Geographical Survey of Sambor Prei Kuk
— A World Heritage Archaeological Site in Cambodia —

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Geographical survey of Sambor Prei Kuk Archaeological Site started in 1999 by S. Kubo in cooperation with late Dr. Y. Kojo (archaeology), Prof. T. Nakagawa (Architecture) and Cambodian Ministry of Culture and Fine Arts. N. Nagumo joined from 2004. Our main results are as follows: 1) Monuments and relics were mapped by using aerial photos and ground reconnaissance with GPS. 2) Geomorphological map of the area was made by interpreting of stereo pairs of aerial photos and ground survey. 3) Stratigraphy of subsurface deposits was researched by manual and mechanical drillings. 4) Landform evolution of the Stung Sen River lowland was revealed by drillings and radiocarbon (^{14}C) dating of deposits. 5) Archaeological stratigraphy was detected by radiocarbon dating of samples. 6) We published these results in international journals.

1. Introduction

Sambor Prei Kuk is a recently registered UNESCO World Heritage site of Pre-Angkor capital (7th Century), located 20 km northeast of Kampong Thom city in Central Cambodia (Photos 1 and 2). It is about 140 km southeast from Siem Reap, the center of the 9th to 15th century Angkor dynasty.

Sambor Prei Kuk site is located on an upland along the lower Stung Sen River, a tributary of Lake Tonle Sap (Fig.1). Hindu temple complexes, city moats, and several other engineering works have been found at the site (Kojo and Kubo, 2003; Nagumo et al., 2010).

The temple complexes of Prasat Sambor, Prasat Yeai Poeun, and Prasat Tao are situated within dense forest, while the trace of city moats and mounds are located on their western part, as used cropland recently.

The conservation works and efforts of international cooperation resulted the less-known remote site into the UNESCO World Heritage in 2016. This paper introduces the geographical research results that contribute the conservation of the site.

2. Geographical research by Waseda University

Geographical research of Sambo Prei Kuk site by Waseda University started in 1999.

Late Dr. Yasushi Kojo, an archaeologist at Royal University of Fine Arts in Cambodia/ Waseda University initiated the research after the years of civil war.

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Photo 1. Sambor Prei Kuk site in the forest

Photo 2. A Hindu tower of bricks

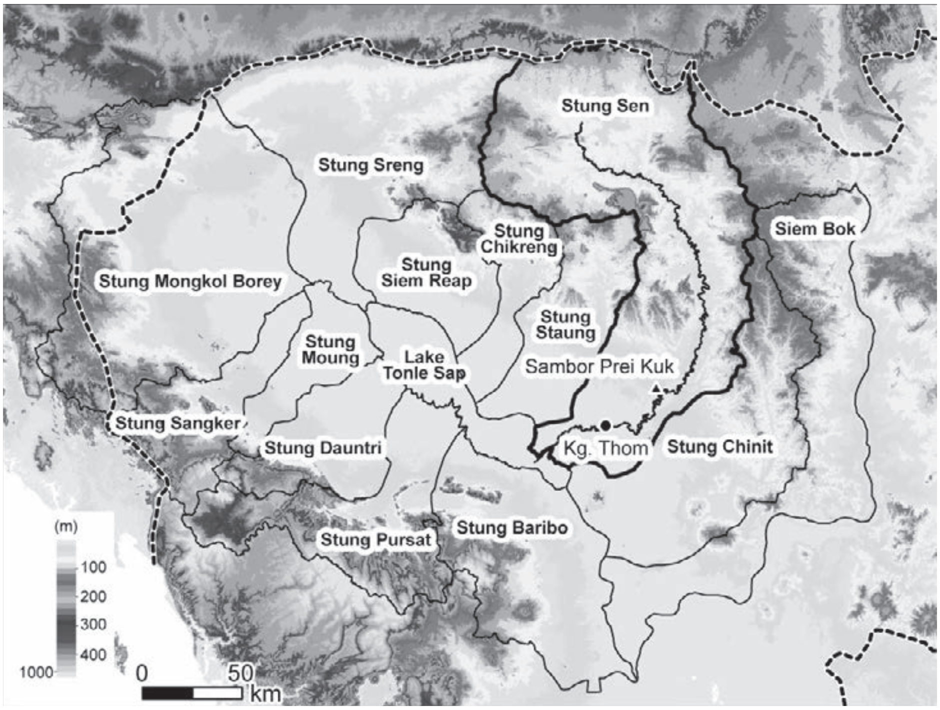

Fig. 1. Location of Sambor Prei Kuk site

A joint team from the Cambodian Ministry of Culture and Fine Arts and Waseda University in Japan started working to investigate and conserve the site in 1998. Prof. Takeshi Nakagawa (Department of Architecture, School of Engineering) led the Waseda Team. The team mainly consists of members of Waseda University.

After the reconnaissance study Dr. Kojo requested the author (SK) to join as a geographer from 1999. Since then, projects have included preparation of an inventory of monuments, geomorphological survey around the site, archaeological survey and restoration of buildings, etc. (Sambor Prei Kuk Conservation Project, 2004). The other author (NN) joined from 2004 and Prof. Toshihiko Sugai (The Univ. of Tokyo) from 2010 as geomorphologists. These projects have also included activities to support local village people and develop of tourism.

3. Geographical Survey of Sambor Prei Kuk site

Geographical survey of Sambor Prei Kuk site includes following studies.

- Mapping of monuments with GPS positioning
- Geomorphological mapping by aerial photo interpretation
- Mapping of artificial traces (canals/communication system) by aerial photo interpretation
- Stratigraphic study of site by drillings and radiocarbon (^{14}C) dating
- Landform analysis of the Stung Sen River floodplain by drillings and radiocarbon dating

3.1 Mapping of monuments

According to the field reconnaissance with portable GPS device and aerial photos taken by FINNMAP in 1992, we mapped many relics and ruins especially in the western area of the site. These ruins include mounds and stone pieces, and located in an area surrounded by rectangular-shaped moats. Canals and number of artificial ponds are also recognized in and around the area (Fig. 2).

Based on this distribution map, Ministry of Fine Arts detected the protection zones for conservation of the site.

3.2 Geomorphological mapping

The interpretation on stereo pairs of 1:25,000 aerial photos taken in 1992 by Finnmap (Photo 3) along with field survey data, we created a geomorphological map around the site. We used 1:40,000 aerial stereo photos taken in January 1958 by the United States Army, and a Landsat ETM+ images taken in July 2001 supplementaly (Kubo et al., 2012, Nagumo et al., 2013).

The geomorphological features around the site consist of uplands and a floodplain of the Stung Sen River. Sambor Prei Kuk site is situated on the sandy upland approximately 5 m higher than the adjacent floodplain of the Stung Sen River (Figs. 3 and 4).

The upland surface is covered with white to pale orange quartz-rich sand and is subdivided into upland surfaces I, II, and III based on relative elevations and land use characteristics (Kubo et al., 2012). Upland surface I is the highest surface around the site and is covered by forest; upland surface II is partly covered by vegetation, and upland surface III is almost barren land with lower moisture content.

The floodplain is divided into fluvial plain and lake plain, and the fluvial plain is further classified into

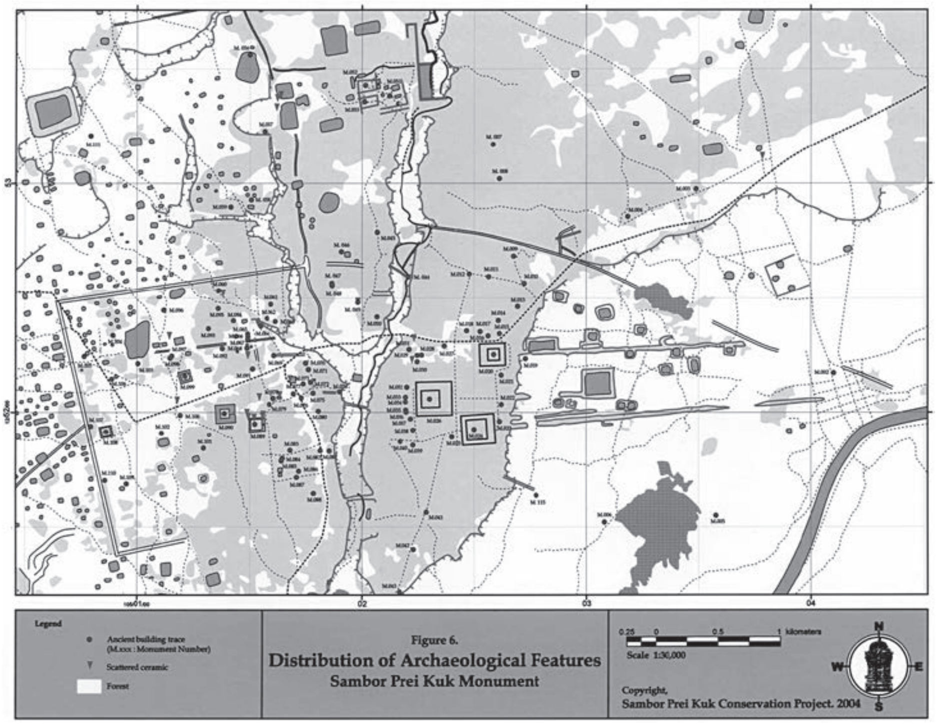

Fig. 2. Distribution of archaeological features (Sambor Prei Kuk Conservation Project, 2004)

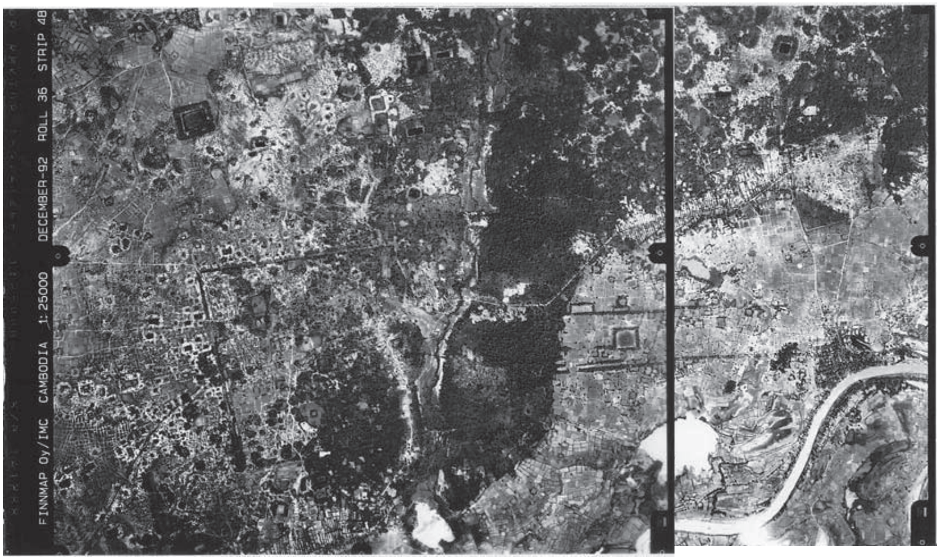

Photo 3. Aerial photos of the study area (FINNMAP)

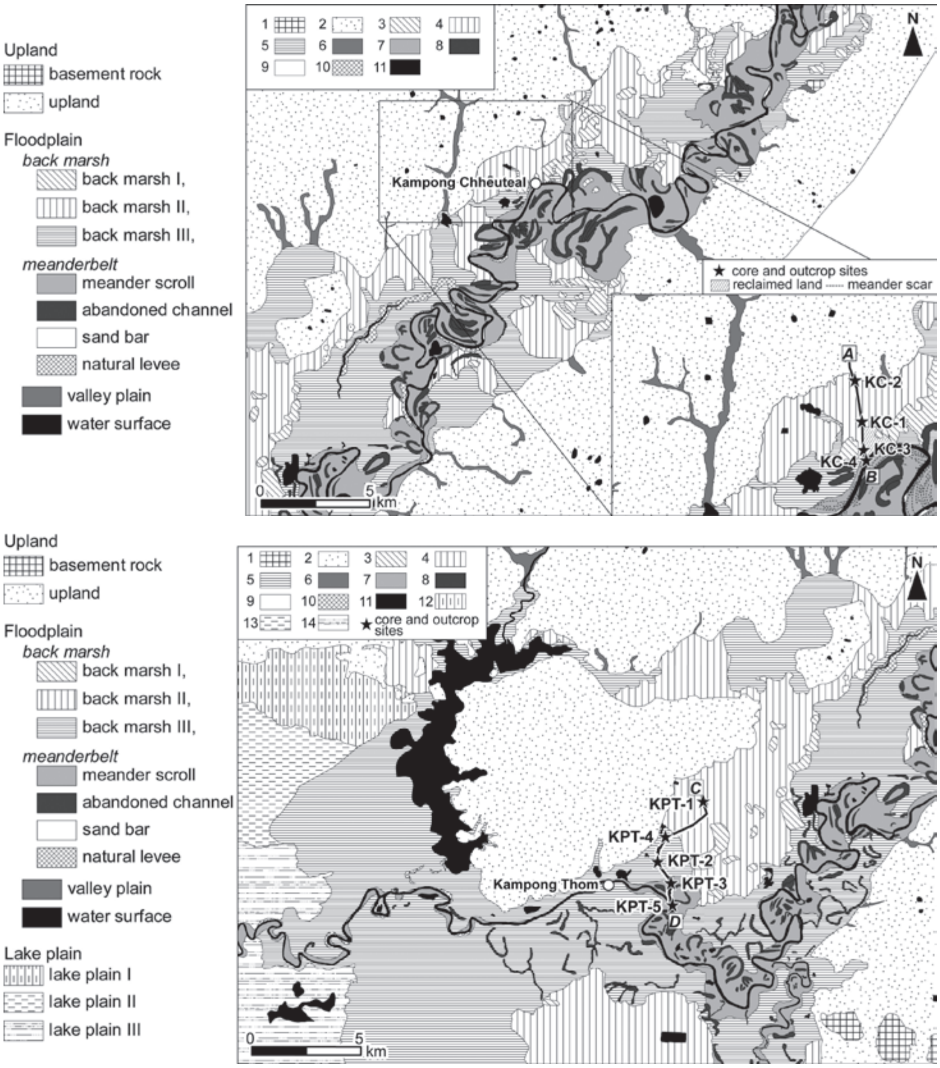

Fig. 3. Geomorphological map of the Stung Sen River basin (Nagumo et al., 2013)

areas of back marsh, valley plain, natural levees, meander scrolls, abandoned channels, water surface, and sand bars. The back marsh is subdivided on the basis of elevation into back marsh I, II, and III in descending order. Back marsh I is rarely submerged during the monsoon season, whereas back marsh III is the first inundated during the monsoon and remains inundated for the longest period.

Abandoned channels and meander scrolls are prominent along the present channel of the Stung Sen, except in the most downstream part. They indicate frequent channel shifts, channel cutoffs, and increasing sinuosity. The meander scrolls show clear concavity and convexity, and natural levees are not well developed along the main channel.

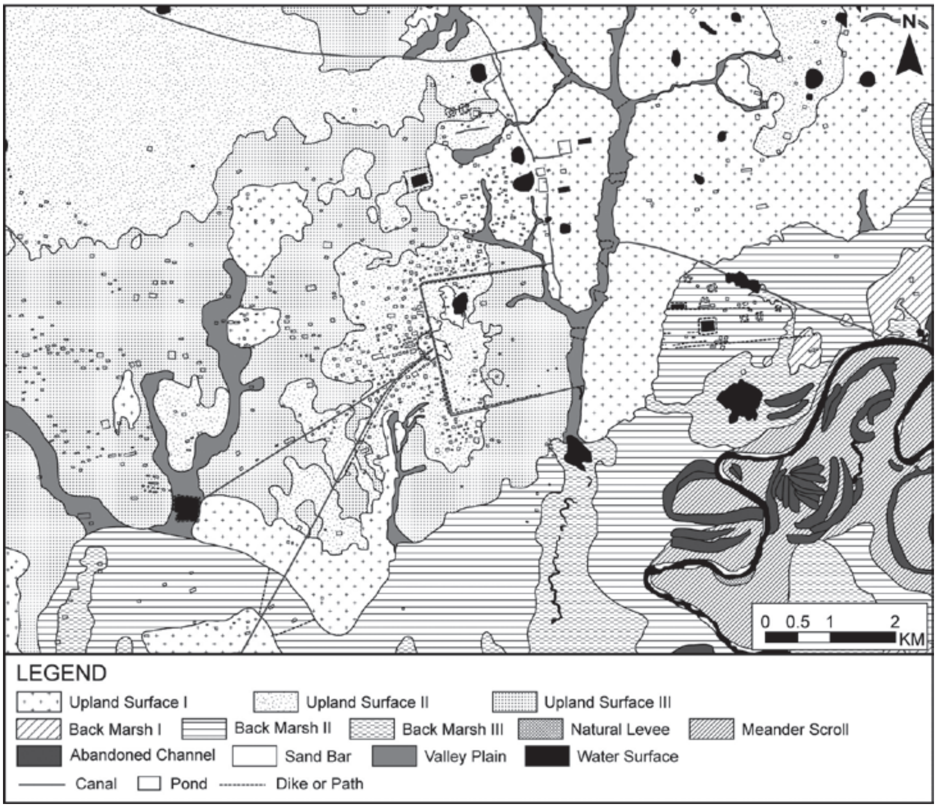

Fig. 4. Geomorphological map around the Sambor Prei Kuk site (Kubo et al., 2012)

3.3 Mapping of artificial traces (canal/ communication system)

Apart from geomorphological features, we detected artificial traces like canals or dikes connected to the site (Fig. 5). The most prominent one is to be an Ancient road to Angkor. This feature is recognizable as a straight embankment or (sometimes) embankments. We have confirmed the feature is traceable to the south of Angkor area (Nagumo and Kubo, 2007; Fig. 6).

This feature runs parallel to the well-known Royal Road in the Angkor Era. This means the different communication system from the Angkor Era. It seems to connect with the surrounding moat of Sambo Prei Kuk. Moreover, a pre-Angkorean monument is located at Prasat Andet along this road. We argue that the road is related to Pre-Angkor Era.

3.4 Stratigraphic study of site by drillings and radiocarbon dating

We carried out several drilling (boring) survey around the site to identify the subsurface deposits and stratigraphy. A hand auger was used and got samples to the maximum depth of 5 m. Figure 7 shows some sections around the site.

The upland surface sediments are composed mainly of sand which is shown by particle size analysis. Upland II sediments around Sambor Prei Kuk are composed mostly of medium to fine sand, more than

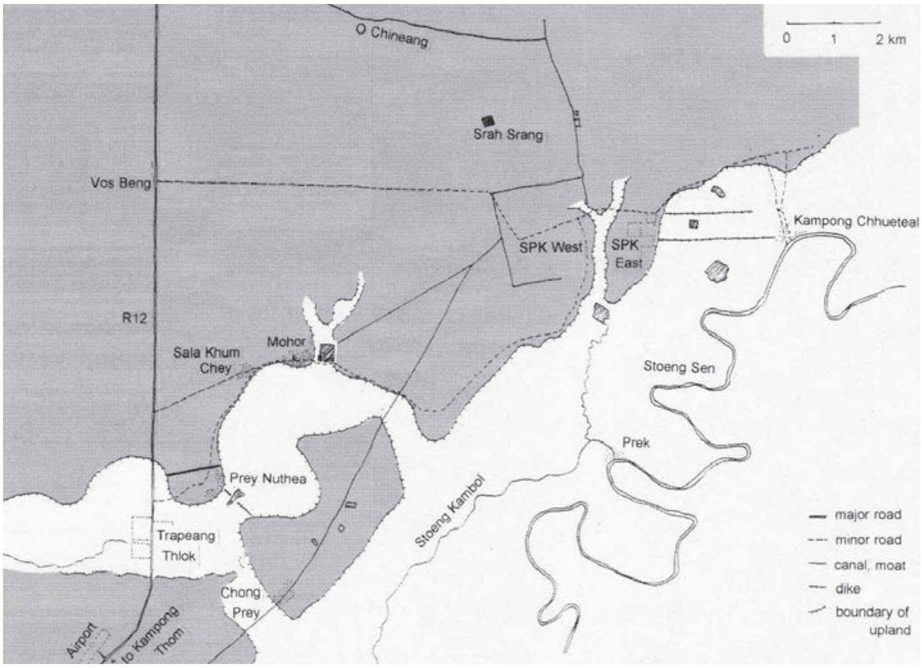

Fig. 5. Distribution of artificial traces (canals etc.) (Kojo and Kubo, 2003)

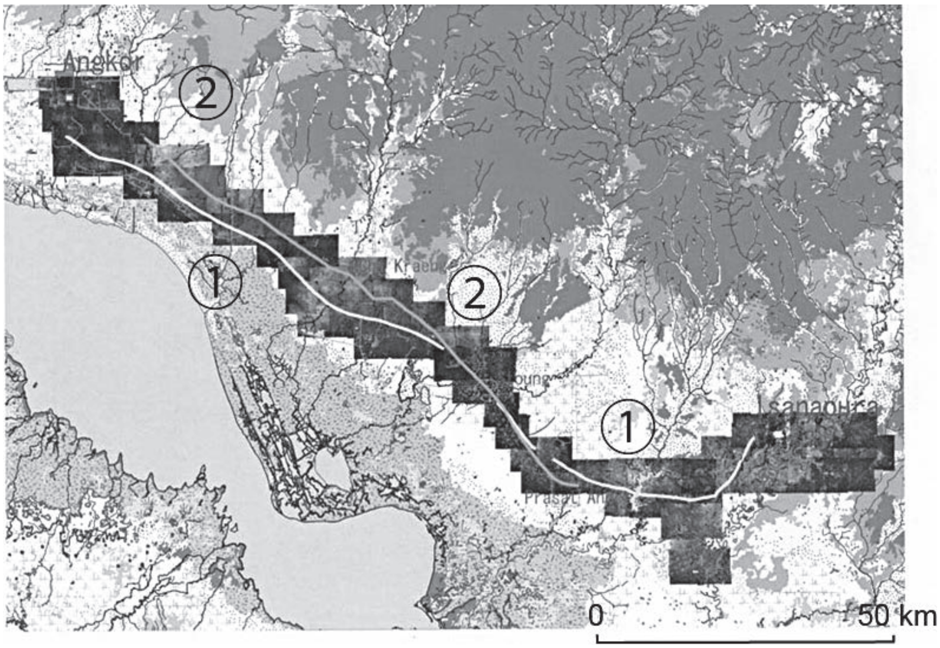

Fig. 6. Ancient roads connecting SPK and Angkor (modified from Nagumo and Kubo 2007). (1): ancient road from SPK to Angkor, (2): "Royal Road"

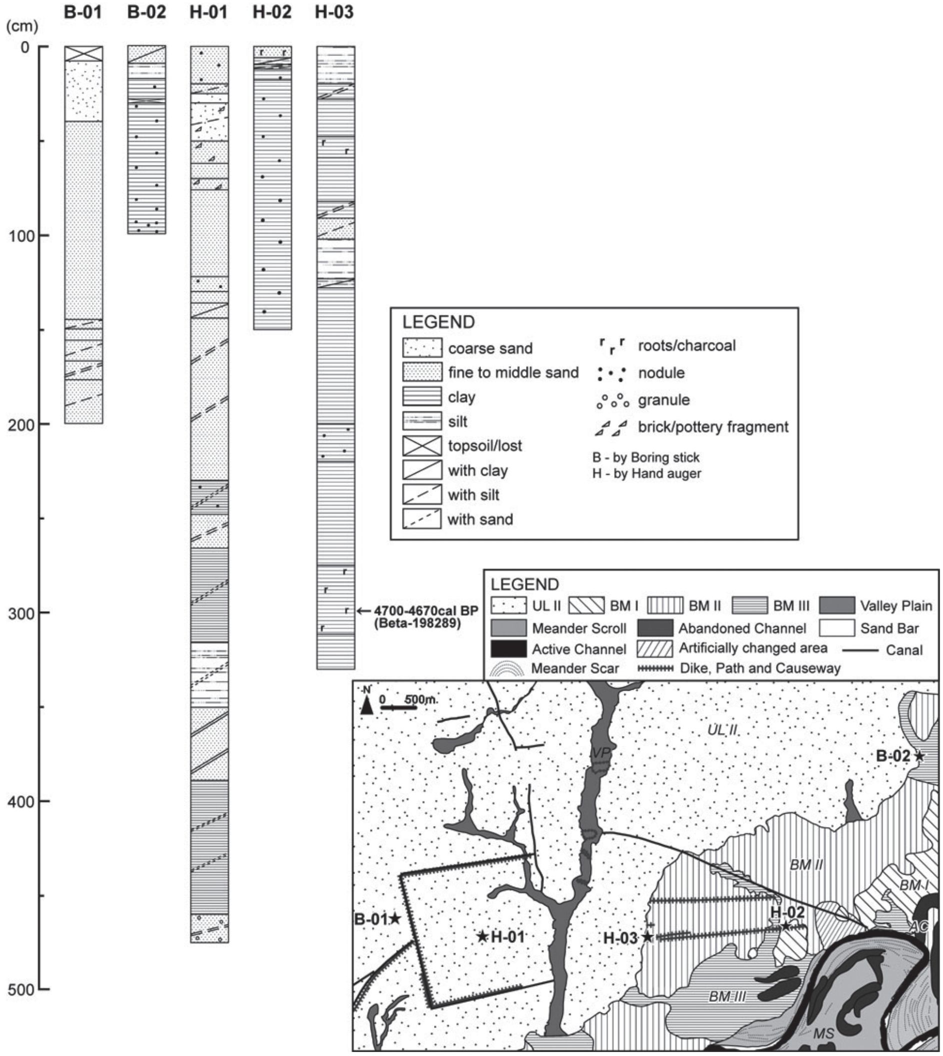

Fig. 7. Columnar sections of hand drillings (Nagumo et al., 2010)

90% of which is quartz with low roundness. The quartz grains are almost translucent and colorless, probably owing to eluviation at high temperatures under heavy rainfall. Linear scars on the surfaces of the sand grains, visible by light microscope and scanning electron microscope (SEM) observation, suggest that the quartz originated from weathered sandstone and was transported a rather short distance. The upland II surface layer is almost composed of medium to fine sand, with finer sediments occasionally found underneath that (Fig. 7, B-01 and H-01). Upland surface sediments are coarser than the back marsh sediments, suggesting that uplands I, II, and III probably formed under the different geomorphic condition, possibly by erosional process.

The Stung Sen River floodplain is mostly composed of silt and clay. In the monsoon season, these deposits become loose with water saturation, whereas in the dry season they are very stiff and hard.

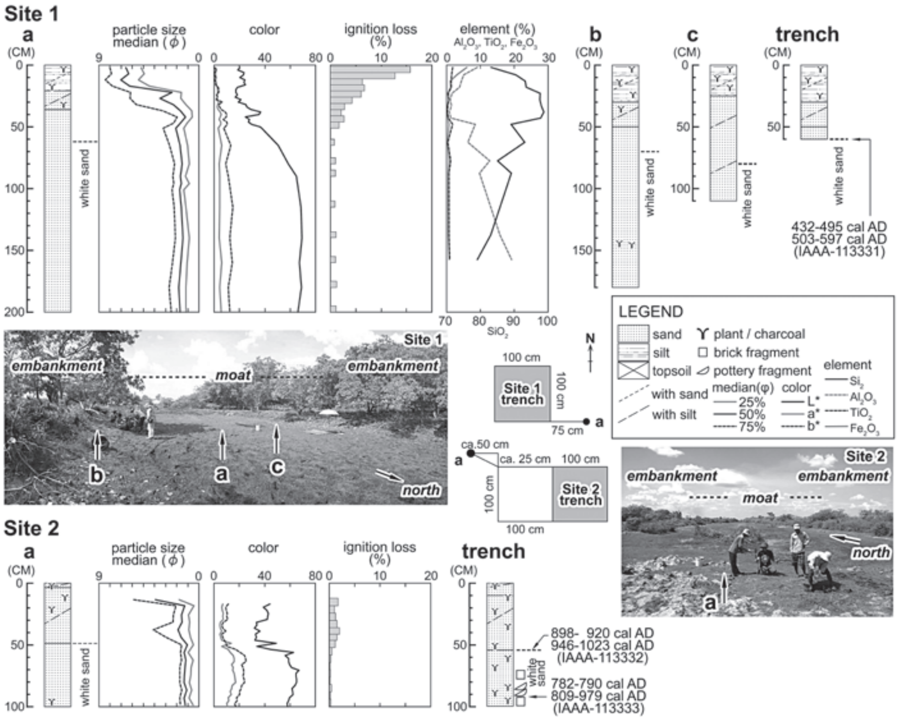

Fig. 8. Columnar sections of city moats (Nagumo et al., 2016)

Sediment cores H-02, H-03, and B-02, obtained from back marsh I, II, and III, respectively (Fig. 7), are mottled orange to red at depth related to groundwater table. A piece of wood collected at 300 cm depth in H-03 was dated to 4700-4670 cal yrs BP, suggesting that monsoonal flooding has occurred for at least about 4600 years. The average sedimentation rate of H-03, assuming no marked unconformities, was about 0.6 mm/yr.

The surrounding moats identified in aerial photos (Kojo and Kubo, 2003) are rain-fed and remain marshy in some areas even during the dry season. In the well-preserved section, the moat is almost 1.5 m deep and more than 20 m wide, whereas embankments on both sides of the moats are almost 1 m high (Shimoda and Nakagawa, 2006). We selected two sites in the western moat (Site 1 and 2) for excavating less than 1 m-deep trenches to observe the moat infill sediments and collect samples for radiocarbon dating.

In the well-preserved moat section (trench in Site 1), dates from the sixth century derived from the upper limit of the basal white sand of the moat, indicating that moat construction dates to the Pre-Angkor Period. The layer with brick and pottery fragments is dated to the ninth to tenth centuries, and the age of the base of upper humic soil dates to the tenth to eleventh centuries (Site 2) (Fig. 8).

Radiocarbon dating from sections in the ancient city area are also obtained. This location includes the cleaned walls of side ditches measuring almost 1 m deep along the newly constructed 1500 m-long road (Kubo et al., 2016; Fig. 9). During the road construction, archaeological remains such as brick structures, laterite, and pottery fragments were exposed on the walls of side ditches. Therefore, urgent architectural

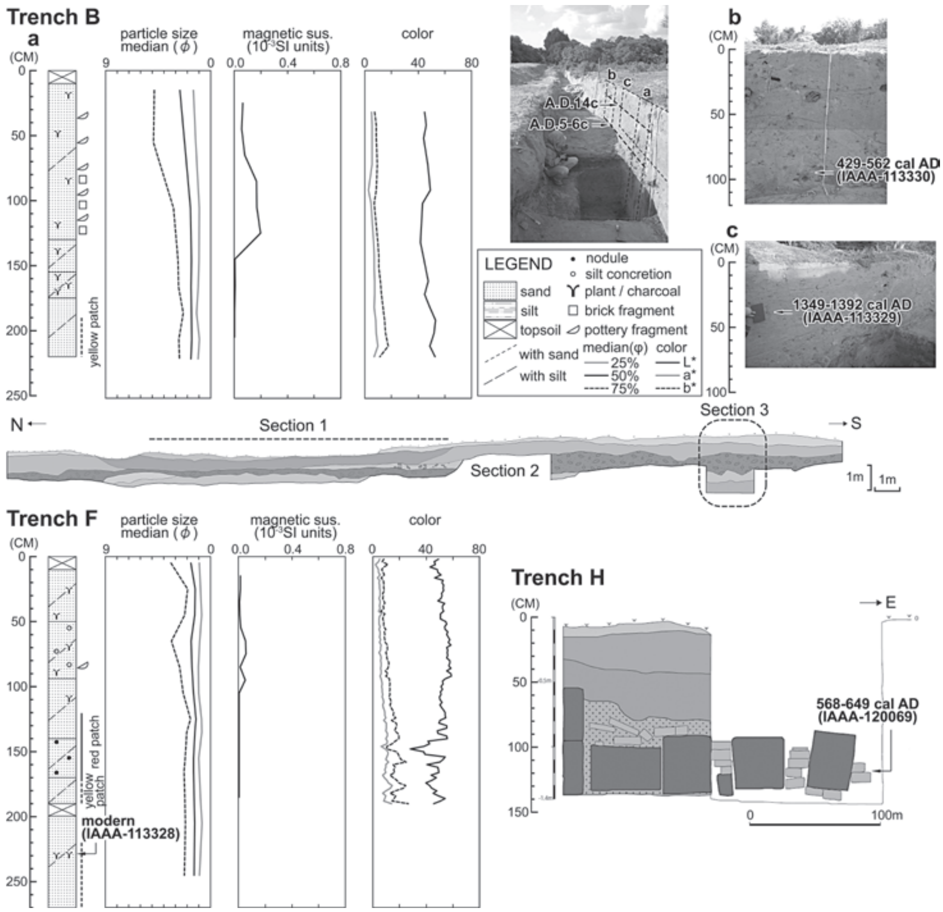

Fig. 9. Road sections in the ancient city area (Kubo et al., 2016)

and archaeological investigations were conducted at nine sites (A, B, B’, C, D, E, F, G, H) after deep trenches were excavated and ditch walls were cleaned.

We observed cultural deposits in the trenches of B, F, and H. Samples were collected to reveal the stratigraphy and geomorphological background of the site as well as to use in radiocarbon dating. Radiocarbon dates from the sixth to seventh centuries in Trench H of the road cut section probably indicate the construction age of structures made from piled laterite and bricks. Ages from Trench B are younger (fifth to sixth centuries) in the lower part of the layer containing brick and pottery fragments; that layer overlapped with the Angkor layer dating to the 14th Century. These ages suggest that the area around M78/79 had been occupied since at least the 5th to 6th Century (Pre-Angkor Period) until the 14th Century (Angkor Period).

3.5 Landform analysis of the Stung Sen River floodplain by drillings and radiocarbon dating

To understand the formation history of the floodplain during Pleistocene and Holocene, we selected two sites for mechanical core drilling: KC (Fig. 10) and KPT (Fig. 11) in the Stung Sen River floodplain north of Kampong Chheuteal and Kampong Thom, respectively. Several nearby outcrops were also investigated.

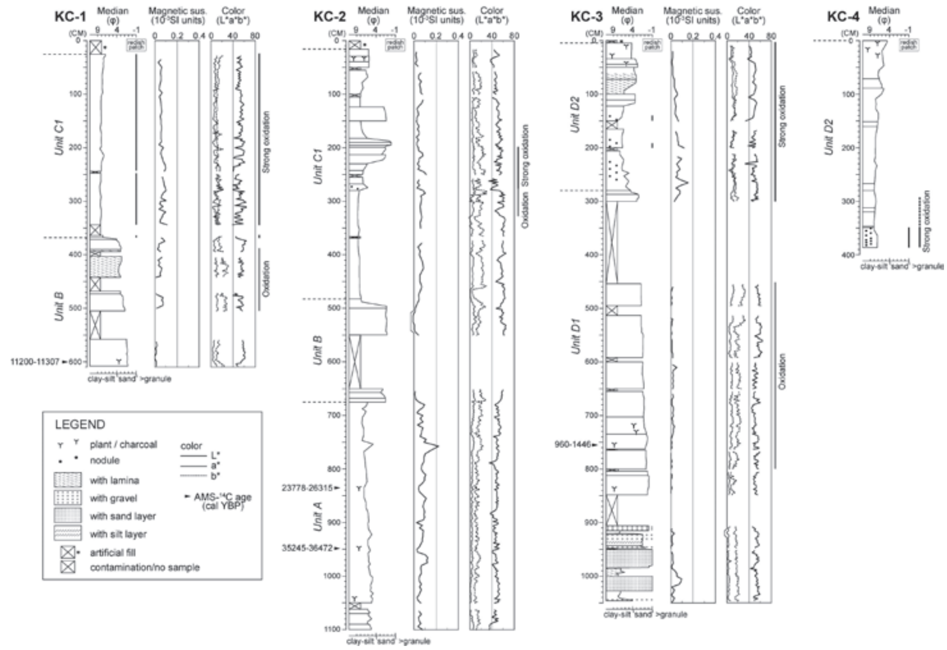

Fig. 10. Columnar sections of mechanical drillings near Kampong Chheuteal (Nagumo et al., 2013) Drilling sites are shown in Fig. 3.

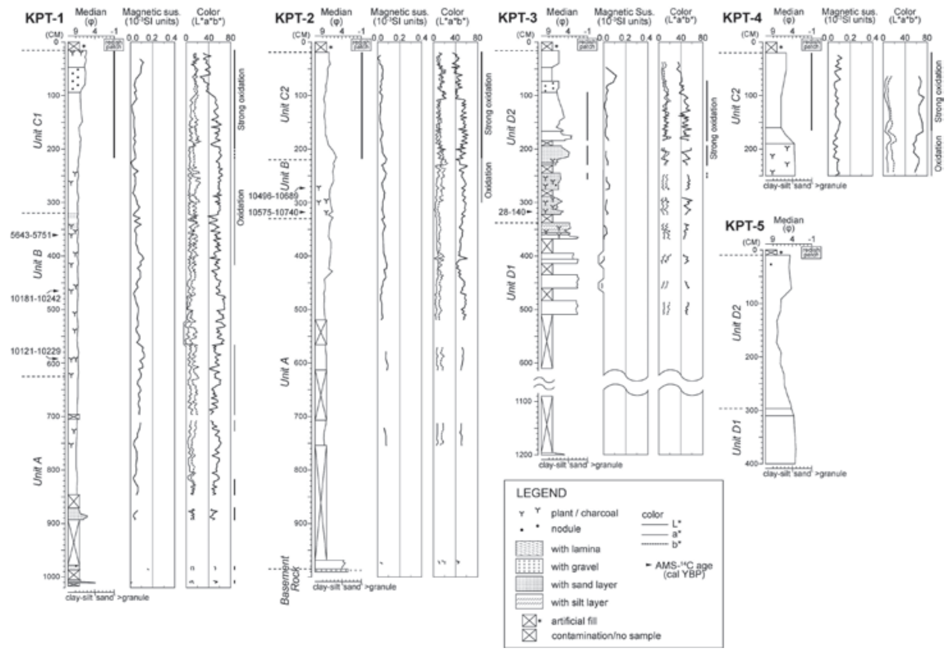

Fig. 11. Columnar sections of mechanical drillings near Kampong Thom (Nagumo et al., 2013) Drilling sites are shown in Fig. 3.

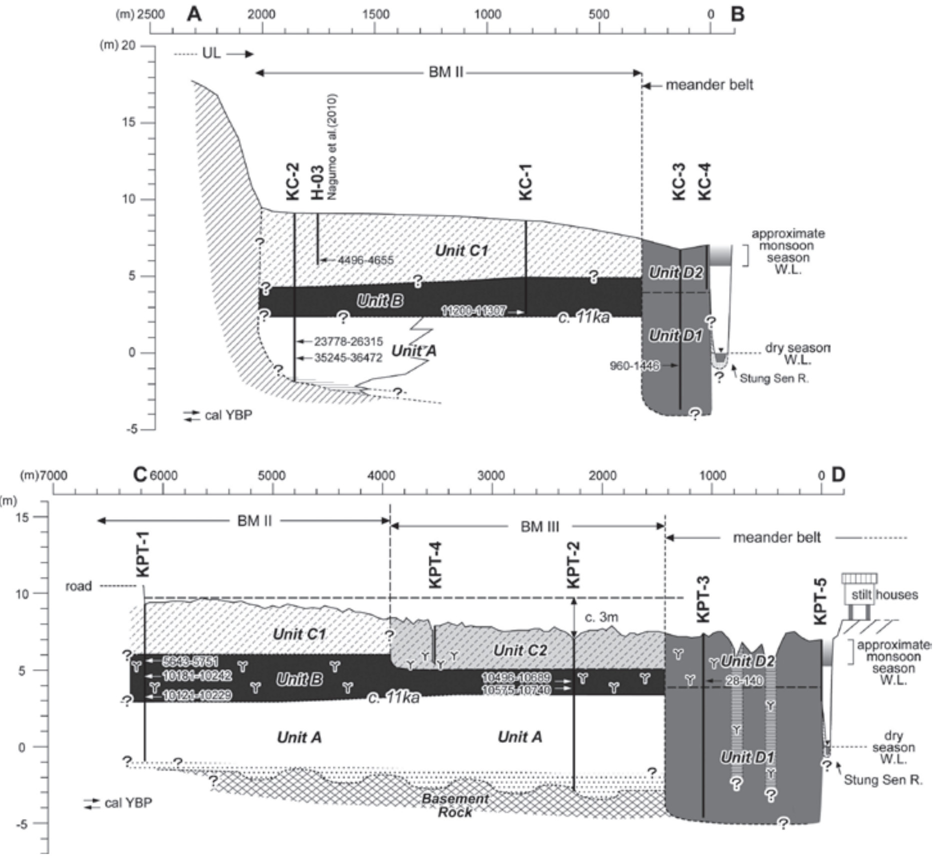

Fig. 12. Cross sections of the Stung Sen floodplain at KC and KPT (Nagumo et al., 2013)

Using sedimentary litho-facies and radiocarbon dates, we classified the deposits at sites KC and KPT into sedimentary units A through D, along with sandstone basement rock found in core KPT-2 (Fig. 12) (Nagumo et al., 2013).

The characteristics of unit A indicate a calm environment on the floodplain, with sedimentation occurring at a quite slow. This calm environment began at or before c. 36 ka and continued until c. 11 ka. The contact of unit A with basement rock at KPT suggests that floodplain deposits in the Stung Sen River valley began during the late Pleistocene.

After c. 11 ka, unit B accumulated until the mid-Holocene, around 5.5 ka, sandy deposits appeared all over the floodplain. These changes imply that more energetic Stung Sen River processes accompanied stronger river flow and increased flow volume, and that the river became braided. At the downstream site of KPT, the area of monsoon flooding was enlarged like the present lake plain, producing more plant materials that were included in unit B.

The finer grained deposits of unit C with their lower humus content started to accumulate at KC and KPT c. 5.5 ka. In addition, unit D began to accumulate with the development of the meander belt. The inception of unit D and the present backmarsh–meander belt geomorphic system probably date to the

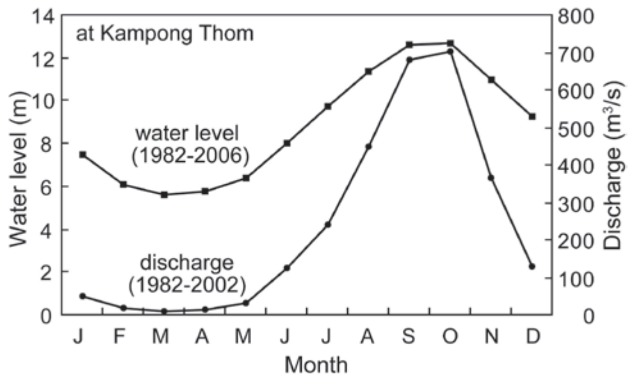

Fig. 13. Average monthly water levels and discharges of the Stung Sen River (Nagumo et al., 2013)

mid-Holocene around 5.5 ka.

During the monsoon season, the majority of the meander belt is inundated by floodwater, just as backmarsh II and backmarsh III reflect the presence of floodwater. The higher water level of the monsoon season (Fig. 13) — combined with the very gentle floodplain gradient surrounded by uplands — prevents rapid drainage, promoting the deposition of suspended materials (unit C) to form the backmarsh units.

The result is to facilitate channel migration to form meander scrolls and abandoned channels, and the transported riverbank materials build fluvial dunes of medium to fine sand on the river bed (Nagumo et al., 2010).

Nagumo et al. (2015 and 2017) examined channel bars at two sites in the lower reach of the Stung Sen River, to identify sediment transport and accumulation processes during monsoon-related flood events. They showed how sediment transport capacity changes as a result of enhanced backwater effect of the lake Tonle Sap.

Channel bars in the lower reach of the Stung Sen River that emerge in the dry season were classified into type A (lateral bars), type B (point bars), type C (concave-bank benches) and type D (diagonal and island bars, or fluvial dunes). Our observations suggest that alternating layers of sand and silt to clay layers accumulate to form type C channel bars, corresponding to changes in sediment transport capacity controlled by backwater effects from Lake Tonle Sap and by changes in flow depths and associated slackwater systems (Nagumo et al., 2017).

4. Geographical research results

Our geographical research results can be summarized in following aspects.

1) Landform condition of ancient Isanapura City

The Sambor Prei Kuk site is correlated as the ancient city of Isanapura, which is written in the Chinese historical documents of Sui-Shu in the 7th Century. A number of Hindu temples and an ancient citadel is mapped in detail.

Based on the geomorphological mapping and distribution of monuments shown above, we demonstrated that the western city area and eastern temple complex are constructed in the upland area. The eastern part faces to the floodplain of the Stung Sen River, and two causeways on embankment connect the temples and the Stung Sen river bank.

In the western part, there are many small water tanks in and out of the moated city. The land use pattern is quite different from those in the floodplain area, where extensive inundation occurs during the monsoon season. We argue that these structures represent the ancient paddy fields.

2) Transportation system of the ancient city

Continuous canal systems and a road-like structure have been recognized in aerial photos. The latter can be traced between Sambor Prei Kuk and south of Angkor continuously. This is different from that called Angkorean Royal Road, so we suppose this is a pre-Angkorean communication system. A pre-Angkorean monument is located at Prasat Andet along this road also.

3) Dating/ chronology of deposits

At some trenches and road-cut sections in Sambor Prei Kuk site, we confirmed the stratigraphy and artefacts. The upper layers with Angkorean artefacts and the lower layers with pre-Angkorean artefacts are detected. Radiocarbon dates derived from these layers support the stratigraphy and chronology.

4) Floodplain deposits and its formation

The detailed analyses of the deposits at KC and KPT sites in the Stung Sen floodplain consist of Unit A (late Pleistocene fluvial deposits), Unit B (early Holocene fluvial deposits), Unit C (late Holocene back-marsh deposits) and Unit D (channel deposits).

Sedimentary facies and radiocarbon ages from these deposits represent the initiation of unit B (early Holocene fluvial deposits) accumulation at around 11 ka. It suggests that enhanced fluvial processes related to intensified monsoon flooding caused greater sedimentary influx at site KC and an expansion of flooded areas at site KPT. The increase of accumulation rate after c. 11 ka also supports the idea that the fluvial system was intensified in the Holocene. Marked environmental change at 11 ka is also recorded in Lake Tonle Sap.

These results suggest the environmental changes from Pleistocene to Holocene, and the influence of Asian monsoon in the area.

5) Reconstruction of Isanapura City and surrounding area’s land-use/ water-use system

The location of Sambor Prei Kuk is considered one of the best areas in which to build a monumental city from the point of view of monsoonal inundation and sufficient water transport. The low tractive force of the Stung Sen around Sambor Prei Kuk ensures efficient water transport in the upstream direction, and means that water transport systems are protected from strong monsoonal flows.

Because Isanapura and the Stung Sen River are connected by a canal, people and loads could easily access the city through the canal when the water level was high. It is not known the name of the port in the 7th century, but a port town must have existed near the present Kampong Chheauteal village that was connected to Sambor Prei Kuk by the canal, and people or a load transported by boat were soon carried into the city center through the canal. The Stung Sen River was one of the most important water transport route connecting the Lake Tonle Sap, the Mekong River, and South China Sea in ancient times, which may have played important role for both development and decline of pre-Angkorean city.

We concluded that the place most favorable year-round was chosen by the ancient people. The ancient Isanapura people understood the severe environmental changes of the bimodal seasonal water cycle. The city would have been settled continuously over several generations, with gradual construction of holy monuments and canal systems to perpetuate the society to provide an adequate system.

Acknowledgements

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