

## Water, Ritual, and Prosperity at the Classical Capital of Bagan, Myanmar (11<sup>th</sup> to 14<sup>th</sup> Centuries CE): Archaeological Exploration of the Tuyin- Thetso “Water Mountain” and the Nat Yekan Sacred Water Tank

၁၁ မွ ၁၄ရာစု ပျမန္နာ့ ဂဒ်ဝ်ငြုဂ်ခေတု၏ ဝေရအသံုးခမ်၊ ပြီးရာဓေလးုဒုဒု  
သာယာဝေပျမာမ - အကြတ္တုမတ္တားရာ နတုေရကန ဝုဒုဒု တုရဒ္ဒကွိုးေတာဒ  
ေရအသံုးခမ်ဆိုဣ ဝေရွးေဟာဒုးသုေတသန စူးစမုးရွာေဖြူဒုး

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**Abstract**

The IRAW@Bagan project is aimed at developing an integrated socio-ecological history for residential patterning, agricultural practices and water management at the Classical Burmese (Bama) capital of Bagan, Myanmar (11th to 14th centuries CE). As part of this long-term research program investigations have been initiated in the Tuyin-Thetso uplands, located 11 km southeast of Bagan’s walled and moated epicenter. This mountainous area figures prominently in the chronicles of early Bagan, given that it was one of five places around the city that a royal white elephant carrying a Buddhist tooth-relic kneeled down, prompting King Anawrahta (1044-1077 CE) to build a pagoda (i.e., temple) there. Numerous 13<sup>th</sup> century religious monuments were subsequently built on the Tuyin Range. Recent explorations in these uplands have drawn attention to an additional feature of historical significance, a rock-cut tank located along the eastern edge of the Thetso-Taung ridge. Referred to by local villagers as Nat Yekan (Spirit Lake), this reservoir appears to have been integral not only to the initial collection and subsequent redistribution of water across the Bagan plain via a series of interconnected canals and reservoirs, but also, through its associated iconographic imagery, it may have been intended to symbolically purify this water, enhancing its fertility prior to its flowing into the city’s peri-urban zone. Hydrological modelling, excavations, and both iconographic and epigraphic analysis are used to build a multilayered understanding of Nat Yekan’s economic, political, religious, and ideological significance during Bagan’s Classical era.

Keywords: Myanmar, Bagan, Water, Ritual, Ideology

IRAW Bagan စီမံကိန်းသည် ၁၁ရာစုမှ ၁၄ရာစုအကြား စညွှန်ကားခဲ့သော ငွေ့မြစ်တို့၏ ပုံစံပြောင်းလဲမှုနှင့် ဘက်ပေါင်းစုံပေါင်းစည်းထားသော လူမှု၊ ဝေဟန သမိုင်းဝင်အရာများဖြစ်သော လူနေထိုင်ပုံစံ၊ စိုက်ပျိုးရေး၊ ဓလေ့စဉ်များ ဝေဖန်ခြင်း ဝေရအရင်းအမြစ်သုံးစွဲမှုများအား ဖြည့်ဆည်းပေးထုတ်ပေး အဓိကရရှိလာပါသည်။ အဆိုပါ ဝေရရှိသည့် သုတေသန စီမံကိန်း ဝေလုလာရေးအား ဗဟိုအင်အားဖြစ်သော ပုံစံမိမိဟောင်း၏ အရွေ့ပြောင်းမှုကို ၁၁<sup>th</sup> လိုမီတာ ဝေးကြာသော တုရင် ဝေဖန်ခြင်း သင်္ကြံတောင့် ဧရိယာမှ စတင်ပြုဆောင်ခဲ့ပါသည်။ ငွေ့မြစ်ဝကျွန်းပေါ်ရှိ ပုံစံပြောင်းလဲမှု အနာရထာမင်းခက် (၁၀၄၄-၁၀၇၇ AD) အဓိကအဖြစ် လက်တွေ့ကျသော ဗုဒ္ဓဘုရားတော်တို့ တင်ဆောင်သည့် ဆင်တင်ပေးကမ်းမှုများ ဝေရတောင့် တစ်ခုအပါအဝင်ဖြစ်သည့် ထိုအရင်းအမြစ်များ ဝေရလဲ ဖြစ်ပါသည်။ မင်းကြီးသည် ၁၃ရာစု ပုံစံတူ သာသနိက အဆောက်အုံ မင်းလည်း တုရင်တောင့်အောက် တစ်ဝိုက်ကို တည်ဆောက်ထား ဖြစ်ပါသည်။ အဆိုပါတောင့်ကြောင့် လက်တွေ့ စူးစမ်းရှာဖွေမှု သည့်သုံး သမိုင်းတမ်းအရ သာသနိက အဆောက်အုံများ ကဲ့သို့ အရင်းအမြစ် သင်္ကြံတောင့်၏ အရွေ့ပြောင်းမှုကြောင့် တည်ရှိသော ဝေရကမ်းများ

အထူးပူဇော်လေ့လာချခင်းပျစေသည်။ ဝေဒသခံ ရှာသူရှာသားမားက ငှက်ကုရေကန္တာ  
 နတုရေကန္တ၊ ခေဒုဆိုမ၊အရ ငှေရေလွှာငွေကီးသည့် ကနဦး ခေရစုဆောင်း  
 သိုလေ့လာပေးနာက ပုဂံပြင်ပပုဏ် တစုလော့ကို ခေရေလွှာငွေ  
 တူးလေ့လာခင်းမားခွင့်၊ ဆကြွယု၍ ခေရပန္နည့် ပျစနုပေးယံုသာ မကဘဲ  
 ထွင်းထုထားသော ဂူပုဏ်ပုဏ်ကြမ်းသည့်ညွှန်း ကနုရေအား ဒုမဂလ  
 သနုပုဏ်ခင်းစွေကယုးသေဘာဆောင်း၍ ပျစနုပေးချခင်းပျစေပုံ ပုဂံမိမိအနီးတဝိုက်  
 ငှက်ကုရေရာရှိရာ ခေရာဝေဒသမား သာယာစည့်ဖြူ ဖြူဖမ်းခေအာပူဇော်ပူဇော်မိမိထားသည့်  
 မွတ္တရပါသည့်။ ဂုဏ်ငွေပုဂံ ခေတ္တကြောင်း ထွင်းခွဲသော နတုရေကနုခွင့်  
 ပတ္တကုဏ်ပုဏ်ပေးသော စီးပြားရေး၊ ဝိုးဝိုင်းရေး၊ ဘာသာရေး  
 စသည့်သေဘာတရားရေးရာ အဆင့်ဆင့်အား နားလည်စေရန်  
 ရေအရင်းအမြစ်သုံးခင်းခင်းသိပလံပညာ၊ ဝေရွေးဟောင်းသုတေသန တူးဖော်မှု  
 ဝိုးဝိုင်းအတူ ဂူပုဏ်ပုဏ်ကြေလေ့လာမ၊ ဝိုးဝိုင်း ဝေကာကွာ စိစစေကြည့်ခင်းကွားအား  
 အသုံးပူဇော်လေ့လာ တပုဏ်ပေးပါမည့်။

Keywords: ပျမန္တာ၊ ပုဂံ၊ ရေ၊ ပြီးရာခေလေ၊ သေဘာတရားရေးရာ

**Introduction**

Bagan (Pagan), like most of the historic Buddhist capitals of Myanmar, was located in the central “dry zone” (Figure 1; Aung-Thwin 1987:88, 1990:1; Aung-Thwin and Aung-Thwin 2012:38; Hudson 2008:553; Stadner 2013:12; Strachan 1989:8) – the country’s “most arid” region (Cooler 1997:19-20) – on the eastern bank of the strategic and economically important Ayeyarwady River (Higham 2001:134; Hudson 2004:221, 265). Recent archaeological assessments support a mid-9<sup>th</sup> century CE date for the establishment of the Bagan community (Hudson 2004:220, 265-266; Moore et al. 2016:285; Nyunt Nyunt Shwe 2011:26), with the 11<sup>th</sup> to 14<sup>th</sup> centuries being the period when Bagan was the capital of a polity that controlled much of what is now the country of Myanmar (Daw Thin Kyi 1966:187; Galloway 2006:35; Higham 2001:134; Hudson 2004:183, 266, 2008:553, 555; Kan Hla 1977:17; Moore et al. 2016:285; Stadner 2011:214-215, 2013:14, 18). Bagan’s florescence was followed by an era of socio-political “collapse” and reorganization, after which time it saw continued usage as a provincial capital and pilgrimage center (Hudson 2004:234-245, 266, Table 15, 2008:555; Hudson et al. 2001:53; Stadner 2011:215-216, 2013:14, 18).

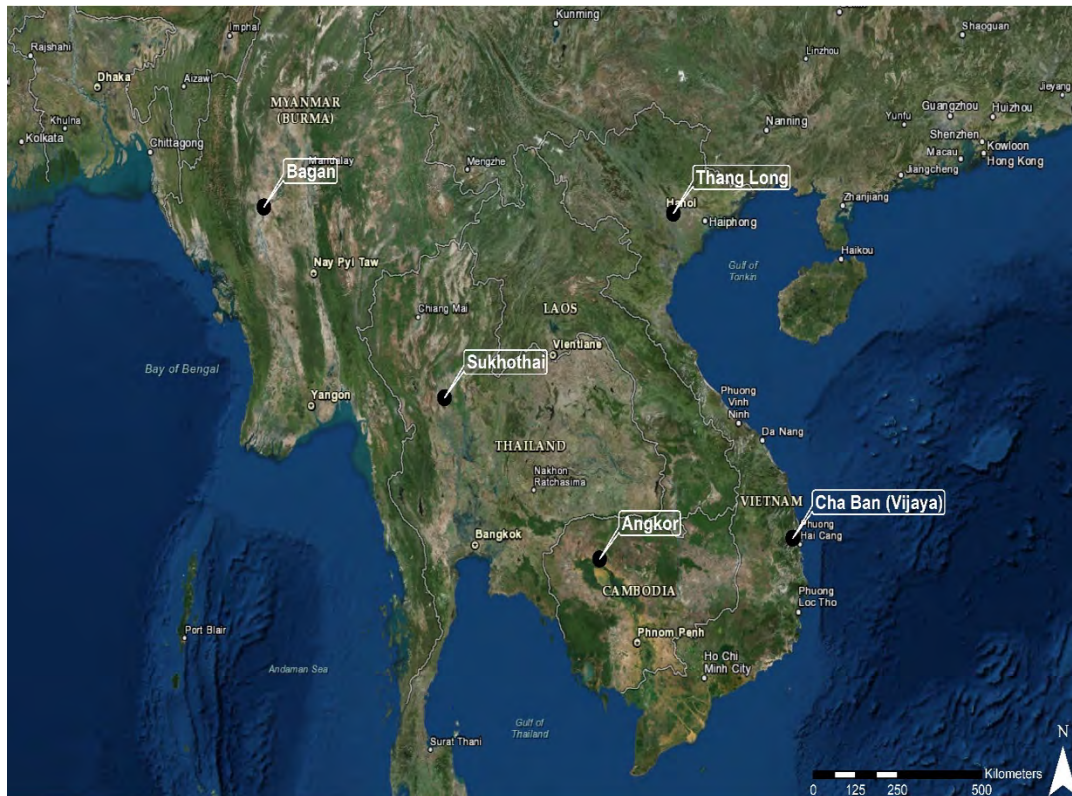


Fig 1. Location of Bagan and some of the other pre-industrial capitals of Southeast Asia. Source: Scott Macrae

Bagan was subject to a monsoonal rainfall regime, and like other early tropical state formations, it must have been challenged by periods of droughts and/or floods, some minor and short-lived, others major and multi-decadal. Indeed, contemporary communities in the region are frequently challenged by droughts, and severe famines have also been historically documented (Scott 1976:1). The low annual rainfall that characterizes Myanmar's dry-zone today (500-1000 mm per annum) has led some to presume that ancient Bagan was likely not particularly well suited for irrigation or wet-rice cultivation (Aung-Thwin 1990:8; Cooler 1997:22-23; c.f., Hudson 2004:45, 194). That said, during its florescence the city likely received more rainfall than at present (Hudson 2004:45; Lieberman 2003:101-112; Stadner 2013:12). This is because Bagan's era of growth and decline coincides with, and was undoubtedly influenced by, two significant climate changes: The Medieval Climate Anomaly (MCA; 900-1300 CE), marked by warmer conditions with increased rainfall, longer monsoon seasons, shorter dry season droughts, and rains more evenly distributed throughout the year – which were ideal conditions for agriculture – and the subsequent Little Ice Age (LIA; 1300-1570 CE), a cooling period that brought negative changes in both rainfall (i.e., droughts and severe storms) and temperature, and hence deteriorating agricultural conditions (Buckley et al. 2010, 2014; Cook et al. 2010; Lieberman 2003:103, 2009:330, 792, 2011:939; Lieberman and Buckley 2012:1052; Wohlfarth et al. 2016; Wündsche et al. 2014; Yamoah et al. 2017).

Given its dry-zone location, and the vagaries of its monsoonal climate (Lieberman 2011; Lieberman and Buckley 2012), one might expect that Bagan would have

developed sophisticated infrastructure to facilitate both the storage and redistribution of water (Hudson 2004:44). Such a complex water management system is, however, not readily apparent in the center's peri-urban (mixed urban-rural) zone (Cooler 1997:22), at least when compared to its regional contemporaries – such as the Khmer capital of Angkor (Kummu 2009) and the Sinhalese capitals of Anuradhapura and Polonnaruwa (Geekiyange and Pushpakumara 2013; Gilliland et al. 2013) – where exceptionally large reservoirs and extensive canal systems are found. Indeed, it has been suggested that – other than the Ayeyarwady River – access to water was likely an endemic issue at Bagan (Cooler 1997; Luce 1969:7). Does this mean that Bagan's citizens survived without the benefit of water management infrastructure? Not necessarily. Bagan's inscriptions and retrospective chronicles inform us that its kings augmented the city's water supply through the construction of wells, dams, canals, and brick or stone-lined holding tanks (Aung-Thwin 1985:63; Kan Hla 1977:22; Luce 1969:76, 84, 256; Pe Muang Tin and Luce 1923:65, 131; Scarborough 2003:62-63; Stargardt 1968:360-361). It is possible that these water management features may have simply silted up over time (Hudson 2004:2, 266). The dearth of such features may also reflect the fact that Bagan's water management system had a subtler character than those of its contemporaries (Moore et al. 2016:283; Win Kyaing 2016, 2018). Considered in unison, these observations imply that more detailed surface reconnaissance and remote sensing strategies are required to fully appreciate how the Bagan metropolis dealt with seasonal rainfall.

#### ***Water Management at Bagan: Investigation by the IRAW@Bagan Research Project***

The *IRAW@Bagan* project – which aims to generate an integrated socio-ecological history for residential patterning, agricultural practices, and water management at Bagan – initiated a more extensive analysis of the metropolis's water management system in May 2017 through visitations to known water management components, and by searching for additional features (e.g., ponds, wells, canals) using both remote sensing and surface reconnaissance (Figure 2). These activities included the preliminary examination and 3D-imaging of Nat Yekan tank (aka Spirit Lake), located atop the Thetso-Taung ridge, in the northern portion of the Tuyin mountain range (Figure 2). Situated 11 km southeast of the Bagan epicenter, the Tuyin mountain range rises roughly 140 m above the Bagan plain (240 m asl) and runs approximately 14 km NNW-SSE (Figure 3). Although it comprises a relatively narrow premonitory (ca. 1 km E-W at its base), the northern end of the range – Mount Tuyin proper – figures prominently in the chronicles of early Bagan, as it was one of five places around the city that a royal white elephant carrying a Buddha-tooth-relic kneeled, prompting King Anawrahta (1044-1077 CE) to build a stupa there, now known as the Tuyin-taung-zedi (Monument #2217; Figure 4; Hudson 2004:27; Pe Muang Tin and Luce 1923:91, 109, 119, 147, 158; Stadtner 2011:222, 230, 2013:43).



Fig 2. Google Earth image showing the location of Bagan’s walled epicenter (“Old Bagan”), its major water management features, the Nat Yekan sacred water tank, and the Mya Kan reservoir. Source: Gyles Iannone



Fig 3. The Tuyin mountain range as seen from the Bagan plain. Source: Gyles Iannone



Fig 4. The Tuyin-taung-zedi (Monument #2217) at the northern end of the Tuyin mountain range.  
Source: Gyles Iannone

The *IRAW@Bagan* research team was initially drawn to the Tuyin range because it constitutes the only significant upland area on the Bagan plain, and as such it was believed that it would have played a significant role in water management strategies at the city, especially because these would have been based on collecting and redistributing runoff from the monsoon showers (Win Kyaing 2016, 2018). Key here is the potential connection between the flow of runoff downslope, from the western side of the Tuyin range, towards the Mya Kan Reservoir (Figure 3; aka Emerald Lake or Kyanzitha Reservoir; Aung-Thwin 1990:28; Luce 1969:56; Moore et al. 2016:294-295). According to an inscribed pillar that once sat on its bank, this reservoir was built in the late 11<sup>th</sup> century by King Kyanzitha (1084-1113 CE), although Luce (1969:76, 345-346) notes that the retrospective chronicles erroneously attribute it to a later ruler, King Kyazwa (1235-1249 CE; see also Cooler 1997:29; Hudson 2004:28).

Intrigued by the role that the Tuyin range likely played in Bagan's broader water management system, we initiated reconnaissance, mapping, hydrological modeling, and excavations on the Thetso-Taung ridge in May 2018. Our excavation program focused on two relic water tanks situated roughly 700 m south of the Tuyin-taung-zedi (Figure 5), one located on the eastern side of the Thetso-Taung ridge – an embankment-style tank known as Ka Tak Kan (sacred garlic pear or temple tree [*Crateva religiosa*] lake) – the other being Nat Yekan, a rock-cut reservoir situated 60 m to the west, directly above the Mya Kan reservoir (Ni Tut 2013:166; see also Moore et al. 2016:295; Nyan Hlaing Lynn 2017; Win Kyaing 2018:283). Having been brought to scholarly attention only recently, Nat Yekan tank had yet to receive any

detailed investigation, although two “popular” publications had previously focused on this important water management feature (Ni Tut 2013 and Nyan Hlaing Lynn 2017; but see also Moore et al. 2016:295; Win Kyaing 2018:283). Our own investigations indicate that Nat Yekan tank was hewn directly from the sandstone substrate, although on its eastern side an 11 m long, 5 m high sandstone slab retaining wall was used to close off the reservoir (Figure 6). A smaller (2.7 m long) section of retaining wall was also used to close of the eastern corner of the north wall. The square tank is roughly 16 m x 16 m in size, and if filled to capacity it would have held as much as 2000 m<sup>3</sup> of water. Today, the tank only holds water on a seasonal basis (Figure 7).

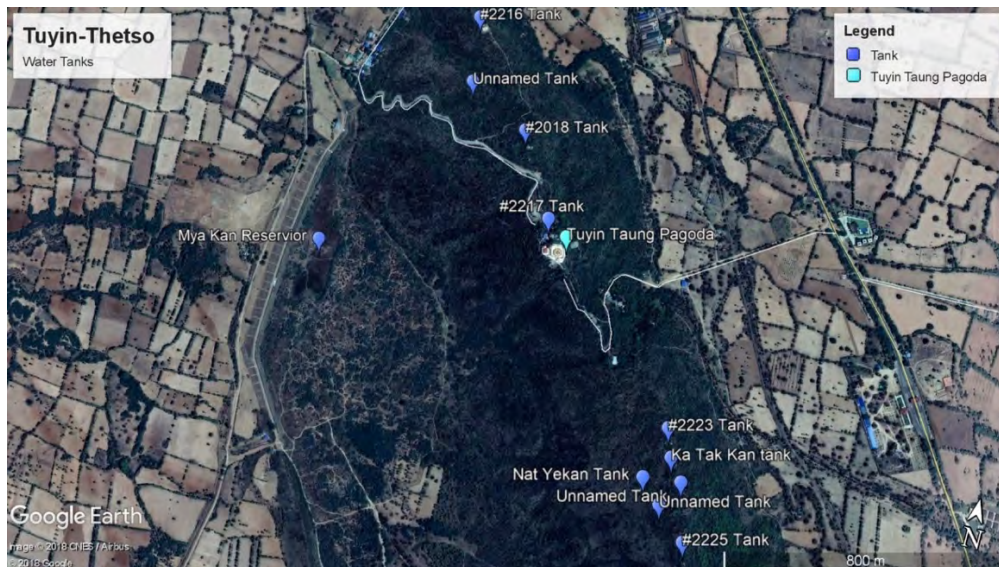


Fig 5. Google Earth map of the Tuyin-Thetso area showing the location of the Ka Tak Kan and Nat Yekan water tanks, along with other related features. Source: Gyles Iannone

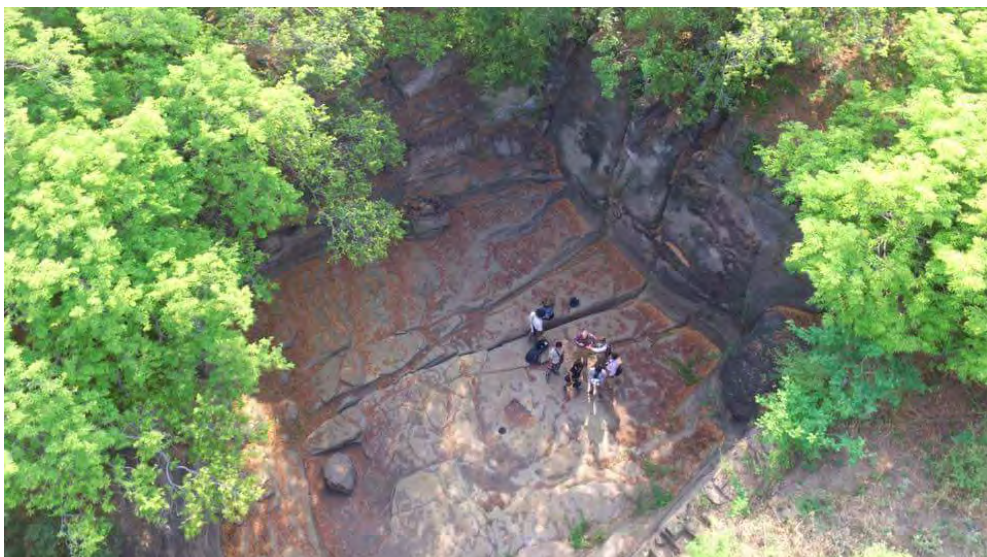


Fig 6. Drone photo of the Nat Yekan sacred water tank in May 2017 (note the carved stair in the foreground). Source: Saw Tun Lin





Fig 7. Pyiet Phyo Kyaw at the Nat Yekan sacred water tank in October 2013 (note the water labyrinth image and carved stair in the background). Source Pyiet Phyo Kyaw

### **A Socio-Ecological History for Nat Yekan Tank and its Water Management System**

Our 2018 excavations examined the area associated with the embankment wall in the northwest corner of Nat Yekan tank, and the central portion and northern embankment wall of the Ka Tak Kan tank (Figure 8). These investigations generated important insights into the basic engineering techniques associated with water tank construction at Classical Bagan. Unfortunately, our excavations did not produce significant quantities of ceramics – bulk lots were limited to small collections of weathered earthenware – and we did not encounter suitable materials for radiocarbon dating. For these reasons, our excavation results have been considered alongside the epigraphic and chronicle histories in our efforts to craft a socio-ecological history for both the Nat Yekan and Ka Tak Kan tanks, and the broader water management system of which they were part.



Fig 8. Excavations in Ka Tak Kan (upper right) and Nat Yekan (lower left) in May 2018. Source: Gyles Iannone

### ***Phase 1: The Late 11<sup>th</sup> Century Quarry Phase***

Nat Yekan saw its first usage as a quarry for sandstone slabs (Figure 9; Nyan Hlaing Lynn 2017; Win Kyaing 2016, 2018:283), and one or more of the three stairs leading into the tank may have been carved during this “quarry phase” to facilitate removal of these building materials (Figure 10). In terms of dating this quarrying activity, the retrospective chronicles relate that stone was quarried from Mount Tuyin to build the Shwe-zigon Pagoda (Monument #1; Figure 11; Pe Maung Tin and Luce 1923:109), which was commissioned by King Kyanzitha and completed in 1086 CE (Luce 1969:43, 77). This is one of only four major architectural features at Bagan constructed from sandstone, the others being the Nan-hpaya (Monument #1239) and Kyauk-ku-umin (Monument #154) temples, and the Mya Kan library (Monument #2241), the latter situated at the base of Mount Tuyin. Also noteworthy is a *Glass Palace Chronicle* entry that states that the Shwe-zigon quarrying activities on Mount Tuyin produced sandstone building blocks “three spans in length, one span in width” (Pe Maung Tin and Luce 1923:109). If the traditional *taung* measurement was used (a measurement from the thumb to the elbow; Moore and Win Maung 2018:124, 129), this would mean that the blocks were 45.72 cm wide and 137.16 cm long. The quarry scars exposed within Nat Yekan, and those found beneath its embankment wall during our 2018 excavations (Figure 12) roughly conform to the Taung width, although they vary in their length. In combination, this evidence provides some support for the idea that Nat Yekan was quarried out in the late 11<sup>th</sup> century as part of the Shwe-zigon construction program. Indeed, this massive pagoda would have called for a significant amount of stone, and Nat Yekan is the largest “quarry” site so far identified on the Tuyin range, other than the more informal quarry area located on the northwestern flanks of Mount Tuyin proper (Figure 13).



Fig 9. Northeastern stairway, symbolic stairway (crude stair), and sandstone “brick” wall enclosing the eastern side of Nat Yekan tank (note quarry scars in the lower left corner of the photo). Source: Gyles Iannone

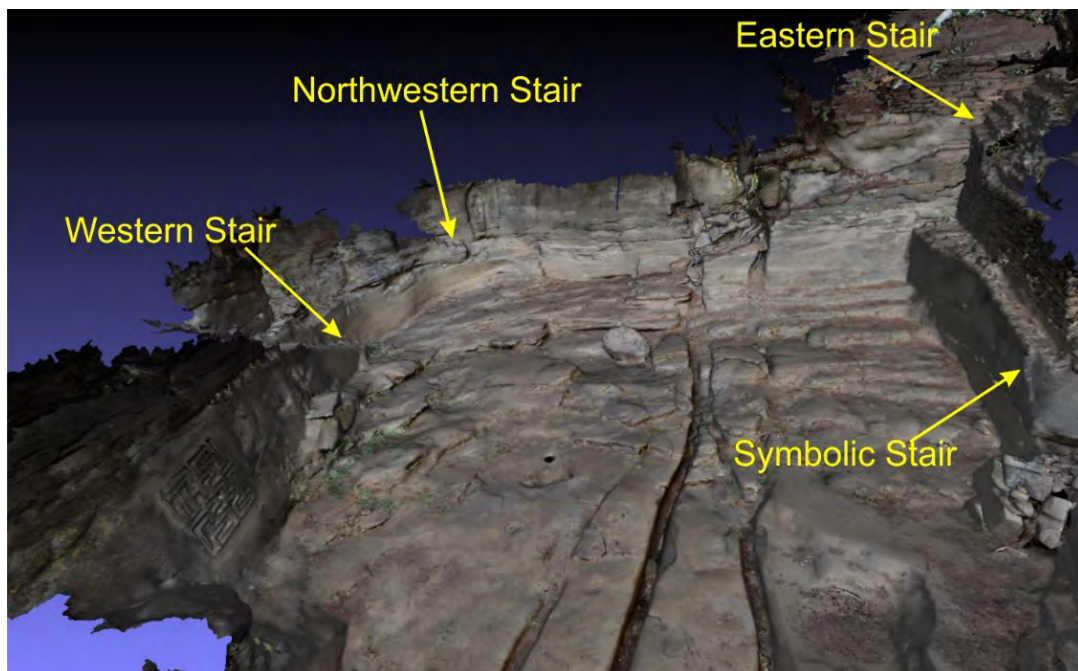


Fig 10. 3D image showing the location of Nat Yekan’s west, northwest, east, and “symbolic” (non-functional) stairs, facing north. Source: Gyles Iannone (3D image courtesy of Nyi Lynn Seck, *3xvivr Virtual Reality*).



Fig 11. The Shwe-zigon Pagoda (Monument #1), Bagan. Source: Gyles Iannone



Fig 12. Quarry scars exposed beneath the northwest embankment wall (forming an in-stepping channel “choke” feature on the left side of the image, and a constricted water channel on the right, both part of the tank’s spillway feature; photo taken facing south, into the Nat Yekan tank). Source: Gyles Iannone



Fig 13. Quarry area located at the northwest base of Mount Tuyin. Source: Gyles Iannone

### ***Phase 2: Late 11<sup>th</sup> – 14<sup>th</sup> Century Spillway Phase***

***The Reservoir.*** The transformation of Nat Yekan quarry into a reservoir with a spillway outlet involved the closing off of a large break in the natural sandstone wall on the east side of the quarry using a thick embankment wall faced with stacked sandstone slabs (Figure 9), and the laying down of a ca. 50 cm thick clay floor lining (the latter was removed during the 2009 cleaning conducted by the Tuyin Monastery and its local village supporters, although remnants of this lining have been identified within the wall and floor crevasses of the stone-cut tank, and a similar lining was exposed in the Ka Tak Kan tank [see Figure 14]). Given the highly compact nature and permeability characteristics of the clay lining, it can be confidentially stated that – as long as sufficient precipitation fell during the monsoon season and as long as the lining was in place and functioning properly – Nat Yekan was capable of retaining water year-round. At the time of its modification into a reservoir, its maximum water holding capacity was somewhere around 1200 m<sup>3</sup>.



Fig 14. Example of a clay floor lining and associated reservoir embankment wall in Ka Tak Kan tank.  
Source: Gyles Iannone

In terms of dating the transformation from a quarry to a reservoir, we feel that this occurred over a fairly short period of time, given that some of the quarry activities were also employed to create the spillway situated in the northwest corner of the tank (see Figure 12). The imprecisely dated Po-daw-mu hpaya inscription does document the donation of a sandstone lake on Thetso-Taung in 1082 CE (Michael Aung-Thwin, personal communication, October 10, 2018), but we cannot directly confirm that it is the Nat Yekan tank that is referred to in this historic record. Other data directly related to Nat Yekan does suggest that the quarry was transformed into a reservoir with a spillway in its northwest corner sometime in the very late 11<sup>th</sup> or early 12<sup>th</sup> century CE, including the application of a basic clay brick chronology outlined by Thet Oo and Maung Hlaing (2014:7; see also Aung Myint and Moore 1991-1992; Moore 2007:18, 2013:313; cf. Hudson 2004:123). Specifically, a large (35 cm long by 5 cm thick) 11<sup>th</sup> to early 12<sup>th</sup> century Early Bagan period (1044 to 1113 CE) brick was included in the cut-stone facing wall that had been used to close off the east side of the tank during its transformation into a reservoir (Figure 15). This brick adheres to the “average” brick size for Bagan suggested by Cooler (2018) to be 36 x 18 x 6 cm (cf. Moore and Win Maung 2018:129, 139). That the reservoir continued to be maintained into the 12<sup>th</sup> and 13<sup>th</sup> centuries is implied by the presence of a smaller brick (22 cm long by 6 cm thick) in the same section of the east wall dating to either the Middle (1113-1174 CE) or Late Bagan (1174-1300 CE) period (Figure 16). This use-life is corroborated by one of the rare iconographic elements found carved on the west wall of Nat Yekan tank – a water labyrinth – which is an image also depicted in a mural inside the early 12<sup>th</sup> century Loka-hteik-pan (#1580) Pagoda (1125 CE), and a similar water labyrinth occurs in the early 13<sup>th</sup> century (1223 CE) Le-myet-hna (Minnanthu, #447) Pagoda murals (Figure 17). These findings support the idea that although this iconographic element was used sparingly at Bagan, it was part of the

iconographic inventory used in the mural corpus during the “spillway phase,” when Nat Yekan is proposed to have served as a water tank that directed its overflow into the Mya Kan reservoir.



Fig 15. Early Bagan Period brick in the east wall of Nat Yekan tank. Source: Gyles Iannone



Fig 16. Middle or Late Bagan Period brick in the east wall of Nat Yekan tank. Source: Gyles Iannone



Fig 17. Left – water labyrinth image from Nat Yekan tank; Right – water labyrinth image from Le-myet-hna (Minnanthu) Pagoda (Monument #447), likely depicting Mahosadha-Jataka #546. Source: Gyles Iannone

*The Spillway.* Additional insights into the timing of the modifications that transformed the quarry into a reservoir come from the spillway outlet itself, a section of which was exposed during our 2018 excavations beneath Nat Yekan’s northwest embankment wall (Figure 12). Our investigations demonstrated that this area was first modified during the removal of hard sandstone slabs destined for construction projects on the Bagan plain, and possibly the mountain top itself. This quarrying not only formed the deep reservoir portion of the tank, and the three stairs leading down into it, but also the spillway. Specifically, the quarrying activities lowered the northwest corner of the tank’s bedrock embankment wall significantly compared to those encircling the rest of the tank, extending down to a layer of softer, laminated mudstone not suitable for building blocks, but still impermeable enough to maintain water flow. The natural south/southeast-to-north/northwest dip of this lower bedrock level would have enhanced the initial gravity-based outflow of water from the tank, thus forming the foundation of the spillway feature.

An exception to the aforementioned quarrying strategy was evident in the eastern side of our excavations, where an elevated section of the harder sandstone suitable for construction projects was preserved. The quarrying in this area formed an in-stepping “choke” feature that would have significantly constricted the width of the flow channel immediately preceding the spillway. In terms of open channel hydraulic engineering (Farrington 1980; Ortloff et al. 1982), the choke feature and spillway – in combination – would have maintained higher water levels and diminished flow velocity behind the spillway, increased the velocity of the water flow but decreased its depth immediately after the spillway (supercritical flow), and stimulated a subsequent “hydraulic jump,” resulting in higher water levels and decreased flow velocity downstream of the spillway (subcritical flow; e.g., Farrington 1980:287-301; Ortloff et al. 1982:582-594). Such engineering would have fostered low velocity flow, maintained critical water depths, and inhibited erosion (Ortloff et al. 1982:583) along a cobble-walled channel that funneled overflow water away from Nat Yekan, to the northwest, and ultimately, the Mya Kan reservoir. Continued use of this tried-and-true



method of gravity-driven, inertia-aided (Farrington 1980:294) aqueduct construction can be witnessed south of Bagan, in the Minbu rice-growing region (see Figure 18).



Fig 18. Contemporary choke and sluice gate along the aqueduct system at Minbu. Source: Gyles Iannone

The spillway interpretation is lent credence by an inscribed pillar (Mya Kan Inscription) and related *Glass Palace Chronicle* entry indicating that King Kyansittha “dammed” the Mya Kan reservoir (Emerald Lake) at the western base of Mount Tuyin “before 1098” CE (Duroiselle 1920:131-143; Luce 1969:76-77; see Table 9.2), and that the water for the Mya Kan reservoir fell from the nearby mountain, clearly referencing the western side of Tuyin-Thetso (Luce 1969:56, 345; Pe Maung Tin and Luce 1923:156; see Figures 19 and 20). The related chronicle entry specifically states that the King:

“dammed the water falling *from the foot of Mt. Tuywin* [Tuyin] and made a great lake. He filled it with the five kinds of lotus and caused all manner of birds, duck, sheldrake, crane, waterfowl, and ruddy goose to take their joy and pastime therein. Near the lake he laid out many *tā* of cultivated fields; it is said he ate [produced] three crops a year. Hard by the lake he built a pleasant royal lodge, and took delight in study seven times a day” (Luce 1969:345; Pe Muang Tin and Luce 1923:156; emphasis ours).

Our 2017-2018 reconnaissance demonstrated that Nat Yekan’s spillway feature is indeed connected to a seasonally dry water fall (Figure 20) situated on the western edge of Thetso-Taung summit via a water channel that is, at least partially, culturally modified. Our on-the-ground investigations also confirmed that water falling from this locale would have flowed directly into the Mya Kan reservoir via a channel that originates at the base of the water fall (Figure 21). We strongly believe that it is this water fall area that is being referenced in the *Glass Palace Chronicle* entry, and we therefore posit that the Nat Yekan reservoir that fed this water fall was likely

functioning coincidentally, or shortly after, the construction of the Mya Kan reservoir, in and around 1098 CE.

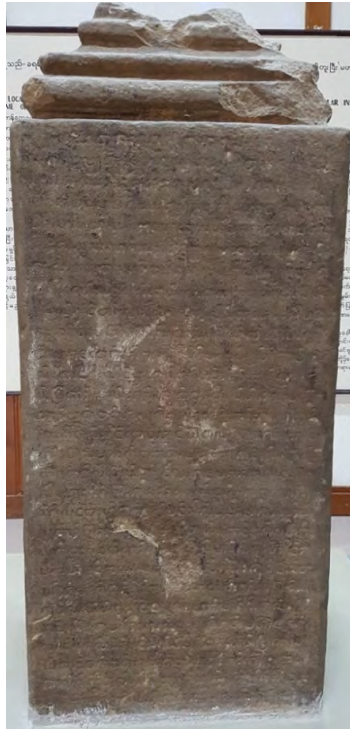


Fig 19. The Mya Kan Inscription. Source: Gyles Iannone



Fig 20. The seasonally dry Thetso-Taung waterfall, (the white spot in the upper center of the picture), with the Mya Kan Reservoir in the foreground (Nat Yekan Tank is located on the ridge in the upper right corner of the image). Source: Gyles Iannone



Fig 21. Drainage channel at the base of the Thetso-Taung waterfall, to the southeast of the Mya Kan reservoir. Source: Gyles Iannone

*The Tank Interior.* Other features of Nat Yekan also speak to its broader function, beyond that of simply water collection. A round hole, ca 20 cm in diameter, is carved into the very center of the tank (Figure 22). This depression likely held a pillar that served as a water depth measuring device, as is seen in some nearby village and pagoda water tanks today (Figures 23 and 24). Such pillars are often topped with carved lotus buds, a symbol that is connected to purity, fertility, and prosperity in the Buddhist belief system (Ward 1952). More specifically, the lotus symbolizes “creation out of water” (Ward 1952:138; Wolters 1999:81). That such a “lotus bud pillar” was once positioned in the center of Nat Yekan tank is leant support by the discovery in 2018 of one half of a stone pillar support with a cavity precisely the same size as the hole in the bottom of the tank (Figure 25).



Fig 22. A hand-cut round hole in the center of the Nat Yekan tank which was possibly used to hold a “lotus pillar” that was symbolic of fertility and useful for gauging water levels. Source: Gyles Iannone



Fig 23. Lotus pillar in the center of the water tank at the Dhamma-yazika Pagoda (Monument #947).  
Source: Gyles Iannone



Fig 24. Lotus pillar in the center of the water tank at Minnanthu Village, the tank being seasonally dry. Source: Gyles Iannone



Fig 25. Half of a pillar support discovered in Nat Yekan during the 2018 field season. Source: Gyles Iannone

As noted previously, Nat Yekan tank also contains three flights of carved stairs, one on the west wall (running from south to north), one in the northwest corner (running roughly southwest to northeast), and one in the northeast corner of the tank (running east to west; see Figure 10). Each of these stairways descends into the tank to a different level. A fourth set of steps was carved into the east wall – below the stone-slab retaining wall – but these are likely symbolic, as they are far too small for actual use (Figure 26). The multiple stairways leading down into the Nat Yekan tank are reminiscent of the intricate stairway systems associated with the stepwells (*baoli*) of Medieval India. These stepwells were long used to provide potable water and to contend with drought conditions, in addition to offering space for leisure, social gatherings, and ritual practices (Bhattacharya 2015:36; Shubhangi and Shireesh 2015). Significantly, Indian stepwells “were often carved profusely with elaborate detail” (Bhattacharya 2015:36), and they were frequently associated with temples (Shubhangi and Shireesh 2015:29). Studies of the Indian stepwells indicate that they vary considerably in terms of their “size and form types, scales, access and use and the potentiality they have” (Shubhangi and Shireesh 2015:32).



Fig 26. Symbolic (non-functional) stair carved into the sandstone bedrock of the east wall. Source: Gyles Iannone

*Iconography.* A number of iconographic images are also carved into Nat Yekan's walls (Ni Tut 2013; Nyan Hlaing Lynn 2017; Win Kyaing 2018:283). These include: 1) a water labyrinth – likely representing the water tank “with a thousand bends in the bank and a hundred bathing places” in the Mahosadha-Jataka #546 (Luce 1956:294, 301) – a water lizard or “water dragon,” a Naga-serpent, two hamsa birds (possibly the Ruddy Shelduck, a goose that migrates from the Himalayas, through India, and into Myanmar; Stadtner 2011:134), a large fish, and a possible third goose, all facing south, and all found in association with the stair carved into the west wall (Figure 27); 2) a Naga-Buddha or Buddha-Muchalinda image situated in a niche – representing the story of the Naga King using his hood and tail to protect the meditating Buddha from a rain storm in the 6<sup>th</sup> week following his enlightenment (Fisher 1993:23, 175; Leidy 2008:170; Luce 1969:171; Moore 2007:244; Stadner 2013:34; Ward 1952:144) – and a crocodile or Makara (water monster), both found in the northwest corner of the tank (Figure 28); and, 3) an egret or crane, three tortoises, and two small fish facing each other, all carved into the tank's southern wall (Figure 29). Water imagery is clearly evident in all of these depictions, not only in basic biological terms, but also with respect to the association that these symbols have with water in the Jataka Stories of the Buddha's previous lives, and in the life of Gautama Buddha himself. Many are also tied to notions of purity, fertility, prosperity, and power within the Buddhist belief system (e.g., Beer 2003:5, 69, 72, 77, 97; Fisher 1993:23; Ward 1952:144-146). Considered in unison, this iconography suggests that, although it undoubtedly served as a source of potable water for both monks and construction crews (Moore et al. 2016:295), broader symbolic meaning is also inherent in Nat Yekan tank. The question remains, to what purpose was such symbolism aimed?

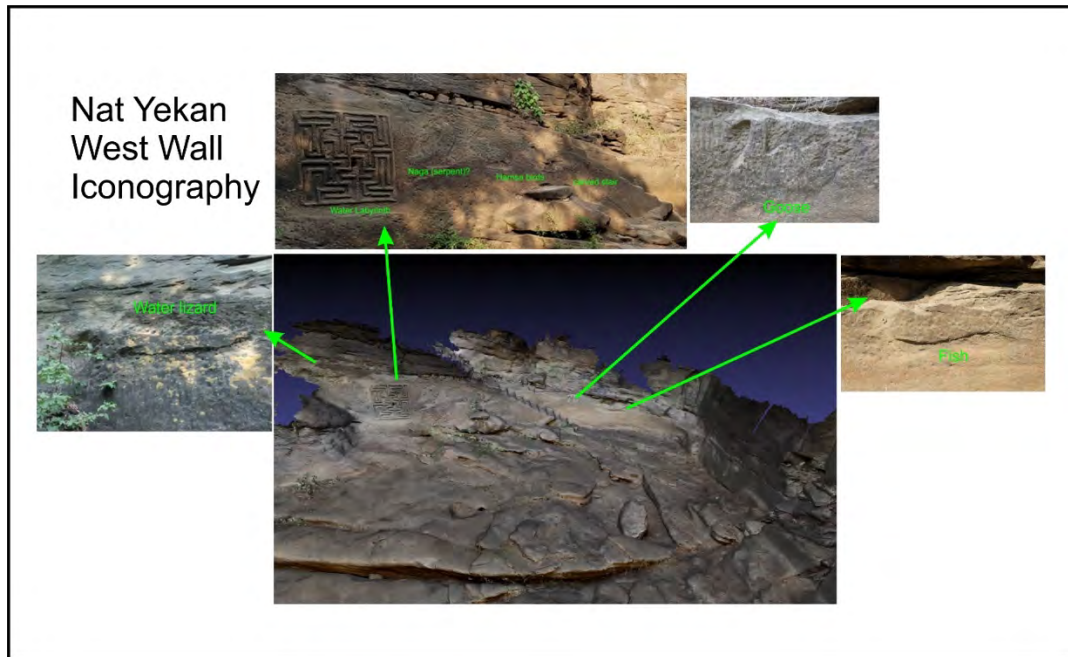


Fig 27. Iconography associated with Nat Yekan’s west wall. Source: Gyles Iannone

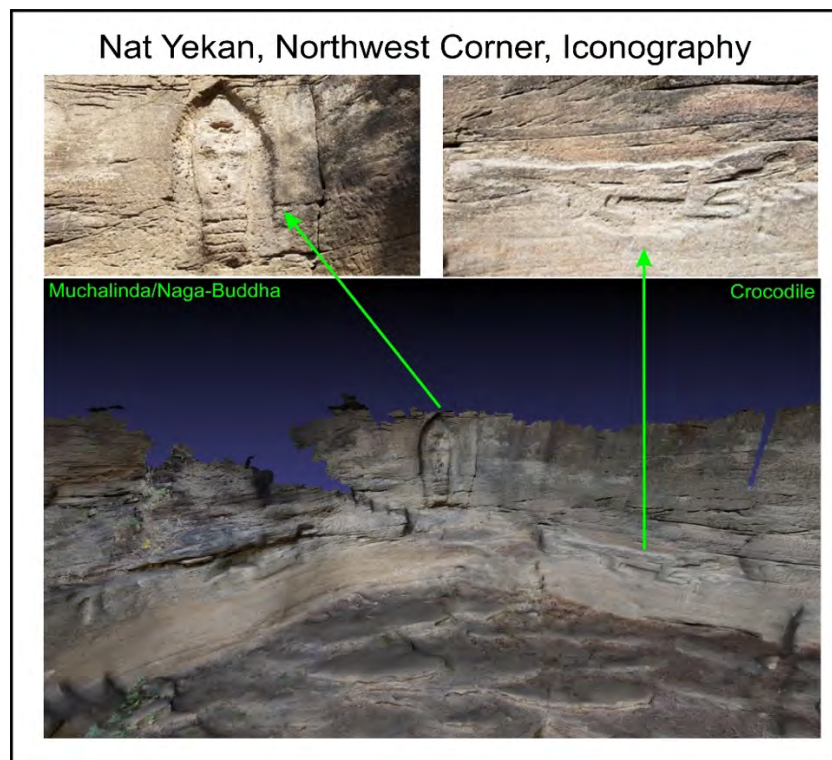


Fig 28. Iconography associated with Nat Yekan’s northwest corner. Source: Gyles Iannone

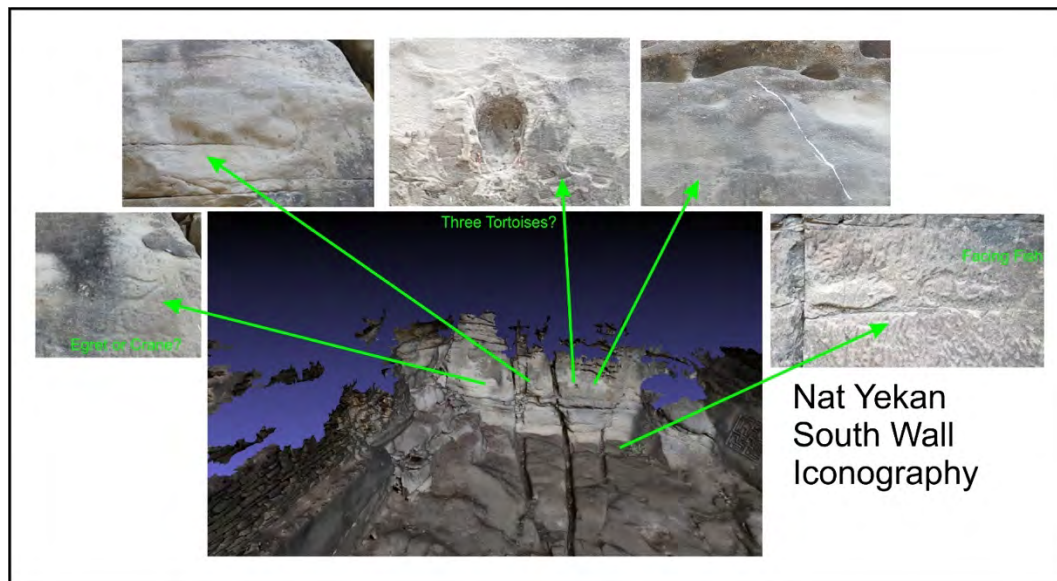


Fig 29. Iconography associated with Nat Yekan's south wall. Source: Gyles Iannone

*Ideology:* One final feature of Nat Yekan provides a clue to the tank's broader significance. As part of the creation of the spillway feature, the northwest corner of the tank's natural sandstone enclosure wall was purposely cut down by roughly 1-1.5 m, in a clearly symmetrically manner (Figure 30). Intriguingly, the very center of this lower portion of the tank's rock-cut wall – which is roughly 8 m in length – articulates precisely with the top of the carved niche containing the Naga-Buddha image, and it is also axially aligned with the most western inside face of the in-stepped choke feature that constricted the flow channel immediately preceding the spillway. Also noteworthy is the fact that the northwest stair begins its descent into the tank at exactly the same elevation as the down-cut portion of the enclosure wall and terminates at an altar feature at the base of the Muchalinda image. In other words, the lower portion of the tank's rock-cut enclosure wall, the northwest stairway, the altar, the Naga-Buddha image, and the spillway were unquestionably all used at the same time, and they were also symmetrically arranged. We therefore suggest that the northwest portion of Nat Yekan tank initially served as a rock-cut spillway that directed overflowing water across the top of the Naga-Buddha image and out of the tank, where it was channeled downslope, into the catchment zone of the Mya Kan Reservoir. This flow pattern, we believe, was aimed at sanctifying the water as it flowed out of the tank, thus tying this life-giving substance, the water tank, and the mountain itself, to notions of purity, fertility, prosperity, and power (e.g., Beer 2003:5, 69, 72, 77, 97; Fisher 1993:23). In other words, we propose that Nat Yekan served as the physical and spiritual apex of Bagan's broader water management system.





Fig 30. Imagery/modifications in the Northwest corner of Nat Yekan. Source: Gyles Iannone

*The Water Management System.* But what of the system that Nat Yekan was presumably part? Our archaeological reconnaissance identified a complex set of water management features that encompass the entirety of the Thetso-Taung ridge (Figure 31). Our findings confirm that Classical engineers used the natural topography, in conjunction with a series of channels, terraces, and tanks, to effectively collect and redistribute water derived entirely from rainfall. Nat Yekan tank was a key node in this water management system, and it functioned as the terminal collection and distribution point that fed the expansive Mya Kan Reservoir situated at the base of the Tuyin-Thetso uplands, to the west (Figure 36; Aung-Thwin 1990:28; Luce 1969:56). Water entered the Nat Yekan tank through two primary rock-cut and stone-lined channels. One channel ran along the western side of the Thetso-Taung ridge, starting from a small collection tank at the base of Monument #2225, eventually discharging into the southwestern corner of Nat Yekan. Two additional collection tanks were located along the northward path of this channel, and these served to collect additional water and to divert it into Nat Yekan's southern feeder system. A second channel fed water from a smaller reservoir on the eastern side the Thetso-Taung ridge, from the southeast to the northwest, where it discharged into the southeast corner of Nat Yekan tank. The creation of this intricate water management system was likely aimed at taking advantage of the beneficial precipitation regime associated with the Medieval Climate Anomaly (MCA; 900-1300 CE).

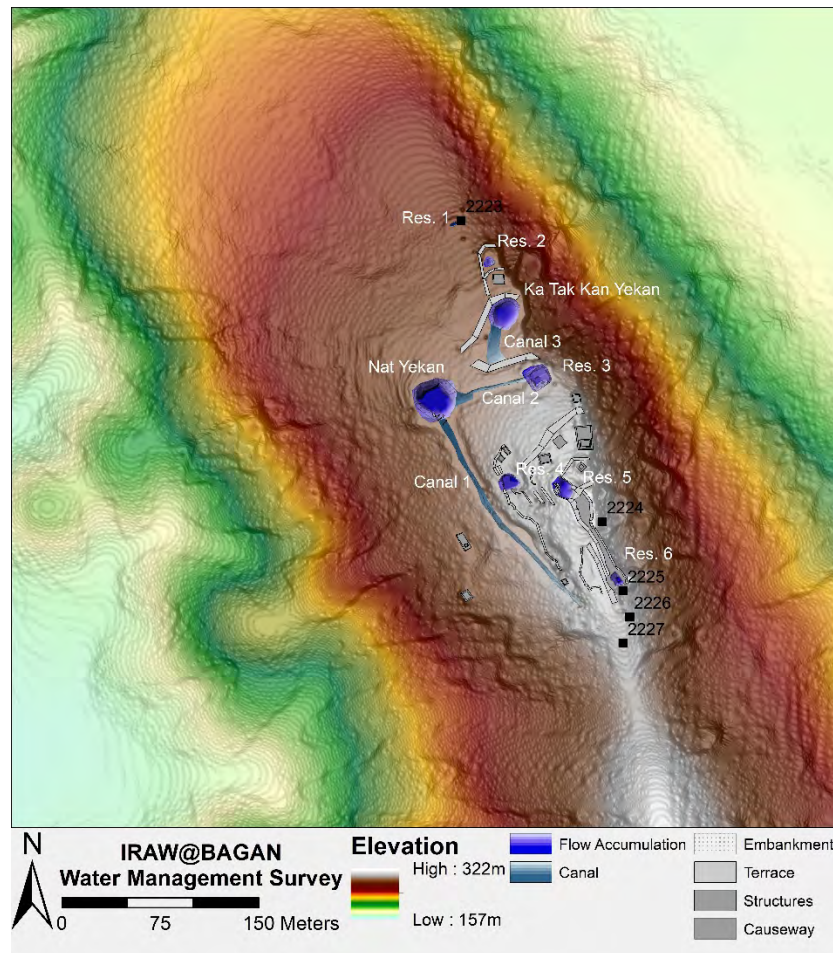


Fig 31. Major components of the Thetso-Taung water management system. Source: Scott Macrae

*Religion.* A series of religious structures, including a number of small temples – some with associated inscription houses and/or small shrines containing Buddha statues – were also established on Thetso-Taung during the spillway phase, including Monuments 2223, 2224, and 2225 (Pichard 2001:202-209; see Figures 31 and 32). Most of these are believed to have been constructed in the 13<sup>th</sup> century, and many have been renovated in more recent times. Significantly, two of these monuments, #s 2223 and 2225, are associated with small rock-cut water tanks (Figure 33). This physically connects them with water storage, and symbolically ties them – at least to some degree – to water-related rituals and broader notions of fertility and prosperity. Intriguingly, not only is Monument 2225 physically connected to a rock-cut tank that serves as the initial collection node in Thetso-Taung’s wider water management system, its building façade incorporates a depiction of the head of a water-serpent, or makara (Figure 34). Although this façade was likely added to the temple in recent times, it is a poignant reminder of the symbolic connection between Thetso-Taung and water-related activities, of both the secular and sacred variety.

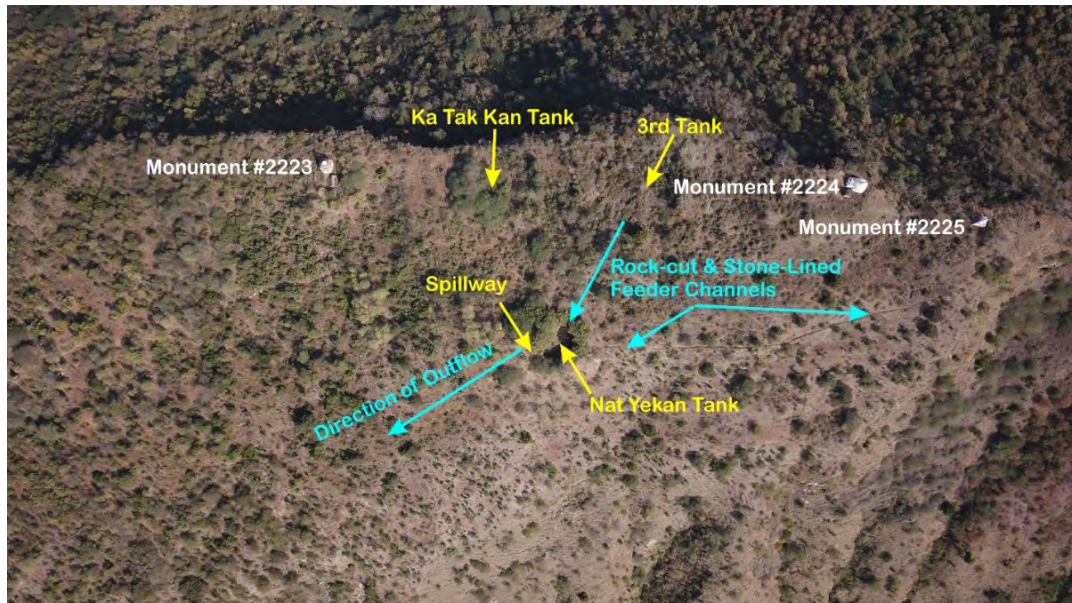


Fig 32. Google earth image of the Thetso-Taung water management system. Source: Gyles Iannone



Fig 33. Rock-cut tank associated with Monument #2225. Source: Gyles Iannone



Fig 34. Makara or water-serpent image (note the protruding mouth and nose/nostrils) associated with the façade of Monument #2225. Source: Gyles Iannone

### ***Phase 3: 14<sup>th</sup> Century Embankment Phase***

Our 2018 excavations above the spillway in the northwest corner of Nat Yekan tank indicate that this water outlet was eventually covered by an embankment engineered to retain water (Figure 35; it remains unclear whether the rest of the tank saw additional embankment work at this time). This would have increased the holding capacity of the tank from 1200 to 2000 m<sup>3</sup> of water. We believe that this modification was carried out in the early 14<sup>th</sup> century, coinciding with the onset of the Little Ice Age (LIA) climate regime (1300-1570 CE), with its marked decline in precipitation and frequent droughts. We surmise that it was a combination of factors that contributed to the decision to modify Nat Yekan into a more traditional water collection and storage feature: 1) the drier climate regime may have stimulated a desire to retain as much water on top of the Thetso-Taung ridge as possible, in order to meet the needs of the monasteries, monks, temple personnel, and pilgrims that frequented this place; 2) the breakdown of Bagan's overarching political and economic systems may have also diminished the Crown's ability to maintain the large-scale, tightly integrated, water management system that had manifest during times of plenty; and, 3) the general trend towards decentralization may have fostered more localized control of resources of all kinds, including water, resulting in the disarticulation of state infrastructure and concomitant efforts to enhance village-level autonomy and resilience, all at the expense of the Crown (this is a common response to significant climate perturbances). We suspect that Ka Tak Kan, the fully embanked water tank on the east side of the Thetso-Taung ridge – which is not fully integrated into the rest of the Nat Yekan water management system – was likely also built at this time to enhance the water collection and storage capacity of the Thetso-Taung ridge (see Figures 31 and 32).



Fig 35. Excavations into the reservoir embankment wall in the northwest corner of Nat Yekan tank.  
Source: Gyles Iannone

### Discussion and Conclusions

In summary, we propose that Nat Yekan was not simply a collection node within Bagan's broader water management system. Rather, during the spillway phase this reservoir appears to have been integral not only to the initial collection and subsequent redistribution of water across the Bagan plain via a series of interconnected canals and reservoirs, but also, through its associated iconographic imagery, it may have been intended to symbolically purify this water, enhancing its fertility prior to its flowing downslope, into the city's peri-urban zone. Indeed, we believe that Nat Yekan's iconographic elements served a similar purpose as the imagery found in association with the intricately carved river beds along the Stung Kbal Spean River in the Kulen Hills, northeast of the Khmer city of Angkor (Figure 36). Here, water was made to flow over and around a series of Shaivite symbols (Boulbet 1979; Chevance 2005; Feneley et al. 2016:282-284; Hendrickson 2011:451; Jacques and Dumont 1999; Tan 2014:3), many of which – such as carved linga – are clearly tied to notions of fertility (Tawa 2001:134). These symbolically charged water management nodes, and the extensive water storage and redistribution system of which they were part, celebrated the Angkor king's role as guarantor of prosperity for the Khmer kingdom (Tawa 2001:141). Similar Hindu iconography is also associated with the river bed at the Sahasralinga pilgrimage site on the Shalmala River, in the Indian state of Karnataka. Apparently, iconographic embellishments to river beds and stone-cut tanks was a common means through which water was transformed into a more sacred, and ideologically vital, substance in the pre-industrial states of monsoonal South and Southeast Asia. This may explain why the iconography of Kbal Spean and Nat Yekan overlaps in some significant ways, including the use of similar Naga-serpent themes (Figure 37) and crocodile images (Figure 38), even though the Khmer symbolism references Hindu beliefs, and the Burmese context favors Buddhist principles.



Fig 36. The carved river bed at Kbal Spean, Phnom Kulen, Cambodia (note the abundance of yoni and linga). Source: Gyles Iannone



Fig 37. Left – Kbal Spean iconography depicting Vishnu resting on Ananta (Sesha), both floating on the cosmic ocean at the time of creation; Right – Nat Yekan iconography depicting the Naga King using his hood and tail to protect the meditating Buddha from a rain storm. Source: Gyles Iannone



Fig 38. Crocodile images at Kbal Spean (left) and Nat Yekan (right). Source: Gyles Iannone

The integral relationship between water management and ritual practice – and the broader implications this relationship has for the development of state ideologies, the characteristics of political organizations, and the nature of societal inequalities – has been demonstrated throughout the world’s monsoonal regions (e.g., Boomgaard 2007:15; Lansing 1991; Scarborough and Lucero 2010; Scarborough 2003:84, 88). Across Southeast Asia, iconographic imagery has long been employed to reaffirm the ideological connection between water and ritual (Boomgaard 2007:6). As has been underscored by Barbara Andaya (2016:243): “For Southeast Asian societies generally, ritual water was highly valued because of its life-giving, healing, and transformative properties. Together with the appropriate ceremonial, the very act of pouring water over a tangible emblem of fertility (like an upright linga) could ensure the community’s well-being.” Similarly, Bob Hudson (2004:209) underscores that: “Buddhist cosmology and practice are bound up with the ritual pouring of water, reflecting the story of how Buddha, at the moment of his enlightenment, was able to call on the water he had poured in previous lives to witness his good deeds to come back and wash away the forces of evil.” We surmise that at Bagan, similar ideological principals underpinned the basic construction and symbolic embellishment of the Nat Yekan “sacred water tank.” This would also imply that the Tuyin-Thetso uplands are an example of what Vernon Scarborough (1998) has referred to as “water mountains”: specialized ritual and economic nodes that enhance basic lifeways, socio-political integration, and agricultural production through the collection, sanctification, and redistribution of water, often under the auspices and patronage of societal elites (Scarborough 2003:84).

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## References

- Andaya, B (2016) Rivers, Oceans, and Spirits: Water Cosmologies, Gender, and Religious Change in Southeast Asia. *Trans-Regional and -National Studies of Southeast Asia* 4(2): 239–263. [Crossref](#)
- Aung Myint and Moore, EH (1991-1992) *Finger-Marked Designs on Ancient Bricks in Myanmar*. London: School for Oriental and African Studies, University of London. [Google Scholar search](#)
- Aung-Thwin, M (1985) *Pagan: The Origins of Modern Burma*. Honolulu: University of Hawaii Press. [Google Scholar search](#)
- Aung-Thwin, M (1987) Heaven, Earth, and the Supernatural World: Dimensions of the Exemplary Center in Burmese History. In: B Smith and H Baker (eds) *The City as Sacred Center: Essays on Six Asian Contexts*. New York: E. J. Brill, 88-102. [Google Scholar search](#)
- Aung-Thwin, M (1990) Irrigation in the Heartland of Burma: Foundations of the Pre-Colonial Burmese State. Occasional Paper No. 15. DeKalb: Center for Southeast Asian Studies Monograph, Northern Illinois University. [Google Scholar search](#)
- Aung-Thwin, M, and Aung-Thwin, M (2012) *A History of Myanmar Since Ancient Times: Traditions and Transformations*. London: Reaktion Books. [Google Scholar search](#)
- Beer, R (2003) *The Handbook of Tibetan Buddhist Symbols*. Boulder: Shambhala. [Google Scholar search](#)
- Bhattacharya, S (2015) Traditional Water Harvesting Structures and Sustainable Water Management in India: A Socio-hydrological Review. *International Letters of Natural Sciences* 37: 30-38. [Crossref](#)
- Boomgaard, P (2007) In a State of Flux: Water as a Deadly and a Life-Giving Force in Southeast Asia. In: P Boomgaard (ed.) *A World of Water: Rain, Rivers and Seas in Southeast Asian Histories*. Leiden: KITLV Press, 1-23. [Crossref](#)
- Boulbet, J (1979) *Le Phnom Kulen et sa Region*. Paris: Ecole Franchise d'Extreme Orient. [Google Scholar search](#)
- Buckley, BM, Anchukaitis, KJ, Penny, D, Fletcher, R, Cook, ER, Sano, M, Nam, LC, Wichienkeo, A, Minh, TT, and Hong, TM (2010) Climate as a Contributing Factor in the Demise of Angkor, Cambodia. *Proceedings of the National Academy of Sciences* 107(15): 6748-6752. [Crossref](#)
- Buckley, BM, Fletcher, R, Wang, S-YS, Zottoli, B, and Pottier, C (2014) Monsoon Extremes and Society Over the Past Millennium on Mainland Southeast Asia. *Quaternary Science Reviews* 95: 1-19. [Crossref](#)
- Chevance, J-B, (2005) *L'Architecture et le Décor des Temples du Phnom Kulen Cambodge*. PhD Thesis, University Paris III Sorbonne, Paris. [Google Scholar search](#)
- Cook, ER, Anchukaitis, KJ, Buckley, BM, D'Arrigo, RD, Jacoby, GC, and Wright, WE (2010) Asian Monsoon Failure and Megadrought During the Last Millennium. *Science* 328: 486-489. [Crossref](#)
- Cooler, RM (1997) Sacred Buildings for an Arid Climate: Architectural Evidence for Low Rainfall in Ancient Pagan. *Journal of Burma Studies* 1: 19-44. [Crossref](#)
- Cooler, RM (2018) *The Art and Culture of Burma*. Online Study Guide. Electronic document, book. Available at: [http://seasite.niu.edu/burmese/Cooler/BurmaArt\\_TOC.htm](http://seasite.niu.edu/burmese/Cooler/BurmaArt_TOC.htm) (accessed 1 July 2018).



- Daw Thin Kyi (1966) The Old City of Pagan. *Artibus Asiae. Supplementum* 23: 179-188. [Crossref](#)
- Duroiselle, C (ed.) (1920) *Epigraphia Birmanica Being Lithic and Other Inscriptions of Burma: Volume I Part II*. Rangoon: Archaeological Survey of Burma. [Google Scholar search](#)
- Farrington, IS (1980) The Archaeology of Irrigation Canals, with Special Reference to Peru. *World Archaeology* 11(3): 287-305. [Crossref](#)
- Feneley, M, Penny, D, and Fletcher, R (2016) Claiming the Hydraulic Network of Angkor With Viṣṇu: A Multidisciplinary Approach Including the Analysis of Archaeological Remains, Digital Modelling and Radiocarbon Dating: With Evidence for A 12th Century Renovation of The West Mebon. *Journal of Archaeological Science: Reports* 9: 275-292. [Crossref](#)
- Fisher, RE (1993) *Buddhist Art and Architecture*. London: Thames and Hudson. [Google Scholar search](#)
- Galloway, CK (2006) *Burmese Buddhist Imagery of the Early Bagan Period (1044-1113)*. PhD Thesis, Australian National University, Canberra. [Google Scholar search](#)
- Geekiyange, N, and Pushpakumara, DKN (2013) Ecology of Ancient Tank Cascade Systems in Island Sri Lanka. *Journal of Marine and Island Cultures* 2: 93-101. [Crossref](#)
- Gilliland, K, Simpson, IA, Adderly, WP, Burbige, CI, Cresswell, AJ, Sanderson, DCW, Conningham, RAE, Manuel, M, Strickland, K, Gunawarhana, P, and Adikari, G (2013) The Dry Tank: Development and Disuse of Water Management Infrastructure in the Anuradhapura Hinterland, Sri Lanka. *Journal of Archaeological Science* 40: 1012-1028. [Crossref](#)
- Hendrickson, M (2011) A Transport Geographic Perspective on Travel and Communication in Angkorian Southeast Asia (Ninth to Fifteenth Centuries AD). *World Archaeology* 43(3): 444-457. [Crossref](#)
- Higham, CFW (2001) Commentary: Archaeology in Myanmar: Past, Present, and Future. *Asian Perspectives* 40(1): 127-138. [Crossref](#)
- Hudson, B (2004) *The Origins of Bagan: The Archaeological Landscape of Upper Burma to AD 1300*. PhD Thesis, University of Sydney, Sydney. [Google Scholar search](#)
- Hudson, B (2008) Restoration and Reconstruction of Monuments at Bagan (Pagan), Myanmar (Burma), 1995-2008. *World Archaeology* 40(4): 553-571. [Crossref](#)
- Hudson, B, Lwin Nyein, and Win Maung (Tanpawady) (2001) The Origins of Bagan: New Dates and Old Inhabitants. *Asian Perspectives* 40(1): 48-74. [Crossref](#)
- Jacques, C, and Dumont, R (1999) *Angkor*. Cologne: Konemann. [Google Scholar search](#)
- Kan Hla (1977) Pagan: Development and Town Planning. *Journal of the Society of Architectural Historians* 36(1): 15-29. [Google Scholar search](#)
- Kummu, M (2009) Water Management in Angkor: Human Impacts on Hydrology and Sediment Transportation. *Journal of Environmental Management* 90: 1413-1421. [Crossref](#)
- Lansing, JS (1991) *Priests and Programmers: Technologies of Power in the Engineered Landscape of Bali*. Princeton: Princeton University Press. [Google Scholar search](#)
- Leidy, DP (2008) *The Art of Buddhism: An Introduction to its History and Meaning*. Shambhala, Boston. [Google Scholar search](#)

- Lieberman, VB (2003) *Strange Parallels: Southeast Asia in Global Context, c. 800-1830 (Volume 1: Integration on the Mainland)*. Cambridge: Cambridge University Press. [Google Scholar search](#)
- Lieberman, VB (2009) *Strange Parallels – Southeast Asia in Global Context, c. 800-1300 (Volume 2: Mainland Mirrors: Europe, Japan, China, South Asia, and the Island)*. Cambridge: Cambridge University Press. [Google Scholar search](#)
- Lieberman, VB (2011) Charter State Collapse in Southeast Asia, ca. 1250–1400, as a Problem in Regional and World History. *The American Historical Review* 116(4): 937-963. [Crossref](#)
- Lieberman, VB and Buckley, BM (2012) The Impact of Climate on Southeast Asia, circa 950-1820: New Findings. *Modern Asian Studies* 46(5): 1049–1096. [Crossref](#)
- Luce, GH (1956) The 550 Jatakas in Old Burma. *Artibus Asiae* 19(3/4): 291-307. [Crossref](#)
- Luce, GH (1969) *Old Burma: Early Bagan*. New York: Artibus Asiae and the Institute of Fine Arts. [Google Scholar search](#)
- Moore, EH (2007) *Early Landscapes of Myanmar*. Bangkok: River Books. [Google Scholar search](#)
- Moore, EH (2013) The Sacred Geography of Dawei: Buddhism In Peninsular Myanmar (Burma). *Contemporary Buddhism: An Interdisciplinary Journal* 14(2): 298-319. [Crossref](#)
- Moore, EH, U San Win, and Pyiet Phyo Kyaw (2016) Water Management in the Urban Cultural Heritage of Myanmar. *Trans-Regional and -National Studies of Southeast Asia* 4(2): 283–305. [Crossref](#)
- Moore, EH and Win Maung (Tampawaddy) (2018) Ta Mok Shwe-Gu-Gyi Temple Kyaukse and Bagan. In: Goh Geok Yian, JN Miksic and M Aung-Thwin (eds) *Bagan and the World: Early Myanmar and its Global Connections*. Singapore: ISEAS Publishing, 127-152. [Google Scholar search](#)
- Ni Tut (translated by Nyien Chan Soe) (2013) Thetso Taung. Yangon: *Yadanabon Annual Magazine*. [Google Scholar search](#)
- Nyan Hlaing Lynn (2017) A Forgotten Heritage Site Near Bagan. *Frontier Magazine*. Available at: <https://frontiermyanmar.net/en/a-forgotten-heritage-site-near-bagan> (accessed 10 October 2018)
- Nyunt Nyunt Shwe (2011) The Social Life of Bagan Period. *Dagon University Research Journal* 3: 25-31. [Google Scholar search](#)
- Ortloff, CR, Moseley, ME and Feldman, RA (1982) Hydraulic Engineering Aspects of the Chimu Chicama-Moche Intervalley Canal. *American Antiquity* 47: 572-595. [Crossref](#)
- Pe Muang Tin and Luce GH (1923) *The Glass Palace Chronicle of the Kings of Burma*. London: Oxford University Press. [Google Scholar search](#)
- Pichard, P (2001) *Inventory of Monuments at Pagan, Volume 8*. Paris: UNESCO. [Google Scholar search](#)
- Scarborough, VL (1998) Ecology and Ritual: Water Management and the Maya. *Latin American Antiquity* 9(2): 135-159. [Crossref](#)
- Scarborough, VL (2003) *The Flow of Power: Ancient Water Systems and Landscapes*. Santa Fe: SAR Press. [Google Scholar search](#)
- Scarborough, VL and Lucero, LJ (2010) The Non-Hierarchical Development of Complexity in The Semitropics: Water and Cooperation. *Water History* 2(2): 185–205. [Crossref](#)

- Scott, JC (1976) *The Moral Economy of the Peasant: Rebellion and Subsistence in Southeast Asia*. New Haven: Yale University Press. [Google Scholar search](#)
- Shubhangi, K and Shireesh D (2015) Water-Related Architecture as an Identity Anchor of Chandernagore, India. *Bonfring International Journal of Industrial Engineering and Management Science* 5(2): 29-32. [Crossref](#)
- Stadtner, DM (2011) *Sacred Sites of Burma: Myth and Folklore in an Evolving Spiritual Realm*. Bangkok: River Books. [Google Scholar search](#)
- Stadtner, DM (2013) *Ancient Pagan: Buddhist Plain of Merit*. Bangkok: River Books. [Google Scholar search](#)
- Stargardt, J (1968) Government and Irrigation in Burma: A Comparative Survey. *Asian Studies* 6(3): 358-371. [Google Scholar search](#)
- Strachan, P (1989) *Imperial Pagan: Art and Architecture of Burma*. Edinburgh: Kiscadale. [Google Scholar search](#)
- Tan, NH (2014) Rock Art Research in Southeast Asia: A Synthesis. *Arts* 3: 73-104. [Crossref](#)
- Tawa, M (2001) At Kbal Spean. *Architectural Theory Review* 6(1): 134-155. [Crossref](#)
- Thet Oo, and Maung Hlaing (2014) Architectural Aspects of Stupas During the Reign of King Narapatisithu in Bagan, Myanmar. Paper presented at the Asia Pacific Sociological Association (APSA) Conference – Transforming Societies: Contestations and Convergences in Asia and The Pacific. Chiang Mai, Thailand. [Google Scholar search](#)
- Ward, WE (1952) The Lotus Symbol: Its Meaning in Buddhist Art and Philosophy. *The Journal of Aesthetics and Art Criticism* 11(2): 135-146. [Crossref](#)
- Win Kyaing (U) (2016) The Hydraulic Works of Pagan and the Ancient City. Paper presented at the Paper presented at the 2nd SEAMEO SPAFA International Conference, Bangkok. [Google Scholar search](#)
- Win Kyaing (U) 2018 The Water Management of Historic Bagan: The Chronology and Typology of Hydraulic Works in the Ancient Buddhist City. In: NH Tan (ed.) *Advancing Southeast Asian Archaeology 2016: Selected Papers from the Second SEAMEO SPAFA International Conference on Southeast Asian Archaeology*. Bangkok: SEAMEO SPAFA Regional Centre for Archaeology and Fine Arts, 276-286. [Google Scholar search](#)
- Wohlfarth, B, Higham, CFW, Yamoah, KA, Chabangborn, A, Chawchai, S, and Smittenberg, RH (2016) Human Adaptation to Mid- to Late-Holocene Climate Change in Northeast Thailand. *The Holocene* 26(11): 1875-1886. [Crossref](#)
- Wolters, OW (1999) *History, Culture, and Region in Southeast Asian Perspectives* (revised edition). Ithaca: Southeast Asia Program, Cornell University. [Google Scholar search](#)
- Wüdsch, M, Biagioni, S, Behling, H, Reinwarth, B, Franz, S, Bierbaß, P, Daut, G, Mäusbacher, R, and Habertzettl, T (2014) ENSO and Monsoon Variability During the Past 1.5 kyr as Reflected in Sediments from Lake Kalimpa, Central Sulawesi (Indonesia). *The Holocene* 24(12): 1743-1756. [Crossref](#)
- Yamoah, KA, Higham, CFW, Wohlfarth, B, Chabangborn, A, Chawchai, S, Schenk, F, and Smittenberg, RH (2017) Societal Response to Monsoonal Fluctuations in NE Thailand During the Demise of Angkor Civilisation. *The Holocene* 27(10): 1455-1464. [Crossref](#)