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Reconstructing the paleoshoreline of Bukit Choras based on geochemical and microfossil studies

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Abstract: The archaeological findings in Bukit Choras are among the best preserved structural remains of Bujang Valley. Previous studies have revealed sacred buildings made of laterite blocks, ancient water reservoirs, as well as a Buddhist inscription which can be dated back to the 6th/7th Century C.E. Although Bukit Choras is currently located 8 km inland, in ancient times, it could have been nearer to the shoreline similar to other pre-14th Century coastal sites of Bujang Valley. Thus, this research attempts to reconstruct the paleoshoreline of the area by determining whether the dryland surrounding Bukit Choras was once submerged under the sea. In this study, hand-augered soil samples from the surrounding areas of Bukit Choras were analysed by using X-Ray Fluorescence (XRF), Scanning Electron Microscopy (SEM) and digital microscopy, while ^{14}C dating was carried out on two organic samples extracted from the sediments. The possible locations of the paleoshoreline were deduced based on the analysis of geochemical and microfossil contents of the sediments while taking into account the sea-level fluctuations and the geomorphology of the area. Thus, it is concluded that Bukit Choras was once a coastal site, surrounded by a marine and swampy environment, while the archaeological site functioned as one of the coastal settlements of the Bujang Valley.

Keywords: Bukit Choras, archaeology, geomorphological survey, sedimentation, palaeontology

INTRODUCTION

Bukit Choras is a crescent-shaped ridge extending from north to south with an altitude of 57.6 meters (5º 57'52'' N 100º 25' 03'' E). The site is surrounded by flat terrains of <7 meters from sea level, consisting of paddy fields and settlements (Figures 1 & 2). The foothill of Bukit Choras is located near the Sala River, which flows eastward into the Straits of Malacca. The estuary of Sala River is muddy, with mangrove trees growing along the banks. At the southwestern tip of Bukit Choras, an archaeological site consisting of structural remains and two ancient water reservoirs were found (Wales, 1940; Kamaruddin, 1989; Nasha *et al.*, 2020; Nordiana *et al.*, 2020; Nini *et al.*, 2022; Nini, 2022). The date of these archaeological findings could be interpreted based on the palaeography of a Buddhist inscription excavated underneath the structural remains, assigning the structures to the 6th/7th C.E. (Wales, 1940; Allen, 1988). These archaeological findings show the presence of local and foreign communities around Sungai Sala and Bukit Choras, who were involved in the seaborne trade of Ancient Kedah before the 14th Century C.E., at the same time establishing the site as a Buddhist religious complex (Nasha *et al.,* 2020; Nini *et al.,* 2022; Nini, 2022). Such communities were known to have settled very near to the shoreline in locations directly accessible to seaports and coastal exchange sites (Allen, 1988; Nasha, 2011).

Figure 1: Location of Bukit Choras (Source: Google Earth).

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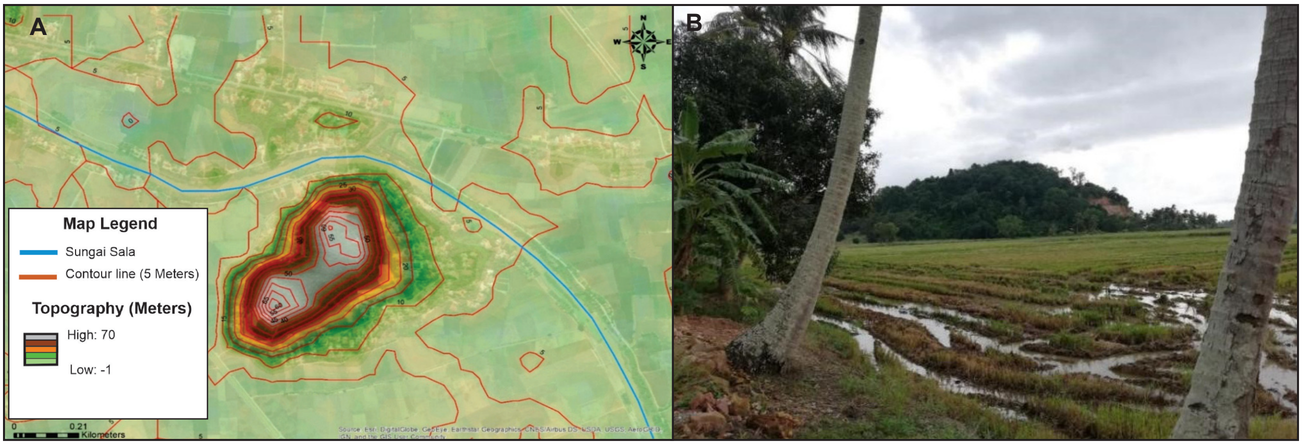

Figure 2: A-Contour map of Bukit Choras and its adjacent areas (Source: Google Earth). B-Bukit Choras as viewed from the south.

However, Bukit Choras is currently located 8 km inland, hardly accessible from the shoreline except through the narrow Sungai Sala. This has raised questions especially whether or not the shoreline was once located nearer to the foothill of Bukit Choras before the 14th Century C.E., as the structural remains appears to have been built to cater for the need of traders and coastal settlers (Nini *et al.,* 2022).

Bukit Choras marks the northernmost limit of the Bujang Valley, a historical region where the population and economic centre of Ancient Kedah was located between the 2nd to the 14th Century C.E. Bujang Valley extends from Bukit Choras in the north, trailing southwards to Gunung Jerai and the Merbok-Muda River down to Cherok Tokkun in the south (Nasha, 2011; Nasha *et al*., 2020). There are many other archaeological sites found south of Gunung Jerai with similar cultural features and date with Bukit Choras, especially near the Merbok-Muda river valleys (Allen, 1988). These include Pengkalan Bujang, Kampung Sungai Mas and Sungai Batu Archaeological Complex (Allen, 1988; Khoo, 1996; Mokhtar *et al*., 2019). In ancient times, these religious sites and centres for commodity exchange were positioned near to the coastline in order to cater to the need of traders who lived near the harbours (Allen, 1988; Jacq-Hergoualc'h, 2002; Nasha, 2011). Studies have shown that although these sites are currently located several kilometers inland, they were once situated very near to the shoreline before the sea receded due to the process of sedimentation and changes of the sea level (Allen, 1988; Khoo, 1996; Mokhtar *et al*., 2019).

Geomorphological changes from the decline of Ancient Kedah until today have significantly shifted the shoreline and silted up the ancient rivers, to the extent that the once strategic and accessible location of certain sites have been rendered obsolete (Allen, 1988; Khoo, 1996; Mokhtar *et al.,* 2019). Thus, it is important to model the geomorphological and geological setting during the period of occupation of archaeological sites using the paleoshoreline approach. Studies on the paleoshoreline of Bujang Valley by Intra-Asean (1985), Allen (1988), Khoo (1996) and Mokhtar *et al.* (2019) involved the analysis on various soil samples, core drilling and marine sediment deposits while correlating them with the chronology and distribution of archaeological sites. The paleoshoreline reconstructions in these works had provided important insights into the strategic positions of most archaeological sites of the Bujang Valley. Before the 14th Century C.E., Bujang Valley consisted of a bay surrounded by small islands, with long coastlines and networks of rivers (Allen, 1988, 1991; Khoo, 1996). Gunung Jerai on the other hand was a promontory and served as a major landmark for the port of Bujang Valley (Allen, 1988, 1991; Khoo, 1996). Most pre-14th Century C.E. archaeological sites in the study areas were located directly on the paleoshoreline or near to ancient riverbanks. Their studies only focused in the area between the south of Gunung Jerai to the Muda River, where most of the archaeological sites were found. However, the areas to the north of Gunung Jerai, especially in Bukit Choras had not yet been properly analysed.

By analysing the soil samples from the surrounding area, this paper attempts to reconstruct the paleoshoreline of Bukit Choras.

RESEARCH METHODS

Studies regarding the paleoshoreline of Bukit Choras involves the interpretation of natural features of the area as well as the analysis of collected soil samples. Radiocarbon dating was also carried out on two organic samples found in the sediment. Thus, the research methods adopted involved four main stages, which are: (1) Geomorphological survey, (2) Collection of soil samples, (3) Analysis of soil samples and sediment dating, and lastly, (4) Reconstruction of the paleoshoreline.

The research began with a geomorphological survey in Bukit Choras to document the geological and geomorphological features of the site and the surrounding area. Among the information that were prepared included the topography, contour and geological settings of the area, as well as the geomorphological features such as types of soils, sediments and minerals available. During this survey, Geographic Information System (GIS) Mapping Technology was used to convert the study area's three-dimensional landscape into a two-dimensional topographic map (Marble *et al*., 1984). Studies on the geological and topographic maps, published papers, as well as the pilot survey had given important insights into the natural surroundings and its relation to the archaeological site.

The geomorphological survey was followed by the collection of soil samples in Bukit Choras, Sungai Sala and the surrounding area. Seventeen augering points were chosen within the area of 5 km radius around Bukit Choras. These augering points were positioned along the axis of four cardinal points from Bukit Choras; 7 from the west, and 3 from the east, north and south (Figure 3). The soil samples were collected by using the bucket auger technique, designed to extract soil at different depths within its bucket (Public Work Technical Bulletin, 2010). Distinctions between different sediment layers in terms of their colours were determined by using the Munsell chart while the depth of each layer was measured and recorded to establish the stratigraphy.

The soil samples carry important data in the form of geochemical composition and presence of microfossils. The major and trace elements were determined by using the X-Ray Fluorescence (XRF) analysis. The microfossils on the other hand were detected and imaged by using the FEI Quanta 650 FEG Scanning Electron Microscope (SEM) and VHX-7000 digital microscope. SEM produces images of the sample's surface in high magnification, giving users the capability to study the morphology and microstructures of the sample in great detail. The images produced are presented in greyscale and created by electrons instead of light energy (Ponting, 2004). The fully-integrated digital microscope head of the VHX-7000 is equipped with lens pieces from x20 to x6000 magnification. The digital processing software includes image stitching, depth composition, 3-dimensional depth composition and 2-dimensional digital measurements. The radiocarbon dating method was employed to determine the age of the sediments. The ^{14}C samples consisting of shells and charcoal were sent to the Beta Analytic Lab in Miami, Florida (United States of America) to be dated. However, due to limitation of funds, only two ^{14}C samples could be analysed.

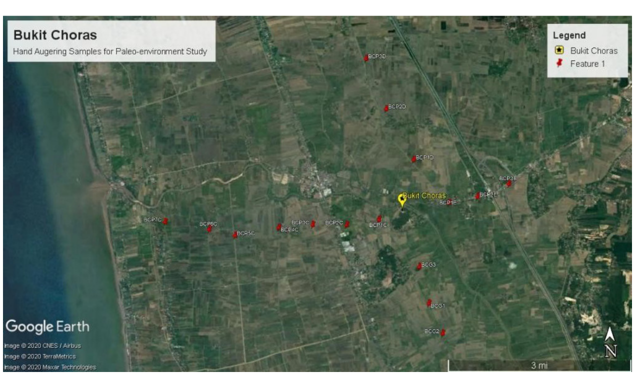

Figure 3: Hand auger points around Bukit Choras. (Map source: Google Earth)

Studies on geochemical composition, dating of sediments and analysis of microfossils in the soil samples were correlated with the geomorphology of the area as well as the regional fluctuations of sea level. The paleoshoreline was reconstructed by using ArcGIS, a software capable of integrating, editing, storing, sharing, analysing and displaying the geographical information (Marble *et al*., 1984; Kvamme, 1999; Fletcher, 2008). ArcGIS can also recreate 2-D and 3-D images of the area (Figure 15A & 15B), especially in terms of the location of the ancient body of water and other geomorphological features based on the contour of the area, archaeological data, soil profile of the hand-auger samples as well as previous works on the fluctuations of sea level.

RESULTS

The field survey, collection of soil samples, as well as scientific analysis had revealed important data which helps in reconstructing the paleoshoreline of the area surrounding Bukit Choras. Detailed studies on the soil samples around Bukit Choras unveiled sediments containing plant fibres, shells and the microfossils of diatoms. Chemical analyses on the other hand show increasing trends in the concentration of the elements commonly found in seawater such as sodium (Na), chlorine (Cl) and sulphur (S) as the samples approach the present shoreline.

Geology, sediment stratigraphy and environment of survey area

The northwestern part of Kedah where Bukit Choras is located consists of the Kubang Pasu Formation overlying the Mahang Formation (Figure 4). This formation contains an interval of chert, mudstone interbedded with sandstone and thick sandstone sequence representing the upper layer of the formation (Zaitun & Basir, 2000). The formation was deposited in a shallow marine environment on the continental shelf in Perlis (Yap, 1991). In the northern part of Kedah, the Mahang Formation became deeper while the lower part of the formation contains bedded chert overlain by rhythmic sand and shale. The top layer of this formation is dominated by the thick sandstone interbedded with mudstone (Basir, 1995). Bukit Choras is part of sedimentary Kubang Pasu Formation, a shallow marine shelf sediment located eastwards of the Mahang Formation (Lee, 2009). The lithology is composed of phyllite, slate, shale and sandstone where grey argillaceous rocks are from the Carboniferous period (Jones, 1973). The thick-bedded quartz and feldspathic grey, red and purple sandstone are interbedded with subordinate varicoloured mudstone. The formation's outcrops could be found in the central and eastern parts of Perlis, as well as northwest of Kedah where they are distinguished for their lighter-coloured sediment

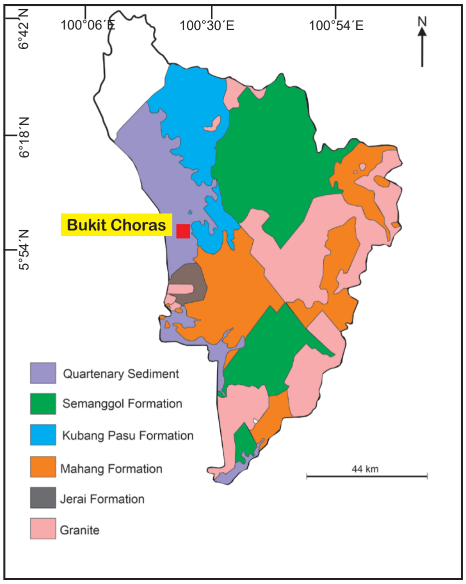

Figure 4: Geological Map of Kedah.
(Source: Zakariah *et al*., 2021; Jasin *et al*., 2010)

and sandy composition compared to their equivalent, the Singa Formation in Langkawi (Burton, 1967).

Bukit Choras is surrounded by a flat terrain with unconsolidated Quaternary marine and continental deposits consisting of clay, silt, sand, peat and minor gravel. The northwestern coastal plain of Kedah where Bukit Choras is located consists of marine sediments from the Quaternary period, made up of marine clay deposited in limited areas inland. Quaternary sediments in the area around Gunung Jerai consist of two sequences, which are surface deposits consisting of unconsolidated sediments and sediments deeper below the surface. Surface sediments are formed by marine alluvium known as the Gula Formation and terrestrial alluvium, namely the Beruas Formation (Mokhtar *et al*., 2019). For the study area, most of the sediments at the foothill of Bukit Choras are part of the Gula Formation. The Gula Formation consists of organic-rich marine mud, silt and sand with some gravel, shells and coral fragments deposited in the vicinity of shallow seas to estuaries during the Holocene period. The thickness of the Gula Formation sediments varies from 10 m to 20 m (Suntharalingam, 1984). The Gula Formation represents the Holocene marine deposits of estuarine to shallow marine, mangrove and beach ridges (Kamaludin, 2002). The older beach ridge was mapped based on the Alor Setar coastal plain with the width stretching over 10 kilometers (Tjia, 2013). The coastal plains in Peninsular Malaysia possess transition zones such as estuaries and deltas, as well as sandy ridges (Tjia, 2013). Hand auger samples obtained suggest that Bukit Choras was once surrounded by sediments dominated by marine and mangrove environments.

The Malay Peninsula consists of low-relief coastal plains, with the elevation in south and central Kedah being generally between 10-30 m above the sea level. However, there could be variations depending on the local topographies of specific locations. The Mid-Holocene position (ca. 5 ka) presented maximum sea level on the coast of the Straits Malacca (Geyh *et al*., 1979) and along the northwestern coasts of Peninsular Malaysia (Kamaludin, 1990; Tjia, 1992). Based on data from various localities during the Mid-Holocene period, sea level had risen to its maximum position to about 2-4 m above present mean sea level (Kamaludin, 2002). Studies on the coastal lowlands showed that during that time, transgression had greatly affected the evolution of Peninsular coastal plains (Abdullah *et al*., 1999). This process has caused marine sediments to stretch more than 20 km inland, especially in the coastal plains of Kedah, Selangor, and the west coast of Johor. These plains developed through the accumulation of fluvial, coastal and marine sediments (Hutchison & Tan, 2009).

Hutchison & Tan (2009) suggested that mangrove swamp belt stretches practically uninterruptedly from Perlis to Johor. Hand auger samplings in eastern part of Bukit Choras show the traces of mangrove roots at the depth between 2.2 m to 3.0 m at points BCP1E, BCP2E and BCP3E (Figure 5). Rapid sedimentation and the calm seas of the Strait of Malacca led to the building up of large strips of tidal sediments along the coast, providing a suitable environment for mangrove forests to thrive (Hutchison & Tan, 2009). As time passed by, the coastline slowly receded towards the Straits of Malacca, when the mangrove swamps began to spread outwards (Ooi, 1968). The inland mangrove limits the initial position of the coastline about 4000-6000 years ago when the sea level at its highest (Mid-Holocene Optimum in Malaysia). The combined effects of the Holocene transgression and sediment deposition resulted in coastal progradation and development of coastal plain (Abdullah *et al*., 1999).

Clay was encountered from each hand auger point around Bukit Choras from the depth between 1.2 m to 3 m. The clay is greenish grey in colour, also containing shells. The grey colour is possibly due to the oxidation of sulphur and iron after being exposed to the atmosphere (Taha *et al*., 2000). The clay is of soft soil, commonly found along the west coast of Peninsular Malaysia (Nur Aisyah, 2006). The Quaternary sediments found within the coastal plain usually consist of bluish and greenish clay containing shells (Hutchison & Tan, 2009). The colour of the samples taken at 3 m depth is greenish grey and dark greenish grey with Munsell Chart code Gley 1 5/10Y, Gley 1 5/5GY, Gley 1 4/10Y and Gley 4/5GY. The clay becomes thicker towards the coast in the west, with depths up to 20 m thick overlain with sandy clay layers up to 6 m thick. The hand auger point of BCG3 was extracted from the south of Bukit Choras, showing the presence of river gravels at the depth from 0.4 m to 1.57 m. These river gravels were reddish yellow in colour, with Munsell Chart code 5YR 6/8. The elevation of the area is slightly higher as compared to its surrounding and is covered in secondary jungle. These findings give

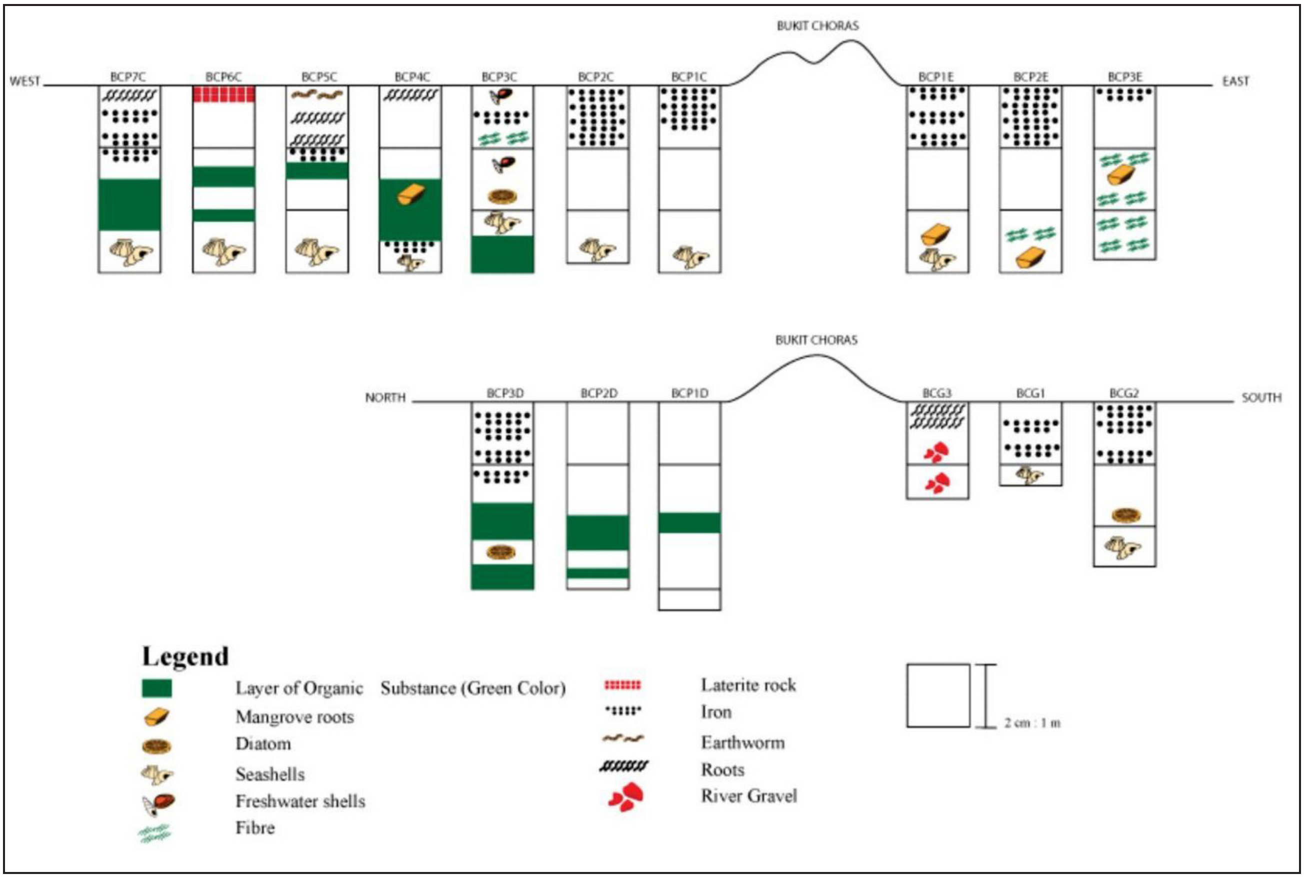

Figure 5: Quaternary sediment profile for North-South and East-West cross-sections from hand auger sampling.

valuable insight into the subsurface soil composition and ancient landscape surrounding Bukit Choras, as well as providing important data in the effort to reconstruct the paleoshoreline of the area.

Scientific analysis of soil samples

The soil samples extracted from the area surrounding Bukit Choras were analysed to detect traces of microscopic faunal remains as well as major and trace geochemical elements by using SEM-EDX, digital microscopy and XRF methods. In addition, two organic samples were also extracted from the soil samples for radiocarbon dating.

a. Scanning Electron Microscopy (SEM) and Energy-Dispersive X-Ray (EDX) spectroscopy

SEM studies were conducted on the sample BCP3A extracted at the southwestern foothill of Bukit Choras to detect any trace of microscopic floral or faunal remains. At the surface of the sample, fossilized diatoms were detected (Figure 6). Diatoms are unicellular *eukaryotes* with sizes usually ranging between 10 to 200 µm (Kooistra *et al.,* 2007). These microscopic organisms can be found all over the world in aquatic and terrestrial ecosystems and are classified as photosynthetic algae. Diatoms are placed at the base of the food chain in an aquatic ecosystem and have silica cell walls known as frustules (Richardson-Coy & Teed, 2018). Diatoms can become splendid fossils due to the presence of silica frustules (Kooistra *et al.,* 2007). The diatom fossils found in the sample BCP3A are identified as *Melosira Sulcata,* belonging to Centricae group of littoral species that live exclusively in shallow waters near to the shoreline and are either motile or fixed to a substrate (Cupp, 1943). Known as centric diatoms, they are radially symmetrical, having a cylindrical appearance with their valves looking like an orange cut in half (Richardson-Coy & Teed, 2018).

b. Digital microscope

The discovery of diatom fossils in sample BCP3A indicates the possibility that the area around Bukit Choras used to be submerged under a shallow sea. To further prove the presence of diatoms, a digital microscope is used to analyse the soils samples of BCP3C, BCP3A, BCG2 and BCP3D (Figure 7, 8 & 9). Sample BCG2 was hand-augered 3 km south of Bukit Choras at the depth of 200-220 cm. Three types of oceanic Diatoms were found inside the soil samples: *Asterolampra marylandica*, *Coscinodiscus centralis* and *Rhizosolenia Styliformis*. *Asterolampra Marylandica* has the size between 31-122 µm, characterized by a valve with large hyaline middle region and one-third of the diameter of the valve is divided into 6 or 7 sectors (Cupp, 1943). *Coscinodiscus Centralis* has the size between 31-122 µm. This diatom has valves with arched sides and nearly flat or slightly concave center (Cupp, 1943). The *Rhizosolenia Styliformis* is an oceanic type of diatom with cylindrical cell as well as valves obliquely pointed (Cupp, 1943).

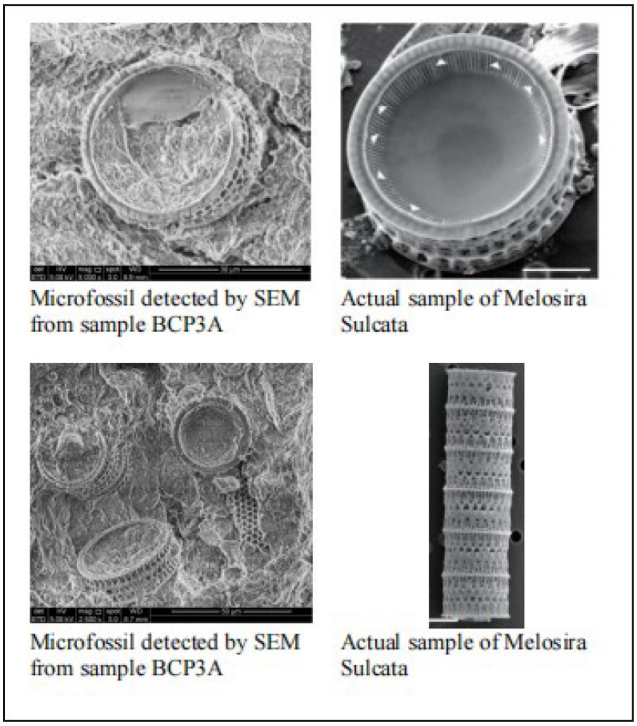

Figure 6: Microfossil images by SEM compared with reference samples of *Melosira Sulcata* from Suk *et al.,* 2016.

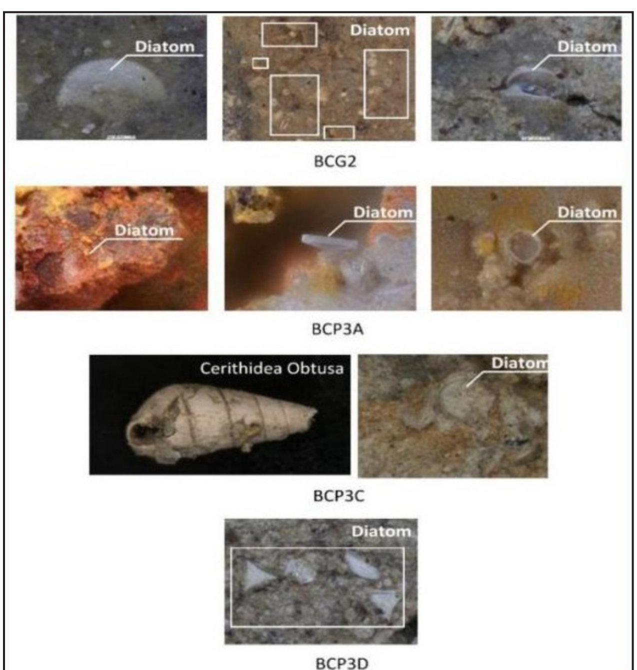

Figure 7: Digital microscope image of samples BCG2, BCP3A, BCP3C and BCP3D.

Sample BCP3D was hand-augered 3 km north of Bukit Choras, at the depth of 260-280 cm. Four types of diatoms were found in the soil samples which are *Biddhulphia Alternans*, *Surirella Fastuosa*, *Rhizosolenia Alata* and *Ceratium Furca*. *Biddhulphia Alternans* is a centricate type of diatom belonging to the neritic family commonly found near the shoreline. It has triangular valves and unevenly concave sides (Cupp, 1943). The *Surirella Fastuosa* is a littoral species and shaped like a wedge with ovate valves (Cupp, 1943). Meanwhile, *Rhizosolenia Alata* is a rod-shaped and cylindrical diatom which can usually be found near to the coast (Cupp, 1943). *Ceratium furca* is a marine diatom that can be found in coastal waters of Kuantan,

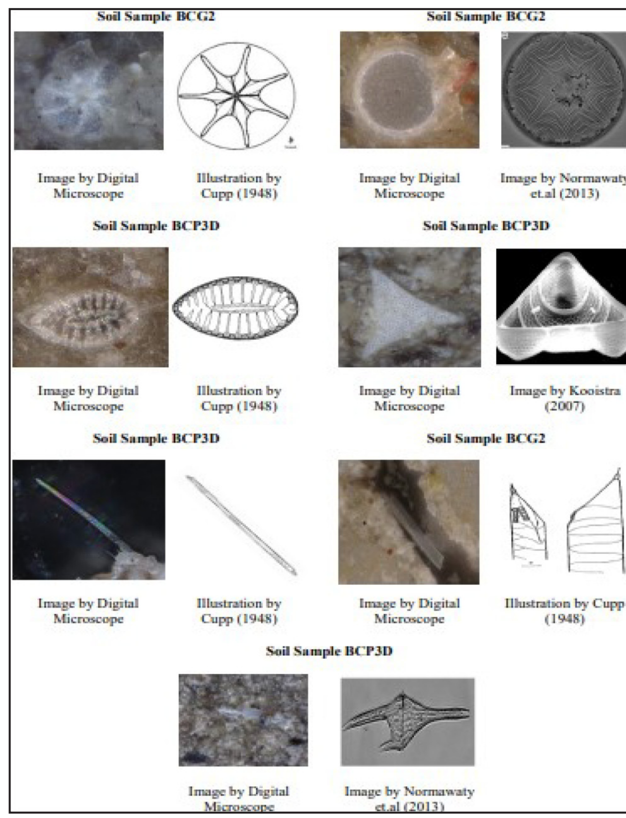

Figure 8: Diatom images in samples BCG2, BCP3A, BCP3C and BCP3D with their comparisons.

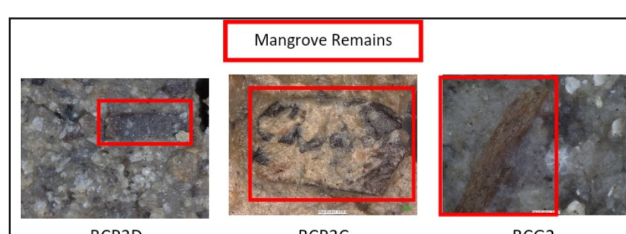

Figure 9: Mangrove roots in samples BCP3D, BCP3C and BCPG2.

Pahang (Normawaty *et al*., 2013). Sample BCP3C was hand-augered 3 km west of Bukit Choras at the depth of 280-300 cm while sample BCP3A was hand-augered at the foothill of Bukit Choras, at the depth of 280-300 cm. In BCP3C, symmetrical and cylindrical centric diatom were found while in BCP3A, an unidentified diatom fossil was found in a fragile state. Figure 9 shows the presence organic fibres in the soil samples of BCP3D, BCP3C and BCG2 believed to be mangrove roots as these plants are quite common in the coastal areas (Figure 10). The diatoms found around Bukit Choras came from the species which lived in the ecosystem of shallow waters and coastal areas. The presence of diatoms as well as other organic fibres in the soil samples around Bukit Choras provide valuable information regarding its proximity to the coast in ancient times and demonstrating the fluctuations of sea level.

c. X-Ray Fluorescence (XRF)

XRF analysis was carried out on 10 hand auger soil samples, extracted from the four cardinal points of Bukit Choras. For this research, this analysis was done to obtain geochemical composition data of the soil samples to provide gross explanation on environmental condition, and does not involve the study regarding the degree of weathering of these samples.

Three samples (BCP7C, BCP4C & BCP1C) were extracted from the west, two samples (BCP3D & BCP1D) from the north, three samples (BCP3A, BCG1 & BCG2) from the south and two samples (BCP1E & BCP2E) from the east. These analyses were conducted to detect the major and trace elements of the samples. During the XRF analyses, the chemical content of the soil samples were identified, consisting of several major and trace elements. From the list of these elements, three were selected for 3-dimensional scatter plots. The correlations between the concentration and composition of these various major and trace elements can give important clues regarding the form of environment under which the samples existed in the past. During the XRF analyses on the 10 soil samples, 10 major elements and 20 trace elements were detected.

Figure 10: Present day Sungai Sala estuary with mangrove jungle, and example of present day mangrove root (insert).

Out of the 10 major elements found in all the samples, the elements of Fe_2O_3, Na_2O and MgO were selected for a 3-Dimensional scatter plot (Figure 11A). Fe_2O_3 is known to be among the main chemical composition for the lateritic soils in Bukit Choras while Na_2O and MgO are the main chemical compositions for seawater (Wiesenburg & Little, 1987; Nini *et al*., 2022).

Samples BCP7C (located nearest to the coastline) and BCP3A (located at the southwestern foothill of Bukit Choras) were selected as the main reference for this study, as they present the largest contrast in their readings. BCP3A shows the highest percentage for Fe_2O_3 (10.77%) and low percentage of Na_2O (0.09%) and MgO (0.67%). The high iron content in this sample was probably due to the dominant type of soil near Bukit Choras, which is lateritic soil. BCP7C on the other hand show the highest percentage in Na_2O (0.28%) and MgO (1.68%) and low percentage in Fe_2O_3 (4.16%). Except BCP3A and BCG1, all samples in the 3-Dimensional scatter plot are clustered together towards BCP7C with the high Na_2O and MgO content. Samples BCP1C, BCP3D, BCP2E, BCP4C, BCP1D, BCG2 and BCP1E exhibit a gradually decreasing trend for the percentage of Fe_2O_3, but increasing trend for percentage of Na_2O and MgO as they draw closer to the coastline. However, sample BCG1 shows the second highest reading for Fe_2O_3 (6.04%) and a relatively medium reading for Na_2O (0.21%) and MgO (1.30%). The scatter plot shows a big gap in terms of the percentage of major elements between sample BCP3A which was taken at the foothill of Bukit Choras, with those taken from the surrounding areas.

Aside from the major elements, the XRF analysis also provided information regarding the concentration of 20 trace elements in the 10 samples. Three elements were chosen for a 3-Dimensional scatter plot for all the samples which are zirconium (Zr), chlorine (Cl) and sulphur (S) (Figure 11B). Zr was chosen because it is among the common trace element found in the rocks, while Cl and S were chosen because, they are commonly found in ionized form in seawater (Wiesenburg & Little, 1987). The 3D plot represents the pattern of concentration for Zr, Cl and S for all samples. From the graph, two distinct clusters can be identified. In the first cluster, samples BCP3A, BCG1, BCG2 and BCP1E had a very high Zr concentration but low Cl and S. The high content of Zr in BCP3A is probably due to its location just at the foothill of Bukit Choras, where the element is commonly found in the laterite rocks of the area (Nini *et al.*, 2022). The high concentration of Zr in samples BCG1, BCG2 and BCP1E is due to their locations near to the Sala River, which could transport and deposit Zr rich minerals at the areas where the samples are extracted. It could be inferred that the low Cl and S concentration in all the 4 samples

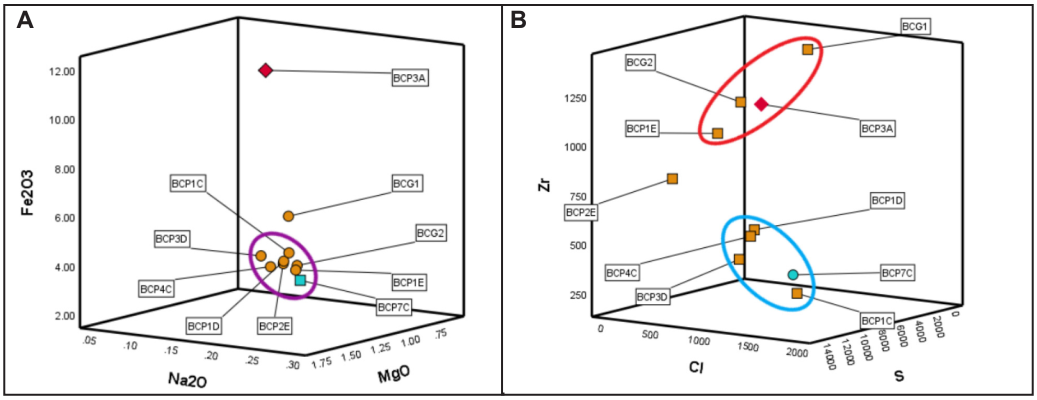

Figure 11: A. 3-Dimensional scatter plot of Na, Mg and Fe, B. 3-Dimensional scatter plot of Zr, Cl and S.

was due to their locations which were further from the coastline and were less affected by sea water coming inland during tide cycle. In the second cluster, samples, BCP4C, BCP7C, BCP1D, BCP3D and BCP1C had low Zr with varying Cl and S concentration. This probably was due to the location of the sample approaching the coastline where river deposit diminished, and the area was more susceptible to tidal cycle effect.

d. Accelerator Mass Spectrometry (AMS) dating

Organic samples from two hand auger points (BCP1C & BCP2E) were dated by using the ^{14}C AMS dating. Both samples were taken from the flat terrains surrounding Bukit Choras at the depths of 2.8 to 3.0 m. For point BCP1C (5°57'52.23"N 100°24'50.65"E), the sample consisted of seashells hand-augered at a paddy field at the western foothill of Bukit Choras. As for the sample BCP2E (5°58'11.75"N 100°26'15.38"E), the sample consisted of charcoals, hand-augered also at a paddy field 2 km eastwards from Bukit Choras. Both samples were carefully selected and sent to the facility in Miami, Florida for radiocarbon dating. The seashell sample is dated around 5727-5638 B.C. (6790 ± 30 BP) and the mangrove root around 5846-5720 B.C. (6900 ± 30 BP).

DISCUSSIONS

The XRF, SEM and digital microscope analyses had given important insight into the paleoshoreline of the area. For XRF, major elements commonly found in seawater such as magnesium (Mg) and sodium (Na) were detected in soil samples around Bukit Choras, especially in those located to the west of the site. As the samples approach the coastline, the percentages of Na and Mg increase. A similar trend is observed in the concentration of trace elements such as sulphur (S) and chlorine (Cl), also commonly found in seawater. Further studies on the soil samples by using the SEM and digital microscope revealed the presence of fossilized algae known as diatoms. These marine littoral species are commonly found in shallow waters near coastal areas. The data collectively show that Bukit Choras that at certain period of time was once surrounded by a seawater as well as mangrove. Studies by Allen (1988), Khoo (1996) and Mokhtar *et al*. (2019) in the areas south of Gunung Jerai had demonstrated that the paleoshoreline was once located far inland, but gradually receded from the 2nd to the 14th Century C.E. to form the present-day coastal configuration.

The lack of ^{14}C dating samples in this research hinders the effort to demonstrate how the shoreline receded or advanced over the period of 2nd to the 14th Century C.E. The two ^{14}C dated samples found near Bukit Choras could only establish that by the late-6th Millennium B.C., the paleoshoreline was located on the western foothill of Bukit Choras. One of the important period of cultural development of Bukit Choras is in the mid-1st Millennium C.E. (6th/7th Century C.E.) when the structural remains were built by the ancient communities (Wales, 1940). Although ^{14}C dating evidence to establish the location of the paleoshoreline during this period is not yet available, it still can be conjecturally reconstructed by applying the ArcGIS methods while taking into account the result of the geochemical and microfossil studies. The contours of Bukit Choras and its surrounding first need to be observed by studying the cross sections of the area, which are lines representing the topographical form of the landscape in a 2-Dimensional view. The cross sections are drawn by using the Ruler Tool in Google Earth Pro. In this study, two lines were drawn, running through the north-south axis and east-west axis, intersecting at Bukit Choras. Each line provides information regarding the elevation and the contours of the area. The additional data used in the cross-section study were the 16 hand auger samples, each bearing detailed geological information regarding the study area.

For the north-south axis, the hand auger samples BCP1D, BCP2D and BCP3D show green sandy soil containing marine sediments (Figure 12). Seashells can be found in BCP2D (260-280 cm in depth). Neritic, littoral and oceanic diatoms were detected in BCP3D (280-300 cm in depth). The fibre detected in BCP3D could possibly be remains of mangrove roots. To the south, hand auger samples BCG1, BCG2 and BCG3 show the presence of seashells and diatoms, except for BCG3 which contains river gravel. In BCG2, mangrove roots were detected. The presence of greenish soft sandy clay, marine diatoms, and barnacles in the north-south axis of hand-auger samples (BCP1D, BCP2D, BCP3D, BCG1, BCG2 & BCG3) attest the presence of marine and swampy environment during this time. The thickness of the greenish soft sandy clay, which is a form of marine sediment, was between 1.0-1.2 m thick and is found at the depth of 1.6 m to 3.0 m. To the south of Bukit Choras, marine sediments were found in BCG1 and BCG2, consisting of greenish soft sandy clay with the thickness of less than 1.0 at the depth of 1.0-1.2 m depth. Overall, the hand auger samples extracted from the north-south axis of the cross-section generally suggest the presence of mangrove and marine environments.

For the east-west axis, the hand auger samples of BCP1E, BCP2E and BCP3E show an abundance of mangrove root remains (Figure 13). Seashells were detected in BCP1E (260-280 cm in depth) located only 1 km eastwards of Bukit Choras. To the west, the hand auger samples of BCP1C, BCP2C, BCP3C, BCP4C, BCP5C, BCP6C and BCP7C show the presence of seashells in every hand auger point, all at the depth between 260-300 cm. The littoral type of diatom species were found in BCP3C at the depth of 280-300 cm. In the same sample, fibres which could have been part of a mangrove root were found at the depth between 260-280 cm. Freshwater shells were found in BCP3C and BCP6C. The layer of green sandy soil becomes thicker as the samples approach the coastline. The east-west axis of the cross-section suggests the presence of mangrove swamp in the east and shallow ocean to the west of Bukit Choras. A clump of seashells was found in the hand auger point of BCP1C at the depth of 140 cm was dated by using the ^{14}C AMS dating, giving the date of late-6th Millennium B.C. (6790 ± 30 BP). Presence of mangrove remains in BCP2E also dated around the late-6th Millennium B.C. (6920 ± 30 BP) suggests the presence of a mangrove swamp to the east of Bukit Choras during this time.

The samples of marine sediments, seashells or in situ mangrove roots could be good indicators with respect to the corresponding sea levels (Tjia & Fuji, 1992; Tjia, 2013). The ^{14}C dating of the organic materials as well as the presence of marine sediments are consistent with the study by Tjia (1992a & 1992b) arguing that the sea level especially in the west coast of the Thai-Malay Peninsula was 3.5 meters higher than it is today (Tjia & Fuji, 1989, 1992; Figure 14). A high sea stand during the Holocene in Peninsular Malaysia was also mentioned by Tjia (1970), Biswas (1973), Geyh *et al*. (1979), Suntharalingarn (1982), Tjia (1987, 1992b, 1992c), and Kamaludin (2002) based on evidence of marine incursions. The Holocene Sea level curve for the Malay Peninsula shows the trend that prior to 6 ka, sea level rose to its maximum Mid-Holocene position at about 2 m to 4 m above present sea level. Based on the study of Tjia (2013),

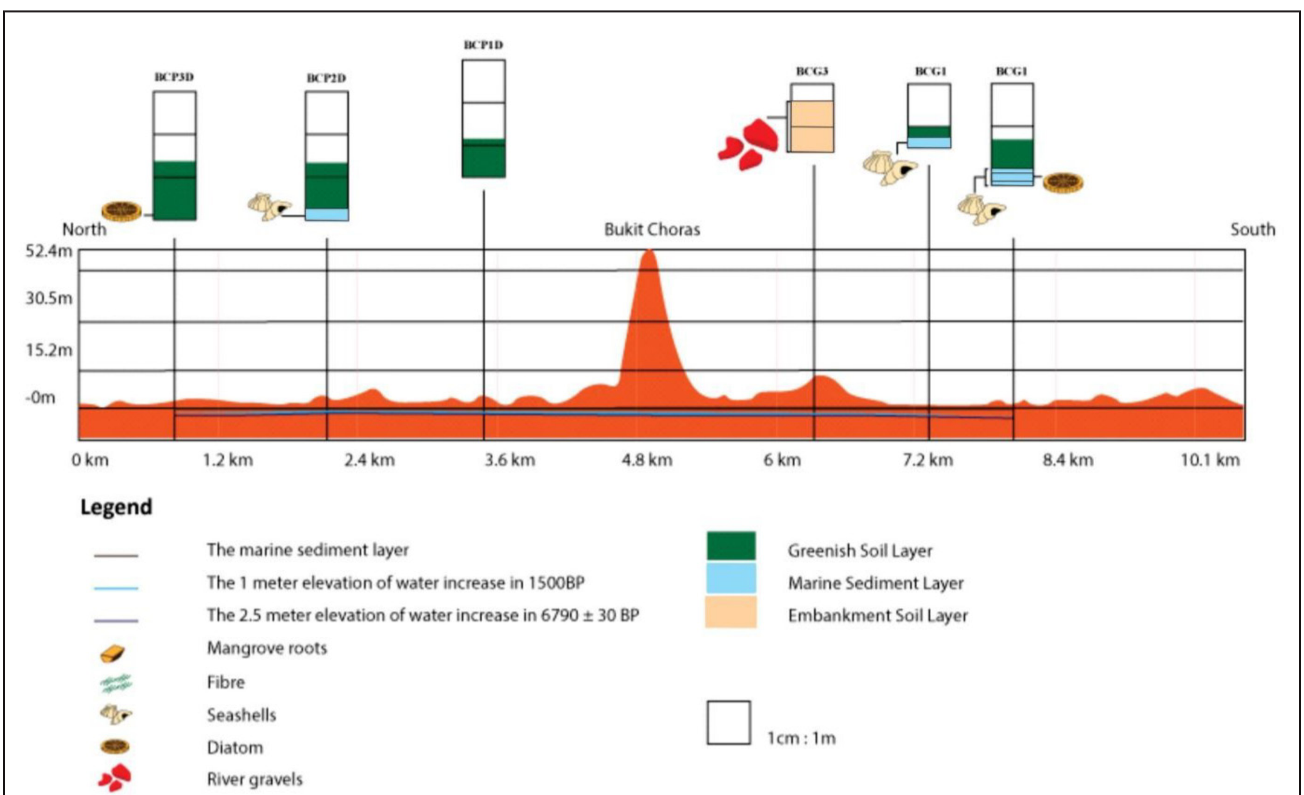

Figure 12: Cross-section from north to south.

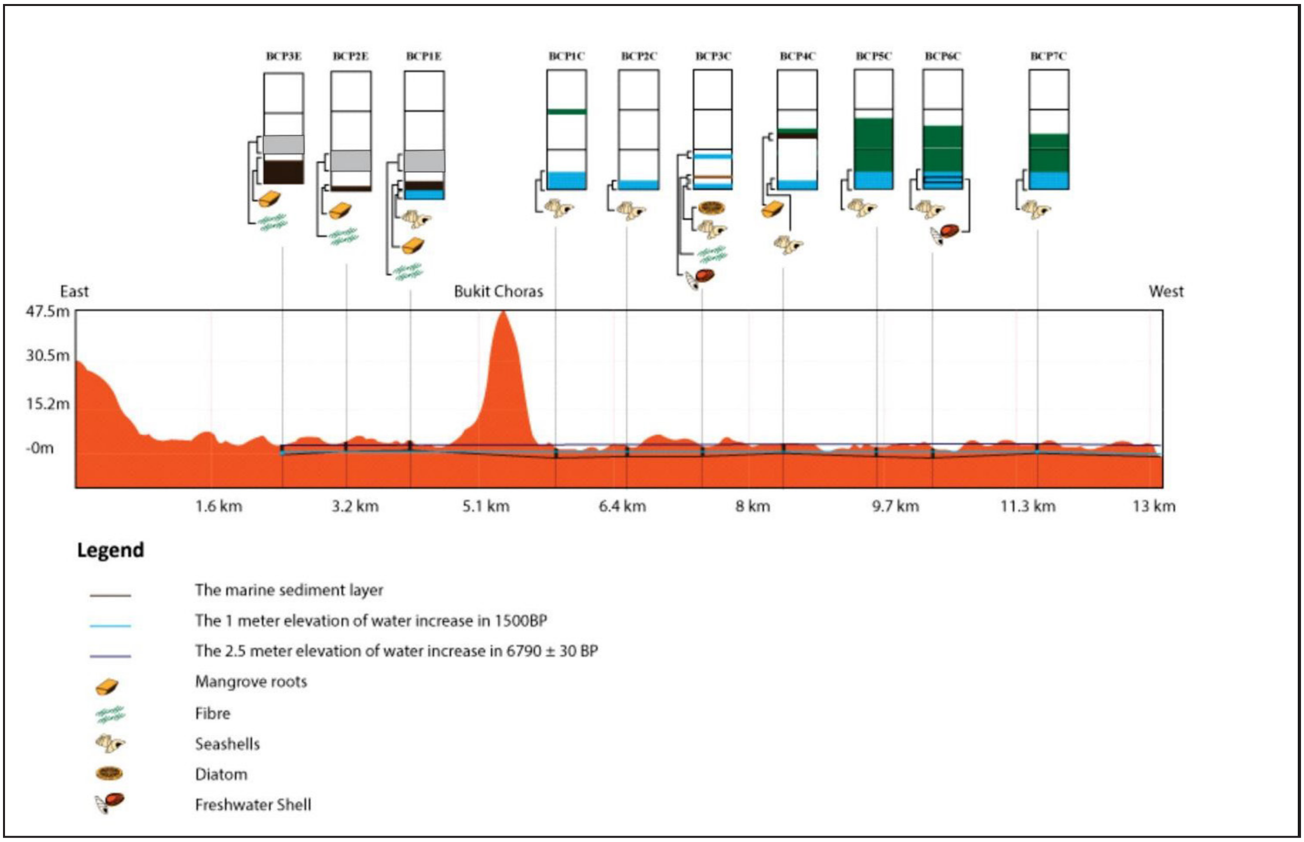

Figure 13: Cross-section from east to west.

the sea level in the mid-1st Millennium C.E. (1500 BP) was 1 metre higher than the present level, and 2.5 meters lower than the level during late-6th Millennium B.C. (6790 ± 30 BP). Figure 14 shows the fluctuation of sea level from 7000 BP to present day, and the red dots mark the sea level in Bukit Choras area during late-6th Millennium B.C. and mid-1st Millennium C.E.

By using the ArcGIS software, the 2D images of Bukit Choras paleoshoreline were reconstructed by virtually submerging the area according to the fluctuation of sea level suggested by Tjia (Tjia & Fuji, 1992) while correlating them with the geochemical and microfossil data. By putting in the sea level of 3.5 m for late-6th Millennium B.C. (6790± 30 BP) and and 1.0 m for mid-1st Millennium C.E. (1500 BP), the location of coastlines during these epochs appear to be consistent with the major and trace element composition of the soil samples as well as the presence of diatom microfossils. Figure 15A shows the paleoshoreline in the late-6th Millennium B.C., which ran though the western half of Bukit Choras. As compared to the coastline in late-6th Millennium B.C., the coastline in the mid-1st Millennium C.E. must have retreated westwards due to the lowering of the sea level. Figure 15B shows that the coastline in mid-1st Millennium C.E. was located 3 km to the west of foothill of Bukit Choras, while the hill itself was possibly surrounded by mangrove swamps. It is during this period that the ancient trading communities thrived, and constructed the 6th/ 7th Century C.E. structures found at the summit of Bukit Choras.

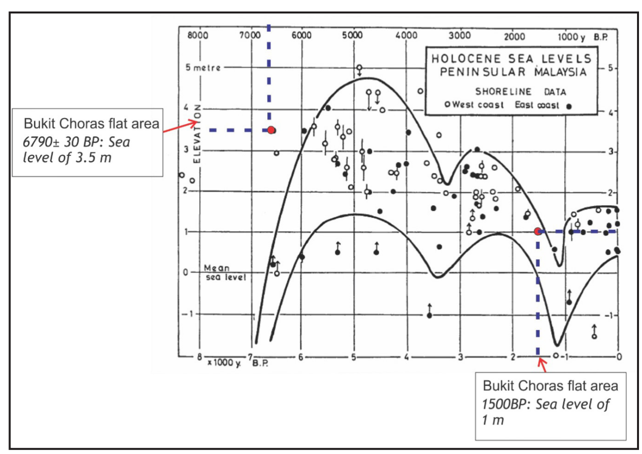

Figure 14: Fluctuation of sea level from 7000 BP (Tjia & Fuji, 1989; Tjia, 1992a, 1992b).

CONCLUSION

Currently, Bukit Choras is located 8 km from the coastline, surrounded by dry land consisting of paddy fields. The Sala River slightly meanders around the northern slope of Bukit Choras, where the bank is only 40 m from the foot of Bukit Choras at its nearest point. In the present research,

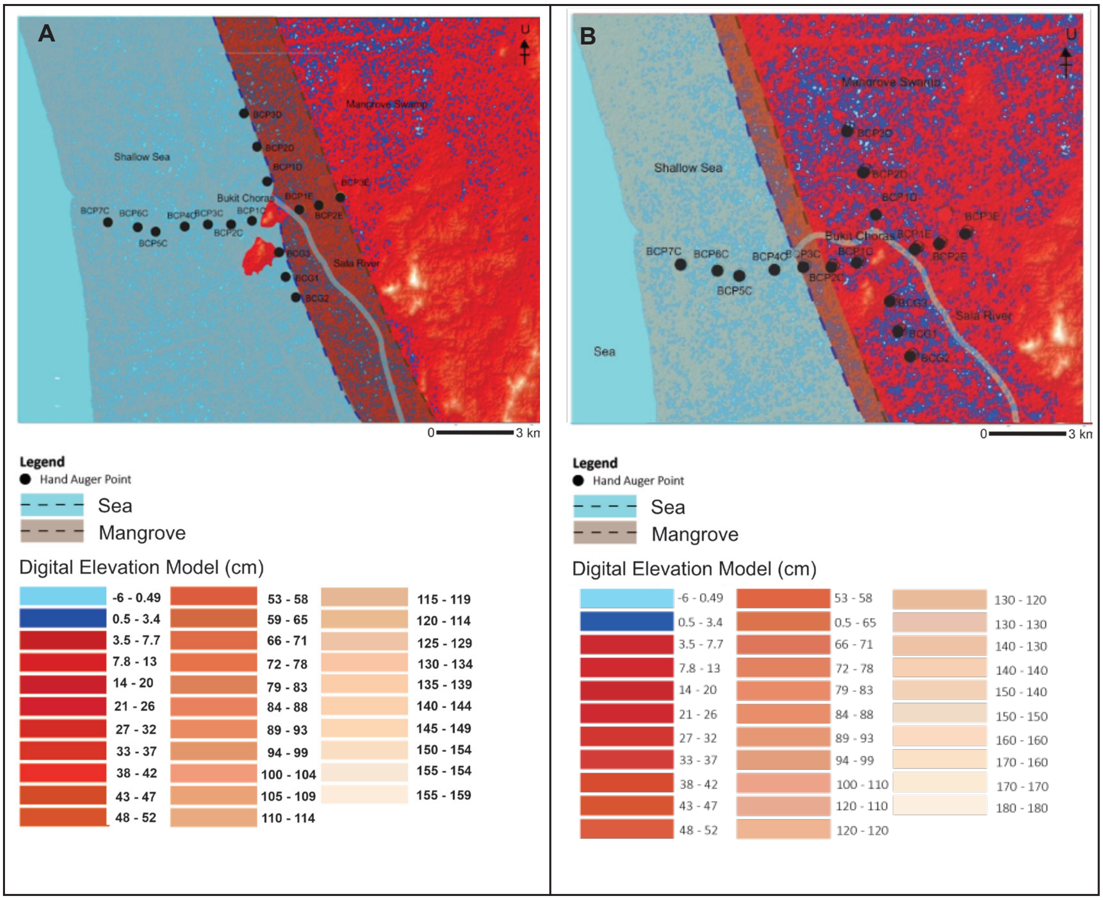

Figure 15: A. Paleoshoreline of Bukit Choras in late-6th Millennium B.C. The Paleoshoreline ran along the western half of Bukit Choras. B. Paleoshoreline of Bukit Choras in mid-1st Millennium C.E. The paleoshoreline receded 3 km westwards from the foothill of Bukit Choras.

16 points of hand-auger soil samples in regular intervals were taken from north to south, and east to west to study the soil profile. To the north of Bukit Choras, greenish soft sandy clay was found in every sample, while in sample BCP2D, remains of seashells were detected. Similarly, samples of greenish soft sandy soil with seashell remains were found to the south Bukit Choras. To the east, alongside with clay and sand, remains of mangrove roots were found. Most importantly, to the west of Bukit Choras, all hand auger samples collected every 1 km towards to coastline reveal sediments containing seashell remains at the depth of 1 meter and below.

Geochemical studies on these soil samples show increasing trend for the percentage of major elements Na and Mg as they move from the foothill towards the coastline. Similar trend is observed for trace elements S and Cl. The presence of such elements which are abundant in seawater suggest that the soils once existed under marine environment. The findings from the SEM and digital microscope analysis were consistent in showing that the soil was once part of a marine environment, with the discovery of possilised marine algae known as diatoms. All these findings show that although Bukit Choras today is surrounded by dry land, in the past, it was possibly surrounded by a marine and swampy landscape. These soil and faunal remains can be used as a point of departure for the palaeshoreline reconstruction of Bukit Choras, by applying the cross-section studies on the area and recreating the landscape by using the ArcGIS software.

Two ^{14}C datings were carried out on samples extracted from BCP1C and BCP2E, located in the western foothill of Bukit Choras and 2 km eastwards of Bukit Choras respectively. These samples gave the date of the late-6th Millennium B.C. During the late-6th Millennium B.C., the western half of Bukit Choras projected outwards into a shallow sea. This can be suggested based on the seashell samples found in BCP1C, located on the supposed ancient coastline of the area, dated at 6790±30 BP. At this time, Bukit Besar, located southwest of Bukit Choras was probably a promontory. The mid-1st Millennium C.E. presents another period of interest as this marks when the structural remains found at the summit of Bukit Choras is known to have been constructed. No ^{14}C dating samples were available to clearly establish the chronometric dates of the sediment samples located westwards of Bukit

Choras. However, the location of ancient coastline at this time could still be deduced based on the sea-level fluctuation model suggested by Tjia & Fuji (1992) as well as the discoveries of seashell, diatom and mangrove remains in the soil samples. In the mid-1st Millennium C.E., the coastline was located 3 km to the west of Bukit Choras, while the foothill itself was likely made up by an ecosystem of mangrove swamp, with the ancient settlements located on the coast and river estuaries, overlooked by Bukit Choras.

Studies by previous researchers had already established that the paleoshoreline of the areas south of Gunung Jerai to be located further inland before the 14th Century C.E. The present study had proven that similar to the area south of Gunung Jerai, the paleoshoreline of Bukit Choras was also once located further inland. However, more samplings and ^{14}C datings are needed to establish a more robust interpretation regarding paleoshoreline around Bukit Choras, and how it receded over centuries, between the 2nd to the 14th Century C.E.

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AUTHOR CONTRIBUTIONS

All the eight authors have contributed their expertise during the fieldwork in Bukit Choras as well as in conducting the scientific analysis and writing of this article. To be specific, NHD, NKT and SSK were involved in the collection and preparation of clay samples for compositional analyses while NRK, SN, AS, NZ and ZK worked on literature review, analyses, data interpretation and drafting the article.

CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare absence of conflicting interests with the funders.

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