Bulletin of the Geological Society of Malaysia, Volume 62, December 2016, pp. 23 – 29

Late Holocene relative low sea level at Merang, Terengganu

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Abstract: The study identified three sea level index points using the litho-, bio-, and chrono-stratigraphic approach. The sea level indicator is derived from the regressive contact of the intercalated peat and marine deposits. The indicative meaning of the sea level indicator is estimated based upon the microfossil relationship between fossil sea level indicators and the contemporary samples from the present-day ecological environments. The result presents an interesting new finding of low sea levels below the present mean sea level in the late Holocene, viz., 740 to 920, 900 to 960, and 1260 to 1300 calendar years BP. The revelation in Merang indicates that the tropics are sensitive to the effects of hydrostatic process and climate variability that is affecting places around the world.

Keywords: Late Holocene, sea level, Terengganu

INTRODUCTION

The study of paleo sea level changes at Merang, Terengganu was initiated through the Inter-agency Technical Committee Meeting on the impact of sea level rise due to climate change, coordinated by the National Hydraulic Research Institute of Malaysia (NAHRIM). The study was carried out using limited fund disbursed by NAHRIM to the related agencies. The study site was selected based on NAHRIM on-going research at Kuala Terengganu.

The report presents preliminary finding of the paleo sea level study undertaken at Merang, Terengganu. The methodology of sea level study stressed on proper identification and determination of the sea level index points (Shennan *et al*., 1995, 2000; Plassche, 1986; Pirazzoli, 1996; Zong, 1997, 1998; Kamaludin 2002).

The sea level index point is commonly described by its four attributes: geographical location, altitude, age and tendency. The sea-level index point is derived from sea-level indicators, which as illustrated in Plassche (1986), are diverse and range from corals and reefs, marine mollusks, coralline algae, vermetid gastropods, beach rocks, botanical remains, foraminifera, diatoms, ostracods, shell middens, submerged forests, to marine notches, coastal deposits and barrier sands.

In the study, the sea level indicators are derived from Holocene coastal sedimentary deposits. In this sedimentary environment, peat layers overlying marine sediments form the best indicator. The sites selected are those that disclose stratigraphic changes as a result of the Holocene marine transgression or regression.

STUDY SITE

The study site is located at Merang, about 25 km northwest of Kuala Terengganu (Figure 1). Merang is basically a small fishing village at the estuary of the Merang River and it is a 'jumping-off' point for tourists to the famous holiday islands of Pulau Redang and Pulau Bidong. The site was selected based on the accessibility to and availability

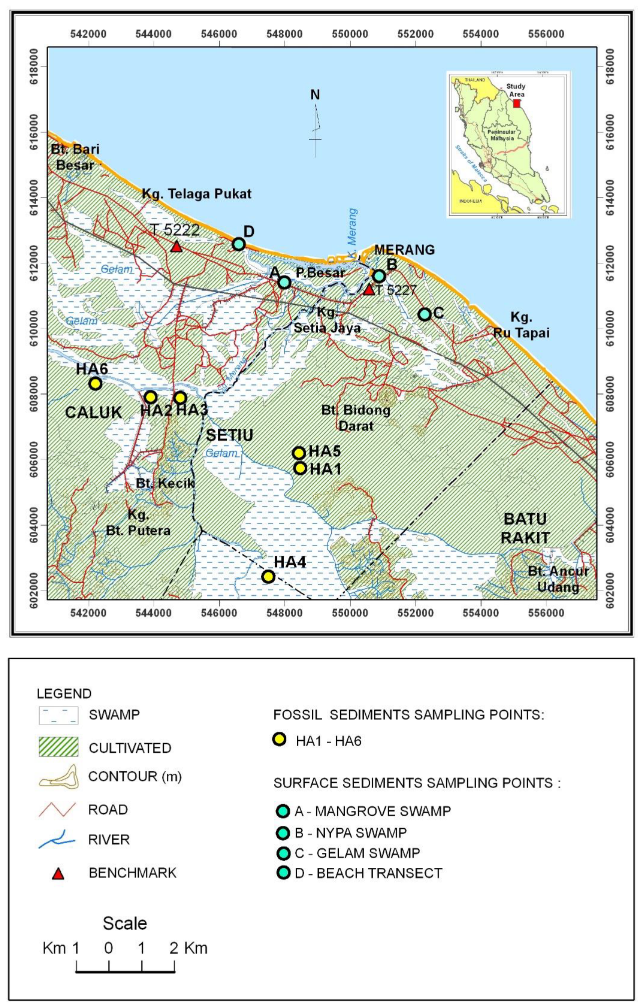

Figure 1: Study site and sediment sampling locations at Merang, Terengganu.

of the sea level indicators and the rather 'unspoilt' natural ecological surroundings. The sea level index points derived from the study site are assumed to be representative of those from Kuala Terengganu considering the area's proximity.

Merang and its surrounding area are basically underlain by Quaternary sediments made up of lowland coastal plain deposits. The lowland coastal elevation, apart from the Bukit Merang hillock and other small hills in the area, is generally less than 3-4 m in height. The Quaternary deposits are made up of unconsolidated sediments of sand, silt, clay and minor peat and gravel. Typical for the east coasts of peninsular Malaysia, sandy coastal sediments predominate, and in Merang more than 2 km wide, northwest-southeast aligned sand ridges are also present. Even though beach ridges form the prominent feature, swales and swampy plains are also present. The swales and swamps were formed due to the impeded drainage and blockage of the river outlets by the younger series of beach ridges which are aligned parallel to the present coasts. The surrounding hills and underlying bedrock in the Merang area are made up of Early Triassic granite (Bignell & Snelling, 1977) and Carboniferous meta-sedimentary rocks (Chand, 1978; Abdullah, 2001) of carbonaceous slate, argillite, phyllite, and schist together with minor lenses of quartzite, metaconglomerate and calc-silicate hornfels.

METHODS

The methods employed in the study involve desktop, field and laboratory analyses. These include the search for the sea level indicator, identify contemporary ecological sites, coring, modern surface sediment sampling, microfossil analyses, and identification of indicative meaning, radiocarbon dating and altitude measurement of sampling sites.

In the field, both fossil sediments and present day newly deposited sediments were sampled. The sea level indicator is derived from the fossil sediment, viz., from the base of peat overlying the marine deposit. Six cores from various locations were taken using the gouge auger and peat corer. The peat corer is very useful in retrieving fairly undisturbed core samples. All the cores HA1 to HA6 (Figure 1) were taken in oil palm plantation where road access was readily available. Sediments investigated revealed the presence of peat and underlying marine clay layers.

The modern surface sediments were sampled from four ecological settings including the *Nypa* swamp (site A), mangrove swamp (site B), *Gelam* forests (site C) and the sandy beach profile (site D) (Figure 1). Three surface samples were each scraped from the newly deposited surface sediments at all the sites, except at site D where 8 samples were made. All the samples were collected during low tide level.

In the laboratory, both the fossil and modern sediments were processed and analysed for diatoms. Diatoms are microscopic unicellular plants (algae) occurring in large numbers in fresh and marine waters, also in moist soils and other wet substrates. They live in naturally illuminated environments as plankton or attached to a substratum. It has long been recognised that many diatom species have depth and, in particular, salinity preferences (i.e. fresh, brackish and marine diatoms (Palmer & Abbott, 1986). Zong (1997) identified indicative diatom groups in relation to reference tidal levels, vegetation zones and sedimentary characteristics to reconstruct the marsh surface elevations at Roudsea Marsh, northwest England. Zong & Kamaludin (2004) indicated relationships between diatom assemblages and environmental variables from two mangrove environments in Kelang and Kuantan, peninsular Malaysia.

Paleo-mean-sea-level (PMSL) is derived from the following steps. Firstly is to determine the altitudinal relationship between modern diatoms and local tidal levels. The diatom data from modern surface sediments provide a diatom–altitude analogue to determine the indicative relationship between the fossil sediments and mean sea level. Secondly is to determine the indicative meaning of each dated sediment horizon (sea level indicator) from each core based on the diatom results. Then calculate the altitude of PMSL for each dated sea level indicator using the formula:

Altitude of PMSL = Altitude of dated sediment horizon (sea level indicator) – indicative meaning

The indicative meaning is derived by comparing diatom assemblages of the sea level indicator and those from

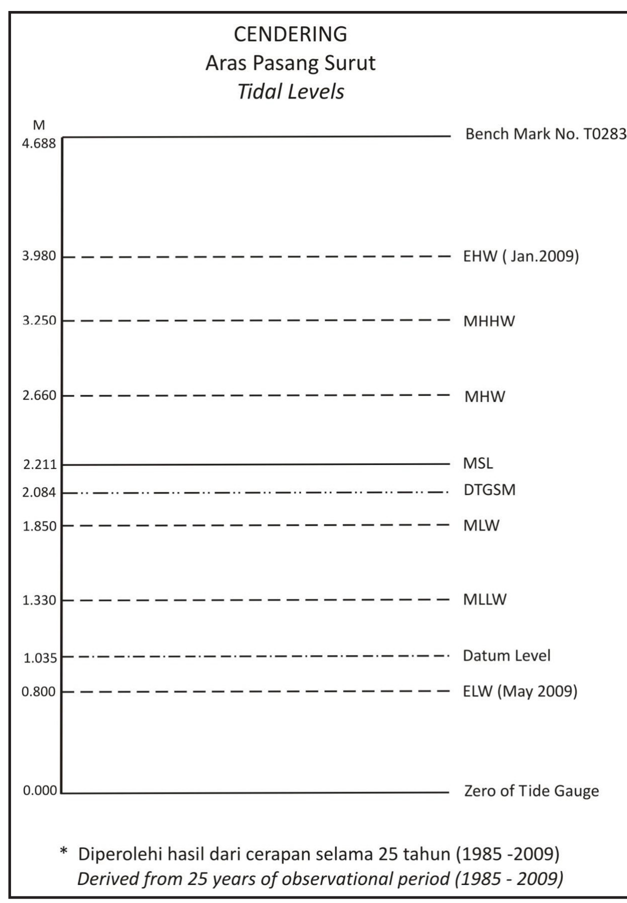

Figure 2: Tidal levels at Chendering, Kuala Terengganu.

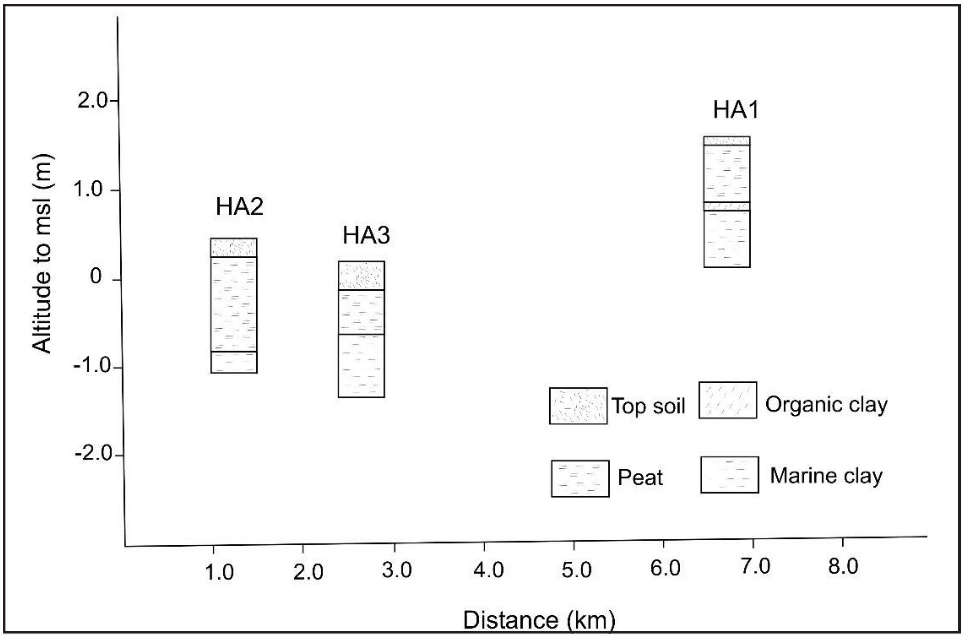

Figure 3: Profile of three cores; HA1, HA2 & HA3. The paleo sea level indicator is derived from the base of the peat/organic clay layer.

modern surface sediment samples, determined according to the known altitudinal relationship between modern diatoms and local tidal levels. The information of local tidal levels is referred from the Chendering Tide Gauge at Kuala Terengganu (Figure 2), the nearest available tidal level measurement.

Both the ground altitude of the modern surface sediment samples and the cores (fossil samples) were levelled to the nearest land survey datum, i.e. the Department of Survey and Mapping (JUPEM) bench mark. There are two benchmarks available near the study site. JUPEM benchmark provide mean sea level (MSL) altitudinal information referred to the peninsular Malaysia vertical datum. The stratigraphic profile of the analysed fossil sampling sites (HA1, HA2, and HA3) is shown in Figure 3.

The sea level indicator from each core (base of peat overlying the marine clay) was selected for radiocarbon dating. AMS radiocarbon dating of the sea level indicators were carried out by Beta Analytic, USA. The radiocarbon dates are presented as calibrated years before present.

RESULTS

The diatom analyses results indicate very good preservation of diatoms from the modern samples sites in the *Nypa* and mangrove swamps (sites A and B respectively), but are rare or absent in samples from the sandy beach site (site D). The latter is probably due to the mainly sand size grains sediment substrate from the sandy beach profile. Diatom presence is known to be associated with various environmental variables including sediment substrate or sediment grain size (Zong and Kamaludin, 2004). Also in site D, the beach is open to the strong wave action which may have washed away diatoms previously deposited. In Site C, the *Gelam* forests sampling site is found to be at a rather high elevation (3.55 to 3.71 m MSL) beyond the intertidal zone. Correspondingly the diatom assemblages are found only from the freshwater variety. Site C is thus not included in the study. The modern sample analogues are thence derived only from the *Nypa* and mangrove swamps sites. Table 1 shows the leveled heights of the surface samples analysed from the *Nypa* and mangrove swamps sites.

Table 1: Leveled heights for modern samples from the *Nypa* and mangrove swamp sites.

Site	Sample No.	Leveled Height (m MSL)
Site A (*Nypa* swamp)	A1	0.604
	A2	0.386
	A3	0.278
Site B (Mangrove swamp)	B1	0.949
	B2	0.878
	B3	0.502

Figure 4 shows the diatom diagram of the modern samples from the mangrove and *Nypa* sites. The contemporary diatom results show significant changes in their assemblages with altitude. The distribution of the assemblages is observed to correlate to a local reference water level, with certain associated assemblages and therefore characterising a particular tidal zone. The marine-brackish water diatom assemblages predominate at around local MHW, at about 0.45 m above MSL. Freshwater diatoms increase and dominate the assemblages at around local MHHW, at about 1.04 m above MSL. This result matches well with previously published data of diatom assemblages from mangrove tidal flats in peninsular Malaysia (Zong and Kamaludin, 2004).

Table 2 shows the elevation of the cores, sampling level of the sea level indicators and its AMS radiocarbon dates. The three sea level indicators are all sampled from the base of peat overlying the marine clay.

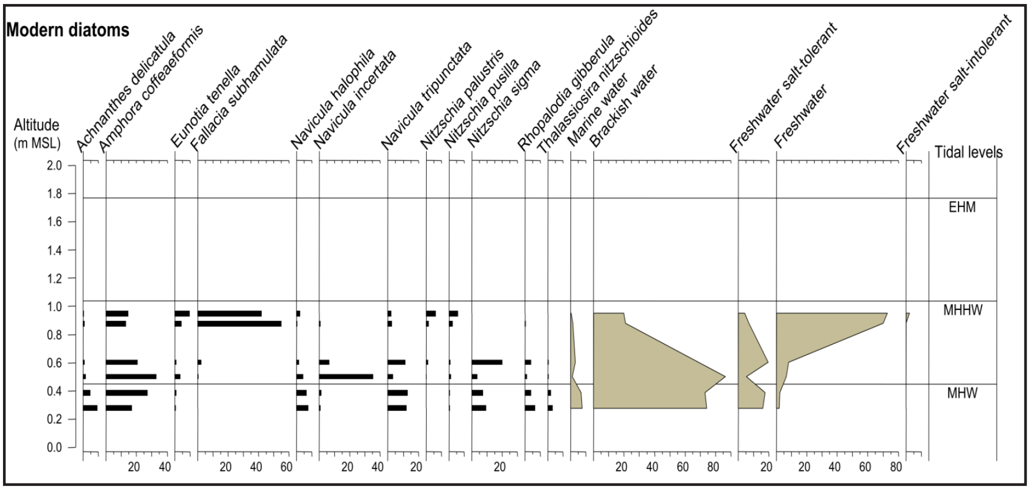

Figure 4: Diatoms from modern surface sediment samples.

Table 2: Elevation of the auger holes and reduced level of the sea level indicator.

Core	Level Height (m MSL)	Depth of Sea Level Indicator (m)	Reduced Level of Sea Level Indicator (m MSL)	AMS Measured Radiocarbon Age
HA1	1.523	0.88-0.90	0.62 to 0.64	1390 ± 30 BP
HA2	0.415	1.23-1.25	-0.81 to -0.83	960 ± 30 BP
HA3	0.180	0.83-0.85	-0.65 to -0.67	1050 ± 30 BP

Table 3: Diatom analyses sampling levels of the fossil sediments.

Core HA1		Core HA2		Core HA3	
Depth of sampling level (m)	Reduced level of sampling level (m MSL)	Depth of sampling level (m)	Reduced level of sampling level (m MSL)	Depth of sampling level (m)	Reduced level of sampling level (m MSL)
0.91	0.61	1.20	-0.78	0.56	-0.38
0.93	0.59	1.22	-0.80	0.58	-0.40
0.95	0.57	1.24	-0.82	0.60	-0.42
0.97	0.55	1.26	-0.84	0.62	-0.44
0.99	0.53	1.28	-0.86	0.64	-0.46
1.01	0.51	1.30	-0.88	0.66	-0.48
1.03	0.49	1.32	-0.90	0.68	-0.50
1.05	0.47	1.34	-0.92	0.70	-0.52
1.07	0.45	1.36	-0.94	0.72	-0.54
1.09	0.43	1.38	-0.96	0.74	-0.56
1.11	0.41	1.40	-0.98	0.76	-0.58
1.13	0.39	1.42	-1.00	0.78	-0.60
1.15	0.37	1.44	-1.02	0.80	-0.62
1.17	0.35			0.82	-0.64
1.19	0.33			0.84	-0.66
1.21	0.31			0.86	-0.68
1.23	0.29			0.88	-0.70
1.25	0.27			0.90	-0.72
1.27	0.25			0.92	-0.74
1,29	0.23			0.94	-0.76
				0.96	-0.78

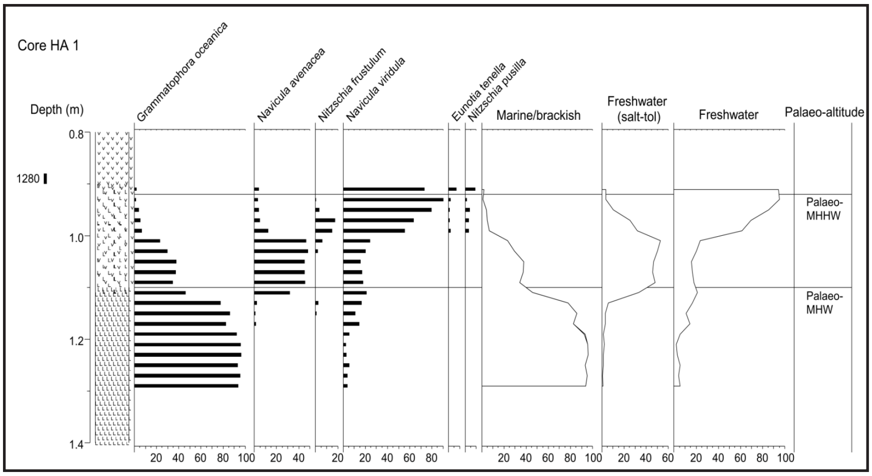

Figure 5: Diatoms assemblages from core HA1.

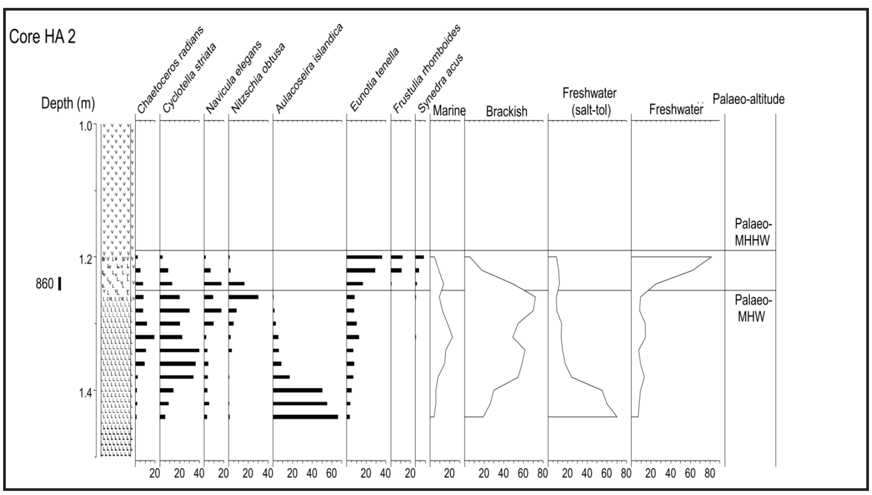

Figure 6: Diatoms assemblages from core HA2.

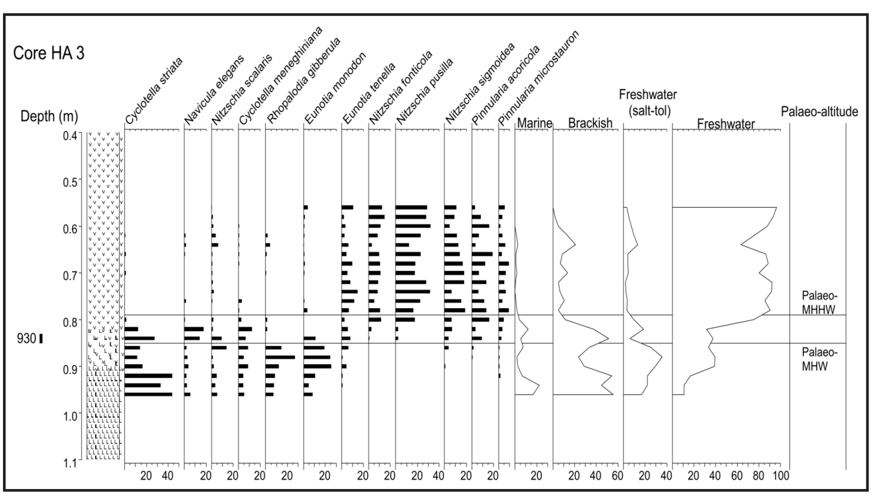

Figure 7: Diatoms assemblages from core HA3.

For the three sea level indicators, a total of 54 sediment samples from cores HA1, HA2 and HA3 were analysed (Table 3). The samples were analysed at 2 cm spacing intervals from levels within the stratigraphic contact horizon of the upper peat and the lower marine clay. The purpose is to ascertain the altitude of deposition of the dated sea level indicator in relation to the contemporary samples.

Diatom assemblage results from core HA1 indicate that the dated sediment horizon, at 0.88-0.90 m depth, was deposited near the paleo-MHHW (Figure 5). This is shown by the freshwater diatoms becoming dominant in the assemblages around the dated depth. The indicative meaning derived from the modern analogue for the dated horizon corresponds to 1.04 m MSL (Figure 4). With reference to the ground altitude of the core (1.523 m MSL) and the dated horizon (0.63 m MSL), the paleo sea level indicator at the time of deposition thus corresponds at -0.41 m MSL (0.63 m-1.04 m).

Table 4: Sea level index points from Merang, Terengganu.

Core	AMS ^{14}C Age BP (1σ)	Calibrated Age Ranges Cal. Years BP (2σ)	Midpoint Value of Calibrated Age Range Cal. years BP	Altitude (m) of Sea Level Indicator (Dated Level)	Indicative Meaning (m MSL)	Relative Paleo Mean Sea Level (m MSL)
HA1	1390 ± 30	1300 to 1260	1280	0.62 to 0.64	1.04	-0.41
HA2	960 ± 30	920 to 740	830	-0.81 to -0.83	0.45	-1.27
HA3	1050 ± 30	960 to 900	930	-0.65 to -0.67	0.45	-1.11

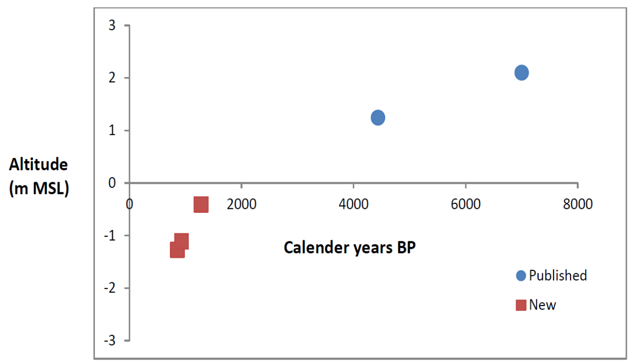

Figure 8: Plot of relative sea level index points from Merang and Kuantan.

Diatoms diagram from core HA2 suggest the dated sediment sample, at 1.23-1.25 m depth, was deposited close to paleo-MHW (Figure 6). The diatom assemblages at the dated depth show the diatom assemblages being dominated by marine-brackish species and the onset of increasing freshwater diatoms. The indicative meaning derived from the modern analogue for the dated horizon corresponds to 0.45 m MSL (Figure 4). As indicated in Table 2, the ground altitude of the core is 0.41 m MSL and the altitude of the dated sediment of -0.82 m MSL, the paleo sea level indicator at time of deposition thus corresponds at -1.27 m MSL (-0.82 m -0.45 m).

Similarly, the diatom data from core HA3 suggests that the dated sediment at depth of 0.83-0.85 m was deposited at about paleo-MHW (Figure 7). This is shown by predominant marine-brackish water diatoms within the level. The indicative meaning derived from the modern analogue for the dated horizon corresponds to 0.45 m MSL (Figure 4). With reference to the altitude of the core at 0.18 m MSL and the altitude of the dated horizon at -0.66 m MSL, the paleo sea level indicator during deposition thus corresponds to -1.11 m MSL m (-0.66 m -0.45 m).

Table 4 shows the sea level index points derived in the study. The relative paleo sea level from Merang is plotted in a time-altitude graph. The midpoint value of calibrated age range in calender years BP is used to plot the sea level points. A sea-level index point (4436 cal. years BP at 1.24 m) from Kuantan (Kamaludin 2001) derived using a similar technique and another sea-level index point (7100 cal. years BP at 1.4-3.0 m) collected by Parham *et al.* (2014) from a coral reef in Terengganu are included in the sea level plot (Figure 8).

DISCUSSION AND CONCLUSIONS

Based on our three new sea-level index points collected from Terengganu, together with the two reported previously from this coast, a new sea-level history for the NE coast of Peninsular Malaysia is reconstructed (Figure 8). This sea-level history illustrates a possible mid-Holocene sea-level highstand at about 2 m in about 7100 years ago, since which relative sea level along this coast dropped gradually towards about 2000 years ago, and the rate of this sea-level drop was about 0.4 mm/a. During the last 2000 years, relative sea level seemed to drop faster and dipped below the present sea level from c. 1500 to 800 years ago. This sea-level drop was at a rate of 1.8 mm/a. Although we have no data to show the sea-level history for the last 800 years, it can be assumed that relative sea level during this time period may have risen back to the present height.

This sea-level history reveals two important processes. Firstly, the mid-Holocene sea-level highstand indicates the effects of hydroisostatic process, which is an important part of the global glacial isostatic adjustment (GIA) since the start of deglaciation (Peltier, 2004). The gradual decline in relative sea level from 7000 to 2000 years ago suggests the GIA effects diminishing as the deglaciation ended by about 7000 years ago when major ice sheets ceased melting. Secondly, the relative sea-level drop below the present during c. 1500 to 800 years ago revealed by our three new sea-level index points is an important discovery. This lower-than-present sea-level record was only reported previously in Greenland (Long *et al.*, 2011), which is attributed to glacial re-advance during the late Holocene culminating in the Little Ice Age (Roberts, 1998). In the east coast of the U.S.A., which is a near-field site and has experienced continuous sea-level rise during the mid- and late Holocene, Kemp *et al.* (2011) reported that the rise of relative sea level slowed down from about 1500 years ago, followed by a period of sea level rise at a reduced rate between 1500 and 300 years ago, but a period of rapid rising sea level was recorded in the past 300 years. In other words, this period of sea-level change may be globally significant.

This period of lowering sea level may be caused by multiple forces. Firstly, as Long *et al.* (2011) explained, the re-advance of ice sheet in Greenland started about 4000 years ago (e.g. Dahl-Jensen *et al.*, 1998; Porter, 2000) may have caused localized subsidence, or in other words, sea-level index points of late Holocene age are now found from altitudes below the present sea level. This process was also predicted by geophysical models (e.g. Lecavalier *et al*., 2014). For far-field site, such as the Peninsular Malaysia, this period of glacial re-advance would certainly result in sea-level drop. Secondly, the last 2000 years were associated with a period of significant climatic cooling, the so-called Little Ice Age, that lasted from AD 1590 to AD 1850. This cooling would certainly result in a contraction of the ocean's surface water (thermal contraction during a period of cold climate as contrary to thermal expansion during a period of climatic warming). Thirdly, it is still unclear about the GIA effects for this period. It is possible that the hydrostatic process associated the GIA may have lowered the relative sea level in this far-field site below the present height during the late Holocene.

In conclusions, through our careful field and laboratory work, three high-quality sea-level index points were produced from a stable far-field coastal site, Terengganu, Peninsular Malaysia. These new data points together with two previously published data points have helped the reconstruction of relative sea-level history of the past 7000 years for this coast. This new sea-level history reveals the tropics are sensitive to the effects of hydrostatic process and climatic fluctuations. Zong (2013) stated the importance of sea level changes study in the tropics, since the tropics are not affected by the glacio-isostatic processes, thus the history of eustatic sea level changes could be more emphasised.

ACKNOWLEDGEMENTS

The authors would like to thank the many persons involved during the data collection in the field as well as in the office and in the drafting of the figures. Permission to publish from the Director General of Minerals and Geoscience Department is acknowledged.

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Manuscript received 5 June 2015
Revised manuscript received 12 January 2016
Manuscript accepted 26 January 2016