhart and Powell (2013).

Koh Ker, Prasat Thom, and the Prang Pyramid

Koh Ker is a sizable ancient city with many temple complexes and a population estimate of at least 15,000 people (Evans, 2010). The entire city's layout follows cardinal or near cardinal directions save the areas of the massive Baray Rahal and the Prasat Thom Complex (Figure 1). The zenith passage alignment of those areas is the central subject of this study.

The main group of Prasat Thom is enclosed by a wall, 328 x 151 meters in size. Its further divided into two sections – the temple complex of Prasat Thom and the Prang Pyramid's courtyard to its west. The complex and its orientation have been known since it was first surveyed in 1921 by Henri Parmentier (Figure 5). Prasat Thom's temple architecture is surrounded by a 47m wide moat on all four sides. Bridges flanked with Naga balustrades cross the moat on the east and west. In its center stands its main

shrine, with a linga-yoni complex inside and the standard Khmer hole in the roof. Despite its broken roof top, light still shines brightly down through the hole at noon on zenith passage (Figure 6).

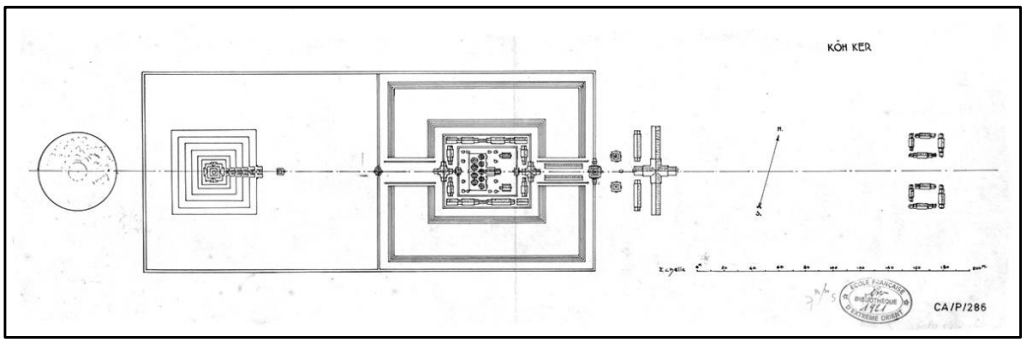


Figure 5. Plan View of the Prasat Thom Complex. From: Parmentier, 1921.


Figure 6. Zenith passage light at noon in Prasat Thom's central temple, 2022. Photo by the author.

The Prang Pyramid towers over Prasat Thom with a clear view over its temple tops towards the flat eastern horizon. At 36m tall and 62m on a side of its square base, it the largest pyramid in all of Cambodia (Gupta, 2022). Its height is broken up into seven terrace tiers with a staircase going up its eastern side. Inscriptions at its base state that Jayavarman IV commissioned it in 928 CE (Chhom, 2011).

On top of the Prang Pyramid was a massive pedestal built with megalithic stones, substantially larger than the stones used to build the lower parts of the structure. Two

large door jamb stones at the top of the stairs remain in place (Figure 7), but the megalithic stones of the pedestal are in a jumbled mess left by the work of looters. A deep shaft down from the center top found underneath the pedestal indicates that they were looking for tombs or offerings. Some archaeologists believe that there was a roofed building on top, but the remaining stones don't allow us to reconstruct it. Others, including your author, believe that there was no roofed structure on top.

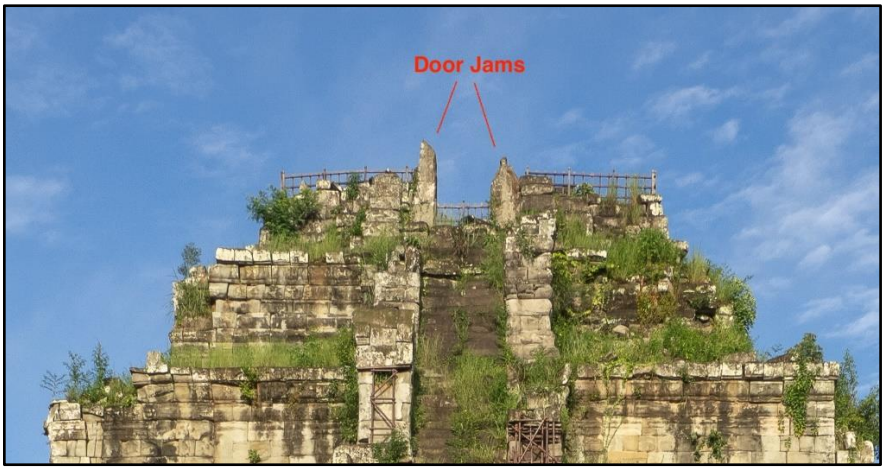


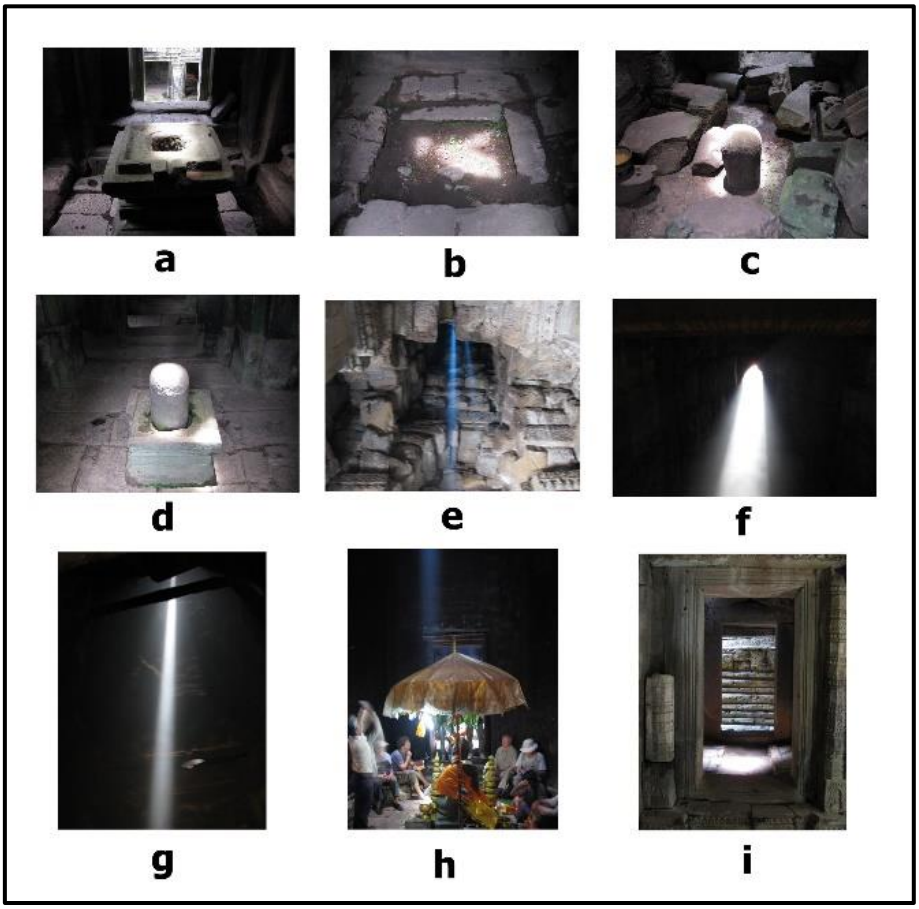
Figure 7. Intact door jams atop the Prang Pyramid. Photo by the author.

The Linga atop Prang Pyramid

There was once a gigantic linga statue erected on top, 4 meters tall and weighing many tons. It was the largest linga in all Southeast Asia. Given the pyramid's alignment towards zenith passage sunrise, the linga may have functioned as the pyramid's gnomon. The taller a gnomon, the more exact its marking of the moment of zenith passage can be. While the statue, like many at Koh Ker, has disappeared, an inscription that the pyramid's base records its erection and height (Chhom, 2011; Gupta, 2022).

As explained in a previous paper (Barnhart & Powell, 2013), many Khmer temples with zenith passage tubes through their capstones also have linga/yoni altars directly beneath those tubes. When the moment of zenith passage happens and the beam of light shines down, the linga atop the flat top of the yoni functions as a short gnomon (Figure 8). The one atop the Prang Pyramid was a giant version of the same concept. The ancient Sanskrit name of Koh Ker was *Lingapura*, meaning "Linga City" (Shimoda &

Sato, 2014). Was the massive linga atop the Prang Pyramid the linga referred to in the city's name?



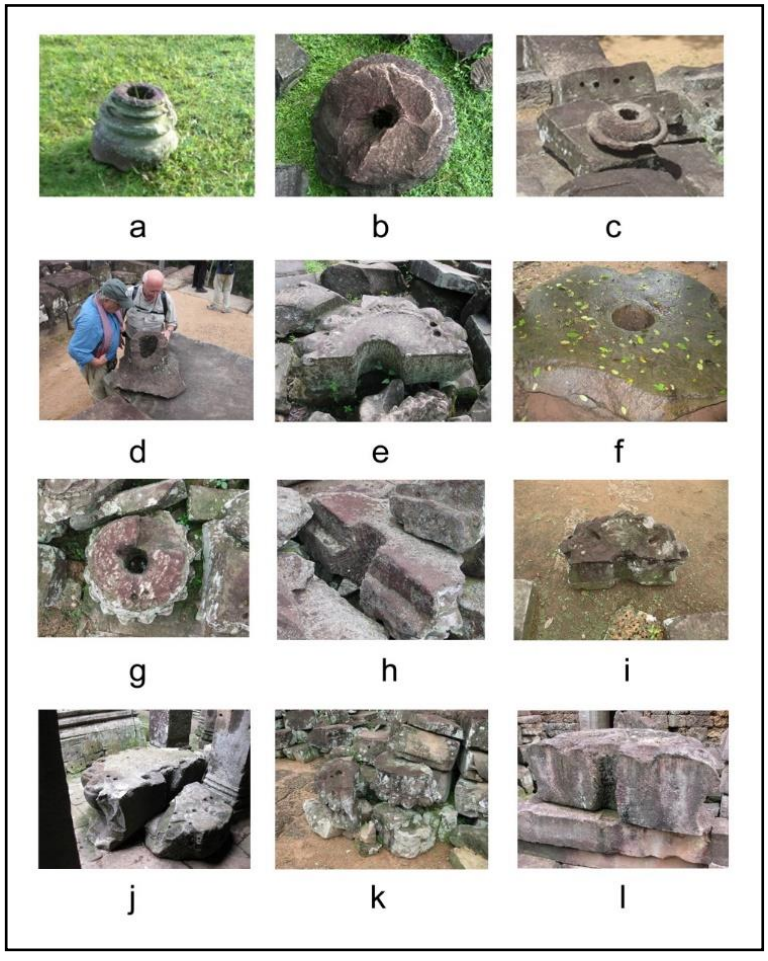
Figures 8 a-i. The moment of true zenith passage in the Bayon in 2010. 8a. light in the center of a yoni in an upper tower of the central tower; 8b. light in the center of a tower in the central lower level; 8c. light striking the top of a linga in the center of a lower level tower; 8d. light striking the top of a linga in a south side corridor below a tower; 8e. light coming from above in a tower in the east side of the Bayon; 8f. close-up of the light coming in the top of the central tower; 8g. 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 8i. light hitting the floor in an upper tower south of the central tower. Photos by the author.

Previous Research

My interest in Khmer archaeoastronomy began 15 years ago. The subject of zenith passage and its recognition among ancient Mesoamerican civilizations had been one of my research foci for almost a decade at that point. To learn more about the ancient understanding of zenith passage, a search for other major ancient civilizations within the

tropics was conducted. Zenith passage is only visible within the tropics – between the latitudes of 23.5° North and 23.5° South. As it turns out, very few advanced ancient civilizations developed within the tropics. All ancient Greece, Rome, Mesopotamia, China, Harappa, and most of Egypt were above 23.5° North.

In the Americas, Mesoamerica and the Andean civilizations of South America lie within the tropics. Outside of the Americas, the only major ancient civilizations that developed within the tropics are found in Southern India and Southeast Asia. Among those in Southeast Asia, the Khmer Empire was perhaps the greatest. Given previous literature documenting ancient Khmer interest in astronomy, a decision to visit the ruins of Angkor Wat was made. Two expeditions were made in 2010 and 2011, both planned to be there during Angkor's 2nd annual zenith passage on August 17th. The findings were reported in a publication entitled "The Importance of Zenith Passage at Angkor, Cambodia" (Barnhart & Powell, 2013). In summary, an abundance of evidence of zenith passage observations was found – in carved imagery, in numerology, but especially in the standard temple design of hollow tubes in their capstones (Figure 9) that allow only zenith passage day sunlight to beam brightly down on their central altars.



Figures 9a-l. Fallen capstone pieces from Angkor area. Figures 9a+b. Angkor Wat, west outer courtyard. Figure 9c. Pre Rup terrace. Figure 9d. Pre Rup terrace with Hal Green and Wally Smith. Figure 9e. Preah Khan rubble pile. Figure 9f. Beng Melea, east side. Figures 9g-l. Various locations within the Bayon.
Photos by the author.

Upon return to the USA, other references to zenith passage observations in ancient Southeast Asia were discovered. One was the writing of a Chinese traveler named I-Tsing who visited the Kingdom of Srivijaya on the Island of Sumatra in the 7th century (I-Tsing, Muller, & Takakusu, 1893). He noted the common use of a small gnomon to detect the two days of zenith passage when a man casts no shadow at the “horse hour” (local noon).

Yet more compelling was the research by Mark Long at the Loro Jonggrang temple complex of Prambanan on the Island of Java. Like many of Angkor’s temples, Loro Jonggrang was clearly Hindu inspired, with three tall shrines at its center dedicated to Brahma, Shiva and Vishnu. Around those central temples were 224 smaller temples, all within the walls of the complex. At Prambanan’s latitude, zenith passage occurs on February 28th and October 10th – with exactly 224 days between them. Add to that the overlooked outermost wall around Loro Jonggrang. Unlike the inner complex, that outermost wall is oriented 8° north of west. Given Prambanan’s latitude of 7°45’ South, that means the outer enclosure is oriented to sunset on the days of zenith passage (Voute & Long, 2008).

My search for the evidence of ancient Khmer recognition of zenith passage continued. While research on ancient Khmer astronomy is on the rise in recent years (Magli, 2016, 2018; Sparavigna 2016, 2018; Romain 2019, 2022), it was impeded by decades of conflict and political upheaval across mainland Southeast Asia. Maps and reports on Khmer cities and temple complexes outside of the Angkor region were sought with limited success. The goal was to find other examples of sunset or sunrise-oriented complexes like at Prambanan, but the Khmer tradition of cardinal or near cardinal direction architectural alignments seemed a hard and fast rule.

In 2018, I came across a paper written by Italian archaeoastronomer Giulio Magli (Magli, 2016). Magli’s paper was an excellent survey of Khmer architectural orientations and clearly documented the predominance of cardinal or near cardinal direction

alignments along major and minor axes of sites. Only two complexes didn't comply with the pattern, the Preah Khan of Kompong Svay and the Prasat Thom at Koh Ker. Magli called them "anomalous". Nevertheless, he noted that the complex at Kompong Svay was oriented to the moon's rise at its major northern standstill – a point in its cycle that only occurs once every 18.6 years. While this discovery is of great importance and of interest to me, it was Magli's conclusion regarding Koh Ker's alignment that precipitated another expedition to Cambodia.

Most of Koh Ker adheres to the Khmer pattern of cardinal or near cardinal direction alignments. However, the temple complex named Prasat Thom does not. Instead, its orientation azimuth is 76°, or 14° north of east. Given that Koh Ker's latitude is 13° 45' North, Magli properly identified its near perfect alignment to the zenith passage sunrise along the eastern horizon. Using the name Koh Ker as a search guide, detailed maps of the site were found, further confirming Prasat Thom's zenith passage sunrise orientation. Those maps were relatively new, completed by a joint Japanese and Cambodian survey team and published in 2011 (Misoguchi & Nakagawa, 2011).

It should be noted that Divay Gupta has proposed an explanation for Prasat Thom's alignment involving the rising sun on the day of the Khmer New Year (Gupta, 2022). However, Gupta's analysis is flawed in at least two major ways. First, he states the complex is aligned to sunrise on April 13th the day of Khmer New Year. As this study documents, it is not. The day of alignment is April 27th, zenith passage. Curiously, he also states that April 13th is zenith passage, citing Kak 2008 which mentions neither zenith passage nor even Koh Ker at all. It would appear he has a basic misunderstanding of what zenith passage is. Second, before the 13th century Khmer New Year was celebrated in November or December. Either Suriyavaraman II or Jayavaraman VII changed it to the fifth lunar month – April in the Gregorian Calendar (Lim, 2002). Since Koh Ker was constructed in the 10th century, it was definitely not aligned to the Khmer New Year sunrise of its day.

Research Plan Development

Analysis of the Koh Ker map indicated ideal conditions for photographic recording of Prasat Thom's solar orientation. On the western end of the complex stands a 36-meter

tall pyramid named the Prang Pyramid. Its top provides an ideal viewing station to see the central temples of the complex just east, a pair of libraries further on, and a large baray all lining up to the sunrise on April 27th, the day of Koh Ker's first annual zenith passage. The second is August 16th.

An important question from afar was – is the horizon to the east of Koh Ker flat, or do distant mountains alter where the actual, on the ground sun rise will occur? Another was – what is the current condition of the architecture? Is it still standing or partially destroyed? Is it cleared, or still covered in trees? The answers to those questions could confirm or complicate our ability to photograph the alignment.

In 2019, plans to return to Cambodia in 2020 were developed. In April of 2020, my Cambodian colleague Phum Kanha would reconnaissance the area of Koh Ker, which lies some three hours north of Angkor and the modern city of Siem Reap. Kanha would look for lodging in the area, check the condition of the ruins, and most importantly stand atop the pyramid to take photos of the sunrise on April 27th. Unfortunately, COVID's global pandemic halted all those plans for more than two years.

Flash forward to 2022, and the plans were picked up again. In April, Kanha was able to travel the 127km NE of his home in Siem Reap to the temples of Koh Ker. Arriving a few days before the April 27th zenith passage, he was able to find suitable lodging for our group to stay and meet with local authorities. Koh Ker is in the Preah Vihear Province and administered by the local authorities. Kanha was able to obtain permission to enter the site before dawn and view the sunrise from the top of the pyramid.

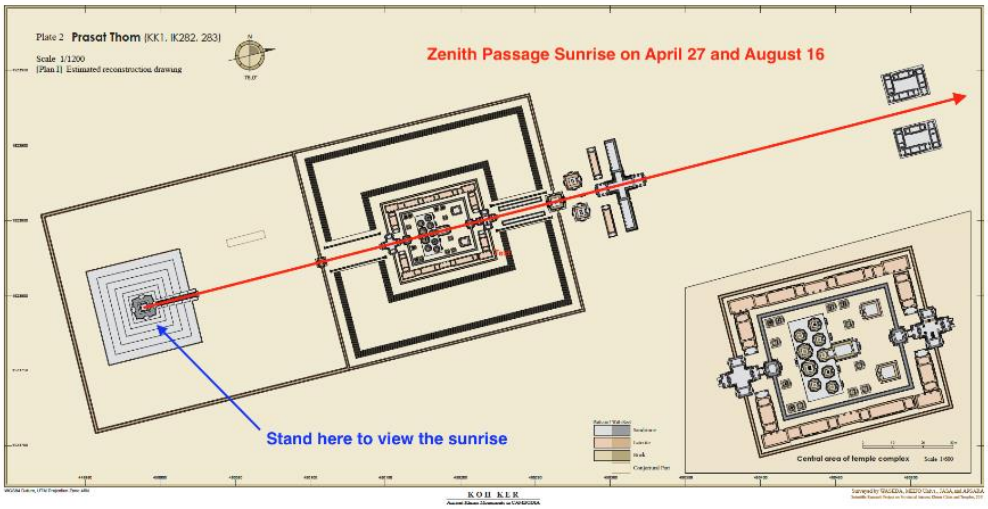


Figure 10. The direction of zenith passage sunrise from the Prang Pyramid. Map from Misoguvchi & Nakagawa, 2011 annotated by present author.

Using an annotated map I provided as a guide (Figure 10), Kanha took the photos and sent them via text that morning. The alignment was confirmed, and the horizon was flat – no interruptions by mountains or other obstructions. But there was an impediment. The trees had completely overgrown the central temple complex of Prasat Thom. It could not be seen from the top of the Prang Pyramid. Though the path leading from the pyramid into the forest-covered complex showed the alignment to be true (Figure 11) – a photo with the temples in line would not be possible. At some point the complex will be liberated from the trees but not in time for the August 16, 2022 zenith passage.

So, a new documentation plan had to be made. The temple atop the Prang Pyramid is mostly destroyed, but two large stones that flanked its front doorway remain in situ. Standing inside the upper temple and looking out between those two stones is on the zenith passage alignment. But there's barely enough space for a photographer to stand there. A wide and very deep looters hole dominated the central space of that upper temple, making it impossible to stand there and take a photo.

It was decided to employ a drone. It could float in the air behind the pyramid and use its front doorway to document the alignment. I contacted my Cambodian friend Po-Kin Thai, who had recently established his own filming company. Thai had the drone and was happy to join the project. Kanha returned to the authorities of Preah Vihear and obtained permission for my team and I, now including a drone and film crew, to enter Koh Ker before dawn on August 16, 2022.

Figure 11. Photo of Prasat Thom zenith passage dawn April 27, 2022. Photo by Phum Kanha.

Field Work

Though the planning phase was long and complex, the actual field work was quite simple and straight forward. Just photograph and film the alignment at dawn.

The crew spent the night of August 15th in the nearby village of Srayang. Loading up in the dark at 5am, they made their way to Koh Ker's Prasat Thom complex. Walking through the complex and climbing the Prang Pyramid in the darkness, the crew arrived in time to set up for the 5:55am sunrise.

It had rained the night before and the sky was still cloudy. The eastern horizon was covered in a blanket of clouds. The drones were flying and the cameras in position, but it looked like the crew would not be able to document what they had come so far for. But then, just 3 minutes after the moment of sunrise, the clouds parted just long enough to get the photos. The sunlight was somewhat diffuse, but its center could be clearly seen right in between the two door jamb stones. Figure 12 is a photo from a drone hovering just behind the temple top and Figure 13 is a photo taken between the door jams by project photographer David Willingham.

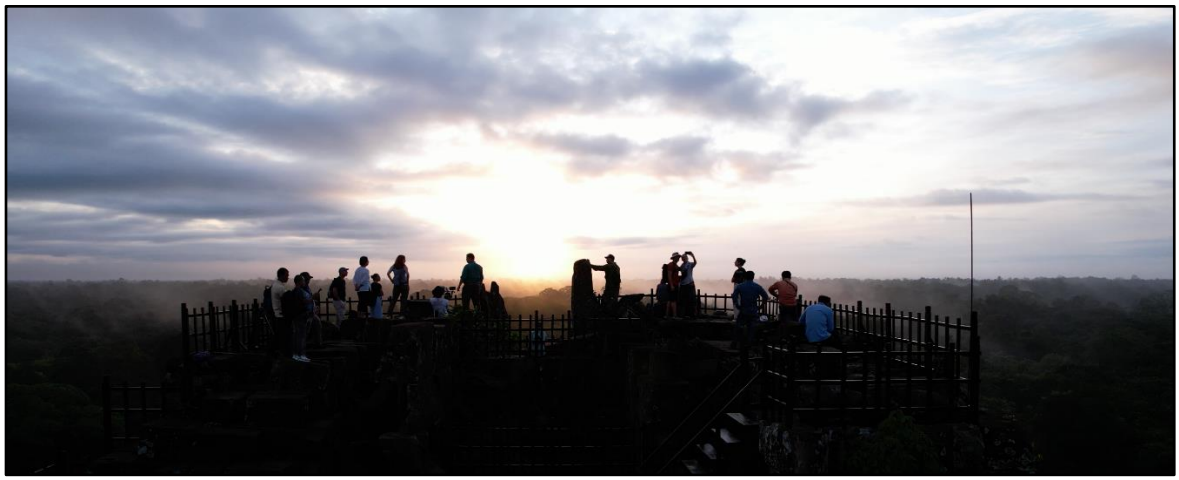


Figure 12. Zenith passage sunrise from the top of the Prang Pyramid on August 16, 2022. Photo by Thai Po Kin.

Figure 13. Zenith passage sunrise through the Prang Pyramids front door on August 16, 2022. Photo by David Willingham 2022.

Staying in the ruins until noon, we also recorded the light coming directly down through the intentional hole in the roof of Prasat Thom's central temple (Figure 6).

I returned in August of 2023 and took the photos again, this time with a clear horizon. One of those shots is seen in Figure 14.

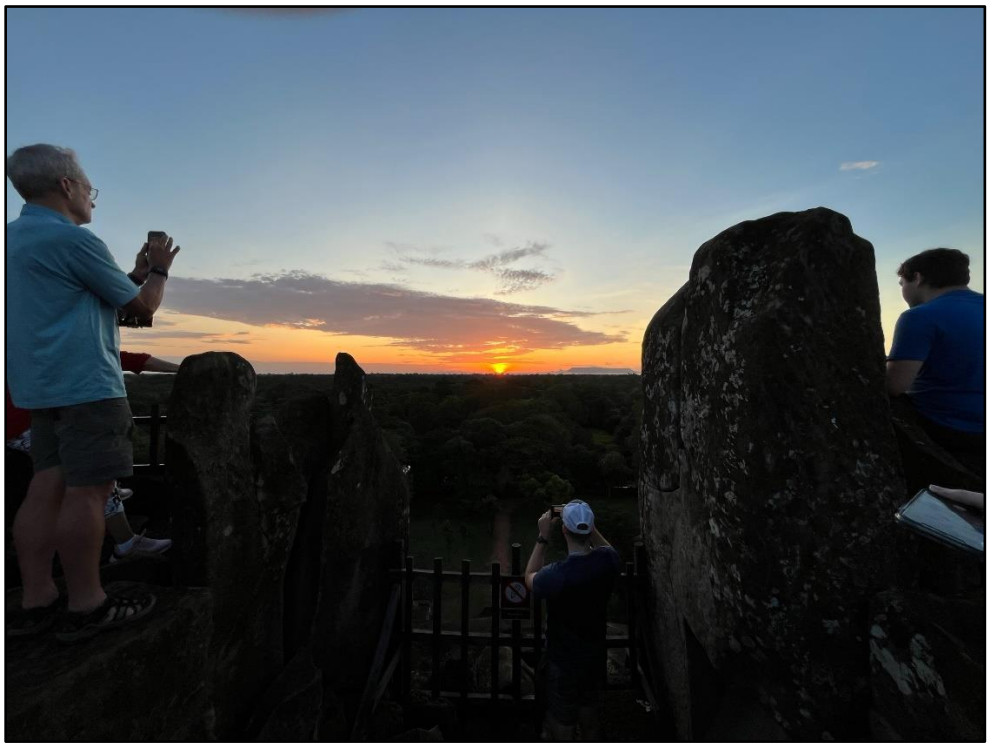


Figure 14. Zenith passage sunrise between the door jams on August 16, 2023. Photo by the author.

Supporting Evidence from Other Sites

The vast majority of known ancient Khmer complexes are aligned to cardinal or near cardinal directions. Magli (2016) found only two exceptions in his review of Cambodian temples. One was the Preah Khan of Kompang Sray, with an alignment of 29° N of E. Magli identified that azimuth as the maximum north the moon will rise in its 18.6-year cycle. The other was Koh Ker's Prasat Thom at 14° N of E (azimuth 76°). It was Magli who first identified that as a zenith passage sunrise alignment.

Since zenith passage is marked by the sun being directly overhead at noon, it seems counter intuitive to mark it on the horizon at dawn. Nevertheless, that's what's happening at Koh Ker. In the Maya area of Central America, there are many documented zenith passage at dawn orientations (Aveni & Hartung, 1981; Friedel & Schele, 1993; Mendez et al., 2005; Broda 2006; Mendez & Karasik, 2014). Perhaps like the Maya, the ancient Khmer were horizon-based astronomers in practice.

Far to the south, on the island of Java, there are other examples of zenith passage related temple complexes. The Loro Janggrang Temple Complex in Prambanan has a cardinal direction-oriented core area surrounded by an enclosure wall oriented at 8° S of E (Figure 15). At its latitude of 7°45' S, that's the direction of zenith passage sunrise. Prambanan's two zenith passages occur on February 27 and October 9th. The number of days between is 224. Spread out in the yard within Loro Janggrang are exactly 224 small prewara temples (Voute & Long, 2008). Between the enclosure's alignment and the count of temples, the zenith passage association with Loro Janggrang is strong evidence that zenith passages were being observed and commemorated. At its center is the main temple, with the same kind of zenith passage hole in its roof as was documented by your author at Angkor (Barnhart & Powell, 2013).

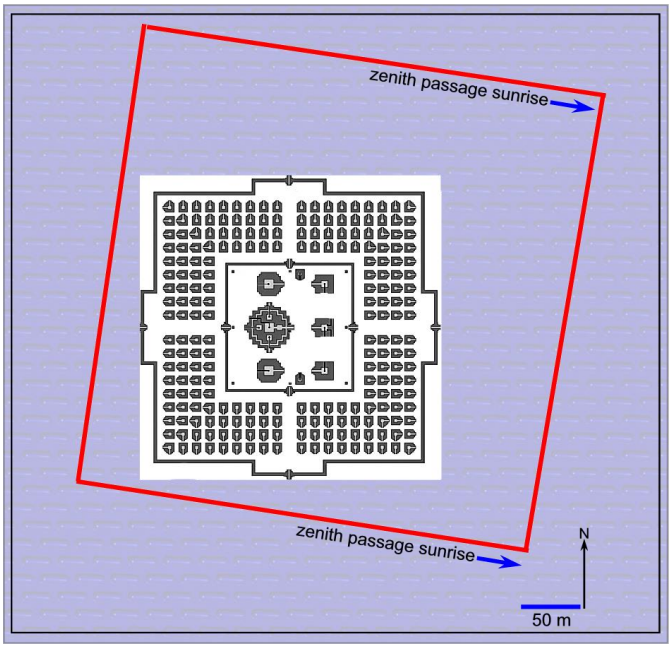


Figure 15. Plan view of Loro Jonggrang and its outer wall (red line) facing zenith passage sunrise. Temple map by Gunawan Kartapranata, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, surrounding wall added by William F. Romain based on map by Archaeological Department for the Preservation of Cultural Heritage of Yogyakarta (Khairunnisa, Hidayat, Orchiston & Nikeu 2021, fig. 14.5).

Also on Java, and not far from Prambanan, is the massive Buddhist pyramid complex named Borobudur. Though its basal alignment is to the cardinal directions, its uppermost Buddha statue group indicate a connection with zenith passage. In total,

there are 72 Buddhas, each in their own perforated stupa. The number of days between Borobudur's October 10th zenith passage and December Solstice (Dec 21st) is also 72. Further, there are five terrace levels of uppermost Buddha statues. The first four have their Buddhas facing the four cardinal directions. The fifth terrace, very highest group of Buddhas face 8° S of W, the direction of zenith passage sunset at that latitude (Voute & Long, 2008; Sparavigna, 2017a).

A third complex in that area with zenith passage related architecture is the Sewu Temple. Just 800 meters north of Prambanan, it was built some 70 years earlier. Like Loro Janggrang, it has a central temple with many smaller perwara temples arranged around it – destruction prevents a full count. But there's an innermost grouping of perwaras that total the same number as Borobudur – 72. Since the Sewu Temple is quite close to the same latitude as Borobudur, its association with the number of days between its Oct 10th zenith passage and the December Solstice also seems likely. Sparavigna (2017b) also notes a zenith passage sunrise alignment between Sewu's central temples and one to the east.

The oldest recorded example of zenith passage aligned architecture in Southeast Asia (just outside of) is Lion's Rock in the middle of Sri Lanka. During the reign of King Kassapa I, 477-495 CE, a large natural outcrop was carved into the form of a lion. On top, he commissioned a temple complex built an angle of 9° N of E (81° azimuth). It aligns to that latitude's zenith passage sunrises on April 9th and September 1st (Sparavigna, 2013). Sewu, the oldest zenith passage related temple in Java, was built perhaps 750 CE (Sparavigna, 2017b). The alignment at Lion's Rock predates that by 250 years, supporting the theory that these zenith passage observance traditions passed from Sri Lanka, to Java, and ultimately Cambodia.

William Romain has documented solstice alignments at over a dozen temple complexes in and around Angkor (Romain, 2019, 2022). Rather than purely looking along the major and minor axes of the sites, Romain's innovative approach was to look at their diagonals. Using entrances and other doorways as the origin points of sightlines, his diagrams repeatedly reveal solstitial alignments. He clarifies that the alignments are not functional sightlines, but rather lines encoded into the conceptual design of the temples.

While Romain's discoveries are not directly related to the zenith passage alignments in this report, they bolster the point that ancient Khmer were interested in the dynamic movements of the Sun. Romain's conclusion was that they purposely incorporated the solstices into the architectural designs as a way of including the dynamic movements the Sun into temple complexes intended to represent cosmic models of the universe centered around Mount Meru.

Conclusion

The purpose of this paper was to demonstrate that the Prasat Thom Complex of Koh Ker is aligned to sunrise on zenith passage at that latitude. The photos presented in this report confirm that.

Aside from the alignment at Koh Ker, two other on-site elements serve as supporting evidence. The first is the four-meter-tall linga standing atop the Prang Pyramid. While it no doubt had religious meaning, practically speaking it served as a very accurate gnomon mounted to observe zenith passage at noon from the temple's summit. The second is the temple in the center of Prasat Thom, in line with the zenith passage sunrise view from atop the Prang Pyramid. It has a zenith passage hole in its roof, the same type as documented all over Angkor (Barnhart & Powell, 2013).

Further supporting evidence comes from three ancient sites in Java – Prambanan, Sewu, and Borobudur. Each of those three have zenith passage orientations and temples numbering the number of days between zenith passages or the days between zenith passage and a solstice. Though far away from Cambodia, historical texts state that the first Khmer king Jayavarman II grew up in Prambanan's court (Coe & Evans, 2018:118) just as its zenith passage related architecture was being built. This paper proposes that he brought the ideas of zenith passage observance with him to Cambodia around 800 CE. Koh Ker's Prasat Thom complex alignment is evidence that the tradition of observing zenith passage continued beyond his reign.

Acknowledgements

Special thanks to Phum Kanha, Kin Po Thai, David Willingham, and Cassandra Barnhart. Our field work would not have succeeded without their participation.

References

Aveni, A. & Hartung, H. (1981). The observation of the Sun at the time of passage through the zenith in Mesoamerica. *Archaeoastronomy (Supplement to the Journal for the History of Astronomy) 12*(3), S51-S70.

Bauer, B. & Dearborn, D. (1995). *Astronomy and empire in the ancient Andes*. University of Texas Press.

Barnhart, E. & Powell, C. (2013). *The importance of zenith passage at Angkor, Cambodia*. https://www.mayaexploration.org/pdf/angkorzenithpassage.pdf

Broda, J. (2006). Zenith observations and the conceptualization of geographical latitude in ancient Mesoamerica: A historical and interdisciplinary approach. *Proceedings of the Oxford Seven Conference in Archaeoastronomy*, T. Bostwick and B. Bates (Eds.), (pp 183-212). Pueblo Grande Museum.

Chhom, K. (2011). *Inscriptions of Koh Ker I*. Publication of the Hungarian Southeast Asian Research Institute.

Chu, C. (1947). The origin of twenty-eight mansions in astronomy. *Popular Astronomy*, 55 (February 9147), 62-77.

Coe, M. & Evans, D. (2018). *Angkor and the Khmer Civilization*. Thames and Hudson.

Coedès, G. & Vella, W. (ed.) (1968). *The Indianized states of Southeast Asia*. translated by Susan Brown Cowing. University of Hawaii Press.

Evans, D. (2010). The archaeological landscape of Koh Ker, Northwest Cambodia. *Bulletin de l'Ecole Francaise d'Etreme-Orient*, Annee 2010, 97-98.

Freidel, D., Schele, L. & Parker, J. (1993). *Maya cosmos: three thousand years on the shaman's path.* William Morrow.

Genetics4good (2013). *World map indicating tropics and subtropics* https://commons.wikimedia.org/wiki/File:World_map_indicating_tropics_and_subtropics.png

Gislen, L. & Eade, J.C. (2019). The calendars of Southeast Asia 2: Burma, Thailand, Laos, and Cambodia. *Journal of Astronomical History and Heritage*, 22(3), 417-430.

Gupta, D. (2022). Resonating cultures: Jayavarman's sacred landscape for Shiva Bhakti, at Koh Ker the ancient Lingapura in early 10th century Cambodia. *Indica*.

I-Tsing, Muller, F. M., & Takakuso, J. (1896). *A record of the Buddhist Religion as practised in India and the Malay Archipelago (A. D. 671-695)*. Clarendon Press.

Kak, S. (2008). *The solar numbers in Angkor Wat*. University of Louisiana.

Khairunnisa, S. A., Hidayat, T., Orchiston, W. & Nikeu, N. (2021). Astronomical aspects of the Prambanan Temple in central Java, Indonesia. In W. Orchiston & N. Vahia (Eds.) *Exploring the History of Southeast Asian Astronomy,* (pp. 487–502). Springer.

Lim, L. (2002). *Khmer New Year*. Secretary of Board of Directors of Khmer Community, Seattle, WA. https://ethnomed.org/resource/khmer-new-year/

Magli, G. (2016). *The role of astronomy in the "anomalous" orientations of two Khmer state-temples*. School of Civil Architecture, Politecnico di Milano.

Magli, G. (2017). Archaeoastronomy in the Khmer Heartland. *Studies in Digital Heritage*, *1*(1), 1–17.

Malmström, V. (1997). *Cycles of the Sun, mysteries of the Moon: The calendar in Mesoamerican civilization.* University of Texas Press.

Mendez, A. & Karasik, C. (2014). Centering the world: Zenith and nadir passages at Palenque. *Archaeoastronomy and the Maya*, G. Aldana & E. Barnhart (Eds), (pp 97-110). Oxbow Books.

Mendez, A., Barnhart, E., Powell, C. & Karasik, C. (2005). Astronomical observations from the Temple of the Sun. *Archaeoastronomy* XIX, 44-73. University of Texas Press.

Mizoguchi, A. & Nakagawa, T. (Eds) (2011). *Koh Ker and Beng Mealea, two large monuments at the eastern portion of the Khmer Empire, Scientific Research Project on Provincial Ancient Khmer Cities and Temples*. Surveyed by Waseda University, Meijo University, JASA and ASPARA.

National Oceanic and Atmospheric Administration. National Weather Service. (2026). The seasons, the equinox, and the solstices. https://www.weather.gov/cle/seasons

Parmentier, H. (1921). Nouvelles decouvertes archaeologiques au Cambodge (Koh Ker, Prasat Thom). *Bullentin de l'Ecole Francaise d' Extreme-Orient*, 21(1), 163-176.

Romain, W. (2019). Solstice alignments at Angkor Wat and nearby temples: connecting to the cycles of time. *Journal of Skyscape Archaeology*, *4*(2), 176-200.

Romain, W. (2022). Angkor Wat: lotus temple at the intersection of celestial azimuths. *Journal of Skyscape Archaeology*, 8(1), 4-35.

Sarkar, K.K. (1966). Dates in Old Khmer (Cambodian) inscriptions. *Proceedings of the Indian History Congress, 28* (1966), 532-534. Indian History Congress.

Sparavigna, A. (2013). The solar orientation of the Lion Rock Complex in Sri Lanka. *International Journal of Sciences*, 2 (Nov 2013), 60-62.

Sparavigna, A. (2016a). *The zenith passage of the Sun and its role in the planning of architectures*. Philica.

Sparavigna, A. (2016b). *Solar alignments of the planning of Angkor Wat Temple Complex*. Philica.

Sparavigna, A. (2017a). *The zenith passage of the Sun at Candi Borobudur*. Philica.

Sparavigna, A. (2017b). *The Sewu Temple and the zenithal passage of the Sun*. Philica.

Shimoda, I. & Sato, K. (2014). *Religious concepts in the layout of the ancient Khmer city of Koh Ker*. Japan-APSARA Team for Safeguarding Angkor, Weseda University.

Subbarayappa, B.V. (1989). Indian astronomy: An historical perspective. *Cosmic Perspectives*. S.K. Biswas, D.C.V Malik & C/V Vishveshwara (Eds.), (pp. 25–41). Cambridge University Press.

Voute, C. & Long, M. (2008). *Borobudur, pyramid of the cosmic Buddha*. D.K Printworld, Ltd.

Urton, G. (1981). *At the crossroads of the earth and the sky: An Andean cosmology*. University of Texas Press.