

Hydro-Oceanographic Modelling Use in Underwater Archaeological Research of Shipwreck Site Discovered in Abang Island Waters, Riau Archipelago, Indonesia

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ABSTRACT

In 2020, the Research Institute for Coastal Resources and Vulnerability (RICRV) conducted an underwater archaeological survey in Abang Island waters, Riau Archipelago Province, Indonesia. The wreck site location is 64.14 km from Batam Island, and the archaeological remains lie at a depth of 20 meters. The underwater findings consist of hundreds of earthenware storage jars and ewers produced in Thailand and some blue-white porcelain plates from the Ming Dynasty era. The hydro-oceanographic data and ocean dynamics back-tracing modelling in the 1600s, along with the sedimentation and bathymetry profiling has been used to predict the sailing route of the ship, sunk in Abang Island waters. The sailing ships in the past would have relied on nature-based generators such as waves, tides, currents, and winds.

According to the hydro-oceanographic modeling result, the extreme current flow generated by tidal and winds in the South China Sea in the 16th century AD peaked at 1.3 m/s during the northeast monsoon. This state could be more weakened during the southeast monsoon. According to the tidal phase delay and asymmetry and the presence of cargoes originating from China and Thailand, the ship was possibly sailing from the north via the South China Sea and cut through the Riau Archipelago from Bintan, which passed through a group of islands, including Abang Island to sail whether toward the north Malacca Strait or Bangka Belitung and Java. Additionally, based on the sediment transport model, the possibility of unidentified artifacts buried by sediment at the depth 60 cm beneath the surface bottom was sufficiently high. An excavation is recommended to prevent the archaeological remains from local looting and natural erosion.

Key words: Hydro-oceanographic data, Back-tracing modelling, Shipwreck site, Abang Island, Indonesia

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INTRODUCTION

According to historical records, the first developed trading relationship was between India and Indonesia, which commenced in the 2nd century AD, followed by China (Flecker, 2001). These trading activities among East-South Asian countries occurred because of the spirit of spreading religion (Buddhism and Hinduism), the distribution demand of luxury goods, and the natural condition (tropical wind) supporting the sea route. (Sulistyono, 2004). The strategic geographical position of Indonesia facilitated the trade route between China and India as the superpower countries at that time (Gupta, 2020). Therefore, Indonesia intentionally has been involved with these trading processes.

The wind system in the Indonesia archipelago, well-known as monsoon systems, influenced the sailing route development systematically from west and east with a uniform pattern (Sulistyono and Rochwulaningsih, 2013). This factor induced the development of new harbor cities and empires, such as Sriwijaya, Majapahit, Malacca, Makassar, Buton, Ternate (Sutherland, 2007). In the 5th century AD, trading ships from China sailed toward Indonesia then continued the journey to India through the East Sumatra waters before turning to the west (Chd Ponto, 1997). Commodities traded were pepper, clove, nutmeg, sandalwood, rice, fabric, and so on, whereby Indonesia was one of the larger producers of those commodities in Southeast Asia. This condition pushed the bustling maritime trade between India and China (Sulistyono, 2004).

The shipwreck findings in Riau Island are related to the history of maritime trade, which occurred centuries ago where the Malacca Strait became the main trade route for both spice and silk commodities (Ali and Sulistyono, 2020). This information sufficiently espoused the other archaeological findings throughout the Malacca Strait. One of which is Batam Island which has plenty of cultural heritage remains, scattered all over the islands that witnessed maritime history in this region. Due to this condition, an integrated archaeology study is crucial to be initiated to preserve and strengthen the historical narration in Riau Islands. Archaeological site findings in Abang island, positioned in the southern Batam Island, consisted of earthenware jars, blue-white ceramics, and the formation of a wooden shipwreck is increasingly convincing that this site is more than 500 years old. Additionally, the wooden cargo shipwreck finding also considers these archaeological remains from China during the 16th century AD.

Concerning the traditional wooden ship during the 16th century AD, the ship was supposed to sail (possibly from China) in accordance with hydro-oceanographic powers (winds, waves, currents,

tides). The paleo-oceanographic data and a back-tracing numerical approach could assist in predicting the provenance of the ship found in Abang Island. Moreover, the bathymetry profiling and sediment transport calculation could be beneficial for predicting the specific age of those remains and the possibility of the buried artefacts. Thus, this study aims to determine the hydro-oceanographic features in the past and their characteristics in the South China Sea to reveal the origin of archaeological findings in Abang Island.

SITE STUDY AND FIELD SURVEY

The study area is located in the southern Abang Island, Batam City, Riau Archipelago Province, Indonesia (Figure 1). The site location is 64.14 km from Batam City, and it can be reached approximately 3 hours road drive and 40 minutes by boat. The Abang Island shipwreck site can be found 20m beneath sea level. Due to the dynamic water motions in the surrounding area, a sedimentation issue was found in the shipwreck site. Many artefacts have been buried underneath the sea substrate. The marine biota varied considerably at the shipwreck site, including different types of reef fish and plenty of major coral clusters. The soft coral and small clams covering the surface of artefacts show that these goods have remained in the bottom of the sea for a considerable period. The current profile in this area is mild. However, the influence of wind-driven current was sufficiently robust in the near-surface. The bathymetry profile and sedimentary characteristics will be elucidated in the next section.

The field survey was performed based on an underwater archaeological approach through scuba diving activities to determine the state and significance of the Abang Island archaeological site. The determination of the datum points, installing the North-South and East-West baselines, labelling and measuring the artefacts, data recording, salvaging of artefact samples, and the desalination processes have been carried out. Site documentation included underwater photography and video recordings. Environmental assessment, including observation of marine biota, have also been conducted (Figure 2). Online oceanographic data were collected from the Geospatial Information Agency of Indonesia (<https://tanahair.indonesia.go.id/demnash/>) and the Marine Research Centre (<http://pusriskel.litbang.kkp.go.id/index.php/en/data/perairan-indonesia/>). Furthermore, interviewing the local people and relevant institutions have been performed to gain information regarding the shipwreck and its cargoes. Literature studies were also conducted to search for the ship's history, environmental conditions, and previous related studies.

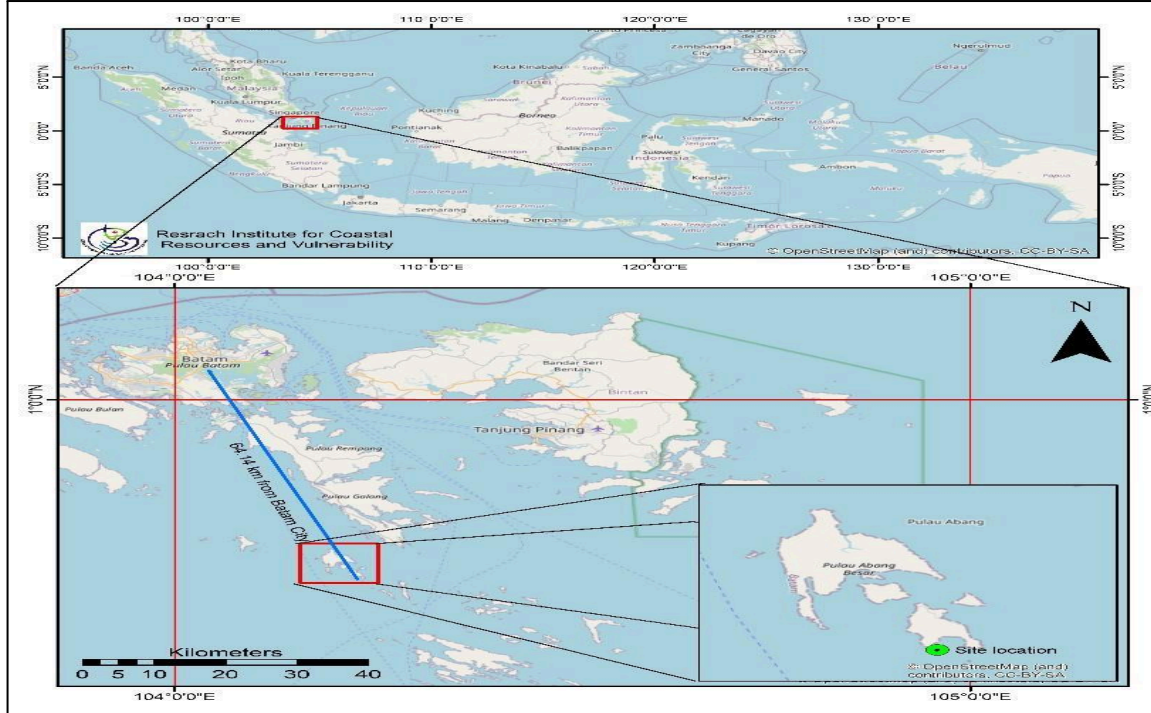


Fig. 1: Site location in the southern Abang Island, Riau Islands Province



Fig.2: Field Survey Documentation. (a). The sample of blue-white ceramic; (b). Earthenware storage jar; (c) Earthenware plate; (d). Underwater survey baseline; (e & f) artifact tagging; (g). artifact samples recovery; (h). artifact samples desalination; (i). local people interview

ARTIFACT SAMPLES AND THEIR POSSIBLE ORIGIN

The artefacts discovered in the Abang Island site were identified according to their type, shape, dimension, decorative patterns and techniques, materials, specific signs and symbols, and its historical context. Overall, the artefacts of Abang Island were classified into earthenware storage jars and ewers; bowl, plate, and tureen blue-white ceramic. According to the shape, the earthenware artefacts are commonly used as kitchen equipment to keep water or food (Yun-xian, 2005). The earthenware-based artefacts have freehand drawing and scratch, while the ceramic artefacts have Chinese hand-painted symbols (Figure 3). The dimension of the sampled artefacts is shown in Table 1.

The location of Abang Island, Riau Archipelago Province, where the archaeological remains were discovered, was the southern lane from Batam Island toward Lingga Island, which is well-known with its hilltop as the main sign of marine navigation. This lane has been tremendously crowded since the 12th century AD, and until now, it is connecting east and west worlds toward East Sumatra and Java through Bangka-Belitung (Tjoa-Bonatz, 2016).

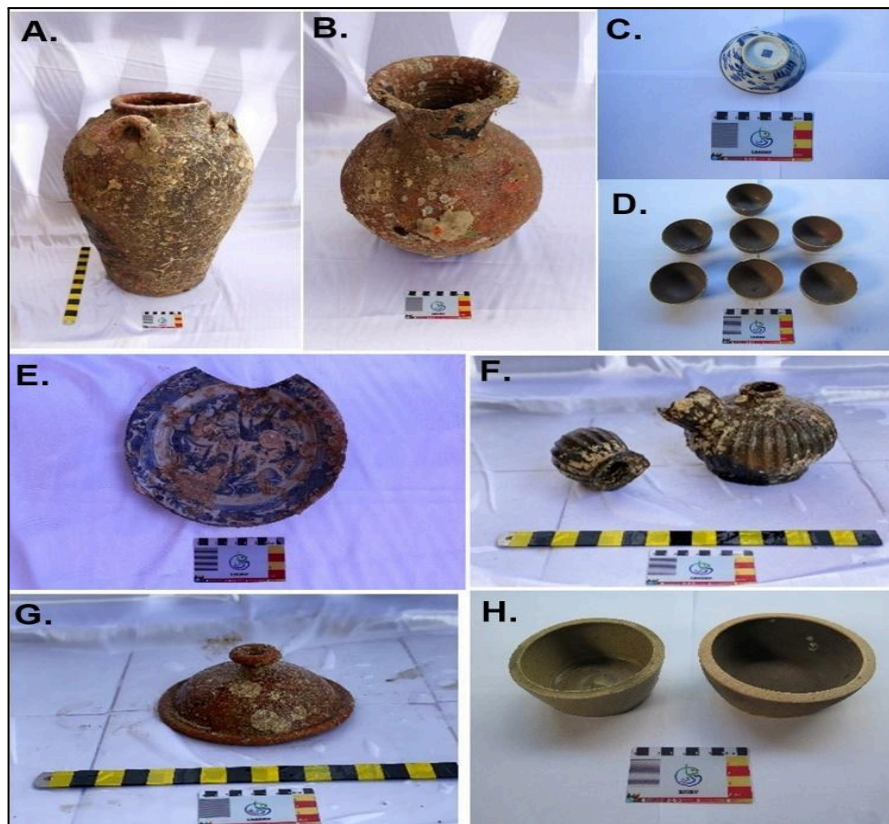


Fig. 3: The sampled artifacts of Abang Island site; (a & b). jar-shaped artifacts; (c & d). dining bowl); (e). blue-white plate; (f). ewer-shaped artifact; (g); and tureen with lid.

Artefacts	Height (cm)	Diameter (cm)	Expected Volume (Liters)	Function
A	71	d1=22 d2= 24 d3=20	28.811	Keeping water/liquids
B	33	d1=16 d2=18 d3=22	9.253	Keeping water/liquids
C	4	d1=3.5 d2=7.5	0.099	Soup bowl
D	4.04	d1=3 d2=7	0.083	Rice bowl
E	2	d1=22 d2=28	0.985	Dinning plate
F	12.5	d1=11 d2=16 d3=4.5	1.473	Keeping water/liquids
G	10	14	0.718	Covering the bowl
H	5	d1=8.5 d2=12	0.416	Keeping food/liquids

Table 1. Dimension of sampled artifacts referring to Figure 3

The production of blue-white ceramics in the form of covered containers, soup bowls, and plates with flora and fauna motifs and two circles in the exterior part was made in China during the Ming Dynasty in the 16th century AD. Another ceramic painting was also observed with brown color on its exterior. The characteristic of beach-sand granules intact on the bottom part of those ceramic findings was well-known as ceramic Swatow/Zhangzhou produced during the 16th-17th century AD (Eriawati, 2014; Adhiyatman, 2000). On the other hand, the earthenware-based jars were made in Southeast Asian countries such as Sawankhalok and Singbhuri, Thailand, during the 15th-17th century AD. This kind of goods was the most demanded commodity aside from Chinese ceramics (Eriawati, 2014). This proves the relation between the Riau's sovereign and the import goods from China and Thailand. Based on the field observation and sampling, the Thai pottery was dominant at the Abang Island site compared to the Chinese blue-white ceramics. At that time, Riau Archipelago

was popular with the gambier industry. In the case of that state, the gambier producer needed the earthenware jars to keep the fresh water in terms of gambier production (Purnawibowo, 2020).

The artefact identification considers the high possibility that the wooden ship discovered in Abang Island site was sailed from China and stopped by in Thailand to load Thai pottery jars and carried all those commodities to Indonesia, regardless of the trading purpose or any other purposes. This analysis could be strengthened by the back-tracing hydrodynamic model simulated during the 16th century AD because the ancient wooden ship was supposed to sail depending on the nature-based generator such as winds, waves, currents, and tides. On the other hand, sediment characteristics and sediment transport models can also detect the depth possibility of the buried artefacts. This enhances the probability that beneath the sediment pile, there are other unidentified artefacts. These model analyses are going to be elucidated in the following subsections.

THE HYDRODYNAMIC OF THE SOUTH CHINA SEA AND THE ANCIENT WOODEN SHIP TRACK ESTIMATION

The 1600s hydrodynamic model in the South China Sea is shown in Figure 4. Overall, an opposite water motion was observed. During the northeast monsoon (October-March), the northerly surface currents tended to move southwestward from China to Indonesia (Figure 4a), and vice versa for the southwest monsoon (Figure 4b). The current speed peaked during the northeast monsoon ranging from 0.5-1.3 m/s. The current magnitude decreased significantly by approximately 0.5 m/s during the southwest monsoon. The wind jet-driven current is the main factor triggering the strong current's features throughout the South China Sea (Wang et al., 2008).

Considering the previous identification of artefacts coming from China and Thailand, the ancient wooden cargo ship was supposed to sail during the northeast monsoon (between October to March), whereby the wind jet-driven current could be the natural-based generator to get the ship moved southwestward to Indonesia through the Vietnam and Thailand maritime boundaries. The Chinese ship would be back again toward China using the backward water flow during the southwest monsoon. Thus, considering the sailing schedule according to the wind-current motions, the tidal model was also simulated during the same monsoon period to strengthen the previous hypothesis.

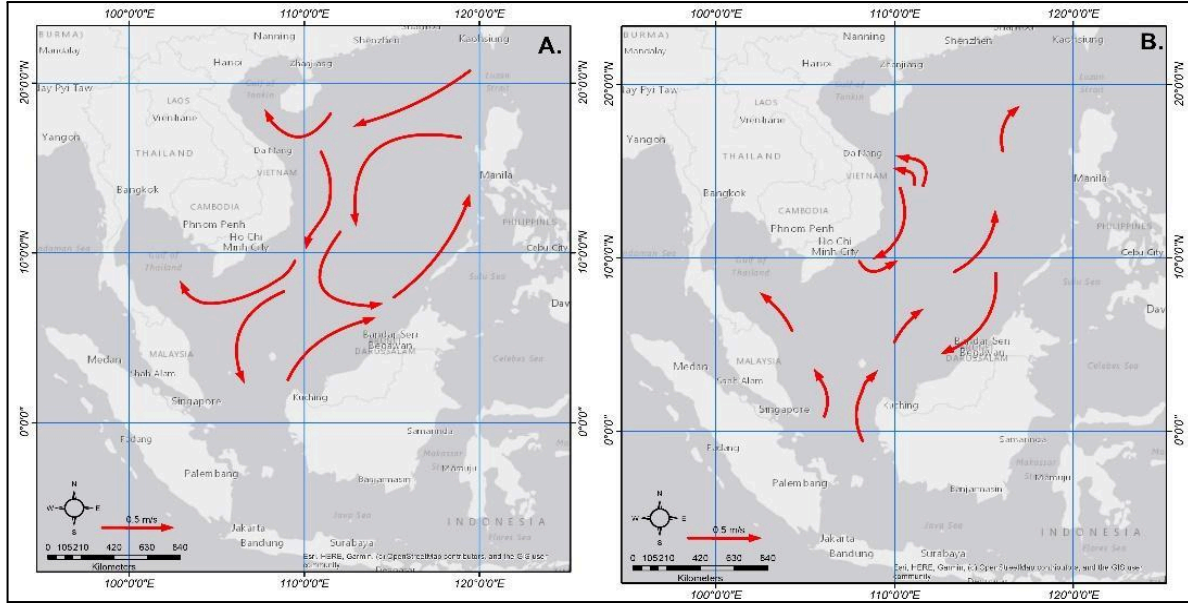


Fig. 4: (a, left). The surface water motions during the Northeast Monsoon (October-March); (b, right). The Southwest Monsoon (April-September).

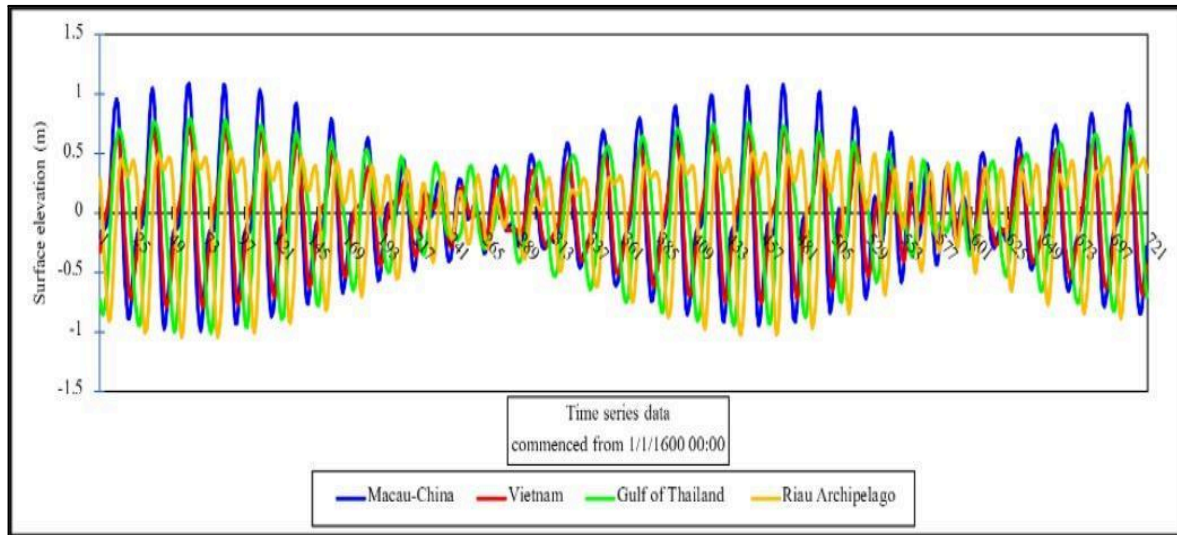


Fig. 5: Nao.99b model of tidal phase delay simulated during the Northeast Monsoon.

Based on the tidal model simulated during the Northwest Monsoon within the 16th century AD, the tidal phase delay was identified between Macau-China, Vietnam Sea, Gulf of Thailand, and Riau Archipelago, where the wooden shipwreck and a plethora of artefacts were found. Theoretically, the displacement of tidal elevation would trigger the wind energy transfer to the surface water, resulting in the waves and current propagations (Bonneton et al., 2007). Even though the tidal type of the sampled observation area is not similar, the tidal phase delay is believed to be used as the ship generator during the 1600s.

In the Macau-China station (blue line in Figure 5), the tidal elevation was the highest (2 meters of tidal range), and the displacement time was going to be quicker than the other station. It was followed by tidal level displacement in the Vietnam Sea with a tidal range of 1.6 meters (red line). The almost similar tidal features were observed between the Vietnam sea and the Gulf of Thailand with a 0.2 lowered tidal range. The phase delay of tides also occurred within 1-2 days (green line). Entering the Riau archipelago, the tidal features were slightly different. The elevation lowered by around 0.4 meters, with a phase delay of approximately two days (yellow line). Thus, based on the Tidal model, it was logical that the Chinese cargo wooden ship sailed depending on tides, winds, and currents power sources from China to Indonesia through the South China Sea and reaching Malacca Strait.

Aside from the hydrodynamic profile of the South China Sea elucidated earlier, a back-tracing model shows a similar possibility (Figure 6). Commenced from China waters, the ship sailed southwestward following the maritime boundaries of Vietnam, Thailand, before arriving at Riau Archipelago. It was supposed to visit Saigon-Vietnam and Thailand, proven by the earthenware jar artefacts, which have many similarities with Vietnam-Thailand pottery. Another prediction is that the ship sailed toward Indonesia for trading, or perhaps the ship from Thailand that directly sailed to Indonesia to provide the earthenware ewers due to the demand for espousing the gambier industry in Riau Archipelago (blue arrows).

It was also estimated that the cargo ship planned to continue its journey, whether toward India through Malacca Strait or going south toward Java via Bangka-Belitung Islands (dashed red arrows in Figure 6). Before continuing its journey toward the estimated destination, the ship drowned in southern Abang Island.

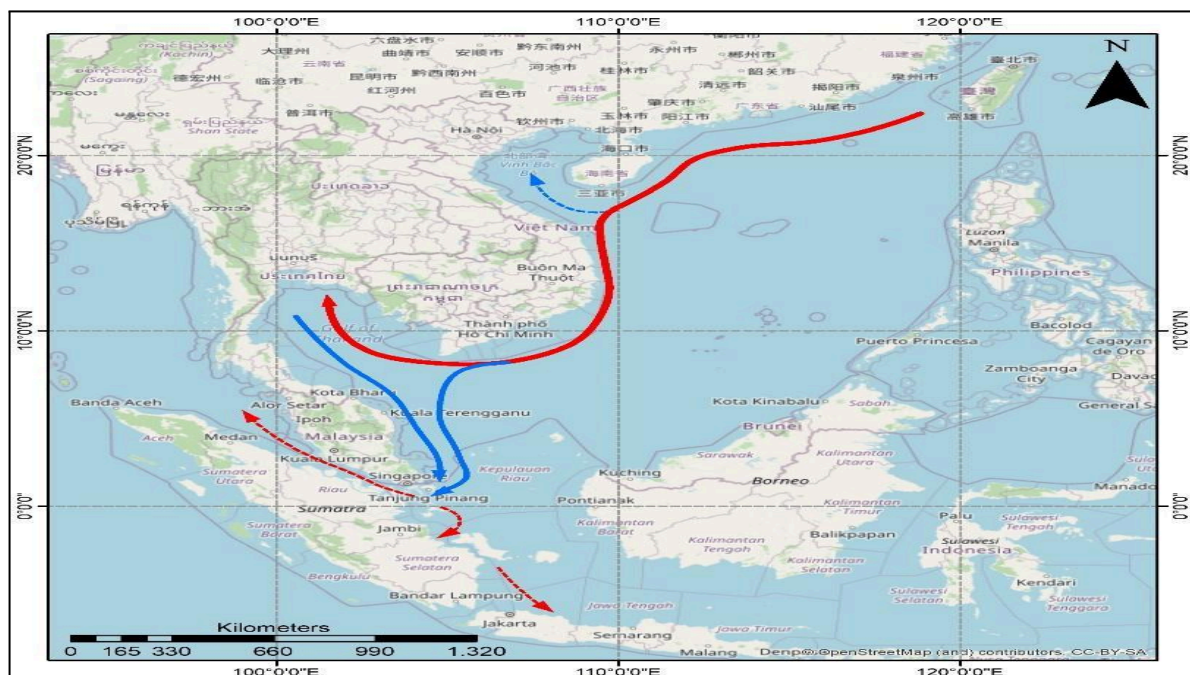


Fig. 6: The estimated track of the ancient wooden ship before eventually drowned in the Abang Island. The dashed red arrows show the probability of ship destination after landing in Abang Island.

SEDIMENT TYPE AND BATHYMETRY PROFILING IN THE SURROUNDING SITE

The sediment sampling was performed using a grab sampler. The result of grain size sediment showed that it was dominated by clayey sand in the surrounding site with 90 % of sand-amalgamated 10 % of clay (slit) (Figure 7). The absence of river-sourced sediment in the study area affects the predominance of homogeneity sediment (Pratomo and Riyantini, 2012).

According to the grain size sediment analysis, it was interpreted that wind-driven current and hydro-oceanographic features in the study area took place in distributing local sediment. It was proven by the poorly sorted sediment samples in Abang Island, illustrating the influence of unstable waves and current. The varied oceanographic profile surrounding Abang Island affects the nonuniform sediment deposition proven by the grain size gradation of sand and silt.

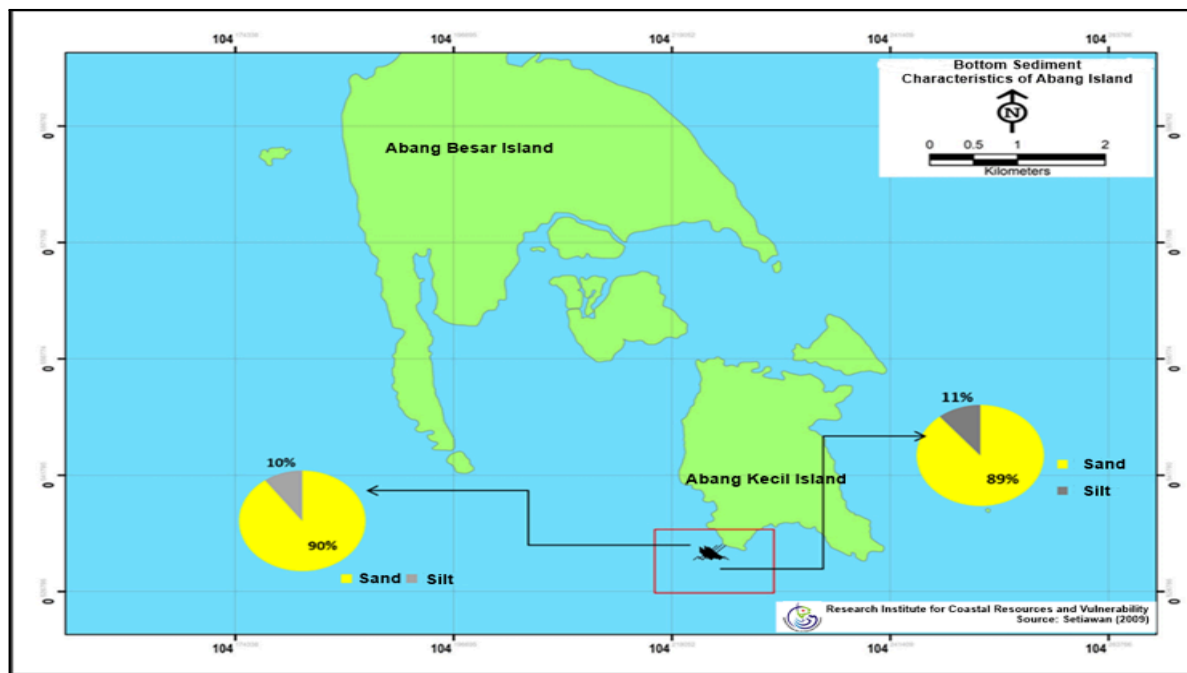


Fig. 7: Sediment type in the surrounding archaeological site of Abang Island

The presence of coarse sediment reflected the relatively robust oceanographic profile. Coarse fractions, scattered in the surrounding archaeological site, were generally deposited in the open ocean connected to the Malacca Strait while the fine particles were in the calmer situation near the coast, plateau, and estuary (Gemilang et al., 2021).

According to the sediment type predominance that was elaborated earlier, excavation of the archaeological remains is necessary due to unstable sedimentation which potentially threatens the site. The sand sediment type could not be natural protection for those remains because the sediment materials are easily transported and eroded by sea current. That is why estimation of sediment transport should be analyzed to determine the impact of sedimentation on the archaeological remains and the possibility of the artefact beneath the sediment pile.

The sedimentation process is always related to the bathymetry profile because the sedimentary behavior reflects the form of the bottom morphology (Gemilang et al., 2021). Based on the bathymetric map provided by the Indonesian Navy, the archaeological site in Abang Island lies between 10-30 meters deep. The bathymetry profile in an archipelagic region is arbitrarily erratic due to the unstable oceanographic features, resulting in the unstable sediment transport influencing the alteration in bathymetry and bottom morphology.

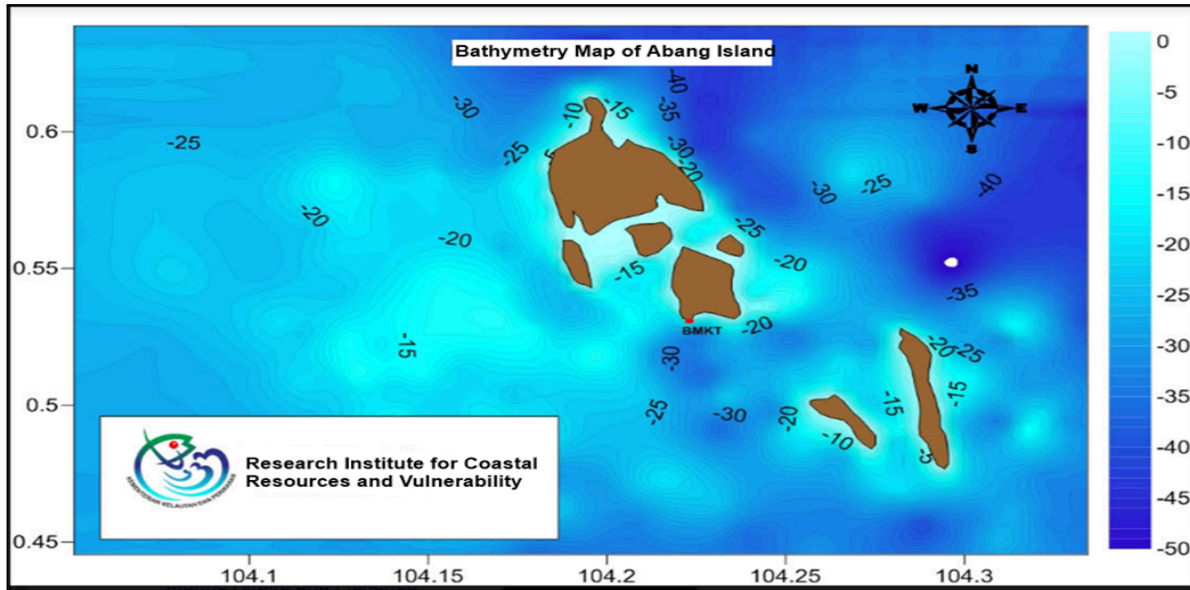


Fig. 8: Bathymetric profile in the surrounding archaeological site of Abang Island

Figure 8 shows the bottom morphology of Abang Island. It was categorized as a steep slope with a declivous slope in specific depths. The archaeological remains in Abang Island were in a flat bottom morphology. It can be said that the position of those remains was relatively safe from landslip. However, the declivous slope contributed to the local looting activity because it was easier to reach the site and take the artefacts away from their source.

SEDIMENT TRANSPORT MODEL IN THE SURROUNDING ABANG ISLAND SITE

The sediment transport was simulated following the correlation between wave energy flux and sediment transport. This model was based on a coupled model (spectral waves and Flow model) previously performed (Wisha et al., 2019). Overall, the average sediment transport was higher during the northeast monsoon than the Southwest Monsoon (Figure 9). As discussed in the previous subsection, the current profile would be more robust during the northeast monsoon. Because of the higher magnitude of current, the sediment transport would highly take place. The most elevated transported sediment occurred during December of $245.88 \text{ m}^3/\text{day}$. In contrast, the lowest sediment transport was observed during May, with a rate of $100.794 \text{ m}^3/\text{day}$.

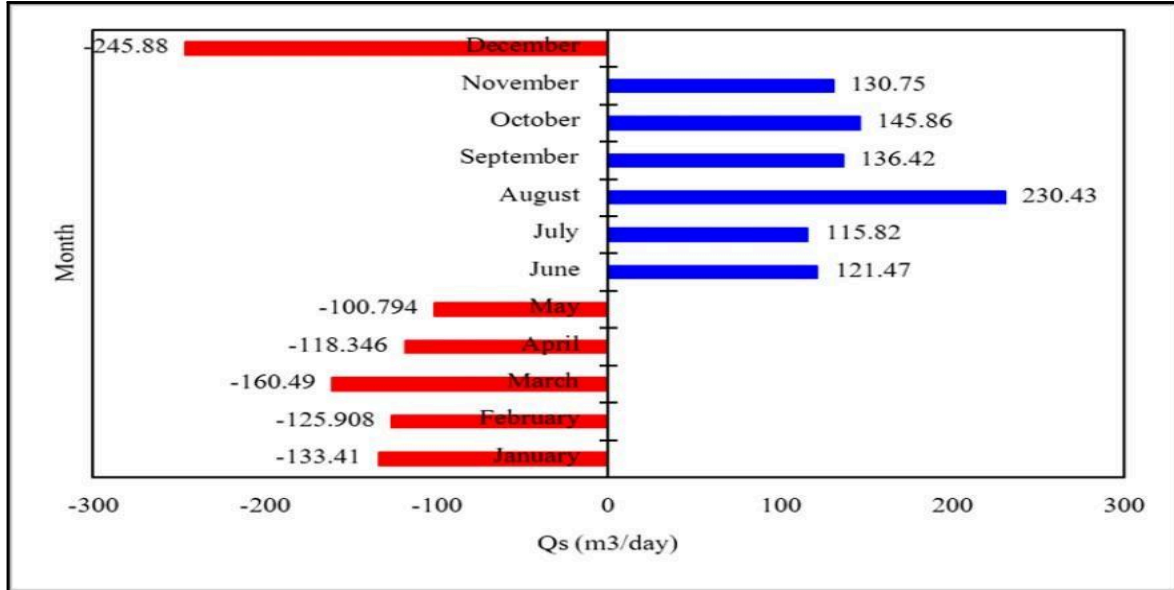


Fig. 9: The annum sediment transport model in the Abang Island site. The blue bars show the additional sediment flux, and the red bars show the reduced sediment flux.

According to the previous sediment transport model results, the total annual sediment transport was approximately 4.078 m³/day. By applying a cube volume with a grid of 1 km x 1 km, the annual thickness of sedimentation was 1.488 x meters. Therefore, the estimated sediment accumulation for 420 years commenced from 1600 to 2020 could be approached with an approximate sediment thickness of 62.51 cm (Table 2). These results create a consideration that around 62 cm beneath the surface bottom, there are many buried undiscovered artefacts petrified in the bottom of the Abang island site. Figure 10 shows the present condition of the artefacts in the surrounding Abang Island site. Concerning the sand-sediment domination in the surrounding Abang Island site, which has a compact property, it makes sense that the buried artefacts were fossilized and petrified beneath the sediment silting (Dobre, 2017). Thus, an excavation is recommended to prevent these archaeological remains from further local looting and natural erosion.

Site	Annual total sediment transport (m ³ /day)	The annual thickness of sediment silting within grid 1 km x 1 km (m)	The estimated sedimentation thickness over the 420 years (cm)
Abang Island site	4.078	1.488×10^{-3}	62.51

Table 2. Estimation of the sediment accumulation thickness over 420 years (1600-2020)

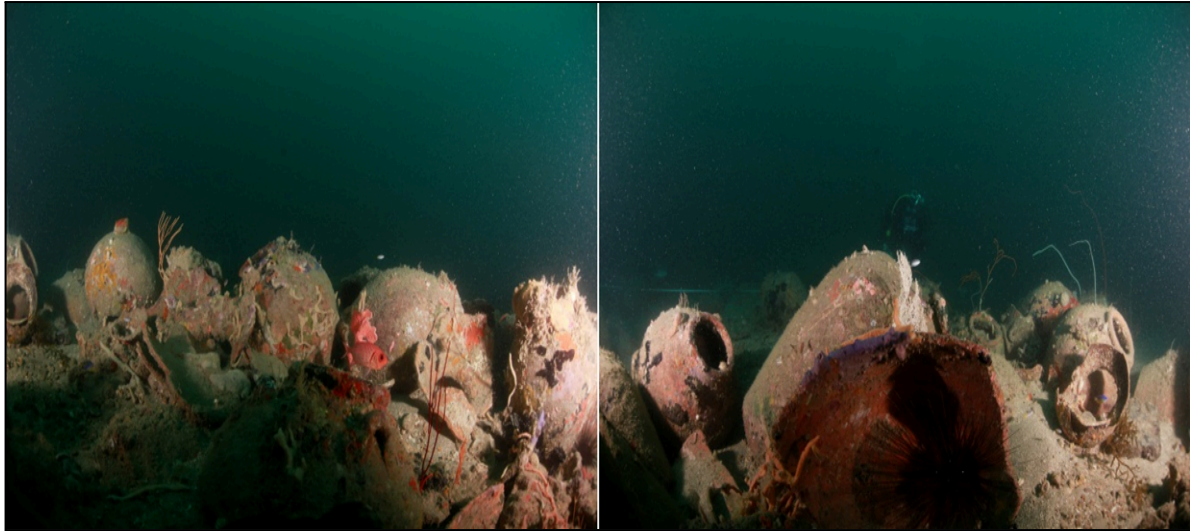


Fig. 10: The sediment-covered the artifact in the Abang Island site

CONCLUSION

According to the artefact's surface appearance and motifs, the archaeological remains discovered in Abang Island were from China-Thailand provenance during the Ming Dynasty era (16th century AD). Several sampled artefacts were kitchen equipment used for keeping water and food in the past. This identification was strengthened by the paleo-hydrodynamic and back-tracing model showing that the wooden ship from China sailed to Riau Archipelago through the South China Sea during the Northeast Monsoon because, at that time, the traditional wooden ship depended on the natural-based generator such as winds, tides, and currents. During its journey, the ship might have landed in Vietnam and Thailand, then brought the earthenware ewers to Riau Archipelago due to the high demand of ewers for the gambier industry.

Based on the sediment and morphological analysis, the archaeological remains sank in Abang Island were covered by sediment deposits. By calculating sediment accumulation flux, it was estimated that there are many undiscovered artefacts beneath the sediment silting in the surrounding Abang Island site, fossilized and petrified by sand sediment. It is recommended to excavate the artefacts as a preservation effort to prevent the remains from local looting and natural erosion. However, it is possible to display the artefacts in a mini gallery to strengthen the historical narration of Riau Archipelago maritime history and espouse tourism.

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