



Temple occupation and the tempo of collapse at Angkor Wat, Cambodia

Alison K. Carter^{a,1}, Miriam T. Stark^b, Seth Quintus^b, Yijie Zhuang^c, Hong Wang^d, Piphah Heng^b, and Rachna Chhay^e

^aDepartment of Anthropology, University of Oregon, Eugene, OR 97403; ^bDepartment of Anthropology, The University of Hawai'i at Mānoa, Honolulu, HI 96822; ^cInstitute of Archaeology, University College London, London WC1H 0PY, United Kingdom; ^dState Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, Chinese Academy of Sciences, Xian 710061, People's Republic of China; and ^eInternational Center of Research and Documentation of Angkor, Authority for the Protection and Management of Angkor and the Region of Siem Reap, Siem Reap, Cambodia

Edited by Michael D. Coe, Yale University, New Haven, CT, and approved April 30, 2019 (received for review January 2, 2019)

The 9th–15th century Angkorian state was Southeast Asia's greatest premodern empire and Angkor Wat in the World Heritage site of Angkor is one of its largest religious monuments. Here we use excavation and chronometric data from three field seasons at Angkor Wat to understand the decline and reorganization of the Angkorian Empire, which was a more protracted and complex process than historians imagined. Excavation data and Bayesian modeling on a corpus of 16 radiocarbon dates in particular demand a revised chronology for the Angkor Wat landscape. It was initially in use from the 11th century CE with subsequent habitation until the 13th century CE. Following this period, there is a gap in our dates, which we hypothesize signifies a change in the use of the occupation mounds during this period. However, Angkor Wat was never completely abandoned, as the dates suggest that the mounds were in use again in the late 14th–early 15th centuries until the 17th or 18th centuries CE. This break in dates points toward a reorganization of Angkor Wat's enclosure space, but not during the historically recorded 15th century collapse. Our excavation data are consistent with multiple lines of evidence demonstrating the region's continued ideological importance and residential use, even after the collapse and shift southward of the polity's capital. We argue that fine-grained chronological analysis is critical to building local historical sequences and illustrate how such granularity adds nuance to how we interpret the tempo of organizational change before, during, and after the decline of Angkor.

archaeology | collapse | Angkor | Cambodia | Angkor Wat

The Angkorian civilization at its height covered large portions of mainland Southeast Asia, and its heartland and capital were located on the banks of the Tonle Sap lake, near the town of Siem Reap in Cambodia (Fig. 1). Archaeologists and historians have dated the beginning of the Angkor Empire to 802 CE when, as an 11th century inscription describes, King Jayavarman II united disparate factions within the region and declared himself a universal king (1). Angkor's demise has conventionally been dated to 1431 CE, when Thai chronicles state the city was attacked by the neighboring Kingdom of Ayutthaya and the elites and royals fled south to settle near the modern capital of Phnom Penh (1). This violent and dramatic 15th century downfall of Angkor dominates popular narratives (2–4), but scholars have long acknowledged problems with this catastrophic scenario (5–8). Recent archaeological research underscores assessments that the decline of Angkor involved multiple organizational transformations, rather than abrupt collapse (9).

In this paper, we use excavation data and Bayesian modeling of radiocarbon dates from the Angkor Wat enclosure to present a revised picture of the timing of occupation around this temple (Fig. 1). We argue that such high-resolution chronological analysis is necessary for understanding local historical sequences and that this contributes to our understanding of the tempo of organizational change taking place during the “collapse” of Angkor. We begin by reviewing the current state of evidence regarding Angkor's decline, then present a brief chronology and background on

the temple of Angkor Wat itself, followed by a discussion of our recent fieldwork, including a suite of radiocarbon dates in which we identify a chronometric gap that does not correlate with documented historical events. The gap most likely centers around the late 12th to early 13th centuries until at least the late 14th or early 15th centuries. By contextualizing these dates within the broader milieu of activities taking place across Angkor and the region, we argue that the break in our radiocarbon chronology reflects a shift in temple enclosure use that parallels broader transformations across the Angkor region from the 13th to the 15th centuries CE. Such changes represent both a shifting philosophy of organization at Angkor Wat and a reaction to increasing sociopolitical and environmental challenges. Elite political power shifted out of the region and many temples fell out of use, but our research supports a model of long-term landscape use in Greater Angkor, with people returning to the Angkor Wat temple enclosure by the 14th/15th centuries CE. Contrary to documentary accounts, the Angkor Wat temple was never abandoned or forgotten by descendant communities (10–16).

The Collapse of Angkor: Reviewing the Evidence

When French explorers and scholars visited Angkor in the late 19th century they found many, though not all, of the area's stone temples abandoned and overgrown (6). Early scholars traced the decline of Angkor to historic royal chronicles describing an attack by the Kingdom of Ayutthaya and the abandonment of Angkor for new capitals further south in 1431 by the last Angkorian king, Ponhea Yat (8). The Angkorians were not unfamiliar with conflicts

Significance

The Angkorian Empire was Southeast Asia's largest premodern polity. Its ancient temple of Angkor Wat has been a religious center since its construction in the 12th century CE and remains a contemporary icon for the wider Angkor polity, even appearing on Cambodia's flag. Our paper draws from intensive excavations in the Angkor Wat enclosure to present a fine-grained chronological analysis of the temple's use history. We focus on where people lived in the temple complex rather than on the temple itself, and identify a chronometric gap that does not fully correlate with documented historical events. This granular study of Angkor Wat's historical sequence contributes to understanding the tempo of organizational change taking place during Angkor's collapse.

Author contributions: A.K.C., M.T.S., Y.Z., P.H., and R.C. designed research; A.K.C., M.T.S., Y.Z., P.H., and R.C. performed research; A.K.C., M.T.S., S.Q., Y.Z., H.W., P.H., and R.C. analyzed data; and A.K.C., M.T.S., S.Q., Y.Z., and H.W. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

This open access article is distributed under [Creative Commons Attribution-NonCommercial-NoDerivatives License 4.0 \(CC BY-NC-ND\)](https://creativecommons.org/licenses/by-nc-nd/4.0/).

¹To whom correspondence may be addressed. Email: arcerter4@uoregon.edu.

This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1821879116/-DCSupplemental.

Published online June 3, 2019.

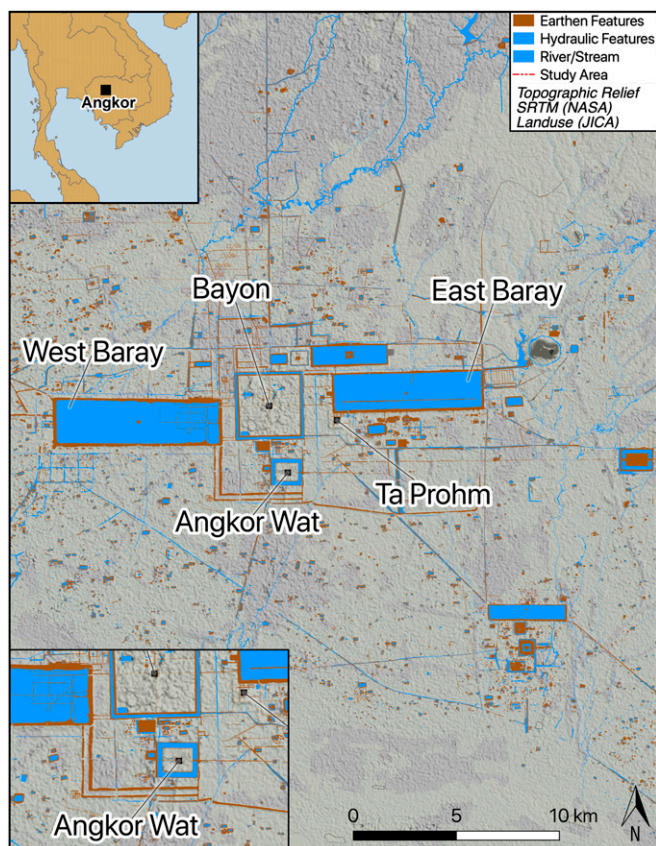


Fig. 1. Map of Greater Angkor including major temple sites and features; (Inset Top Left) regional view; (Inset Bottom Left) detail of Angkor Wat temple. Data courtesy of National Aeronautics and Space Administration Shuttle Radar Topography Mission (NASA-SRTM) and the Japanese International Cooperation Agency (JICA), Damian Evans, and Christophe Pottier.

with regional powers; the Chinese ambassador to Angkor, Zhou Daguan, wrote in 1296 CE about the countryside having been devastated by recurrent conflicts with Thailand (17). However, numerous epigraphic, historic, art historic, architectural, environmental, and archaeological studies (summarized below) have challenged this particular narrative for the end of Angkor. In fact, increasing evidence supports the interpretation that the decline of the Angkorian state was prolonged and multifaceted.

Developments in the 14th Century. Several scholars have identified evidence for important changes at Angkor before the 1431 date, beginning around the 14th century. The last major stone temple at Angkor, the Mangalartha or West Prasat Top, was constructed in 1295 CE by a high-ranking official during the reign of Jayavarman VIII. There is also a decline in the number of inscriptions during this period (18). The last dated Sanskrit inscription recorded at Angkor (designated K.488) dates to 1295 CE. The last clearly dated inscription in Khmer at Angkor (K.470) is from 1327 CE, found at the Bayon temple, although a handful of other undated inscriptions may have been written in the 14th–15th centuries (19). Some scholars have attributed this decline in epigraphy and architecture to exhaustion following the reign of Jayavarman VII, who ruled from 1181 to 1218 CE (e.g., ref. 20). Arguably the most famous and powerful of the Angkorian kings, Jayavarman VII took back Angkor from a rival Cham king, established Buddhism as the state religion, expanded the polity's borders, and built multiple temples and public works projects (21). While this building campaign certainly would have drawn on the

Angkor's human and natural resources, the idea that it led to the downfall of Angkor has been widely challenged (5, 6, 12, 22).

A decline in temple construction activities coincided with other internal and external developments, notably the region-wide adoption of Theravada Buddhism. This ideological shift moved emphasis from state-sponsored stone temples with their associated bureaucracy to community-based Buddhist pagodas, disrupting preexisting Hindu-based power structures at Angkor (13). Importantly, Zhou Daguan notes Theravada Buddhist monks in Angkor in 1296 CE (17), and royal support for Theravada Buddhism, is also seen in a 1308 CE inscription by King Srindravarmadeva (K.754) in Pali (ref. 15, pp. 275, 279).

At the same time, the importance of maritime trade with China was growing during the late 14th century; historic documents record a greater number of contacts between Cambodia and China during 1371–1419 than in any other period (15). Angkor, situated far inland, was not as well-positioned to participate in international maritime trade as the post-Angkorian cities located further south. The increasing economic opportunities with China may have exerted a pull out of Angkor and a reorganization of the preexisting socioeconomic power structures (5, 15). Angkorian stoneware ceramic production also appears to have changed during this period, moving from the central core region to kiln locations along the eastern edge of the provinces and in Northeast Thailand (23).

Lastly, regionwide environmental studies have aided in reconstructing the climate of early second millennium CE mainland Southeast Asia, pointing toward a period of climatic instability that had far-reaching effects on multiple polities in the area (24). Southeast Asia's monsoonal climate involves annual cycles of rainy and dry seasons. While Angkor and other regional states grew during a period of favorable climatic conditions, hydroclimate data suggest two regionwide droughts that occurred during the decline of Angkor and other regional powers: Angkor Drought I (1345–1374 CE) and Angkor Drought II (1401–1425 CE) (25–27). Between these “megadroughts” were periods of “megamonsoons,” in which Angkor was challenged by severe floods (25). Archaeological and paleoenvironmental work has identified on-the-ground impacts of these climatic changes within Greater Angkor. Angkorians managed their seasonal monsoon climate by constructing a massive water network, which included large water storage tanks called *baray* as well as canals, dykes, and smaller ponds (28, 29). The largest of these features was the 11th century West Baray, whose dimensions were 8 × 2 km (Fig. 1). However, palynological studies from a pond within a man-made island in the center of the West Baray point toward partial drying during the late 12th century, indicating a longer history of climatic challenges to the water management network than previously imagined (30). Other paleoenvironmental studies from the West Baray identify increased sedimentation and drought conditions in the 13th century, and again in the 14–15th century (31). Elsewhere in Angkor, canals demonstrate evidence for excess water, presumably from the megamonsoons, and LIDAR survey data clearly highlights areas where water destroyed infrastructure and flooded residential areas (32, 33). A recent study of Angkor Thom's moats suggest that there was a demographic decline, perhaps including the city's elite, and lack of water management as early as the 14th century CE (9). These disruptions would have created increasing challenges for Angkorian people living in this landscape.

Fifteenth Century Angkor and Beyond. Conventional interpretations attribute Angkor's collapse to rival regional power Ayutthaya (or Ayudhya), based near Bangkok, Thailand. B. P. Groslier argued that excavations within the Royal Palace at Angkor Thom indicated the city was abandoned around 1430 (34). Vickery (ref. 15, p. 274) notes that “an Ayutthayan intervention of some type” occurred in Angkor around 1431 and

certainly influenced the decision to relocate the political capital. However, Groslier also observed that only part of Angkor, specifically the walled precinct of Angkor Thom, was abandoned and “invaded by the jungle” while other areas remained open for occupation and worship (ref. 34, p. 16). Portuguese and Spanish visitors to Cambodia in the 16th century described a seemingly abandoned Angkor Thom, but one that was rediscovered by a Cambodian king in the mid-late 1500s (34). These 16th century European accounts also mention a functioning hydraulic system in Angkor Thom, but that it seems to have been abandoned again in the 17th century, such that 19th century European visitors described the area as covered by forest (ref. 34, pp. 82–83, 94–95).

Recent art historical and archaeological work also argue for a demographic decline and transformation, rather than complete abandonment. Art historical and compositional studies of 15th century Buddhas at Angkor has led some scholars to argue that there were Ayutthayan sculptors living at Angkor in the 15th century (12). Additionally, the 11th century Baphuon temple was modified to include a giant Theravada Buddhist reclining Buddha during the early-mid 15th century, although it is unclear who oversaw this modification (35). While Ayutthaya is currently associated with the modern nation of Thailand, it may be a mistake to consider the Ayutthayan occupation of Angkor as that of an invading foreign power. The Ayutthayan royal court contained many Khmer officials and artisans, Khmer was the official language of written documents, and Ayutthayan elite culture drew heavily on Angkor (5). The brief occupation of Angkor by powers based in Ayutthaya could be seen as another permutation of the Angkorian state and not a total collapse or colonization.

Excavations at the Royal Palace in Angkor Thom have also uncovered macrobotanical remains and evidence for continued use and occupation within this location during the 14th–early 15th centuries (36). Although the royal elite may have left the city during this period, the presence of botanical remains at this site suggest continued habitation in the area, perhaps by a Buddhist or lay community associated with the nearby Tep Pranam temple (36). Evidence at Angkor Wat and additional studies of tradeware ceramics in the Greater Angkor region reveal a continued, though reduced, population during the 15th–16th centuries (37, 38). Paleobotanical and radiocarbon dating of moats and water features around Angkor show continued “maintenance and modification” in the late Angkorian and post-Angkorian periods (30).

The Life History of the Angkor Wat Temple

Despite the shifting demography of Angkor, Angkor Wat has remained an important temple that was never abandoned; inscriptions and modifications on the temple itself testify to its long history and importance. Although a precise construction date is unknown, it is believed the temple of Angkor Wat was built in the early 12th century by King Suryavarman II, who began his reign in 1113 CE (39, 40) (Fig. 1). This was a period of expansion for the Angkor Empire as Suryavarman II extended the borders and in addition to Angkor Wat, built several striking temples in both the Angkor region and parts of what is now Northeast Thailand.

The landscape of Angkor Wat consists of a sandstone temple, made up of three enclosures and five towers that invoke the mythical Mount Meru. The sandstone temple sits within a large fourth enclosure that measures $\sim 1,000 \times 815$ m and is surrounded by a 200-m wide moat that measures $1,300 \times 1,500$ m (41, 42). There is considerable open space between the sandstone temple and the laterite wall bounding the fourth enclosure. Currently, this open space is predominantly covered by trees, though LIDAR survey has identified an orthogonal series of mounds and depressions or ponds that surrounded the temple and even extended beyond the eastern moat (41, 43) (Fig. 2).

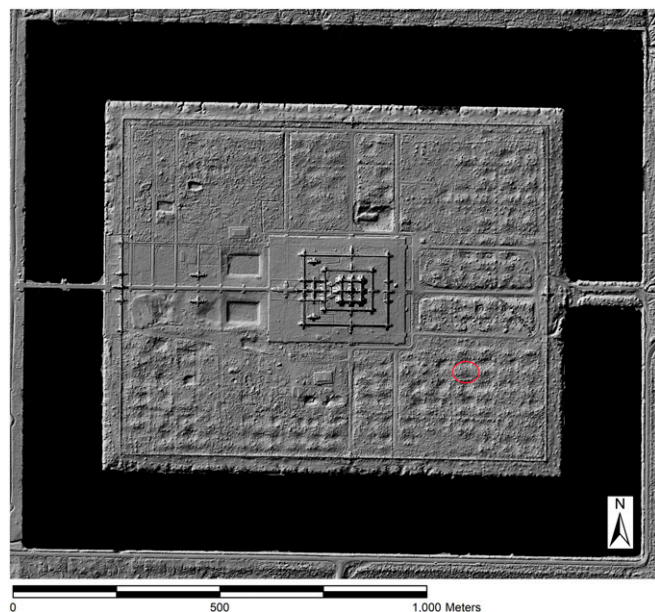


Fig. 2. LIDAR image of formal grid system across Angkor Wat enclosure with location of mound S1E2M1 circled. Digital terrain image courtesy of Khmer Archaeology Lidar Consortium.

Excavations by the Greater Angkor Project (henceforth GAP) have demonstrated that these mounds were used for habitation (44).

After its construction Angkor Wat was mentioned by Zhou Daguan in 1296 (17). The laterite wall around Angkor Wat was also modified, perhaps for defensive purposes, at some point between the 13th and 17th centuries CE (45). Over 30 Khmer inscriptions were inscribed on the pillars of the temple between 1541 and 1747, which recorded visits from pilgrims and Buddhist ceremonies (10, 11, 46). Angkor Wat was transformed into a Buddhist temple in the late 16th century (14), and recently identified paintings on the walls of Angkor Wat appear to be from this period as well (47). European visitors to Cambodia specifically described visiting Angkor Wat in the 16th century (34). In the 17th century, Japanese pilgrims visited Angkor Wat leaving behind inscriptions and the oldest map of the temple, believed to have been drawn in 1630 (48). By 1632, historical texts refer to the temple specifically as Angkor Wat (49) and in the early 18th century an inscription by a court dignitary was added, as well as the possible installation of a stupa on the east side of the third gallery (14, 50). These data indicate that Angkor Wat was a significant religious center and in near continuous use from the time of its construction.

Timing and Tempo of Collapse

In sum, while the end of Angkor has traditionally been dated to 1431 CE, evidence from multiple sources reveals numerous changes and challenges to Angkor that began in the late 13th century CE. No ruler after Jayavarman VII was able to command the same amount of labor and resources. Concurrently, region-wide religious changes in the 13th–14th centuries were shifting focus away from the previous Hindu-Brahmanical elite, with an increasing emphasis on Theravada Buddhism. This carried with it a decline in stone inscriptions and architecture that would be erected in association with religious structures. Furthermore, the opportunity for increasing trade in the 14th–15th centuries pulled Angkor’s royalty and elite further south to take better advantage of maritime trade and to avoid conflict with regional neighbors. Lastly, fluctuating droughts and monsoons in the 14th–15th centuries strained and destroyed parts of Angkor’s complex water

management network, which surely affected the resident population. Many of Angkor's sociopolitical elite left the region, but the area was not entirely depopulated or forgotten.

Angkor Wat in particular remained a place of central importance, but how the regionwide changes taking place in the 13th–15th centuries affected the temple's functions, activities, and occupants has been poorly understood. Our fieldwork at Angkor Wat aimed to address this question. By focusing on where people live rather than on the temple itself, we have identified transformations in the use of the temple enclosure and a chronometric gap that does not fully correlate with documented historical events. This granular study of Angkor Wat's historical sequence contributes to understanding the tempo of organizational change taking place during Angkor's collapse.

GAP Fieldwork at Angkor Wat in 2010, 2013, and 2015. GAP fieldwork at Angkor Wat began in 2010, before the availability of LIDAR survey data and focused on mounds that were visible within the eastern portion of the enclosure. The 2013 fieldwork took advantage of the available LIDAR data to continue 1 × 2 m test trenches within the eastern enclosure and the orthogonal grid outside the eastern moat (the external eastern enclosure) (44). The GAP 2015 fieldwork returned to one mound (identified S1E2M1 in our grid system see Fig. 2, see also *SI Appendix, Fig. S1*) within the Angkor Wat enclosure to conduct a horizontal excavation to better understand the spatial distribution of occupation activities. These excavations demonstrated that the mounds within and outside the enclosure were used for habitation, including ceramics associated with cooking, floor/occupation surfaces, and plant remains (44, 51). The depressions functioned as ponds; however, the ponds appear to have periodically cycled between wet and dry phases (44) (*SI Appendix, Table S3*). Three cultural layers were identified across all mounds. Ceramic data, including Khmer stoneware and Chinese tradeware, and preliminary radiocarbon dates helped to broadly associate these layers with the 11th–13th centuries (layers 3 and 2) and the 15th–17th centuries or post-Angkorian period (layer 1), which have been discussed in previous publications and are reviewed in *SI Appendix* (44, 51). Additional radiocarbon dates and Bayesian analysis discussed here have allowed us to further refine these dates and the timing of occupation within the Angkor Wat enclosure.

Analysis and Discussion

Fig. 3 presents the results of the three-phase Bayesian model for the Angkor temple enclosure using 16 radiocarbon dates from well-defined stratigraphic contexts from the 2010, 2013, and 2015 excavations (see also *SI Appendix, Tables S1 and S2*). The most likely beginning to the sequence ranges from 1035 to 1075 CE [68.2% high-probability density (HPD)], which we associate with the construction of the initial mound-depression grid system around the temple of Angkor Wat (layer 3). Following the construction of the mound-depression grid we proposed a subsequent Angkorian period habitation on top of the mounds (layer 2). The transition between layers 2 and 3 is quite constrained in radiocarbon terms, conceivably ranging from 1055 to 1142 CE (95.4% HPD) and most likely between 1060 and 1100 CE (68.2% HPD). Following layer 2, we identified a post-Angkorian occupation layer (layer 1) discussed further below. The most likely end of the sequence (layer 1) ranges from 1689 to 1786 CE (68.2% HPD).

What is notable based on visual examination of radiocarbon dates is an apparent gap between layers 1 and 2, although the variance of this gap is somewhat ambiguous (Fig. 3, see also *SI Appendix*). The most likely length of the gap, modeled in OxCal as an interval, is 128–295 y (68.2% HPD). While individual calendar years cannot be assigned to the gap, it most likely extends from the late 12th or early 13th centuries to the late 14th

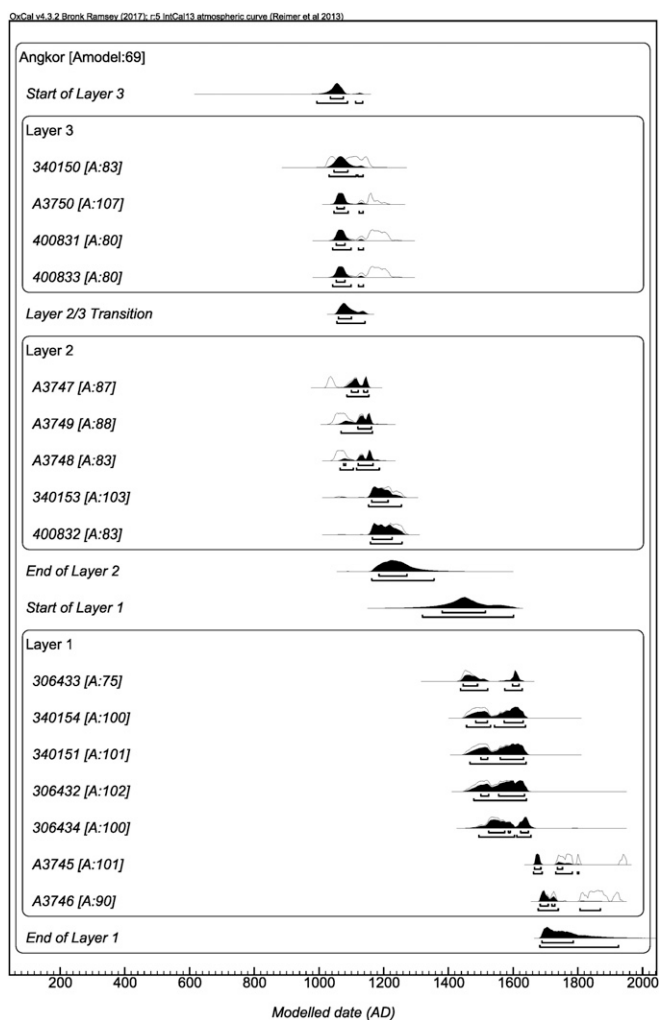


Fig. 3. The results of the three-phase Bayesian model for the Angkor temple enclosure using OxCal 4.3.2 and calibrated using the IntCal 13 atmospheric calibration curve. Agreement indices are included in brackets. See *SI Appendix Tables S1 and S2*.

or early 15th centuries. However, the actual gap may extend beyond or be within this range because it is conceivable that the gap is as small as 33 y and as large as 375 y (95.4% HPD). We find the lower tail of the gap's 95.4% HPD range to be unlikely based on available radiocarbon dates as well as the raw data from the Bayesian model. Instead, the statistical tails for boundaries modeling the end of layer 2 and start of layer 1, which are used to calculate the interval between layers, are explained as a product of the lack of constraints in the model and the assumed uniform distribution of each phase. This is hinted at by the skewed nature of each boundary's posterior probability plot (Fig. 3).

The radiocarbon dates from the Angkor Wat enclosure combined with our recent excavation data provide a revised view of the historical sequence of Angkor Wat. The initial dates for layer 3 predate the consensus date of the temple construction during the early-mid 12th century CE and the date of the reign of Suryavarman II. Further data are needed to upend the traditional timing of the construction of Angkor Wat. However, we note that excavations around the "buried towers" near the West Gopura of Angkor Wat also produced radiocarbon dates in the 11th century in their lower layers (52). Preliminary geomorphological analysis from the 2015 trenches suggests that the

landscape of the Angkor Wat enclosure was part of the wider alluvial plain, although date of the formation of the plain is unknown. This was followed by construction activities in which the ground surface was raised and flattened, which we associate with the construction of the mound-depression grid system. In the case of mound S1E2M1 and its associated depression or pond, it appears that the builders dug directly into the alluvial sediments and managed their immediate microtopographic environment to construct the depression, mound, and other living spaces (*SI Appendix*).

Layer 2 is associated with Angkorian period habitation on top of the mounds. It is presumed that habitation on top of the mounds was in houses on stilts or piles, as described by Zhou Duguan and has been common in the region for thousands of years, up to today (17, 53, 54). It is unclear who was living in these houses, although workers associated with the functions of the temple are likely candidates. Inscriptions describe thousands of laborers who were required for the ritual and day-to-day activities at state temples (55). Ongoing work will continue to explore questions about the nature of household activities and the people who lived within the enclosure (56). Geomorphological analysis from one trench in the center of mound S1E2M1 (trench 36) did not have habitational deposits, but may have been used for other purposes such as horticulture or as an open area or courtyard (*SI Appendix, Table S3*). This change in the use of space is evidenced by the presence of typical soil formation micromorphological features such as layered clay coatings that were formed during periods of surface disturbance with periodic wet-dry alternations of soil hydrology. Layer 2 is associated with an increase in the quantity of ceramics at the site and multiple *in situ* features, including flat-laying stones and a possible hearth or cooking area (*SI Appendix, Figs. S2–S4 and Table S4*).

The gap in our radiocarbon dates between layers 2 and 1 point to a change in the use of the mounds around the Angkor Wat enclosure during the late Angkorian and early post-Angkorian period and the potential for a previously unknown break in habitation or use of the temple enclosure space. Layer 1, associated with the post-Angkorian period, is generally thinner than our Angkorian habitation deposits (layers 2 and 3), falling within the top 30–40 cm our trenches. Few *in situ* features were recovered in layer 1, which were also bioturbated from the more recent forest cover of the enclosure. Approximately 25% fewer ceramics were found in layer 1 than layer 2 (*SI Appendix, Fig. S1*). Micromorphological and geophysical analyses reveal clear sedimentation changes in the transition from layer 2 to layer 1. Compared with the relatively well-sorted and rounded-shaped sediments of layer 2, layer 1 contains abundant poorly sorted, angular-shaped sediments, including very coarse-sized gravels. Micromorphological features related to soil formation are only occasionally present. Such sedimentation change must be associated with changing land use (*SI Appendix*).

Based on these data and our radiocarbon dates, we propose that during this period from the late 12th or early 13th century to the late 14th or early 15th centuries the occupation areas and activities surrounding the Angkor Wat temple may have been reduced or transformed. This break in radiocarbon dates was taking place within the broader transformations at Angkor discussed above, including a reduction in the number of stone inscriptions, the cessation of stone temple construction, a regional shift toward Theravada Buddhism, and especially the breakdown of the water management system due to climatic changes. Nevertheless, as early as the late 14th century CE, but more likely in the 15th century, the mounds appear to have come back into use, although less intensively.

There are several possible reasons for the seeming reorganization of the mounds. It is possible that there was a shift in the functions or activities at the Angkor Wat temple itself, but this is complicated due to our current inability to identify the occupations of the people living on the mounds. Although

inscriptions indicate Angkor Wat's central sanctuary was not modified until 1580, it is possible that the shift toward Theravada Buddhism began centuries earlier and that space within the enclosure was also reorganized at this time. We know, for example, that when the French arrived there were several structures and residences of local Buddhist monks directly in front of the main western entrance of the temple that were subsequently moved as Angkor Wat was transformed into a locus of tourism (57, 58). It is also possible that Hindu ritual functions of the temple were reduced following the death of Suryavarman II. We might also consider that the new temple constructions during the reign of Jayavarman VII could have pulled labor and attention away from Angkor Wat. Others have proposed that external conflicts during the 13th–17th centuries necessitated the modification of the laterite fourth enclosure wall to fortify the temple (45). Although the exact dates of these modifications are not clear, the threat of external conflict might have also caused people to abandon the enclosure's habitation mounds.

While occupation activities at Angkor Wat seem to have changed in the 12th or 13th centuries, our layer 1 dates and archaeological evidence reveal that the mounds were back in use by the 14th or early 15th centuries and used consistently until the 17th or 18th centuries. This coincides with Angkor Wat's transformation into an important Buddhist pilgrimage center (14). Layer 1 experienced heavy bioturbation and was also thinner than layers 2 and 3. One possibility is that the mounds housed structures for pilgrims and other worshippers rather than long-term inhabitants. In the early 20th century, visitors to Angkor Wat noted both the residences of Buddhist monks and presence of pilgrims camping near the temple (59).

Conclusions

Angkor Wat temple's radiocarbon dates offer a revised view of the life history of this temple and more nuanced view of its chronology. Dates from layer 3 suggest the landscape around what would become the Angkor Wat temple enclosure may have been in use and undergoing reorganization in the 11th century, before the reign of Suryavarman II and the typical early-mid 11th century dates for the temple's construction. Following the construction of the mound-depression grid system, there was habitation on top of the mounds from approximately the 11th–13th centuries. After this initial phase of habitation there is a break in our radiocarbon sequence across the enclosure, which we argue indicates a restructuring of the use of the fourth enclosure space. We propose that this may be related to the multiple sociopolitical, ideological, economic, and climatic changes taking place at Angkor in the 13th–14th centuries CE. The mounds were then reoccupied, although less intensely, from the 14th–15th centuries onward. This roughly coincides with Angkor Wat's transformation into a Buddhist pilgrimage site.

The changing nature of activities within Angkor Wat are informative for understanding the nature of organizational changes taking place during the decline of Angkor and how urban systems reconfigure with the collapse of their elite sectors. The excavation data and our radiocarbon dates demonstrate that the landscape around Angkor Wat was dynamic and underwent changes in response to both internal and external factors and challenges. We argue that our radiocarbon dates coupled with geoarchaeological and excavation data taken in consideration with other evidence at Angkor from the 15th century onward, confirms a more nuanced view of the “collapse” of the Angkor Empire. While Angkor certainly underwent a demographic shift, including the seeming relocation of the city's elite (9), the region was not completely abandoned and forgotten. After a period of reorganization, certain aspects of the landscape were back in use although in the case of Angkor Wat, the function and activities taking place appear to have been transformed. As Angkor's largest temple and long-time symbol of Cambodian national identity Angkor Wat maintained a central

place in 16th century royal inscriptions and Cambodia's historical imagination until contact with the French in the 19th century (5).

Methods

Multiple charcoal samples were collected for radiocarbon dating. Samples were selected to date specific features or layers (see *SI Appendix, Table S1* for a complete list of dates from the 2010, 2013, and 2015 field seasons). The supplemental information text contains further discussion of the radiocarbon methods for the 2015 dates and the Bayesian analysis (*SI Appendix*). The geoarchaeological investigation was carried out during the 2015 fieldwork season and samples were collected on mound S1E2M1. Further details on the methods and results of the geoarchaeological analysis are listed in *SI Appendix*. *SI Appendix* also includes a discussion of our excavation methodology.

- G. Coedes, *The Indonesian States of Southeast Asia* (The University of Hawaii Press, Honolulu, ed. 3, 1968).
- W. R. Moore, Angkor, jewel of the jungle. *Natl. Geogr. Mag.* **117**, 516–569 (1960).
- D. F. Rooney, *Angkor: An Introduction to the Temples* (W.V. Norton and Company, New York, ed. 4, 2004).
- C. Higham, *The Civilization of Angkor* (University of California Press, Berkeley, 2001).
- D. Chandler, *A History of Cambodia* (Silkworm Books, Chiang Mai, ed. 4, 2008).
- M. D. Coe, D. Evans, *Angkor and the Khmer Civilization* (Thames & Hudson, New York, ed. 2, 2018).
- M. Polkinghorne, C. Pottier, C. Fischer, One Buddha can hide another. *J. Asiat.* **301**, 575–624 (2013).
- O. W. Wolters, The Khmer King at Basan (1371-3) and the restoration of the Cambodian chronology during the fourteenth and fifteenth centuries. *Asia Major* **12**, 44089 (1966).
- D. Penny, T. Hall, D. Evans, M. Polkinghorne, Geoarchaeological evidence from Angkor, Cambodia, reveals a gradual decline rather than a catastrophic 15th-century collapse. *Proc. Natl. Acad. Sci. U.S.A.* **260**, 4871–4876 (2019).
- S. Lewitz, Les inscriptions modernes d'Angkor Wat. *J. Asiat.* **260**, 107–129 (1972).
- S. Lewitz, IX. Inscriptions modernes d'Angkor 26, 27, 28, 29, 30, 31, 32, 33. *Bull. Ec. Fr. Extr. Orient* **60**, 205–242 (1973).
- M. Polkinghorne, C. Pottier, C. Fischer, "Evidence for the 15th century Ayutthayan occupation of Angkor" in *The Renaissance Princess Lectures in Honour of Her Royal Highness Princess Maha Chakri Sirindhorn on Her Fifth Cycle Anniversary* (The Siam Society, Bangkok, 2018).
- A. Thompson, "Changing perspectives: Cambodia after Angkor" in *Sculpture of Angkor and Ancient Cambodia: Millennium of Glory*, H. I. Jessup, T. Zephir, Eds. (National Gallery of Art, Washington, DC, 1997), pp. 22–32.
- A. Thompson, Pilgrims to Angkor: A Buddhist "Cosmopolis" in Southeast Asia? *Bull. Stud. Dep. Archaeol.* **3**, 88–119 (2004).
- M. Vickery, "Cambodia and its neighbours in the 15th Century" in *Southeast Asia in the Fifteenth Century: The China Factor*, G. Wade, S. Laichen, Eds. (NUS Press, Singapore, 2010), pp. 271–303.
- M. Polkinghorne, "Seventeenth and eighteenth century images of the Buddha from Ayutthaya and Lan Xang at Angkor Wat" in *The Emergence of Theravada Buddhism in Cambodia: Southeast Asian Perspectives*, A. Thompson, H. W. Woodward, Eds. (National University of Singapore Press, Singapore, 2018).
- Z. Daguang, P. Harris, *A Record of Cambodia: The Land and Its People* (Silkworm Books, Chiang Mai, 2007).
- E. Lustig, Using inscription data to investigate power in Angkor's empire. *Aseanie* **27**, 35–66 (2011).
- E. Lustig, "Power and pragmatism in the political economy of Angkor," PhD dissertation, University of Sydney, Sydney (2009).
- L. P. Briggs, *The Ancient Khmer Empire* (American Philosophical Society, Philadelphia, 1951).
- M. Hendrickson, Historic routes to Angkor: Development of the Khmer road system (ninth to thirteenth centuries AD) in mainland Southeast Asia. *Antiq.* **84**, 480–496 (2010).
- C. Jacques, "The historical development of Khmer Culture from the death of Suryavarman II to the 16th century" in *Bayon: New Perspectives*, J. Clark, Ed. (River Books, Bangkok, 2007), pp. 30–49.
- G. P. Marriner et al., New dates for old kilns: A revised radiocarbon chronology of stoneware production for Angkorian Cambodia. *Radiocarbon* **60**, 901–924 (2018).
- V. Lieberman, B. Buckley, The impact of climate on Southeast Asia, circa 950–1820: New findings. *Mod. Asian Stud.* **46**, 1049–1096 (2012).
- B. M. Buckley et al., Climate as a contributing factor in the demise of Angkor, Cambodia. *Proc. Natl. Acad. Sci. U.S.A.* **107**, 6748–6752 (2010).
- B. M. Buckley, R. Fletcher, S.-Y. S. Wang, B. Zottoli, C. Pottier, Monsoon extremes and society over the past millennium on mainland Southeast Asia. *Quat. Sci. Rev.* **95**, 1–19 (2014).
- Q. Hua et al., Radiocarbon dating of a speleothem record of paleoclimate for Angkor, Cambodia. *Radiocarbon* **59**, 1873–1890 (2017).
- R. Fletcher et al., The water management network of Angkor, Cambodia. *Antiquity* **82**, 658–670 (2008).
- R. Fletcher, C. Pottier, D. Evans, M. Kumm, The development of the water management system of Angkor: A provisional model. *Bull. Indo-Pac. Prehistory Assoc.* **28**, 57–66 (2008).
- D. Penny, Q. Hua, C. Pottier, R. Fletcher, M. Barbetti, The use of AMS 14C dating to explore issues of occupation and demise at the medieval city of Angkor, Cambodia. *Nucl. Instrum. Methods Phys. Res. B* **259**, 388–394 (2007).
- M. B. Day et al., Paleoenvironmental history of the West Baray, Angkor (Cambodia). *Proc. Natl. Acad. Sci. U.S.A.* **260**, 1046–1051 (2012).
- R. Fletcher, B. M. Buckley, C. Pottier, S.-Y. S. Wang, "Fourteenth to sixteenth centuries AD. The case of Angkor and monsoon extremes in mainland Southeast Asia" in *Megadrought and Collapse: From Early Agriculture to Angkor*, H. Weiss, Ed. (Oxford University Press, Oxford, UK, 2017), pp. 275–314.
- D. Penny et al., The demise of Angkor: Systemic vulnerability of urban infrastructure to climatic variations. *Sci. Adv.* **4**, u4029 (2018).
- B. P. Groslier, *Angkor and Cambodia in the Sixteenth Century According to Portuguese and Spanish Sources*, M. Smithies, Ed. (trans.) (Orchid Press, Bangkok, 2006).
- S. Leroy, M. Hendrickson, E. Delqué-Kolic, E. Vega, P. Dillmann, First direct dating for the construction and modification of the Baphuon temple mountain in Angkor, Cambodia. *PLoS One* **10**, e0141052 (2015).
- C. C. Castillo, M. Polkinghorne, B. Vincent, T. B. Suy, D. Q. Fuller, Life goes on: Archaeobotanical investigations of diet and ritual at Angkor Thom, Cambodia (14th–15th centuries CE). *Holocene* **28**, 930–944 (2018).
- D. Brotherson, "Commerce, the capital, & community. Trade ceramics, settlement patterns, & continuity throughout the demise of Angkor," PhD dissertation, University of Sydney, Sydney (2018).
- A. Desbat Une production originale à Angkor: Les céramiques glaçurées de l'atelier de Kôk Phnéao. *Sikšacakr* **11**, 43–60 (2009).
- G. Coedès Etudes cambodgiennes. *Bull. Ec. Fr. Extr. Orient* **29**, 289–330 (1929).
- J. Boisselier, "Bên Mälä and the Chronology of the Monuments of the Angkor Wat Style" in *Studies on the Art of Ancient Cambodia. Ten Articles by Jean Boisselier*, N. Eilenberg, R. L. Brown, Eds. (Reyung Publishing, Phnom Penh, Cambodia, 2010), pp. 68–150.
- D. Evans, R. Fletcher, The landscape of Angkor Wat redefined. *Antiquity* **89**, 1402–1419 (2015).
- R. Fletcher, D. Evans, C. Pottier, C. Rachna, Angkor Wat: An introduction. *Antiquity* **89**, 1388–1401 (2015).
- D. H. Evans et al., Uncovering archaeological landscapes at Angkor using lidar. *Proc. Natl. Acad. Sci. U.S.A.* **110**, 12595–12600 (2013).
- M. T. Stark, D. Evans, C. Rachna, H. Piphala, A. Carter, Residential patterning at Angkor Wat. *Antiquity* **89**, 1439–1455 (2015).
- D. Brotherson, The fortification of Angkor Wat. *Antiquity* **89**, 1456–1472 (2015).
- D. Chandler, An eighteenth century inscription from Angkor Wat. *J. Siam Soc.* **59**, 151–159 (1971).
- N. H. Tan, S. Im, T. Heng, C. Khieu, The hidden paintings of Angkor Wat. *Antiquity* **88**, 549–565 (2014).
- Y. Ishizawa, The worlds oldest plan of Angkor Vat: The Japanese so-called Jetavana, an illustrated plan of the seventeenth century. *UDAYA J. Khmer Stud.* **47**–61 (2015).
- S. Pakdeekham, À propos de l'origine des noms d'Angkor Vat et de Siem Reap. *Sikšacakr* **10**, 39–50 (2008).
- S. Pou, VII. Inscriptions modernes d'Angkor 34 et 38. *Bull. Ec. Fr. Extr. Orient* **62**, 283–353 (1975).
- A. K. Carter, P. Heng, M. T. Stark, R. Chhay, D. Evans, Urbanism and residential patterning in Angkor. *J. Field Archaeol.* **43**, 492–506 (2018).
- T. F. Sonnemann, D. O'Reilly, C. Rachna, R. Fletcher, C. Pottier, The buried 'towers' of Angkor Wat. *Antiquity* **89**, 1420–1438 (2015).
- M. A. Henriksen, "The first excavated prehistoric house site in Southeast Asia" in *The House in East and Southeast Asia. Anthropological and Architectural Aspects*, K. G. Izikowitz, P. Sorensen, Eds. (Scandinavian Institute of Asian Studies, Copenhagen, 1982), pp. 17–24.
- F. Tainturier, M. R. Antelme, M. C. Lalonde, *Wooden Architecture of Cambodia: A Disappearing Heritage* (Center for Khmer Studies, Siem Reap, 2006).
- E. Lustig, T. Lustig, New insights into "les interminables listes nominatives d'esclaves" from numerical analyses of the personnel in Angkorian inscriptions. *Aseanie* **31**, 55–83 (2013).
- A. K. Carter, M. Stark, P. Heng, R. Chhay, "The Angkorian house" in *The Angkorian World*, D. Evans, M. Stark, M. Hendrickson, Eds. (Routledge, London, 2020).
- M. Falser, "From Colonial map to visitors Parcours: Tourist guides and the spatiotemporal making of the archaeological park of Angkor." *'Archaeologizing' Heritage?: Transcultural Engagements Between Local Social Practices and Global Virtual Realities*, M. Falser, M. Juneja, Eds. (Springer-Verlag, Berlin, Heidelberg, 2013), pp. 81–106.
- K. Miura, "Contested heritage: The People of Angkor," PhD dissertation, School of Oriental and African Studies, London (2004).
- C. Madrolle, *De Marseille à Canton: Guide du voyageur* (Comité Asie française, Paris, 1902).