Recent agglutinated foraminiferal trends and assemblages of the Sedili Besar River and its adjacent offshore area, Southeastern Peninsular Malaysia

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ABSTRACT

The Sedili Besar River is strongly tidally influenced and its lower areas reach into a well-developed estuary. It enters the South China Sea along the wave-dominated southeastern coast of the Malay Peninsula. A total of 103 surface sediment and 48 shallow core samples from the tidal part of the river and the adjacent offshore area of Jason Bay were studied for Recent foraminiferal assemblages. The distribution of the agglutinated foraminifera shows abundance trends from the river estuary to the shallow marine offshore. Calcareous forms increase with water depth, but agglutinated foraminifera show a reverse trend.

Five biofacies zones can be differentiated based on the abundance and species diversity of the dominant agglutinated foraminifera. These coincide with the upper brackish intertidal, lower brackish intertidal, estuary mouth, beach/nearshore and inner shelf depositional settings. Identification of the assemblages within the rock record from the Malay Basin and elsewhere will help considerably in a more precise characterization of the paleoenvironments of hydrocarbon reservoir intervals.

INTRODUCTION

Foraminifera are very good indicators of depositional environments, and assemblages from brackish water coastal environments tend to be dominated by agglutinated foraminifera. A good understanding of their distribution in modern environments will allow them to be used as high resolution indicators of depositional facies, sea-level changes, etc. This is particularly important in the interpretation of the Oligocene-Miocene hydrocarbon-bearing intervals of the Malay Basin, which are dominated by fluvial-alluvial and deltaic sediments, without any good marine microfaunas present.

The main objective of this study is to characterize the microfaunal distribution in different depositional facies within the marginal marine environments of the Sedili River estuary and the adjacent shallow marine Jason Bay (Teluk Mahkota). Other parameters such as grain size, water depth and salinity were also utilised to see any significant trends of the foraminiferal assemblages.

Earlier papers on the ecology and microfossil fossil distributions in the Sedili River- Jason Bay area include Corner (1978), Varol (1984; calcareous nannofossils distribution), Zhao and Whatley (1989; ostracode distribution), Yakzan et al. (2010; palynomorphs distribution) and Hughes (2000; foraminifera). Comparable studies on marginal marine modern foraminifera were conducted along the NE Peninsular Malaysia coast by Culver et al. (2012, 2013).

THE SEDILI ESTUARY STUDY AREA ECOSYSTEM

The Sedili Besar River Basin is in the eastern part of the state of Johor, along the southeastern coast of the Malay Peninsula, about 40km from Kota Tinggi (Figure 1). The climate is tropical and humid, hot and wet, with an average annual rainfall between 3,000 - 3,500mm. Rainfall is extremely high at 3550mm/year, with a maximum of 696 mm in January and a minimum of 136mm in February. The average daily rainfall in 2007 is 9.7mm. Highest rainfall is recorded from November to January during the northeast monsoon whereas the dried season is from February to April, which is during the southwest monsoon. Mean humidity ranges from 78-86 % mean daily temperature ranges from 26-28 °C, while the mean tidal range is 1.8m (Meteorological Department).

The Sedili Besar River is a coastal plain estuary with riverine vegetation in a pristine condition. The Sedili Besar River estuary meanders through the low-lying basins and forms distinct mangrove, nypa and freshwater swamps. The mangroves *Rhizophora apiculata*, *Rhizophora mucronata* and *Sonneratia*

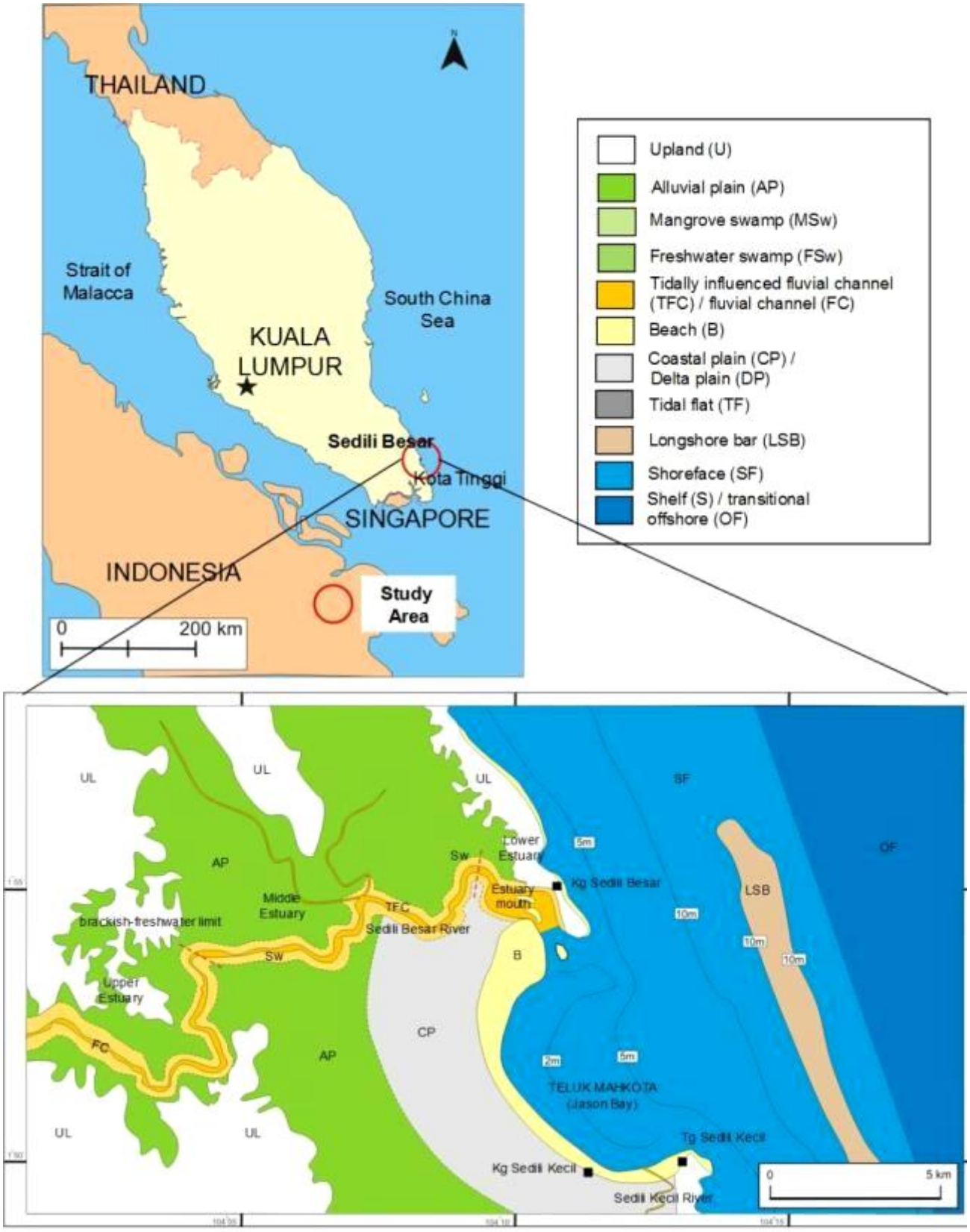


Figure 1. *Location map of Sedili Besar River and Estuary*

alba are common, especially near the river mouth while *Kandelia candel* are dispersed along the river bank. *Nypa fruticans* are dominant along the channel edge about 15km upstream from the river estuary.

The main Sedili Besar River has a length of about 50 km. The main catchment is located in the forested area within the Sedili Forest Reserve. The upstream Sedili River basin consists of tropical and subtropical primary forest, with scattered oil palm and rubber plantations dominating the agricultural landscape. Major economic activities are fishing and agriculture. The Sedili wetland is home for diverse flora and fauna and is located close to the Panti Forest Reserve which is famous for bird watching. There is not much published information on the channel geometry and flow discharge of Sedili Besar River

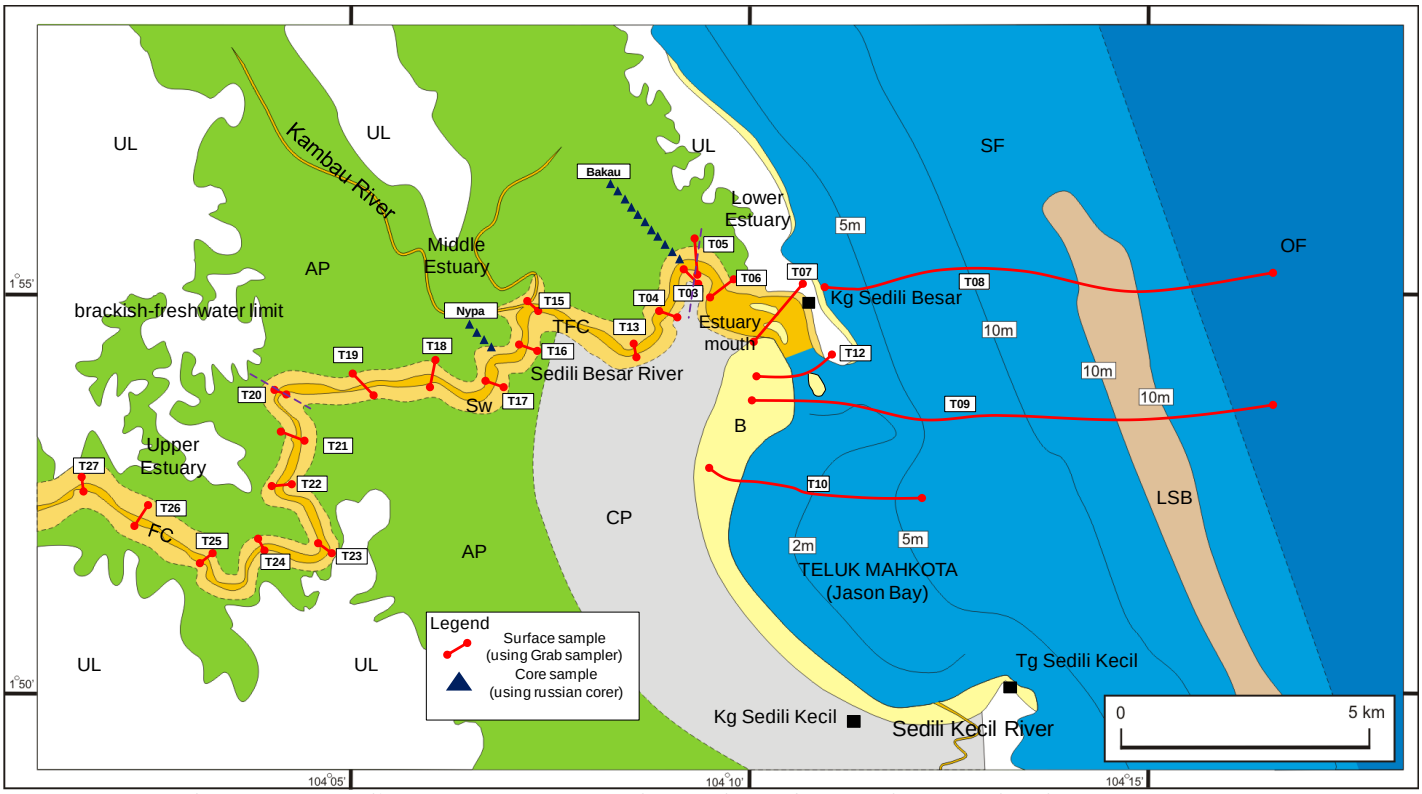


Figure 2. *Study area, sampling transects, type of samples taken and water depth.*

from literature or public domain. The study area includes part of the Sedili Besar River, its estuary and the adjacent offshore area, Telok Mahkota; also known as Jason Bay. Telok Mahkota is a small embayment opening eastwards into the South China Sea.

MATERIAL AND METHODS

A total of 151 samples were collected for this study, either by using a Russian corer or a Van Veen grab sampler. The Russian corer was ideal for use in peat swamp, clay, silt and muddy areas, whereas the grab sampler was used for collecting the seabed sediments. Samples were taken from different water salinities of the Sedili Besar River and its estuary, from the river mouth to approximately 30km upstream, and along the west coast of Telok Mahkota up to10km further offshore (Figure 2). Water depths of samples range from 0.5m to16m. The water salinity at the river mouth shows an average value of 33.0 ppt while the salinity value drops to 0.0 ppt approximately 20km upstream from the river mouth.

A total of 48 samples were collected for foraminiferal and palynological analysis from three transects during the first visit (Nov 2006) and 103 samples collected from 27 transects at the second visit (May 2007). Out of this, 95 surface sediments samples were collected using the grab sampler while 56 samples were taken using the Russian corer. In the three offshore transects T8, T9 and T10, samples were taken at 500m intervals, whereas the others were taken in the fluvial channel. Shallow cores were also collected at two transects, i.e. *Bakau* and *Nypa* on the mangrove and *Nypa* swamp respectively. The Bakau transect is located close to T3 while *Nypa* transect is near T15 (Figure 2).

This paper presents the results of the foraminiferal analysis only. Samples were processed quantitatively to reflect absolute frequencies of microfauna per unit weight of sediment. At least 50g of the dry samples were weighed and processed for foraminiferal analysis as per PETRONAS Research Sdn Bhd (PRSB) standard procedures. All of the dried residues were picked and identified using the following mesh sizes: 500-250mm, 250-125mm and 125-63mm.

RESULTS

Two types of foraminiferal distribution charts were plotted in this study; one using the Stratabugs software (not included here) and the other as pie chart maps. The foraminiferal distributions were first interpreted using the Stratabugs program to determine the principal distribution pattern. Then the main trends were depicted using a pie chart map showing the major agglutinated foraminiferal assemblages. Only species with counts more than ten are grouped as the major agglutinated assemblages. Agglutinated foraminifera, represented by 13 common species, are grouped in the pie chart to determine for any possible biofacies trends. These common species are *Miliammina fusca, Ammobaculites exiguus, Arenoparrella mexicana, Arenoparrella* spp., *Bruneica clypea, Eggerelloides scaber, Haplophragmoides wilbertii, Textularia* spp., *Trematophragmoides* spp., *Trochammina* spp., *Acupeina triperforata, Bigenerina* spp. and *Ammotium* spp.

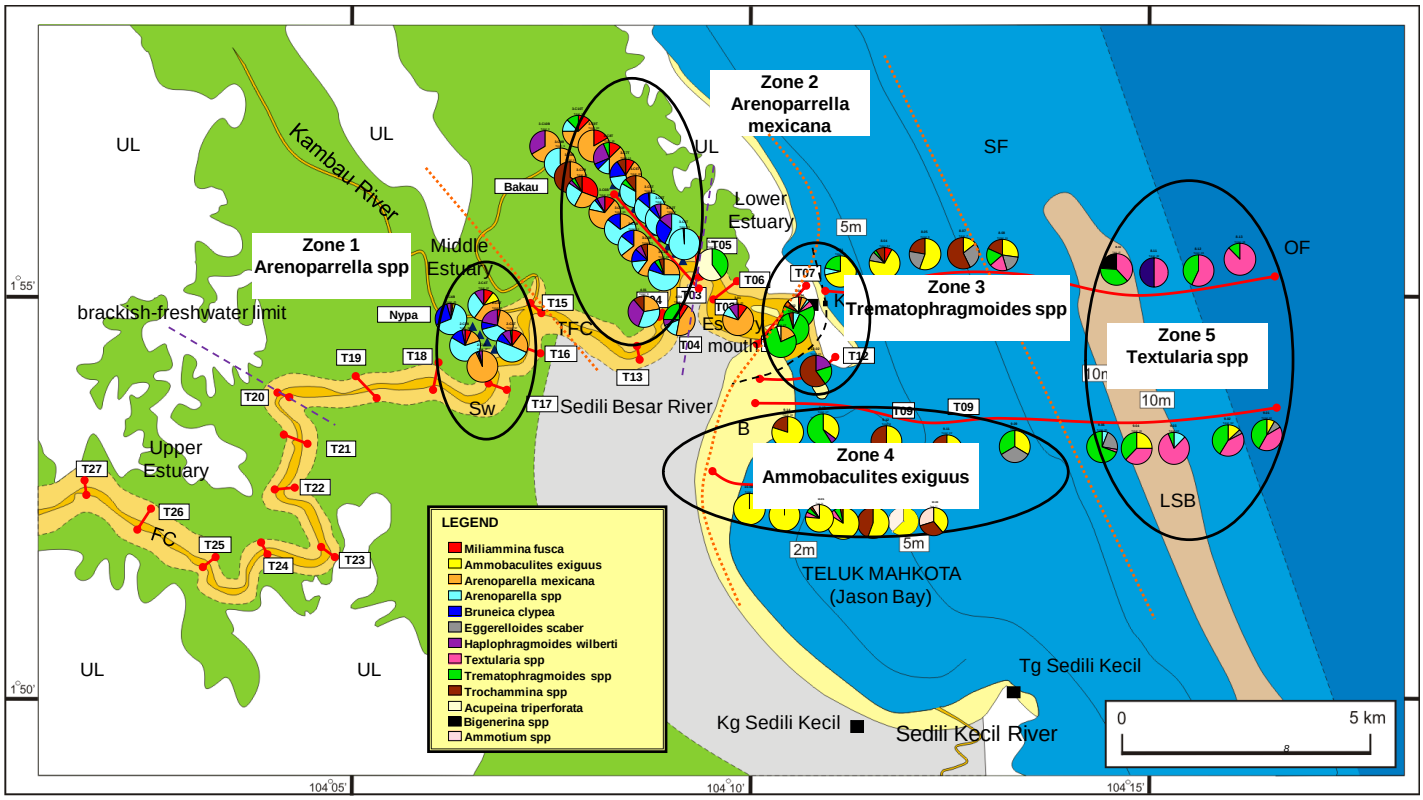


Figure 3. *Distribution of five biofacies based on agglutinated foraminifera assemblages.*

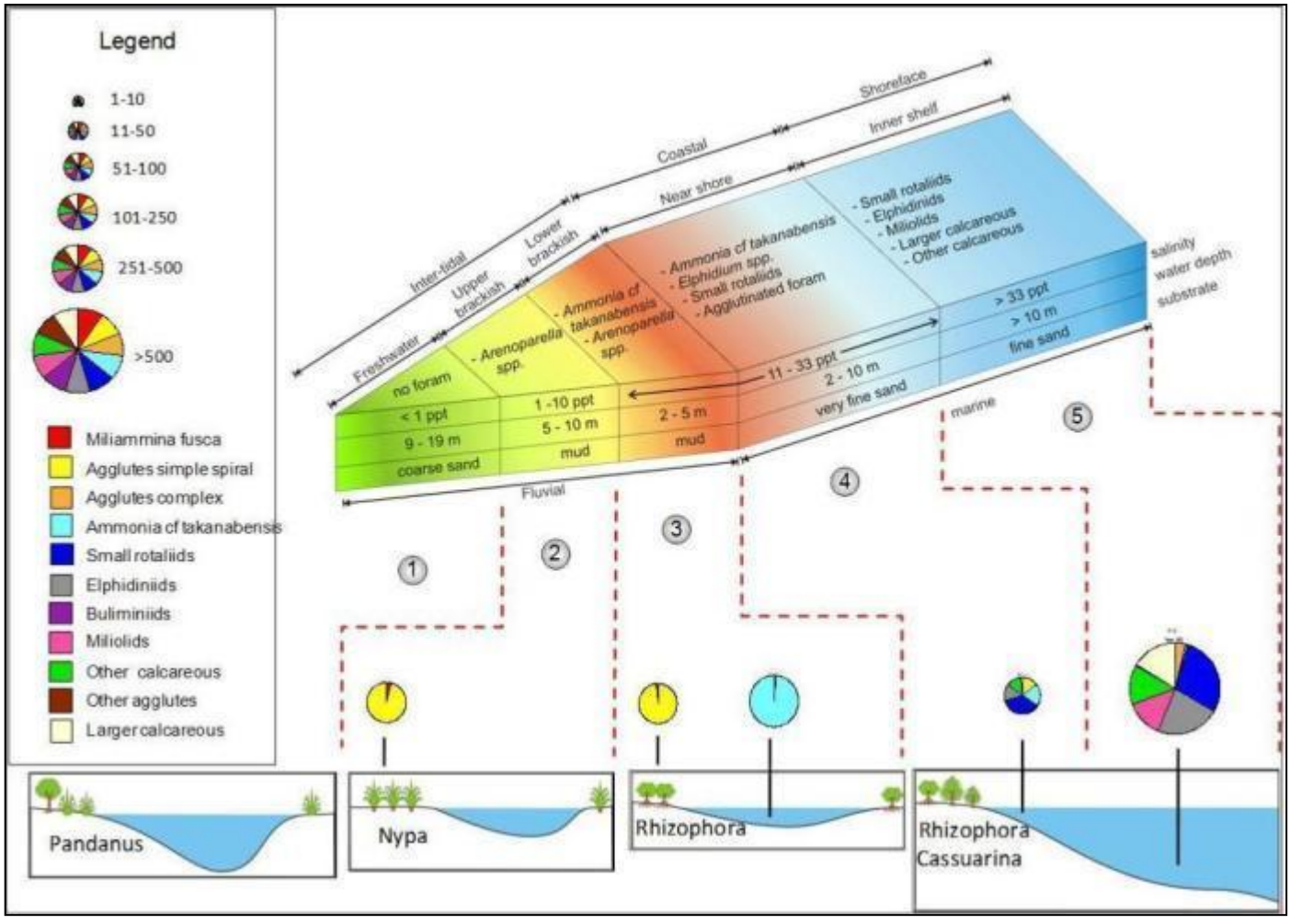


Figure 4. *Lateral distribution of biofacies zones based on salinity, water depth and grain size.*

Five main biofacies zones are distinguishable based on the general pattern of distribution of the agglutinated foraminiferal assemblages (Figure 3). The zones are:

Zone 1 – *Arenoparrella* spp. / Upper brackish intertidal

This zone is dominated by a mixture of *Arenoparrella mexicana* and other *Arenoparrella* species. Nypa vegetation is quite common along the river within this biofacies zone. Other assemblages recorded from this zone are *Haplophragmoides wilberti, Bruneica clypea* and *Miliammina* spp. *Arenoparrella* and *Miliammina* are two hyposaline species usually found in the tidal marshes, especially in the intertidal zone. *Miliammina* is usually euryhaline and can tolerate various ranges of salinity.

Zone 2 – *Arenoparrella mexicana* / Lower brackish intertidal

Major assemblages within this zone are *Arenoparrella mexicana*. This species is quite abundant in the Bakau area and close to the estuary. Other species found are *Arenoparrella mexicana, Haplophragmoides wilberti* and *Miliammina fusca. Miliammina fusca* can be found at the uppermost transect of the mangrove swamp. This is the most proximal zone reached by the tidal currents. The occurrence of this species within the lowest salinity range to almost 0.00 ppt confirms that it can tolerate a very low salinity and is strongly euryhaline.

Zone 3 – *Trematophragmoides* spp. / Estuary mouth

This zone is mainly centered near the river mouth and is dominated by *Trematophragmoides* spp. Other species recorded are *Acupeina triperforata* and *Arenoparrella mexicana. Trematophragmoides* is a brackish water species and differs from *Haplophragmoides* by having a small pore-like supplementary aperture. It was first reported by Bronnimann and Keij (1986) and was also found in

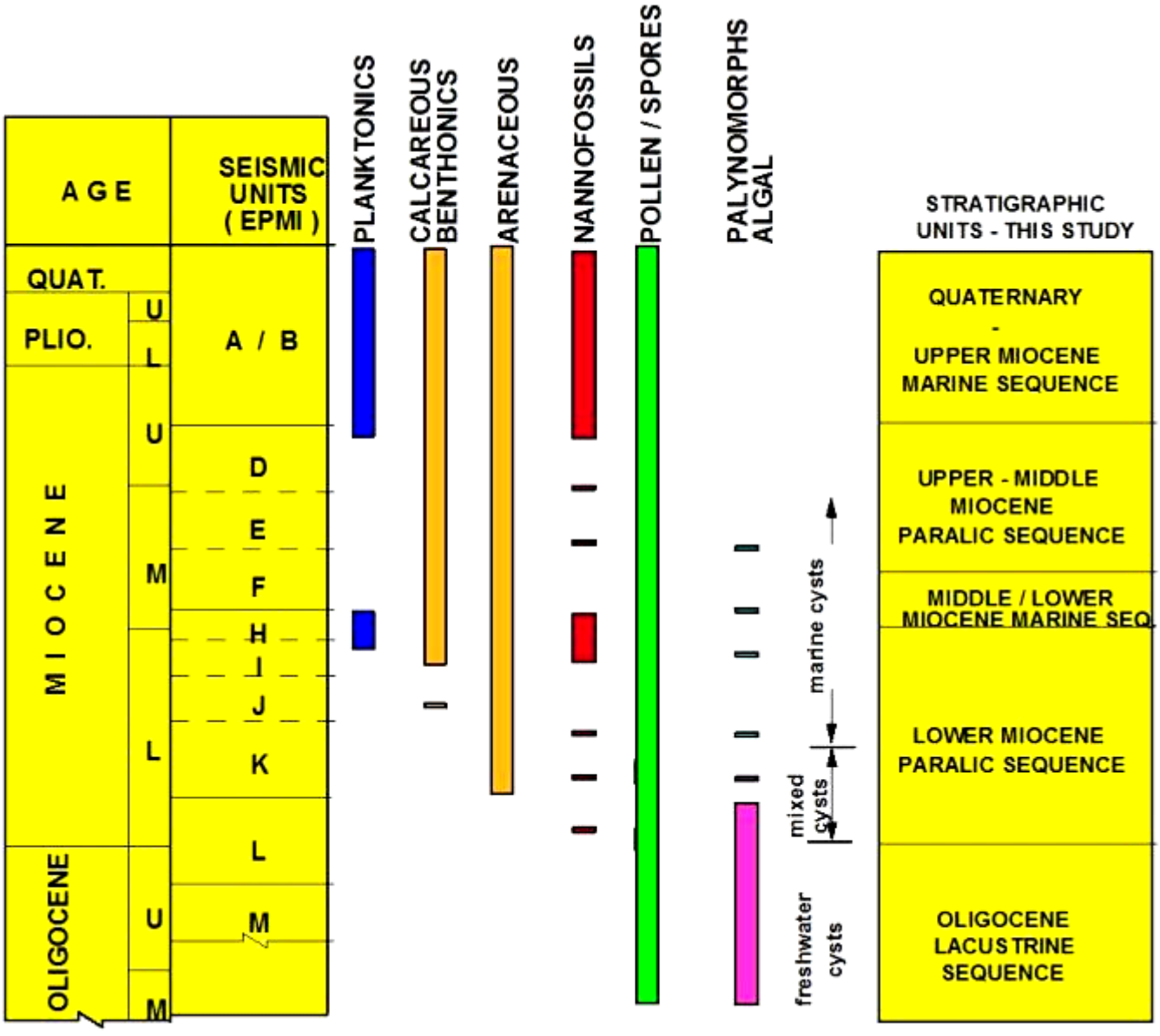


Figure 5. *Generalised microfossil distributions in the Malay Basin sedimentary sequence*

brackish water of Brunei.

Zone 4 – *Ammobaculites exiguus* / Beach and nearshore

Ammobaculites exiguus species is quite common in this zone. Its high abundance could be related to the sandy substrate as depicted from the very fine grain size data. Other species that are common within this zone are *Ammotium salsum*, *Trochammina* spp, *Eggerelloides scaber* and *Acupeina triperforata. Ammobaculites* and *Ammotium* are two hyposaline species that are usually found in tidal marshes, brackish lagoons and estuaries (Murray 2006).

Zone 5 – *Textularia* spp / Inner shelf

This zone is mainly dominated by *Textularia* spp. The mean grain size varies from fine to medium sand. This substrate could be suitable for the *Textularia* spp as the species is quite robust. Other assemblages recovered from this zone are *Trematophragmoides* spp, *Trochammina* spp. and *Bigenerina* spp. According to Murray (2006) *Textularia* is normally being found in the open marine facies and prefers sandy sediments. *Trochammina*, on the other hand can be found from brackish water zone to bathyal environments. Its type species and the association with other foraminiferal species characterize this environment of deposition.

The main salinity intervals and associated foraminifera assemblages are summarised in Figure 4.

DISCUSSION

A few observations were made based on parameters such as grain size and salinity that are associated with the agglutinated foraminifera distribution pattern.

Overall, the substrate of the Sedili Besar River and its adjacent offshore parts of Jason Bay are dominated by sandy lithologies, with limited muddy facies developed. Sandy facies encompasses most of nearshore facies, including beach, foreshore and the shoreface area (inner shelf). In general calcareous foraminifera are associated with shoreface sandy facies. The agglutinated forms that are associated with sandy sediments are of the *Textularia* group while *Ammobaculites exiguus* is often found in very fine sand or silt and clay facies.

Muddy facies are primarily in the fluvial- estuarine channel, estuary mouth and the brackish swamps. These facies are associated with agglutinated foraminifera of mainly *Arenoparrella* group and have a pronounced lower abundance and diversity of foraminifera. Other agglutinated foraminifera that are found associated with the muddy sediments are *Haplophragmoides* and *Ammotium spp.*.

The main objective of this study was to characterize the microfaunal distribution in different depositional facies in the Malay Basin. Figure 5 shows the general microfossil distributions in the Malay Basin sedimentary sequence. As depicted, the sediments in the Malay Basin are mainly deposited in paralic or marginal marine environment. Hence, the biofacies assemblages recorded from this study are used to interpret marginal marine environments of deposition, especially during the Middle Miocene.

CONCLUSIONS

Agglutinated foraminifera are one of the most widespread groups of benthic foraminifera as they are well represented from marginal marine to deep water bathyal regions. The use of their distribution trends in the marginal marine environments would infer a certain depth range and improve our current understanding on different depositional environments in the Malay Basin. Thus this biofacies model can be applied in the high resolution study at reservoir scale. In general, the distribution patterns of the agglutinated foraminiferal assemblages in this study are controlled by several factors, such as grain size variation, substrate content, salinity gradient and water depth. A general trend of the agglutinated foraminiferal distribution can be characterized based on all of the above observations.

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