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Preliminary Study on Geoarchaeology of the Batu Kalde Temple, Pangandaran, West Java, Indonesia

Eko Yulianto[1], Purna S. Putra[1], Septriono H. Nugroho[1], Yayat Sudrajat[1], Agus Men Riyanto[1], Yuka N. Cahyaningtyas[2], Januar Ridwan[1] & Amar[1]

[1] Research Center for Geological Hazards, National Research and Innovation Agency, Bandung, Indonesia

[2] Research Center for Environmental Archaeology, Maritime Archaeology, and Cultural Sustainability, National Research and Innovation Agency, Jakarta, Indonesia

Correspondence: Eko Yulianto, Research Center for Geological Hazards, National Research and Innovation Agency, KST Samaun Samadikun, Jl. Sangkuriang Bandung 40135, Indonesia. Tel: 62-22-250-3654. E-mail: Ekoy909@gmail.com

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Abstract

The Batu Kalde Site is a ruin of Hindu Temple in Pangandaran, West Java, Indonesia. Despite it has been reported since 1915 and subsequently studied by several archaeological teams, a lot of aspects including geoarchaeology of this temple are still unrevealed. This preliminary study was an overview of general aspects of geoarchaeology of the temple. The result shows that the temple was constructed before the 14th century by a population of farmers and fishermen lived on the fertile coastal plain of Pangandaran in south coast of Java Island. The temple was constructed in a narrow coastal plain of a small island on a Quaternary marine sediment offshore of the present Pangandaran coast. The existing tombolo morphology of Penanjung has not been completely formed when the temple was being constructed. The temple was constructed using bedded sandstone of the Pamutuan Formation quarried from outcrops in the vicinity of the temple. This study shows that utilization of materials from local available resource might have been a model of temple construction within the classical period in the period of between the 7-14th century in West Java, Indonesia.

Keywords: Batu Kalde temple, classical period, geology, archaeology, Pamutuan formation, local resource

1. Introduction

To meet the needs of life, humans act intelligently and creatively in utilizing various resources available from their environment. The ability to utilize any resources available from the environment has been growing since humans lived sedentary lives. In fact, the factors that encourage this sedentary lifestyle are most likely related to the ease and practicality of obtaining resources available from the surrounding environment. This is the reason why many archaeological studies employ general principles of ecology (Hardesty, 1980; Kirch, 1980).

The dependence and interaction of humans with their environment in an ecosystem takes place in two main aspects. These two aspects are the fulfillment of basic needs and the security of life, both physiologically and psychologically. Efforts to fulfill these two aspects become a continuous and evolutionary learning process. This effort then gave birth to various forms of culture, both tangible and intangible. Forms of tangible culture include various hunting equipment, farming, jewelry, various houses and worship buildings, and various other forms of cultural objects. Even the development of various intangible cultures might also initially be related to practical reasons in obtaining resources from the environment in which the culture develops. This then gave birth to ethnic traditions (ethnocultural) in various aspects of life (Sumner, 1906[1907]; Mathias, 2015). Therefore, artefacts need to be positioned as intermediaries that connect humans with their environment (Watson et al., 1971). Various findings of prehistoric artefacts prove that the cultural objects created by humans are mostly made using various materials available in the environment around their dwellings. This is most likely related to the aspect of convenience and practicality. Stone tools from the Paleolithic, Mesolithic, and Neolithic periods, for example, each have a distinctive typology. But in many different places, stone tools with the same typology and function are often made using different materials. This indicates the ability of early humans to select various types of rocks that are suitable as materials for making various types of stone tools. In Wallanae River, South Sulawesi, prehistoric stone tools were made from predominantly silicified limestone and chert (Alink et al., 2017).

Quartzite, lava, and chert, dominate the archaeological record of stone tools of Beds I and II of Olduvai Gorge (Hay, 1976). In the north of Bandung, West Java, similar prehistoric stone tools were made from basalt rocks whose raw material is commonly found in the vicinity (Ferdianto, 2012). Most Korean Paleolithic materials are quartzite and vein quartz artefacts (Seong, 2004). Most artefacts in the Mata Menge assemblage were made on volcanic/metavolcanic stones, chiefly basalt, andesite, and chlorite (Brumm et al., 2010).

The ease and practicality in obtaining materials from the immediate environment also became a practice in building temples during the Classical Period in Indonesia. Hindu and Buddhist temples were built using materials that were easily obtained from their immediate environment. Although there are guidelines and rules in the construction of temples, they often need to be adapted when dealing with unavoidable local challenges. The temples found in wetlands and floodplains in Sumatra, such as the Muara Jambi temple complex in Jambi and the Bumi Ayu temple complex near Palembang, and the Batujaya temple complex in Karawang, West Java were built using bricks (Tjoa-Bonatz et al., 2009; Djafar, 2010; Purwanti, 2014). Clay as raw material for making bricks and statues is the most readily available material in wetlands and floodplains. Meanwhile, the temples from the classical periods in Central Java and Yogyakarta, which are located on the slopes of the mountains, were built using andesite rocks. Andesite rocks are abundantly available on the slopes of the mountains, either in the form of boulders in lahar deposits, lava, or in the form of intrusive rock bodies. The difference in the type of material used to build the temple is probably related to the availability of raw materials near the site.

The aspect of ease of obtaining materials is hypothesized to be applied in the construction of the Batu Kalde Temple in Pangandaran, West Java, Indonesia. The findings of yoni and Nandi, as well as the Lingga (Krom, 1915) indicated this site as a temple ruin (Ferdinandus et al., 1986, 1987). For this reason, in this paper this site is hereinafter referred to as Batu Kalde Temple, abbreviated as BKT. This paper describes an initial analysis of environmental considerations, especially geological aspects in the construction of BKT. The results of this analysis are expected to be the basis for further geoarchaeological studies at BKT and at other sites built during the Classical Period as well as before and after, especially in the West Java region.

2. Method

This study was conducted with an overview approach. The data used in this study are mostly the results of previous studies, especially geological and archaeological studies. Some of the primary data obtained in a short observation in the field. All data were carefully examined and analyzed qualitatively to get an overview of the geoarchaeological aspects of BKT. The results of the study are conclusions drawn based on the synchronization between geological aspects related to the archaeological context of BKT. The result of this study is an ethical view, which is taken from the researcher's point of view.

3. Results

3.1 Environmental Setting

Batu Kalde is the name of a heritage site that is thought to have been built in the classical period and has Hindu characteristics. This site is in the Pananjung Pangandaran Nature Reserve Forest, West Java, Indonesia. The coordinate position of the site is 108 °39'27.1" East Longitude and 7 °42'21.5" South Latitude. (Fig. 1). The site is located on a coastal plain surrounded by limestone hills with a height of up to 20 meters above sea level. The site is in a tropical climate with rainfall reaching 3196 mm/year, daily temperatures ranging from 25-30oC and humidity 80-90% (Ferdinandus et al., 1984).

Local people named this site Batu Kalde because of the remains of a statue of a cow (Nandi) which was mistakenly identified as a calf (calf – kalde, in Sundanese). The existence of this site was first reported by N.J. Krom in 1915. The report mentions the existence of artefacts in the form of yoni, lingga, flat-sided cylindrical stones and a statue of Nandi (Krom, 1915). Furthermore, this site was investigated by a research team from the National Research Center of Archaeology Indonesia led by Hasan Musarif Ambary in 1977 (Ferdinandus et al., 1986). Subsequent studies were carried out by several teams from this Research Center in 1983, 1984, 1986 (Ferdinandus et al., 1986) and 1987 (Ferdinandus et al., 1987). These studies identified the presence of a Hindu icon in the form of a bull statue (Nandi), yoni, lapik (plinth), intact temple stone structures and fragments of various types of pottery and did not report the presence of a lingga as reported by Krom (1915). The results of the study concluded that the temple in BKT was probably only a hallway, without stone walls and stone roofs.

BKT is situated on a narrow coastal plain on the north side of a small hill. This hill is currently connected to the island of Java to the north by a morphology of a knob of about 300 m wide (Fig. 1). In the geological map compiled by Simandjuntak and Surono (1992), this hill is named Bukit (Pasir) Panenjoan. Panenjoan Hill is composed of the Jampang Formation breccia on the south side and Kalipucang Formation limestone on the north side. The hill is

surrounded by the Indian Ocean on the south side, Parigi Bay on the west-northwest side and Pangandaran Bay on the east-northeast side (Fig. 1). In the limestones of the Kalipucang Formation, karst morphology has developed as isolated hills and caves with stalactites and stalagmites. On some of the northeast, north and northwest sides of Panenjoan Hills, narrow sandy coastal plains develop. Above it, thin silt clay soil has formed with a thickness of 13-172 cm (Kurniawan & Parikesit, 2008). The west, south and east sides of Panenjoan Hill are steep and high cliffs. Two main rivers flow intermittently across Panenjoan Hill, namely the Ciborok River which empties into Cikamal Bay-Parigi Bay, and the Cirengganis River which empties into Pangandaran Bay.

Panenjoan Hill is covered by old secondary forest and a little primary forest. This forest is composed of several main tree species including *Rhodamnia cinerea*, *Vitex pubescens*, *Sterculia urceolata*, *Buchanania arborescens*, *Acronychia laurifolia*, *Baccaurea javanica*, *Dillenia excelsa*, *Flacourtia rukam*, *Decaspermum fruticosum*, *Guioa diplopetala*, *Grewia acuminata* (Kurniawan & Parikesit, 2008). The narrow coastal plains on the northwest, northeast and north are covered by several types of cultivated flora, especially *Tectona grandis*, *Swietenia mahogany* and *Acacia auriculiformis* (Husodo et al., 2015). On the coastal plain in the western part of Panenjoan Hill, several types of coastal forest trees grow, such as *Barringtonia asiatica*, *Terminalia cattapa*, *Calophylum inophylum*, *Hibiscus tiliaceus*. Several types of fauna live in the Pangandaran Nature Reserve Forest including *Cervus timorensis*, *Bos sondaicus*, *Muntiacus muntjak*, *Cynocepalus variegatus*, *Pteropus vampyrus*, *Macaca fascicularis*, *Tracyphithecus auratus*, *Anthracoceros convexus*, *Buceros rhinoceros* and *Gallus gallus* (BBKSDA Jabar, 2016).

In the shallow marine environment around Panenjoan Hill, a shallow marine ecosystem is developed which is inhabited by various types of shallow marine flora and fauna including fish, algae, corals, and mollusks. The dominant types of mollusks include *Cypraea annulus* and *Rhinoclavis sinensis* (Pribadi et al., 2017). Several types of algae that are dominant in the shallow marine environment of Pangandaran are *Padina australis* and *Gracilaria coronopifolia* (Pribadi et al., 2017).

3.2 Regional Geology

Physiographically, the Pangandaran area is included in the Southern Mountain Zone (Bemmelen, 1949). This area is covered by the Oligocene Jampang Formation, the Middle-Late Miocene Kalipucang and Pamutuan Formation and the Quaternary marine and alluvial deposits (Simandjuntak & Surono, 1992) (Figure 2). The Jampang Formation is composed of volcanogenic breccias, tuff with lava lenses intercalated with lithic sandstone, mudstone, marl, and conglomerate pebbly sandstone, and diacmitite intercalation. The Kalipucang Formation is composed of Coralline limestone. The Pamutuan Formation is composed at the bottom by a Marly tuff Member consisting of marly tuffs intercalated with lithic sandstone, mudstone, and limestone, and at the top it is composed of a calcarenite Member consisting of calcarenite and clastic limestone intercalated with marl. Quaternary deposits are composed of alluvium resulting from flood deposits and river deposits.

The rocks of these formations have different hardness and erodibility. The difference in hardness and erodibility is one of the main factors controlling morphology. The hilly morphology with steep slopes develops in the area covered by the Jampang Formation. The hilly morphology with gentle slopes develops in the area covered by carbonate rocks and carbonates of the Kalipucang Formation and the Pamutuan Formation. Isolated hills and caves develop in areas covered by coral reef limestones of the Kalipucang Formation. Plain morphology develops in areas covered by alluvial deposits.

3.3 Geology of the Batu Kalde Temple Site

Geology of the BKT site is presented in Figures 1 and 2. As described above, BKT is situated on a narrow coastal plain about 100 m wide, extending from Muara Cikamal on the west coast to Panggung Cave beach on the east coast for about 350 m. Based on the reconstruction of the National DEM map of the Geospatial Information Agency (Fig. 2), the coastal plain elevation of the BKT is around 15-17 m above sea level. The site is surrounded by limestone hills of the Kalipucang Formation. The southern side of the site is a limestone hill as high as 15-20 meters above sea level, extending east-west to almost reach the coast. At the southern foot of this limestone hill, the Ciborok River flows westward and empties into Muara Cikamal. The Pamutuan Formation outcrops at several points at the bottom of the Ciborok River. In the sediments of the Ciborok River terraces, gravel and various rocks are deposited, possibly derived from fragments of the Jampang Formation.

Reconstruction of a north-south cross-section of the morphology of the limestone hills flanking the Batu Kalde Site indicates the thickness of the Quaternary deposit below the site is less than 5 meters. The thickness was confirmed by the stratigraphy of the walls of two dug wells located to the north of the site. In the western well, limestone is exposed at a depth of 2 m (Figure 2). Meanwhile in the east well, limestone is exposed at a depth of 3 m. The two wells also provide data that the groundwater aquifer in these two wells is limestone of the Kalipucang

Formation. The morphology of isolated hills and caves in the limestones of the Kalipucang Formation indicates the development of a karst system. The formation of this karst system is most likely controlled by the joints formed in the limestones of the Kalipucang Formation.

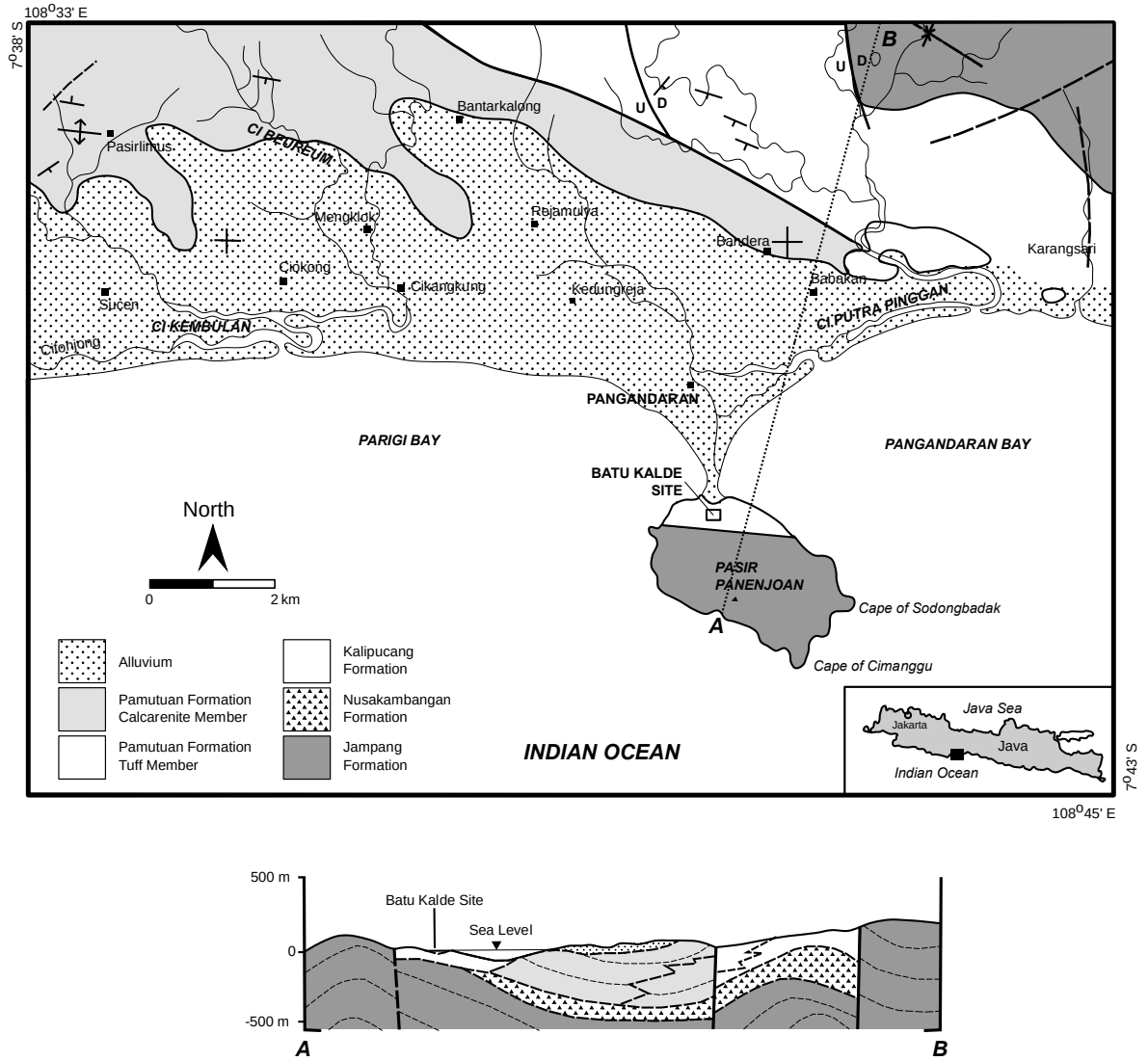

Figure 1. Geological map of Batu Kalde Temple site and the surrounding area, modified from Simandjuntak and Surono (1992), showing a geological cross-section and stratigraphic correlation of the rock formations

3.3.1 Penanjung Tombolo

Tombolo is of Italian origin (meaning pillow or cushion). It is a term used in geomorphology for a narrow sandy landform deposited across the sea that connects two larger lands (islands). Due to its narrowness, the bridge looks like a neck and one of the islands it connects to becomes its head. This small island connected by the tombolo is known as the "Tied Island". In the geological context of Batu Kalde temple, "the tied island" is Panenjoan Island where the BKT is located.

The formation of the "tombolo" occurs when the "tied island" blocks the impact of waves from the open ocean. As a result, the waters behind the island became calmer. If a sufficient supply of sediment is available, the sedimentation process may be concentrated in the shadow area of the island. This build-up of sediment is in some cases accelerated by large waves caused by storms (see Kench et al., 2018).

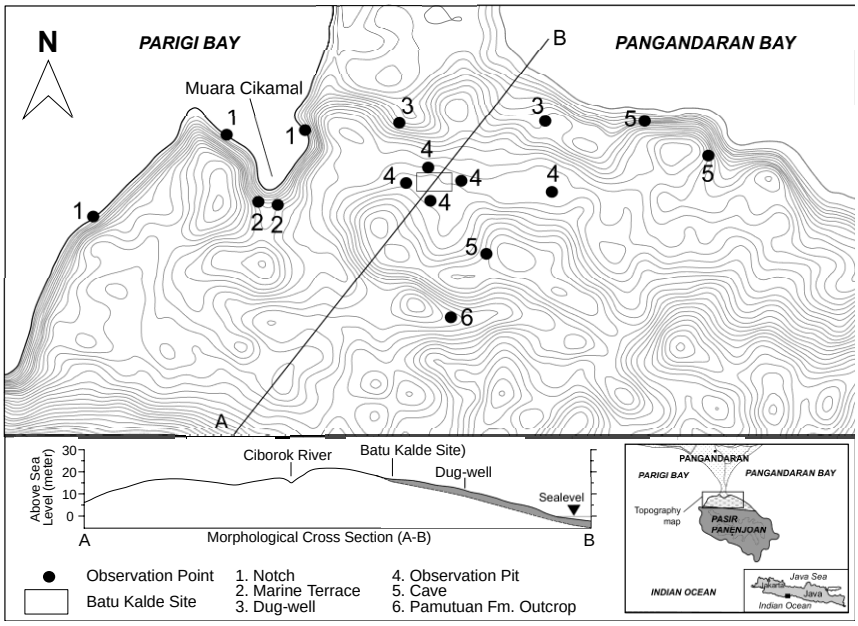

Figure 2. Topographical map of the Batu Kalde Temple site in 1-m contour interval

Note. This map was derived from DEM of Geospatial Information Agency of Indonesia. The morphological cross-section shows estimate of the thickness of the Quaternary deposit (grey shading) on the limestone basement of the Kalipucang Formation. The estimate is based on the positions of limestone outcrop on the slope of the hill and limestone stratigraphy in the dug wells near the temple.

3.3.2 Morphology of Karst Hills and Caves

The northern part of Panenjoan Island is covered by reef limestones of the Kalipucang Formation (see Figure 1). In this limestone complex, small karst hills are formed. In some parts of the hills, caves with stalactites formed.

Caves in limestone areas are often used as shelters by prehistoric humans. Some of the prehistoric human habitation caves were used as shelters during the last glacial period when sea levels dropped to several tens of meters below present sea level. In this period, Panenjoan Island merged with Java Island so that the caves in it may have been used as dwellings by prehistoric humans. The caves might have also been dwelled in later periods because there are findings of prehistoric stone tools at several sites nearby Pangandaran such as in Tasikmalaya (see Handini, 1999; Febrianto, 2013; Laili & Febrianto, 2020).

3.3.3 Artefact Analysis

At the Batu Kalde site there are several artefacts that are exposed above ground level. Two of the artefacts are icons in Hinduism, namely a statue of Nandi and two yonis. The dimension of the statue of Nandi is 69 cm in length, 50 cm in height from leg to the hump and 65 cm from the leg to the head, dan 34 cm of body thickness. Some parts of the hump and mouth were broken. One of the yonis has been put together even though it has been split into several parts (Ferdinandus et al., 1984). Initially, the top of the yoni was above ground level on the east side of the bottom of the yoni, broken into three fragments (Ferdinandus et al., 1984). The yoni is in square shape in a dimension of 94 x 94 cm, 59 cm in height. Another yoni has been broken into several pieces that are not intact, lying on the ground. Another artefact consists of eight flat-sided stone cylinders about 60 cm in diameter, and 20-33 cm in height. Several block-shaped stones which may be temple stones are also lying on the ground. Many similar stone blocks were found in excavation pits when the team from the National Research Center of Archaeology Indonesian conducted research in 1984, 1986 and 1987 (Ferdinandus et al., 1984; 1986; 1987). There are one to three layers of temple stones found in the excavation pits (Ferdinandus et al., 1987).

Most of the artefacts that can be observed above ground level are made of bedded rock. This rock is composed of alternating beds of sandstone and marl. The thickness of the sandstone bed is 2-20 cm. The thickness of the marl bed is from a few millimeters to 3 cm. This bedding is clearly visible on the statues of Nandi, yoni, and flat-sided cylindrical stones. Most of the rock of the artefact is still in fresh condition, white or slightly grayish white. These rocks have a hardness of 2-3 on the Mohs scale. Some of the temple stone artefacts made of tuff are in weathered condition.

The rock beds in the yoni artefact are in a position perpendicular to the direction of yoni's upright position so that

the rock beds are seen parallel to the ground surface. The origin rock of the yoni artefact shows beds with a thickness of about 1-10 cm. In the Nandi statue, the upright position of the Nandi statue is parallel to the rock beds so that the body of the cow statue seems to be sliced vertically by the boundaries of these rock beds.

4. Discussion

4.1 Morphological Toponymy and the Construction Period of the Batu Kalde Temple

Penanjung as the name of the place, has been written in the manuscript of Bujangga Manik's travel notes. Bujangga Manik's journey through the Penanjung region most likely occurred before 1511 (Noorduyn, 1982). Bujangga Manik is a prince from the Pakuan Kingdom whose capital is around the city of Bogor, West Java today. He traveled to visit places of worship and study religion on the island of Java. He traveled from his royal capital all the way to East Java and passed the Penanjung on his way back from the pilgrimage. The note stated that Bujangga Manik reached Bakur at the Citanduy estuary after Segara Anakan. He then reached Cimedang before crossing the Ciputrapinggan river. He then arrived at Pananjung near the island (nusa) of Wuluheun. This record explicitly explains that there was still a strait separating the Penanjung from a small island in the south when Bujangga Manik visited it. This island is called Wuluheun Island. The use of "Penanjung" as a place name implicitly explains that at that time the morphology of the headland had already been formed and the morphology of the Tombolo Penanjung did not yet exist.

Bujangga Manik's notes do not mention his visit to BKT. This shows that perhaps at that time BKT did not exist because Bujangga Manik was a traveling priest. One of the goals of his travels was to visit places of worship. What is interesting is the similarity of the name between "Wuluheun" as the name of the island in Bujanggan Manik's written record, and "Wuluh ên" as the name of a Shiva village which was exempted from taxes by Hayam Wuruk, the king of the Majapahit Kingdom, which is recorded in the Ancient Book. Negarakrtagama Strophe 76 (Mulyana, 1979). If the two names refer to the same place, then BKT already existed and was recognized as a Shiva community when Hayam Wuruk took over the reign of Majapahit in 1350-1389. This means that BKT probably already existed at that time. This is in accordance with the results of the analysis of Rusyanti et al. (2020) who concluded that based on an analysis of the similarity of the temple construction pattern and its historical context, BKT is thought to have been built in the 7-14 century AD. BKT, Ronggeng Temple and Indihiang Temple represent a three-tiered temple building model in the form of a single shelf and hall steps. This temple building model is thought to have existed in West Java since the pre-Sunda kingdom era (Rusyanti et al., 2020).

4.2 Raw Materials of the Batu Kalde Temple

In the context of the type of temple stone, BKT is unique compared to other temples in Indonesia. Most of the temples of the classical period found in Indonesia were built with stone temples made of andesite or brick. The use of other materials for the construction of temples in that period, usually only for the construction of temple supporting buildings such as the use of tuff for fences or as stuffing material for building structures (Sutarto et al., 2018; Riyanto, 2020). However, there are several temples built using stone blocks made of tuff such as Sirih Temple (Sutarto et al., 2018), Indihiang Temple (Widyastuti, 2017) and Ronggeng Temple (Rusyanti et al., 2020). The BKT is different from all the other temples because it is constructed using stone temples made of bedded sandstone. This indicates that there are considerations of practicality and ease in selecting materials for temple stones available around the BKT location.

Materials for temple stones that are available locally at Bukit Panenjoan are breccia stone of the Jampang Formation, reef limestone of the Kalipucang Formation and sandstone-marl of the Pamutuan Formation. Outcrops of the Jampang Formation breccia can be found at several points at the bottom of the Ciborok River. The more visible outcrops are on the coastal cliffs on the west, south and east sides of Bukit Panenjoan but these locations are difficult to access. Reef limestone outcrops of the Kalipucang Formation are easier to find around the BKT site. The Pamutuan Formation is only exposed to a limited extent at some points at the bottom of the Ciborok River. The rocks of these formations are also scattered up to a radius of 20 km from the BKT site. All these formations are Miocene in age so that they have undergone quite intensive tectonic processes. As a result, in the rock body has developed quite intensive joint cracks. This is indicated on the geological map by the presence of faults and folds that intersect all these formations (Figure 1).

Although it has a high level of hardness, Jampang Formation breccias are difficult to use as temple stones because they are composed of various stone fragments of various sizes. As a result, the color of the rock is uneven, and the porosity of the rock also varies across its surface. These two aspects are a requirement in the selection of temple stone materials according to *Çilpa çastra*, a book in India that contains provisions in the making of statues, especially if the rock will be used to make large statues (Lelono, 2013). Breccia rocks are difficult to maintain intact while being carved and smoothed due to the presence of various rock fragments. Moreover, the Jampang

Formation has also been very strongly fractured (Verdiana et al., 2014) so that it is difficult to find a section without cracks in it. The Jampang Formation also contains andesitic porphyry lava inserts. As an insertion in other rocks, this lava is not easy to find. This lava also has a technical weakness as a temple stone material because it has been evenly fractured.

The reef limestones of the Kalipucang Formation also do not qualify as temple stone materials. This reef limestone is composed of various types of coral and marine molluscs so that it shows a non-uniform surface texture. As a result, these rocks are difficult to carve and smooth. This limestone has also been intensively fractured.

Due to limitations or difficulties in obtaining the ideal materials for temple stone, bedded sandstone was selected as the material for the temple stone of BKT. This bedded sandstone is most likely taken from the Pamutuan Formation. The use of local rocks taken from sources near the temple site, as a temple stone material was also applied at Ronggeng Temple and Indihiang Temple in West Java, Indonesia. These two temples were built using temple stones made of tuff (Rusyanti et al., 2020). The use of local rocks as temple stones in these three temples strengthens the assumption of Rusyanti et al. (2020) regarding the typology of models or forms of sacred buildings in West Java which were built in the 7-14th century period, namely the three-tiered temple building model in the form of a single shelf and hall steps. These three temples are not only distinctive in their similarity in construction but are also unique in terms of the use of local rocks as temple stone material even though they do not meet the criteria for temple materials as stated in the book of *Çilpa çastra* (Lelono, 2013).

The use of bedded sandstone as a temple stone may be related to the absence of a plinth under the Nandi statue found at BKT. The Nandi statue at BKT is made of bedded sandstone where the boundaries of the beds are in a vertical position and seem to slice Nandi's body vertically. On Nandi's body, these beds are still firmly attached to each other because they are attached to each other on a wide surface. However, for the plinth, the surfaces that stick together will become much narrower so that the sandstone beds will easily be separated from one another. This issue has most likely been considered by the Nandi statue maker so that the Nandi statue in BKT was made without a plinth, and it looks different from the Nandi statues found in Central and East Java. The flat surface on one side of Nandi's body may be the appearance of the original surface of the sandstone bed after the part of the statue on that side is dislodged, not because the Nandi statue was deliberately designed to stick to the wall as Ferdinandus et al. (1987) suspected. Due to the presence of a bed boundary, tail part could not be carved right in the middle of the statue body and slightly shifted to the left position (Figure 6).

Figure 3. Outcrop of bedded limestone of the Pamutuan Formation in Cigugur Village, Pangandaran area, showing alternation of brownish white limestone and fine-grained reddish-brown limestone

Figure 4. Outcrop of carbonaceous sandstone of the Pamutuan Formation in Kertajaya Village, Pangandaran area

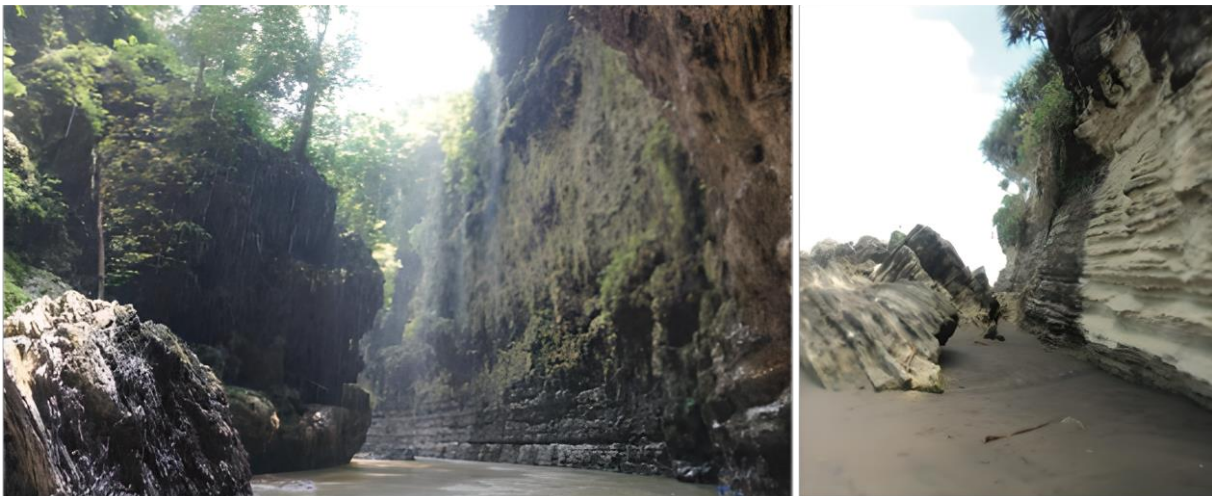

Figure 5. Outcrop in Batu Hiu beach (right) and in Cijulang (left), Pangandaran area, showing alternation of calcarenite sandstone and marl (Anshori et al., 2016)

Figure 6. Oblique picture of yoni (top) and Nandi statue (bottom), showing boundaries of the original bedded sandstone at horizontal (yoni) and vertical (Nandi) position

Note. Due to the presence of a bed boundary, tail part could not be carved right in the middle of the statue body and slightly shifted to the left position. The flat right side of the statue is most likely caused by the dislodgement of rock beds.

4.3 Water Resource and Soil Fertility

In classical times, temples were used as places of worship to Gods and offerings to the spirits of kings. In addition, the temple is also used as a means of invoking wishes and giving thanks for a bountiful harvest to the Gods. This is what causes a connection between the existence of the temple and the presence of the human population where the temple is located. The presence of a temple in an area indicates a large human population nearby. Even the number of temples in an area can indicate the population density and fertility of an area. In the context of the distribution of temples built during the classical period in the Yogyakarta area, there is a pattern that the more fertile an area is, the more temples were built (Mundardjito, 2002). In the context of soil elements, soil fertility is a soil condition where the water, air and nutrients are in a balanced state and are available according to plant needs, both physical, chemical, and biological soils to be able to provide essential nutrients in balanced amounts and proportions without the toxic effects of existing nutrients (Brady, 1990; Effendi, 1995; Foth & Ellis, 1997).

The determinants of soil fertility, besides being related to the nutrient content in the soil, are also closely related to the availability of abundant fresh water which ensures sufficient water content in the soil for plants. Fresh water becomes a more important factor if fertility is related to the productivity of the rice crop. In addition, fresh water is also a basic need for humans. Thus, the availability of abundant fresh water is always closely related to the presence of a large human population.

The floodplain is an area that has a high fertility rate. This is because flood sediments have a high nutrient content (Hirst & Ibrahim, 2008). The area around the BKT has extensive flood deposit alluvium (see Figure 1). This alluvium was deposited by three main rivers, namely the Cikembulan River, the Ciputrapinggan River, and the Cibeureum River. These three rivers have wide watersheds so that they can supply water needs for the people who live in this area. Most of this alluvial plain has been used as irrigated rice fields, until recently. The source of irrigation water comes from the network of these rivers. The tradition of offering to the Goddess of rice in Javanese society in various forms, as well as the etymology of the word “java” which originally “jawawut” which means

rice in the ancient Javanese language indicate that this rice field may have existed since ancient times even before Hindu influence entered this area.

4.4 Uniqueness of the Batu Kalde Location

Soil fertility and abundance of water resources have probably been the trigger factors for the presence of a large population near Tombolo Penanjung since ancient times. This is because rice has been a staple food in Java for thousands of years. However, in the context of BKT construction, the fertility aspect may not only be related to soil. The abundant availability of food from the sea may also have been a consideration. In this context, BKT was built not only as a place to ask for mercy from and give thanks to the Gods for the abundance of agricultural harvests on land but also the abundance of harvests from the sea. Speculatively, the selection of the BKT site on the narrow coastal plain of a small island, rather than on the mainland may be related to the abundance of marine food resources. This also indicates that the Penanjung community consists of farmers and fishermen, at the time the BKT was being constructed.

5. Conclusion

An overview analysis of the geoarchaeological aspects of BKT resulted in several important things as follows:

1) Based on morphological toponymic analysis, BKT was probably built before the 14th century. This is in accordance with the results of an analysis of the relative age of the temple which was carried out based on the similarity of construction patterns and historical contexts.

2) The temple stone used to build the BKT utilizes local resources, particularly the Pamutuan Formation. Utilization of local resources as temple stones is likely to have become a pattern in the construction of three-tiered temples in West Java in the 7-14th century.

3) The construction of BKT indicates the presence of a large population that cultivates the fertility of the flood sediment soil and the surrounding freshwater overflow for agricultural land. The location of BKT on Panenjoan Island also indicates that BKT construction is also related to the abundance of marine resources. When BKT was built, the population of the builders lived as farmers and fishermen.

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