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THREATS OF BIOCORROSION MOSS AND RIVER EROSION ON MEGALITHIC SITES IN LONG PASIA, BORNEO: A CASE STUDY OF PETROGLYPH NARID UPAI SEMARING

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ABSTRACT During ancient times, megalithic sites generally functioned for religious purposes, astronomy, burial monuments, symbols of a man's strength, and markers for land boundaries. Nowadays, megalithic sites have the potential to be used as locations for cultural and heritage tourism, particularly archaeology tourism. This indirectly shows that a megalithic structure is something of great value, especially from economic, historical, and cultural perspectives. Its existence is always relevant. Therefore, the originality of a megalithic monument's structure must be maintained and preserved from any threats of damage and destruction. Unfortunately, a megalithic structure often faces various threats of damage and destruction, be it naturally or from human activities. Hence, this study aims to examine the threat of natural damage through the process of biocorrosion river erosion on megalithic sites in Long Pasia, Borneo, focusing on the case study of petroglyph Narid Upai Semaring. Other than that, this study also suggests mitigation approaches that can be applied to overcome the threats. Insights from the observational data (photo documentation) through a series of field studies were used as evidence to explain the phenomenon under investigation. This research provides an in-depth insight into how the reaction between the natural environment (moss and river flow) and megalithic sites could change the physical structure of

the site. The research finding not only contributes to our understanding of the damage mechanism to ancient artifacts, but it also has crucial implications for the protection, preservation, and management of historic sites in areas that are exposed to the process of biocorrosion and river erosion. The finding is expected to help plan proper preservation and conservation actions for megalithic sites particularly in Long Pasia and generally in Malaysia.

Keywords: Archaeology, historical heritage, megalithic structure, Sabah

INTRODUCTION

A megalithic site refers to an area or location that has megalithic structures. Meanwhile, megalithic structures are large stones placed or arranged by ancient people. The term megalithic comes from the combination of the Greek words "*mega*" and "*lithos*". "*Mega*" means big while "*lithos*" means stone, which when combined means "big stone" or in a literal manner, "a structure built using big stone". There are several examples of megalithic sites known in the world such as the Stonehenge (Nash *et al*., 2020), Aveburry in the United Kingdom (Gillings et al., 2019), Arnac in France (Seglins et al., 2019) and Tongkonan in Indonesia (Sampebua, 2022). In the Malaysian context, megalithic sites can be found in Long Pasia, Sabah (Bala et al., 2021; Sauman et al., 2018; Lotfee, 2018; Jelinus, 2017).

Now, megalithic sites have potential to be developed for archaeo-tourism and as heritage sites (Eboy & Kong, 2019; Bala et al., 2021). Among the megalithic sites that have been successfully turned into tourism products are Gunung Padang Megalithic Site, Indonesia (Hasanah et al., 2020); Cibalay Megalithic Site, Indonesia (Sunkar et al*.,* 2016); Ales Stenar Megalithic Site, Sweden; Lejre Megalithic Site, Denmark; and Wietrzychowice Megalithic Site, Poland (Krzemińska *et al.,* 2018). This indirectly shows that a megalithic structure is something that is of great value, especially from the point of view of economy, history, and culture.

Therefore, the originality of a megalithic monument structure must be maintained and preserved from any threat of damage and destruction.

Unfortunately, megalithic structures located in certain areas often faced with various threats of damage and destruction. Generally, there are two threats that usually threaten the sustainability of megalithic structures, namely natural and non-natural threats. Non-natural threats are usually triggered by human activities such as theft, land use change (Santi et al., 2019), vandalism, development process (Afandi & Bee, 2016), road construction, logging, and land clearing for agriculture purposes (Gani, 2019). On the other hand, natural threats usually result from natural phenomena including landslides, erosions (Dewi et al., 2022), flood, tree overlaps, disturbance by animals and tree roots (Gani, 2019), and biocorrosion (İpekci, 2021).

Long Pasia, Sabah is one of the megalithic sites that has the potentials to be a leading archaeotourism location in Malaysia (Bala et al., 2021). Other than the ability to generate the economy of the local people, the application of archaeotourism based on the megalithic structure in Long Pasia can indirectly preserve the local cultural heritage. Hence, the originality of the megalithic site in this area must continue to be maintained through systematic preservation and conservation approaches. Nevertheless, preservation and conservation approaches are unable to be carried out without first knowing the type of threats experienced by a megalithic structure. Based on that, this study aims to examine the natural threats (biocorrosion and river erosion) on the petroglyph Narid Upai Semaring located in Long Pasia, Sabah. Other than that, this study also suggests several mitigation measures that can be taken to preserve and conserve the petroglyph Narid (carved stone) Upai Semaring from any form of damage due to such natural threats.

Petroglyphs are images chiseled on top the surface of rocks and boulders. Largely an outdoors activity, they have also been found at cave oppenings and rockhangs (Ptery, 2013). As a part of rock carving form in megalithic tradition, it is indirectly reflected in the landscape the way ancient communities lived, their attitude to the environment and the functional significance of its individual components, depending on the level of social and technical development in a particular period of history (Novozhenov, 2024:44).

METHOD

This study was conducted in Kg. Long Pasia which is located in the interior of Sipitang distict, Sabah. Sabah itself is among the states in Malaysia that has large population (3,904,500 people) (Jafar et al*.,* 2021). Kg. Long Pasia borders the state of Sarawak and North Kalimantan, Indonesia (Figure1). The name '*Long Pasia*' comes from the Lundayeh language which means the mouth of the red wated river. This name is in accordance with the geographical position of Long Pasia which is flowed by two branches of big rivers, namely Sg. Pasia and Sg. Matang. Lundayeh is the majority ethnic group that has resided in Long Pasia for generations. The term '*Lundayeh*' was originally used to describe the "*Hulu Sungai*" people (Moody, 1984). Long Pasia is very famous with Upai Semaring which is a one of the legendary figures of the Lundayed community. The main economic activies in this area is agriculture and tourism (Soehady et al*.,* 2017).

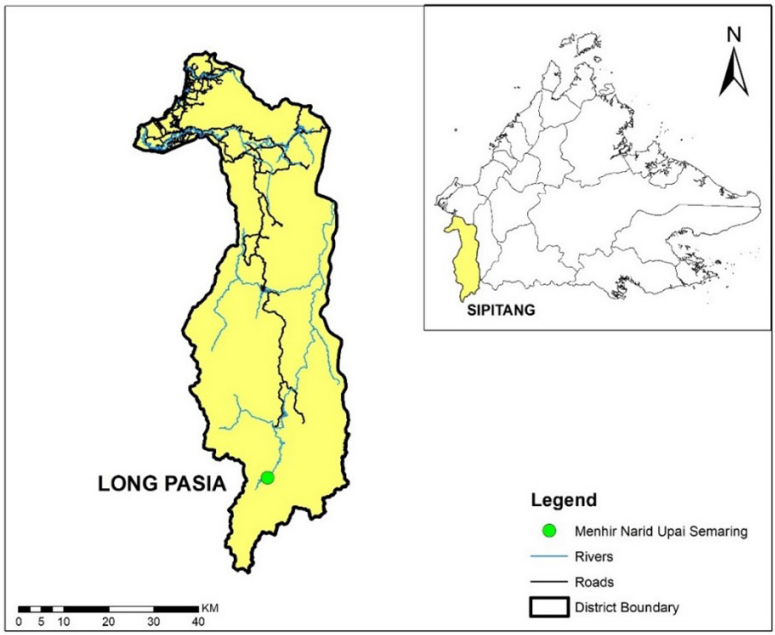

Figure 1 Position of the study location located on the Sarawak-Kalimantan borders

This study applied observation techniques in the process of observing data in the field. Among the things observed were the physical condition of the structure and site of petroglyph Narid Upai Semaring. It included the observation on the presence of moss and the clarity of the carvings on the surface of the boulder, the state of the soil on the petroglyph site, the plants that grow nearby the petroglyph, and more. The information or data obtained through the observation process was then translated into the form of pictures. The process of data collection obtained through the observing approach comprises two phases, namely Year 2017 (Phase 1) and Year 2023 (Phase 2). Throughout the span of the six years, the physical changes on the surface of the structure and site of petroglyph Narid (carved stone) Upai Sumaring have been identified.

FINDINGS AND DISCUSSIONS

The threats of damage or destruction of megalithic structures are generally influenced by two main factors, namely internal and external. The internal factor comprises the types of rock of the megalithic structure itself. In general, megalithic structures can be built from Sedimentary Rocks (Limestone & Sandstone), Igneous Rocks (Granite and Basalt) and Metamorphic Stone (*Gneiss* & *Sepertinite*). From the durability aspect, Igneous and Metamorphic Stones are harder and more durable compared to Sedimentary Rocks (Tsado, 2013; Leroy et al., 2017). Sedimentary Rocks are described as fragile and easily eroded rocks (Roesch et al*.,* 2009). This shows that the megalithic structure built from Sedimentary Stones is internally more at risk of damage and destruction threats compared to the other two stones (Igneous & Metamorphic). Ironically, petroglyph Narid Upai Semaring belongs to the type of sedimentary rock that is sandstone, like the types of stones found in the stream area of Sg. Pasia (Soehady et al., 2017). This is not surprising given that Sungai Pasia and Sungai Matang (the location of petroglyph Upai Semaring site) are in the same drainage basin which is the Ulu Padas Basin (Abd Talip et al., 2022).

Meanwhile, external threats comprise human activities and are caused by natural environmental processes. The location or position of a megalithic

site is an important aspect that influences the type of threats faced. Megalithic sites that are in the environment of human activities for example (agriculture and village areas) are more at risk of damage and destructions by such activities (Gani, 2019). Even so, the absence of human activities does not guarantee the solidity of the original appearance of the megalithic structure. This is because the threat of damage on a megalithic structure or site can happen naturally, particularly through the process of biocorrosion and erosion as happened at the petroglyph Narid Upai Semaring site.

A. Threats of Moss Biocorrosion

A biocorrosion process can happen due to the presence of moss (microscopic organism) on the surface of stones (Cwalina, 2014) as shown in Figure 2. Based on the figure, it is found that there is a significant difference on the surface of petroglyph Narid Upai Semaring at two different times (Year 2017 and Year 2023). The amount of moss growth on the upper surface of petroglyph Narid Upai Semaring was higher in 2023 compared to 2017. This shows that the growth rate of moss on the menhir is increasing from time to time. In fact, in 2023, almost the entire surface on petroglyph Narid Upai Semaring was covered by the microscopic organism (refer to Figure 2).

Figure 2 Surface of petroglyph Narid Upai Semaring on the upper side

Moss that grows on rock surface will release metabolic compounds, including organic acid (Lopez & Bacilio, 2020). Over time, this situation even triggers the dissolution of minerals in the rocks and can weaken the rocks' integrity (Tan, 1986). Other than that, moss can also secrete enzymes that can

break down the mineral structure in rocks. Due to that, the penetration process of roots and hyphae into rock crevices will happen more easily. The overall inclusion process can slowly change the texture and mineral composition of the rock, creating a significant change in the rock structure. Although not visually visible in a short time, a biocorrosion process can change the shape and structure of rocks in a long period of time (Warscheid & Braams, 2000).

The growth rate of moss on rock surfaces is most active in humid environments (Chen et al., 2019). In this environment, moss grows lushly because it gets enough water and nutrition to help the growth process (Windadri, 2023). Ironically, the environment of the petroglyph Narid Upai Semaring site belongs to a humid environment. This is due to the position of the site which is within the river channel and is very exposed to the water splashes of Sg. Matang. Other than that, the megalithic site is also sheltered by the forest canopy cover. This situation minimizes the rate of sunlight access that reaches the forest floor and causes lower environmental temperature in the petroglyph Narid Upai Semaring site. Shaded and cold environmental temperature is also a catalyst for moss growth (Chen *et al.,* 2019). In fact, Long Pasia's own natural environment, which is always shrouded in thick fog at night, also increases the humidity level in the area.

B. Threat of River Erosion

The position of the petroglyph Narid Upai Semaring site that is within the river channel also increases the risk of erosion on the site. Figure 3 shows the condition of the megalithic site in two different periods (Year 2017 & Year 2023). The figure in the year 2017 shows there were piles of trees and small rocks around the megalithic site. This shows that the megalithic structure was exposed to the process of mechanical erosion that was caused by the collision of material washed away by river current (for example, trees and rocks) on the structure and site of the menhir. Continuous collision or impact of the materials (trees & rocks) on the megalithic rocks can result in friction and pressure on the rock surface. Over time, this friction and pressure can cause erosion or stone breakage into smaller fragments.

In addition to being caused by mechanical erosion, the site and structure of petroglyph Narid Upai Semaring are also exposed to hydraulic erosion. Hydraulic action is most active during heavy rains. This is because the occurrence of rain will increase the discharge level and velocity of river water flow (Jafar et al., 2012; Jafar et al., 2020; Jafar et al., 2022a; Jafar et al., 2022b). In fact, in certain situations, the rise in Sg. Pasia water level can submerge a big part of the petroglyph Narid Upai Semaring structure. Ironically, the increase in discharge level velocity of river water (increase in kinetic energy) will also increase the potential force of hydraulic erosion that can cause in the separation of rock particles. In other words, the strong water pressure at the time of the collision can grind and tear the rock particles from the surface. Figure 3 in the year 2023 shows the effects of hydraulic and mechanical erosion on the surface of the petroglyph Narid Upai Semaring structure facing the upstream area. If this situation continues, the hydraulic action of the water flow of Sg. Pasia not only would change the appearance of the petroglyph Narid Upai Semaring structure, but also has the potential to change the position of the megalithic structure.

Figure 3 The state of the petroglyph Narid Upai Semaring site in 2017 and 2023

C. Proposal for Conservation of Petroglyph Narid Upai Semaring from Moss Biocorrosion and River Erosion Threats

To ensure the continuous preservation of the petroglyph Narid Upai Semaring's aesthetic and historical values from the threats of biocorrosion moss and river erosion, several mitigation approaches can be conducted to overcome the problems. Among them is by conducting periodical monitoring

and moss cleaning activities. The stakeholders (Department of National Heritage, archaelogists etc.) and particularly the residents of Kampung Long Pasia must cooperate in carrying out the regular monitoring on the condition of petroglyph Narid Upai Semaring. The purpose is to be able to detect early signs of moss growth on the menhir surface. This is because moss growth is easier to control if cleaning in the early phase of its growth can be done on a routine basis. This cleaning activity can be done whether using a soft brush, high pressure water spray or biocides (Zykubek et al., 2020). Other than that, the control of moss growth on the boulder surface can also be done using protective materials like anti-moss coatings or mineral coatings. These materials function as protective layers to prevent the growth of moss, algae, and fungi. They contain chemical substances or minerals that are disliked by microscopic organisms as they can inhibit its growth.

To reduce the errosion rate of the petroglyph Narid Upai Semaring site, several mitigation measures can be applied which includes planting trees with strong roots (for example, coconut trees, fig trees, and bamboo trees), building stone cages (gabions) (Toriman et al., 2008) or sandbag enbankments (Jaafar et al., 2016) near the megalithic site. These three methods serve to reduce the velocity of Sg. Pasia water flow that arrive at the megalithic site especially during heavy rains. At the same time, these three methods also act as a buffer to prevent any objects (trees, stones & more) that are swept away by the flow of the river water on the megalithic structure. In other words, this method is designed specifically to overcome the erosion problems of the petroglyph Narid Upai Semaring site, be it mechanical or hydraulic. These three proposed mitigation measures, apart from being environmental friendly, they are also easier to apply given that the building materials are easy to get and the construction costs are affordable.

CONCLUSION

In conclusion, this study found that megalithic sites originally served as religious symbols, astronomy and power. Even so, their role has now switched to a new fuction which is to be a cultural and heritage tourism destination, especially in the context of archaetourism. The existence of megalithic

structures in an area has significant economic, historical and cultural implications and continues to be relevant from time to time, including the petroglyph Narid Upai Semaring. Unfortunately, the megalithic site faces damage threats caused by moss biocorrosion process and river erosion. Therefore, several mitigation measures have been proposed to overcome the problems such as conducting tree-planting activities, building stone cage, and sandbag enbankments. Through the application of these mitigation approaches, it is hoped that its authenticity and sustainabiliy of the petroglyph Narid Upai Semaring site can be maintained. This is crucial to preserve the local community's cultural heritage.

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