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Holocene sea level changes in Peninsular Malaysia

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Abstract: In Holocene sea level study, the selection and identification of appropriate sea level indicator is a prerequisite in order that the sea level index points can be useful and significant. This requires the identification and determination of the indicative meaning. The indicative meaning of the sea level indicator is defined as the altitudinal relationship of the local environment in which it accumulated to the contemporaneous reference tide level.

This study identifies the 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 Holocene sequences from Meru and Mardi in Kelang and Penor in Kuantan, while the indicative meaning is estimated based upon the microfossil relationship between the fossil sea level indicator with contemporary samples from various present-day ecological environments.

Seven sea level index points identified in the study are compared to the corrected sea level indicator data from earlier works. In Peninsular Malaysia, a general trend of high sea level from about mid-Holocene to the present is depicted.

Abstrak: Di dalam kajian paras laut Holosen, untuk menjadikan sesuatu titik indeks paras laut itu berguna, pemilihan dan kenalpasti penanda paras laut adalah penting. Ini memerlukan kepada mengenalpasti dan menentukan "indicative meaning" sesuatu penanda paras laut itu. "Indicative meaning" penanda paras laut diertikan sebagai hubungan ketinggian persekitaran setempat dimana sesuatu penanda paras laut itu telah dihimpun/dilonggok dibanding dengan aras pasang surut semasa.

Kajian ini mengenalpasti titik indeks paras laut menggunakan pendekatan "litho-, bio-, dan chrono-" stratigrafi. Penanda paras laut adalah didapati dari sentuhan menurun perlapisan gambut dan samudera Holosen yang dikenalpasti di Meru dan Mardi di Kelang dan Penor di Kuantan. "Indicative meaning" penanda paras laut itu pula dianggar mengikut hubungan fosil-mikro di penanda paras laut dengan yang didapati di sample semasa, diambil dari pelbagai persekitaran ekologi paya pesisir pantai.

Tujuh titik indeks paras laut dikenalpasti dari kajian ini dan di bandingkan dengan data paras laut dari kajian terdahulu, yang telah diperbetulkan. Pada amnya di Semenanjung Malaysia, paras laut didapati tinggi dari pertengahan Holosen sehingga sekarang.

INTRODUCTION

This paper presents current finding and understanding of the Peninsular Malaysia Holocene sea level record. The advances in sea level research necessitate a need for Holocene sea level data and reassessment of the earlier works for the region. The methodology and approach of sea level studies have become more rigorous (Shennan, 1982a,b, 1986a,b; Shennan *et al.*, 1995, 2000; Plassche, 1986; Pirazzoli, 1996; Horton *et al.*, 1999; Zong & Horton, 1999) and stress on the proper identification and determination of sea level index points.

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 molluscs, coralline algae, vermetid gastropods, beach rocks, botanical remains, foraminifera, diatoms, ostracods, shell middens, submerged forests, to marine notches, coastal deposits and barrier sands.

In Peninsular Malaysia, previous sea level investigations were mainly from the Strait of Malacca survey (Streif, 1979; Geyh *et al.*, 1979) and studies of Tjia (Tjia *et al.*, 1977; Tjia, 1980, 1992, 1996). However in these studies the techniques of sea level analysis are quite simplified. In addition, the interpretations are incomplete because of the erroneous determination of the sea level index points.

STUDY AREA

The study areas are selected from two locations, which aims to represent Peninsular Malaysia's general coastal settings, one in the west and the other the east coasts. The sites selected are those that disclose stratigraphic changes as a result of the Holocene marine transgression or regression. Since the study also deals with contemporary environments, surface sampling areas are also identified. Basically, the surface sampling sites are selected within the vicinity of the fossil sampling locations. Based on the criteria identified two coastal sites, in Kelang representing the west, and Kuantan the east, were selected for the study (Figs. 1 and 2).

Holocene stratigraphic transects were investigated, two in Kelang (Figs. 3 and 4) and one in Kuantan (Fig. 5), while two contemporary environments were studied in Kelang and four in Kuantan. The contemporary sites

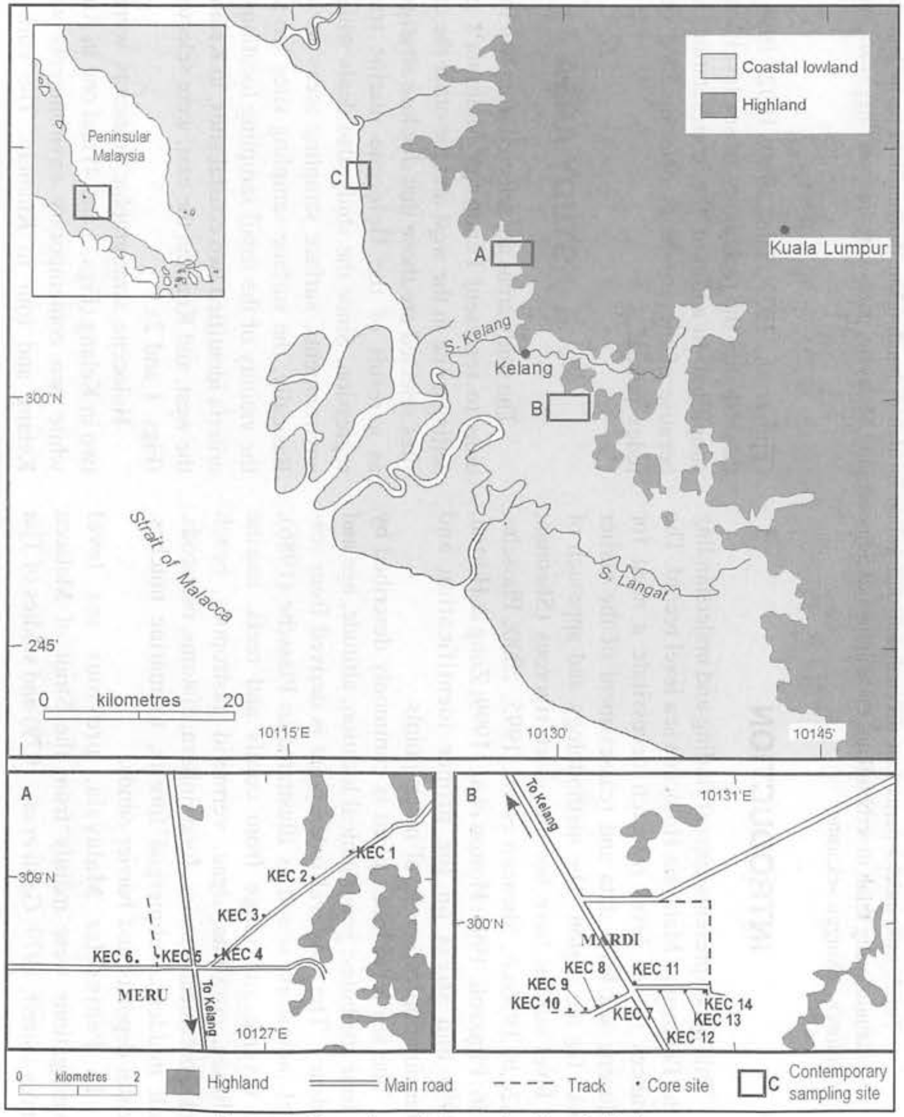

Figure 1. Location of the study sites in Kelang.

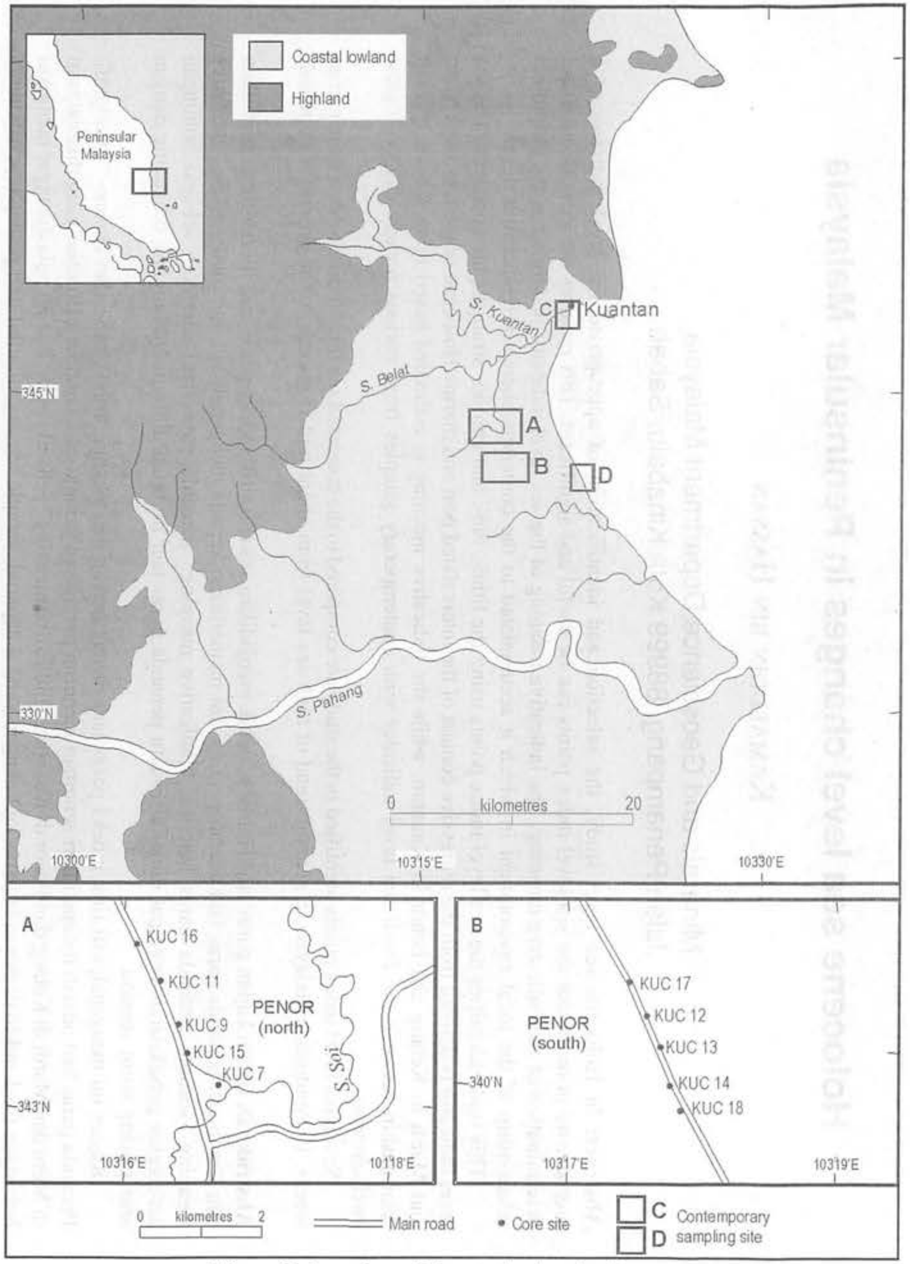

Figure 2. Location of the study sites in Kuantan.

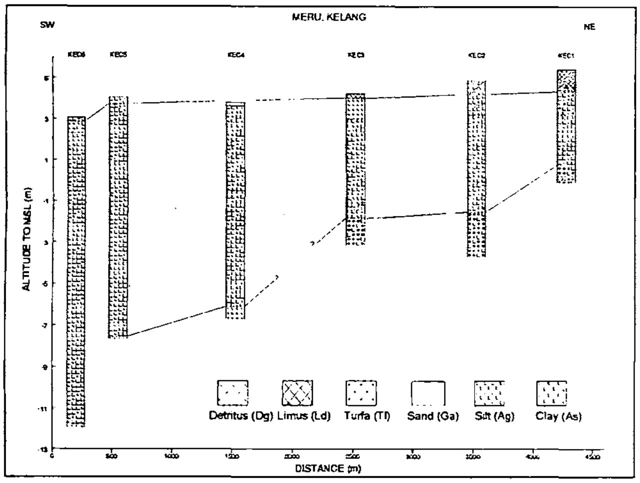

Figure 3. Stratigraphic transect in Meru, Kelang.

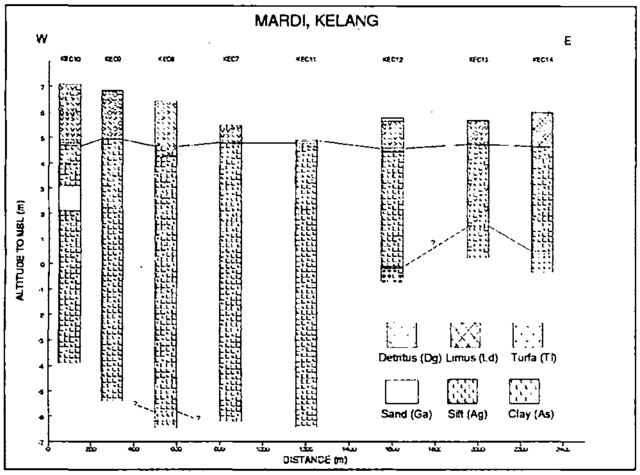

Figure 4. Stratigraphic transect in Mardi, Kelang.

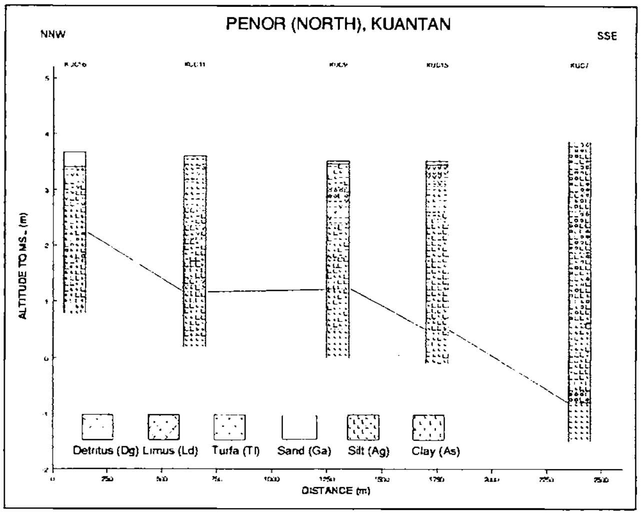

Figure 5. Stratigraphic transect in Penor (north), Kuantan.

provide vital biological information for interpreting the paleo sea level index points. Mangroves dominate the contemporary coastal environments in both the sites. Other ecological settings investigated include the back mangrove *Nypa* swamp, the *Acrostichum aureum* vegetation and the coastal *Pandanus* swamp.

METHODS

The sea level indicators in the study were derived from Holocene coastal sedimentary deposits. In this sedimentary environment, intercalated peat and marine deposits form the best indicator. Biostratigraphy, microfossils (chiefly pollen and diatom) and sratigraphic analyses, define the precise nature of the transgressive or regressive processes. Stratigraphic correlation, including litho-, bio- and chrono-, enables differentiation between local or regional influences.

Field investigation involved augering, lithologic description (logging), sampling and levelling survey. Contemporary surface sediment samples were collected from various representative coastal environments. The altitude of all the sampling sites, both the boreholes and surface samples, were levelled to the nearest benchmark. The sea level index samples were dated using the AMS radiocarbon (^{14}C) dating technique.

The interpretation of the indicative meaning and indicative range of the dated samples are very much emphasised. The indicative meaning of the sea level indicator, or its altitudinal relationship to the contemporaneous reference tide level, is determined by comparing the fossil with the contemporary assemblages, assuming the fossil and present conditions are similar. The approach adopted here is to investigate the relationship between contemporary microfossils found in a range of environments (including habitat and tidal elevation), and the application of this knowledge to the interpretation of fossil situation. Contemporary assemblages are important in establishing the indicative range of the fossil sea level indicator. The indicative range is the vertical range of uncertainty of the fossil sea level indicator's relation to the reference water level, which commonly is the mean high water spring (MHWS), mean high water (MHW) or the mean sea level (MSL).

RESULTS AND INTERPRETATION

A total of 139 pollen types and 61 diatom taxa are differentiated. They are presented in the pollen and diatom frequency diagrams for both the surface and core samples. The palynomorphs and diatoms, both contemporary and fossil, are summarised into their ecological assemblages. The seven ecological divisions of the pollen types differentiated are mangrove, coast, back mangrove, coastal freshwater swamp, swamp and lowland, lowland open and inland. The fern and fungal spores are also plotted in the pollen diagram, their frequencies calculated to the pollen sum. Both the contemporary and fossil diatom species are classified according to their salinity tolerance and life forms.

Contemporary pollen and diatom assemblages

The contemporary pollen and diatom results show significant changes in their assemblages with altitude. The distribution of the microfossil assemblages is observed to correlate to a local reference water level, with certain assemblages associated with and therefore characterising a particular tidal zone. In this study, pollen and diatom associations from about mean low water spring (MLWS) to the supratidal are distinguished (Fig. 6 and 7). In pollen analysis, the main assemblages, the mangrove, back mangrove, coastal freshwater swamp and the inland grouping (including swamp and lowland, lowland open and the inland), are found to be of prime importance. For diatom analysis the salinity and life form classifications provide significant correlations.

Both the pollen and diatoms analyses from the contemporary local environment corroborate and substantiate the interpretation of the indicative meaning. The indicative meanings of two of the dated samples (KEC2 & KEC1) are interpreted from their pollen and diatom assemblages, while in the other five samples from their pollen assemblages since diatoms are rare or absent. Table 1 shows the interpreted indicative meaning and indicative range values of the samples analysed.

Sea level index points

Seven sea level index points are identified in this study, six from Kelang in the west coast and one from Kuantan in the east (Table 2). The index points all show negative tendencies of sea level movement as indicated from the lithology and the microfossil results. The regressive overlaps shown by the peat overlying marine sediments and the results of pollen and limited diatom analyses, point to a removal of marine conditions from the sites.

The sea level index points are plotted on a time-altitude graph (Fig. 8). In this study only errors arising from the estimation of the indicative meaning and the calibrated ages are considered. In the former the error is estimated by comparing the altitude of the fossil with that of the contemporaneous assemblages while the latter is the variation of the calibrated age range from its mid point value.

DISCUSSION

With reference to the present finding, comparison is made with other related Holocene sea level investigations in the region. The significance of this study and its results as compared to previous sea level methodologies are especially stressed.

Comparison between this study and records in the region

The Holocene sea level changes depicted by Geyh *et al.* (1979) from the Strait of Malacca is deficient from the bio- and litho- stratigraphic points of view. Even though Streif (1979) briefly discussed the indicative meaning of the dated material, the indicative range of the sample, uncertainties of height determination and the sigma interval of the ^{14}C dates, the fact that the stratigraphy and most importantly biostratigraphic analysis were not dealt with, reduces the significance of the interpretation. It is found that the sea level index points of the present study show an altitudinally lower value, which equal their indicative meaning, than if they were plotted using the Geyh *et al.* (1979) and Streif (1979) methodology.

In the study by Tjia (1970, 1980, 1992, 1996) and Tjia *et al.* (1977), the mid Holocene to present sea level of Peninsular Malaysia is investigated from the morphological feature and shoreline biological indicator,

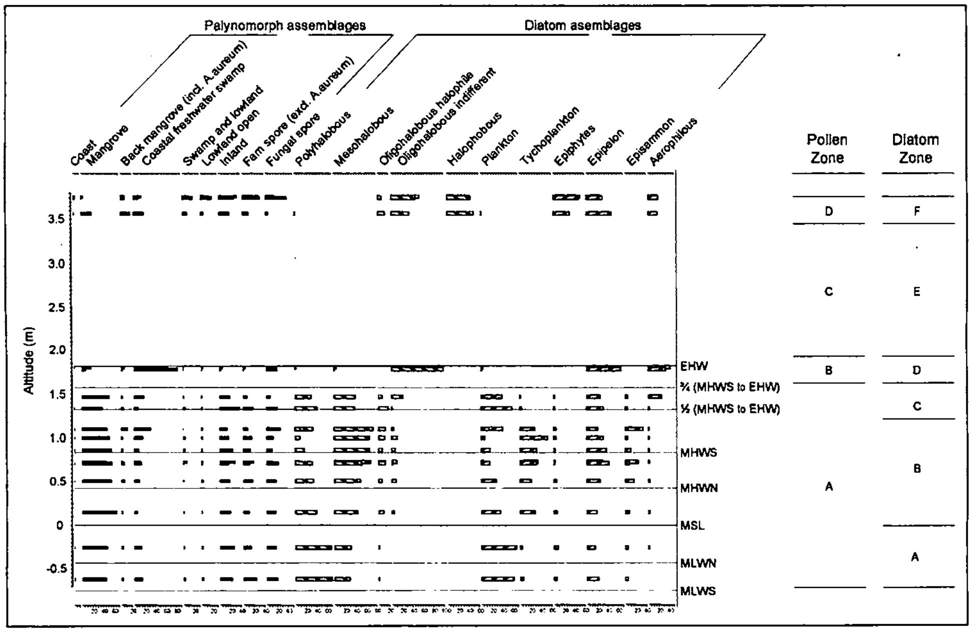

Figure 6. Vertical distribution and zonation of contemporary pollen and diatom assemblages, in Kelang.

Table 1. Indicative meaning estimated from the dated sea level indicator in Kelang and Kuantan.

Core no.	Altitude (m) of sea level indicator (Dated level)	Relation of fossil sea level indicator to contemporary reference water level	
		Indicative range (m)	Indicative meaning (m)
KEC2	4.193-4.203	1.0-1.60	1.30±0.3
KEC1	4.304-4.324	1.40-1.80	1.60±0.2
KEC9	4.936-4.946	1.40-1.60	1.50±0.1
KEC8	4.675-4.690	1.40-1.80	1.60±0.2
KEC7	4.787-4.797	1.40-2.0 (~Pollen Zone C)	1.70±0.3
KEC13	4.738-4.748	1.20-1.60	1.40±0.2
KUC15	3.034-3.054	1.70-1.90 (Pollen Zone B)	1.80±0.1

Table 2. Sea level index points from Kelang and Kuantan

Core no.	AMS ^{14}C age BP (1•)	Calibrated age ranges Cal. years BP (2•)	Altitude (m) of sea level indicator (Dated level) [X]	Indicative meaning (m) [Y]	Relative paleo sea level (m) [(mid X)-Y]	Sea level tendency
KEC2	4045±49	4647-4413	4.193 to 4.203	1.30±0.3	2.898±0.3	-ve
KEC1	4073±86	4831-4404	4.304 to 4.314	1.60±0.2	2.709±0.2	-ve
KEC9	5331±46	6202-5989	4.936 to 4.946	1.50±0.1	3.441±0.1	-ve
KEC8	5270±47	6120-5927	4.675 to 4.69	1.60±0.2	3.08±0.2	-ve
KEC7	5349±65	6213-5989	4.787 to 4.797	1.70±0.3	3.092±0.3	-ve
KEC13	5556±47	6411-6280	4.738 to 4.748	1.40±0.2	3.343±0.2	-ve
KUC15	3967±43	4527-4344	3.034 to 3.054	1.80±0.1	1.244±0.1	-ve

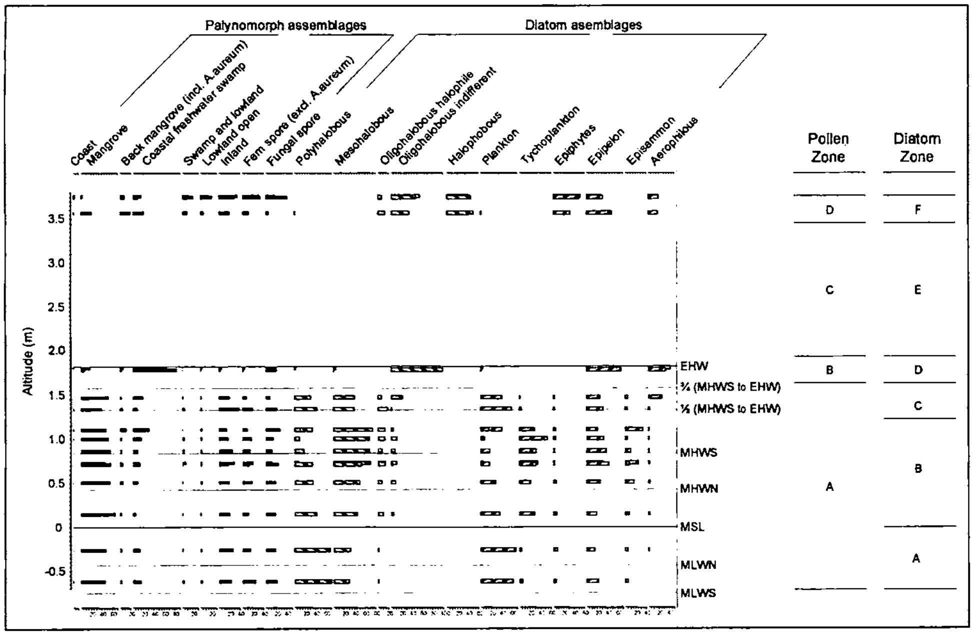

Figure 7. Vertical distribution and zonation of contemporary pollen and diatom assemblages, in Kuantan.

the former includes the coasts and sea floors while the latter such as oysters, barnacles, molluscs and shells. For the sea level methodology to be useful, any index point determined needs to satisfy the criteria of age, altitude, geographical location, tendency and indicative meaning (Plaasche, 1986; Shennan, 1986b). However Tjia's technique lacks the latter two, particularly the indicative meaning of the sea level indicator. The altitude of the indicators was also mostly based on crude measurements like above or below high tides (in Yoshikawa, 1987). In addition, no specific indicative trend could be deciphered from the sea level graph. Nonetheless, a high mid Holocene sea level, up to about 5 m above MSL was interpreted. Tjia's (Tjia, 1992, 1996) three suggested routes of sea level falls depicted as fluctuating, progressive but gradual lowering, and stepwise recession are but mere postulations.

The respective sea level plots from the north and south of Peninsular Malaysia, in Thailand by Sinsakul *et al.* (1985) and Sinsakul (1992), and from Singapore by Hesp *et al.* (1998), similarly, fails the definition of sea

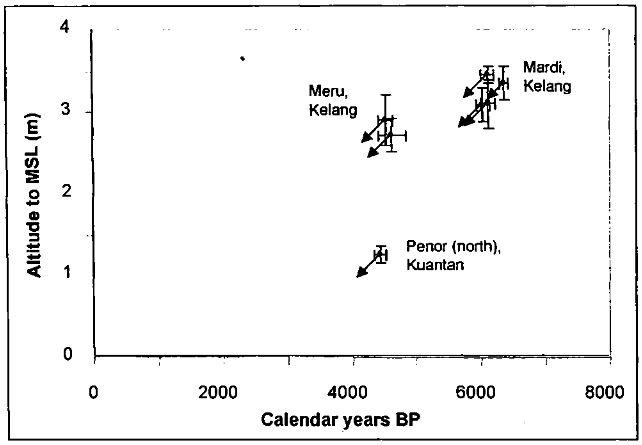

Figure 8. Plot of sea level index points.

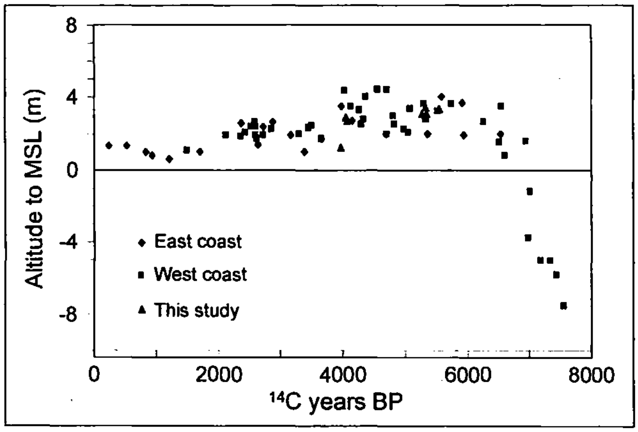

Figure 9. Plot of Peninsular Malaysia sea level index points (indicative meaning and indicative range corrected).

level index points. The majority of the plots in Thailand for instance, are just points which record the altitude of the presumed sea level indicator, which in cases does not even qualify to be a sea level index point. Examples include shells in marine sediments, which could be transported and also difficult or rather impossible to determine their indicative meaning, but have been used as the sea level indicator. In many others, the elevation was estimated using topographic maps. Even though Sinsakul *et al.* (1985) discusses the sea level fundamentals and its error sources, no mention of the sample indicative meaning and tendency is given. Meanwhile, among the Singapore sea level indicators, the ^{14}C dated peat samples were not biostratigraphically examined. In one supposedly sea level indicator sample, the peat was dated 45 cm up from its regressive basal contact. Thus the accuracy of the sea level data is much questioned.

Reassessment of previous Peninsular Malaysia sea level data

Based on the ideas of Shennan (1982a) and Zong (1992), and the results of present study, previous sea level data from the peninsula, chiefly of Geyh *et al.* (1979) and Tjia's (in Yoshikawa, 1987), were reassessed. A total of 66 data points were analysed. The indicative meaning and

Table 3. Estimated indicative meanings of Geyh *et al.* (1979) and Tjia's (shoreline data extracted from Yoshikawa, 1987) sea level data.

Type of indicator	Indicative range (m)	Indicative meaning (m)
Oyster in growth position	±1.5	0
Coral in growth position	±1.5	-1.5
Molluscs in beach sand	±1.5	0
Molluscs in mud	±1.5	-1.5
Beachrock	±1.5	0
Mangrove wood on brackish deposits	±1.5	1.5
Peat on brackish deposits	±1.5	1.5
Wood on brackish deposits	±1.5	1.5

indicative range were estimated and a sea level plot constructed (Fig. 9). Table 3 lists the types of sea level indicators available. Bad data points or difficult to estimate indicative meaning, like wood, peat and algae, were excluded. The oyster, molluscs in beach sand and beachrock are assumed zero indicative meaning because they could be present from the low to high tide range, while coral and molluscs in mud are estimated to occur within the low tidal zone. The mangrove wood, peat and wood on brackish deposits are presumed having similar indicative meaning (average) with the present study.

The sea level graph shows that the plotted error range is particularly notable for Geyh *et al.*s' and Tjia's data. What is evident from Figure 9 is that the postglacial eustatic rise in sea level starts to slow down at about 7 ka Cal. years BP. Subsequently, sea level was maximally about 4 m higher than present until about 4 ka Cal. years BP, and thereafter with lower values. Also, the sea level graph indicates that both organic deposits and biological sea level indicators are invaluable for better relative sea level reconstruction. The direct effect of the high mid Holocene sea level is manifested in Peninsular Malaysia by the evolution of its coastal plains.

CONCLUSIONS

Much more work is needed to attain a detailed picture of the Peninsular Malaysia Holocene sea level history. Nonetheless the outcome of this study has undoubtedly paved the way towards an in-depth appreciation of the subject. By adopting the northwest Europe sea level methodology and techniques, particularly that employed in Britain (Tooley, 1982; Shennan, 1982a, 1986b; Shennan *et al.*, 1983, 1995; Plaasche, 1986), the sea level index points, crucial in the research, have been successfully determined. Although limited index points were recognised, their significance for Peninsular Malaysia Holocene sea level record could not be more emphasised. As far as this study is concerned, the indicative meaning derived from the contemporary mangrove and tropical coastal swamp environments is the first of its kind to be successfully applied in the determination of sea level index points (Kamaludin, 2001).

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