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SUBSURFACE FORAMINIFERAL DISTRIBUTION AND TEST PRESERVATION IN SHORT CORE SAMPLES FROM THE STRAITS OF MALACCA

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Abstract: The Straits of Malacca-A shallow and hyposaline straits-Is one of the busiest shipping routes in the world and divides Sumatra and Peninsular Malaysia. This study assessed the subsurface distribution of benthic foraminifera, their preservation, and their relationship with the sediment characteristics of the Straits of Malacca. One short sediment core sample was collected from the southern part of the Straits of Malacca. The core was then divided into 10 subsamples at every 2 cm interval. The samples were used for foraminifera identification grain size and organic matter analysis. From the approximately 3000 benthic foraminiferal tests that were selected and identified, 17 species exhibited ≥ 2% occurrence in at least one subsample along the core. Out of the 17 species identified, 4 species [*Asterorotalia pulchella* (57%), *Cavarotalia annectens* (13%), *Discorbinella bertheloti* (7%), and *Pseudorotalia schoerteriana* (6%)] exhibited an average relative abundance of > 5% in all core intervals. Cluster analysis subdivided the core intervals into two groups of thanatofacies: T1 and T2. Both groups were dominated by *A. pulchella.* The PCA biplot indicated that T1, which represented the upper subsurface intervals, had relatively more agglutinated species than T2. No significant correlation was observed between test preservation and organic matter composition and sediment type. Additionally, despite being common in surface samples along the Straits of Malacca, species such as *Textularia* sp. were absent further down the core. This study indicated that in the subsurface sediment of the Strait of Malacca, calcareous hyaline species, especially those belonging to Rotaliida, were abundant and readily preserved compared to the agglutinated or calcareous porcelaneous groups. The loss of several agglutinated groups down the cores indicated that a more discreet approach to paleoenvironmental interpretation using benthic foraminifera assemblages should be adopted in this region to avoid bias in the interpretation. This is because different species may have different preservation potential.

Keywords: Benthic foraminifera, tropical waters, indicator, core sample, thanatofacies.

Introduction

The Straits of Malacca is known as one of the busiest straits globally and it connects the Indian Ocean with the South China Sea (Amiruddin *et al*., 2011). This sheltered and shallow strait hosts unique marine and marginal ecosystems along the 800 km long passage (Thia-Eng *et al*., 2000). With 26 major rivers draining into the straits, the depositional environment along the straits is mostly alluvial deposits with sandy patches in a few areas (Thia-Eng *et al*., 2000). The distribution of foraminifera from marginal environments along the Strait of Malacca has been reported by Husain *et al*. (2007) and Satyanarayana *et al*. (2014). Meanwhile, Minhat *et al*. (2014; 2020; 2021) have documented the distribution andecological preference of benthic foraminifera from the shallow coastal waters in the north of the Strait of Malacca. Benthic foraminifera have a unique characteristic, in that they are highly sensitive and can be easily affected by the environment found on the ocean floor (Alve & Goldstein, 2003). Foraminifera are important bioindicators for pollution studies and for the quality of the modern marine environment and has been commonly used in marine monitoring (Frontalini & Coccioni, 2011; Dimiza *et al*., 2016; A'ziz *et al*., 2021).

Additionally, foraminifera are important fossil records for paleoecological reconstruction, including sea level and water temperature changes in the past (Horton *et al*., 1999; Stienke *et al*., 2010; Walker *et al*., 2020). Despite the ability of the foraminiferal tests to be easily fossilized, they are still subjected to taphonomic loss and alteration within the sediment (Berkeley *et al*., 2007). Several studies on the subsurface foraminiferal distribution in tropical intertidal settings (e.g., Wang & Chappell, 2001; Woodroffe *et al*., 2005; Berkeley *et al*., 2009) have reported a taphonomic loss of foraminifera in warm mangrove ecosystems. In most intertidal environments (temperate or tropical), calcareous foraminifera species are often subjected to dissolution tests (Murray & Alve, 1999; Berkeley *et al*., 2009). Meanwhile, the loss of agglutinated species is also associated with test destruction owing to a weak cement and physical mechanism process (Berkeley *et al*., 2007; Berkeley *et al*., 2009).

Despite numerous studies on the taphonomic signature of foraminiferal tests in the intertidal environment, the nature of foraminiferal test preservation on the shelf sea remains poorly understood. Comparison between surface and subsurface foraminifera preservation is crucial because it can help enhance climatic prediction of the past through fossil records. In the Strait of Malacca, a study has reported the absence of agglutinated foraminifera species in core samples (Minhat *et al*., 2019) even though this group is common in contemporary samples (Minhat *et al.,* 2014; 2020; 2021). Comparing the contemporary samples with subsurface distribution can help provide an insight into foraminiferal preservation along the shallow straits and hopefully reduce bias in future past-climatic reconstruction. Therefore, this study aimed to report the distribution of subsurface benthic foraminifera and their preservation downcore in the Strait of Malacca.

Study Area

The Strait of Malacca connects the Andaman Sea to the West of Peninsular Malaysia and the South China Sea to its East (Figure 1). The strait is generally characterized by strong currents (Haditiar *et al*., 2019), muddy bottoms, and microtidal environments (Amiruddin *et al*., 2011). The topographic conditions and funnel shape of the strait cause the prevalence of strong tidal currents (Yamini *et al*., 2018; Haditiar *et al*., 2019). Most parts of the strait have a muddy bottom and this is attributed to sediment deposits from numerous river discharges (Thia-Eng *et al*., 2000; Amiruddin *et al*., 2011). The Strait of Malacca is influenced by the Asian monsoon system, where the seasonal changes of the Northeast Monsoon, Southwest Monsoon, and Inter-Monsoon are driven by wind changes (Tangang *et al*., 2012). The Northeast Monsoon, which occurs between December and February, brings heavy rain to the strait, and causes a decrease in the temperature and salinity (Chandran *et al*., 2018). The southwest monsoon occurs between June and August, a warm and dry season that increases the average sea surface temperature along the Strait of Malacca (Isa *et al*., 2020).

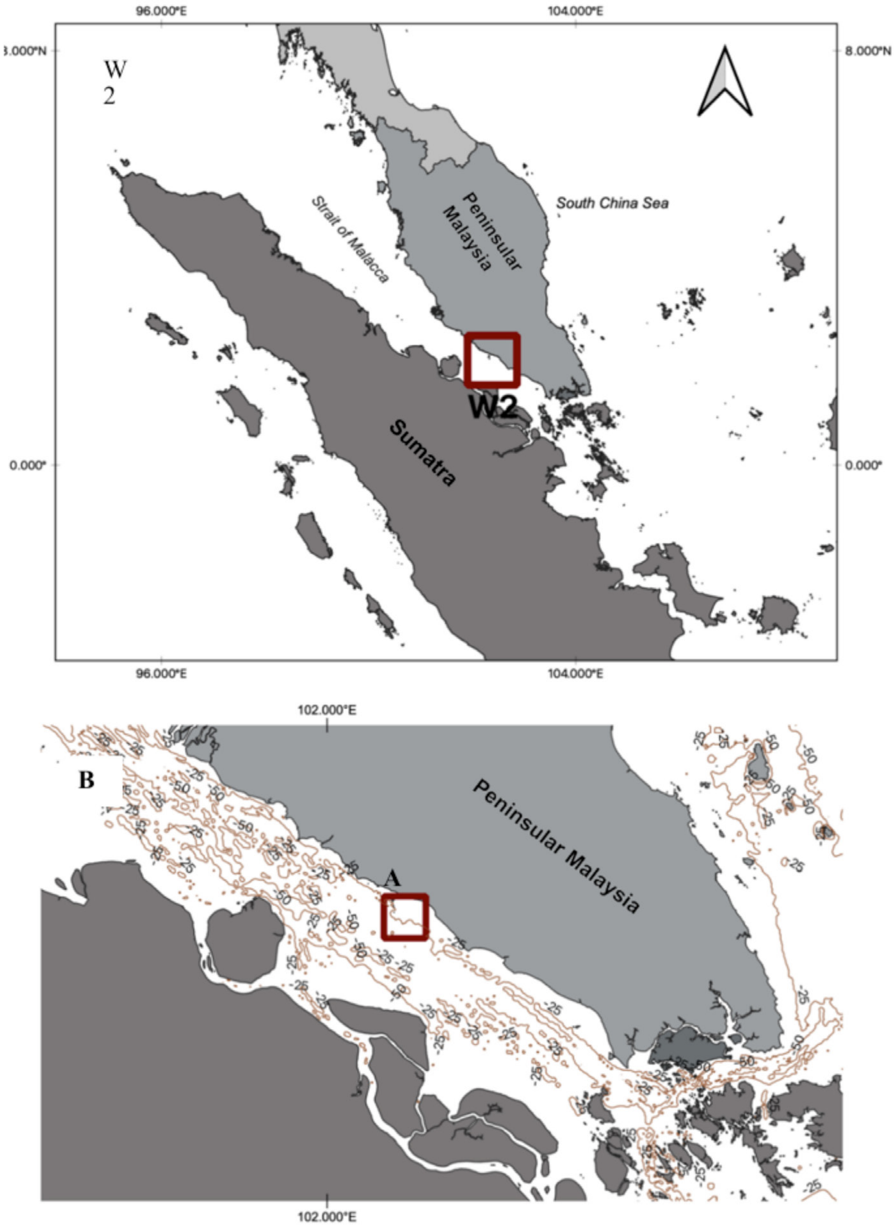

Figure 1: Map of the study area, (A) The location of Strait of Malacca and Peninsular Malaysia.
(B) The location of study area on the southern sector of Strait of Malacca with approximate water depth of the area

Materials and Methods

Sample Collection

This study was conducted at the Straits of Malacca on the West Coast of Peninsular Malaysia. Sediment samples were collected onboard the Universiti Malaysia Terengganu (UMT) RVDiscovery using a gravity corer during the UMT Scientific Expedition Voyage LIMA'19 (March 13–23, 2019). A core sediment sample was collected from the southern part of the Straits of Malacca at station W2 (longitude 102.38917 and latitude 2.02329) (Figure 1). After collection, the core sample was labeled and stored on the research vessel before being brought back to the laboratory.

Subsample Collection

In the laboratory, the length of the sediment core was recorded. Subsequently, the samples were separated and lithological logging was performed. The sediment was then sub-sampled at every 2 cm interval where each interval was divided into two parts, one part for foraminifera analysis and the other was used to analyze the grain size and organic matter composition. The total length of the core collected was 84 cm.

Sediment and Organic Matter Analysis

The sediment grain size was determined based on the dry sieving method put forward by Folk (1980). Before the analysis, all the sediments were oven-dried at 40°C for 24 hours. Subsequently, approximately 100 g of the dried sediment was sieved through a set of sieves (i.e., 500 µm, 250 µm, 150 µm, and 63 µm) for 15 minutes and the weights of the samples left in each sieve were recorded. The organic matter was determined using the loss-on-ignition method (Heiri *et al*., 2001). All samples were oven-dried 24 hours at 40°C, post which, 5 g of each sample was weighed and placed in crucibles that had been weighed beforehand. Subsequently, the sediments were combusted at 550°C for 4 hours. The samples were allowed to cool overnight to room temperature (28°C) before being reweighed to obtain the final weight. Using the final weight obtained, the loss on ignition (%) was calculated using the following formula:

Loss on ignition (%) = (final weight of sample after combustion (g)/(total weight of sample (g) x 100

Foraminiferal Analysis

All sediments containing the foraminifera samples were washed under running tap water using 63 µm sieves to separate the samples from the mud (Murray & Alve, 1999). Once the samples were cleaned, they were transferred to a weighing boat and oven-dried for 24 hours at 60°C. Temperature was maintained throughout the drying process to avoid damage to the foraminifera. The samples containing foraminifera were placed in a small zip-lock bag for sorting and picking process. Prior to the picking and sorting, 5 g of the dried sample was weighed and split into manageable aliquots. A total of 300 foraminifera individual organisms were randomly picked, sorted, and identified from each sample (Schönfeld *et al*., 2012).

Foraminiferal tests that were discolored, broken, or poorly preserved (Yordanova & Hohenegger, 2002) were excluded from the picking process. We noticed several fragmented *Ammobaculites* spp., most of them were left with the initial part of the test, during the picking process. However, to avoid bias, we selected only the intact and well-preserved tests of *Ammobaculites* spp. The selected specimens were sorted onto micropaleontological slides. The identification process was based on Loeblich and Tappan (1988, 1994) and regional taxonomic references (Szarek, 2001; Martin *et al*., 2018; Minhat *et al*., 2020, 2021).

Data Analysis

After the sorting process, the data of the collected foraminifera were analyzed using Paleontological Statistics (PAST) software to obtain the Shannon-Wiener index, dominance index, and evenness index. Next, using the

XLSTAT software, Q-mode hierarchical cluster analysis based on Ward's method was used to classify samples into relative groups (Culver *et al*., 2012). Multivariate Principal Component Analysis (PCA) was also performed using XLSTAT software to determine the influence of environmental variables, such as sediment characteristics, on the foraminiferal distribution down the core.

Results

Core Lithology

The water depth recorded at W2 was 28 meters with a bottom water temperature of 29.5°C and salinity of 32.5 PSU. The total length of the core was 84 cm, and the bottom of the core was composed of wood (Figure 2). Altogether, 10 sediment subsample intervals were obtained from the short core of the Straits of Malacca (Table 1). The topmost section of the core (0-10 cm) was discarded because of the high disturbance and sediment mixing caused by gravity core during sample collection (Figure 2). The sediment grain size analysis showed that the core was sandy (96-98%) throughout, with < 5% mud composition. Meanwhile, the organic matter composition range was 3-6%. No significant trends were observed in the grain size or organic matter composition along the core intervals.

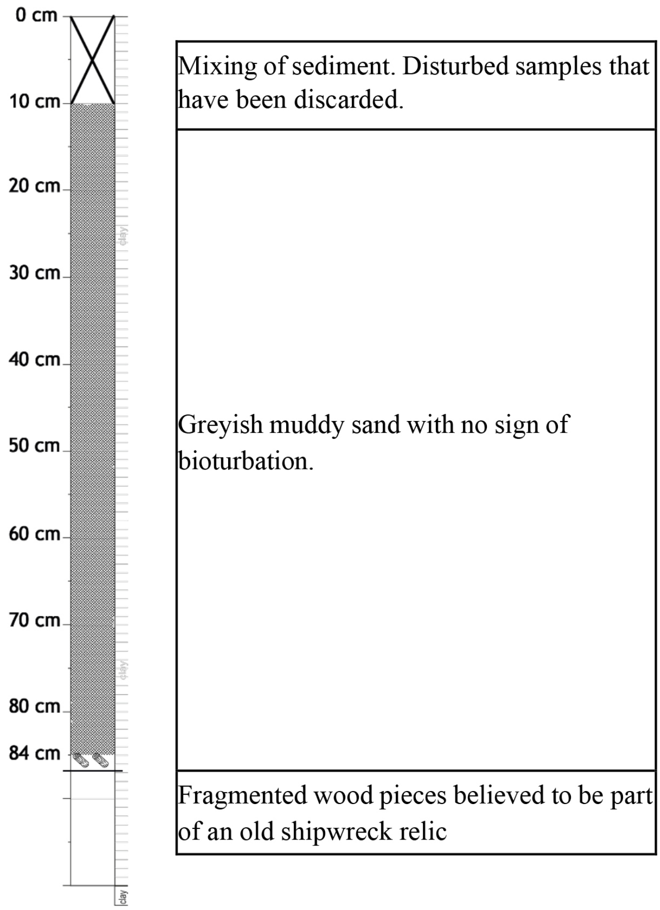

Figure 2: Sediment core logs for samples collected from Malacca Straits. The total length of the core was 84 cm and the bottom of the core was filled with wood

Table 1: The sediment grain size and organic matter composition for each subsamples interval of a short sediment core from Malacca Straits

Percentages of Parameter (%)					
Core Depth Subsample (cm)	Grain Size				Organic Matter
	Very Coarse Sand	Coarse Sand	Sand	Mud	
10 – 12 cm	30	21	46	2	4
12 – 14 cm	41	23	32	3	6
14 – 16 cm	45	19	33	2	3
16 – 18 cm	39	20	37	3	3
18 – 20 cm	32	23	40	4	4
20 – 22 cm	35	21	40	4	5
22 – 24 cm	46	18	28	3	5
24 – 26 cm	40	22	45	2	5
26 – 28 cm	47	23	28	2	5
28 – 30 cm	44	24	29	2	4

Foraminifera Distribution

A total of 17 species of benthic foraminifera were identified from 10 core subsamples (10-30 cm with 2 cm intervals) collected from the southern part of the Straits of Malacca. Calcareous benthic foraminifera group dominated the assemblage along the short core, with a relative abundance range of 91% to 99% (Table 2). A slight increase in the relative abundance of calcareous taxa (91%) at 10 cm to (99%) at 20 cm core intervals was observed in this short core from the Straits of Malacca. Meanwhile, the agglutinated group, which represented 3% to 10% of the foraminifera assemblages, showed the opposite trend (Table 2). One particular species of the agglutinated group, *Textularia foliacea* represent 4% relative abundance at the 10-12 cm intervals but their test reduce in number or absent from the bottom core intervals. Out of the 17 species identified, only 4 species, *Asterorotalia pulchella* (57%), *Cavarotalia annectens* (13%), *Discorbinella bertheloti* (7%), and *Pseudorotalia schoerteriana* (6%), exhibited an average relative abundance of > 5% from all the core intervals. The species *A. pulchella* represented > 50% relative abundance of the foraminifera assemblages in all the core intervals except in the 28-30 cm interval. In addition, seven foraminifera species, *Bigenerina nodosaria, Ammonia tepida, A. pulchella, C. annectens, Pseudorotalia indopacifica, P. schoerteriana,* and *D. bertheloti*, were found in all the core intervals. The diversity indices of benthic foraminifera ranged between H' = 1.22–1.87 with the bottom intervals showing an increased diversity trend (Table 2).

Table 2: The relative abundance of agglutinated and calcareous foraminifera test groups and their diversity indices along the short core collected from Straits of Malacca

Sample Depth (cm)	Type of Test		Diversity Indices			
	Agglutinated (%)	**Calcareous (%)**	**No. of Species (S)**	**Shannon-Wiener (H')**	**Evenness (J')**	**Fisher's Alpha (α)**
10 – 12 cm	10	92	12	1.22	0.28	2.51
12 – 14 cm	9	94	15	1.58	0.32	3.36
14 – 16 cm	3	98	12	1.23	0.29	2.50
16 – 18 cm	4	98	14	1.49	0.32	3.04
18 – 20 cm	4	99	12	1.63	0.43	2.51
20 – 22 cm	3	99	14	1.41	0.29	3.05
22 – 24 cm	4	99	14	1.57	0.34	3.04
24 – 26 cm	5	97	14	1.65	0.37	3.03
26 – 28 cm	7	96	12	1.70	0.45	2.50
28 – 30 cm	9	94	15	1.87	0.43	3.31

Cluster Analysis and Thanatofacies

Cluster analysis subdivided the core intervals into two groups based on foraminiferal assemblage dissimilarities (Figure 3). The first thanatofacies (T1) consisted three core intervals (10-12 cm, 14-16 cm, and 16-18 cm). The second thanatofacies (T2) was made up of seven core intervals (12-14 cm and 18-30 cm), with most intervals deposited at the bottom of the core. T1 exhibited a relatively higher dominance of *A. pulchella* (≥ 62%) with less of *D. bertheloti* (< 6%) (Table 3). Additionally, T1 intervals reveal the presence of sandy substrates (59% sand) and low organic matter content (3% OM). Many of the preserved test in T1. Meanwhile, the average relative abundances of *Ammonia tepida* (6%), *C. annectens* (14%), and *D. bertheloti* (9%) increased in T2. The substrates within T2 core intervals are also sandy (55% sand) with relatively higher organic matter composition (5%). The PCA revealed a small variation between the two axes with a cumulative variability of 47.93% (Figure 4). The intervals that belonged to T2 are distributed to the left side of the diagram and T1 to the right side. Species such as *Textularia foliacea* and *A. pulchella* were correlated with an increase in sand % within intervals of 10-12 cm and 14-16 cm. Species such as *D. bertheloti, Pseudorotalia indopacifica* and *Bolivina sabahensis* were more abundant in substrates with a higher mud composition. Many rotaliids were shown to have correlations with T2 thanatofacies regardless of the sediment grain size characteristic. Disappearance of agglutinated tests were not explained in the results but were included in discussion. An elaboration on the loss of agglutinated tests must be included in the results as well.

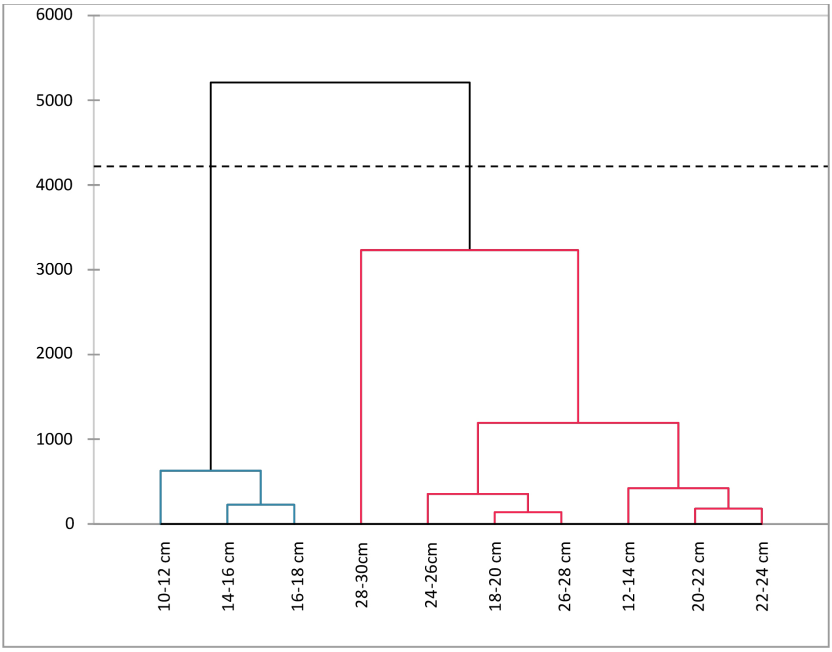

Figure 3: The dendogram based on the hierarchical cluster analysis has defined the core intervals into two thanatofacies (i.e., T1 & T2)

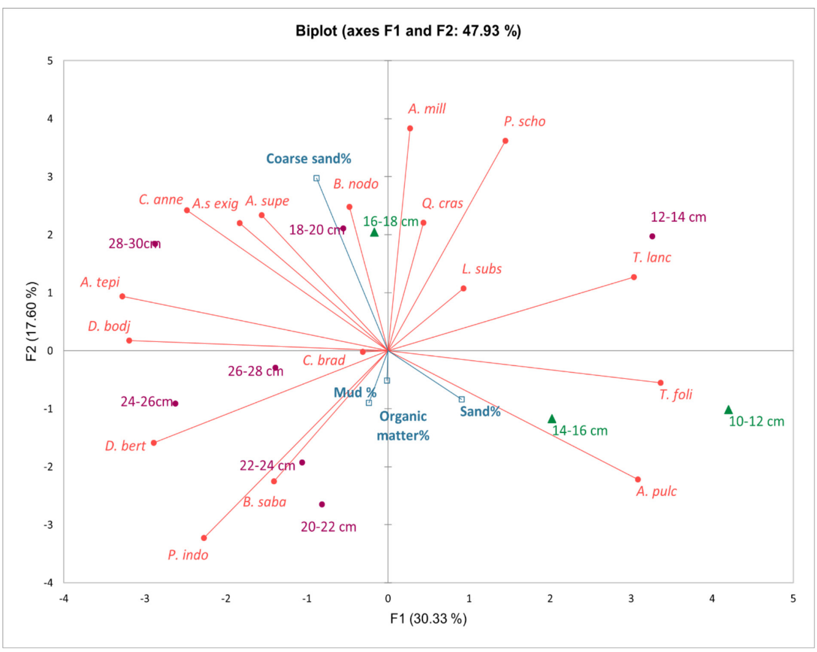

Figure 4: The Principle Component Analysis (PCA) biplot is based on the species and sediment grain size and organic matter relationship within the core sample from the Strait of Malacca. The total variances of both axes were 47.93%

Table 3: The range of foraminifera species distribution in two thanatofacies groups (T1 & T2) based on the cluster analysis performed

T1 Species	Range of Relative Abundance	T2 Species	Range of Relative Abundance
Asterorotalia pulchella	62-71%	*Asterorotalia pulchella*	38-62%
Cavarotalia annectens	5-12%	*Cavarotalia annectens*	10-24%
Pseudorotalia schoerteriana	6-8%	*Discorbinella bertheloti*	6-11%
Discorbinella bertheloti	3-5%	*Ammonia tepida*	3-10%
Textularia fo-liacea	0-4%	*Pseudorotalia schoerteriana*	2-8%
		Bigenerina nodosaria	0.3-5%

Discussion

Environmental Condition and Species Distributions

The sediment grain size composition along the short core samples had a relatively high coarse-sand composition suggesting that the study area was in a high-energy environment. The sediment core which was collected from the narrowest part of the strait, could have been under the influence of a high flowing current moving northwest with a magnitude of 10-70 cm/s (Rizal *et al*., 2010). Additionally, the organic matter composition was relatively low within the sediment core intervals than those reported in the north (Minhat *et al.,* 2014; 2021). We believe that the high current may have pushed much of the sediment or organic material from the nearby river northward reducing both the deposition of mud and organic matter in the sediment core.

The vertical distribution of foraminifera along the short core samples was dominated by rotaliids, a common group reported from intertidal (Malek *et al*., 2021) and subtidal environments (Minhat *et al.,* 2014; 2021) along the Straits of Malacca. The dominance of *A. pulchella* in all core intervals is consistent with the foraminifera distribution observed along a longer core from the northern part of the Straits of Malacca (Minhat *et al*., 2019). Other rotaliids, such as *D. bertheloti*, *P. indopacifica, C. annectens,* and *B. sabahensis*, were also common in the core intervals. *C. annectens* (5-24%) was identified from all core intervals, but their prevalence was relatively less in the surface samples (Minhat *et al*., 2021) and were absent in the older sediment core samples from north of the Straits of Malacca (Minhat *et al*., 2019). Despite this, *C. annectens* is very common in the South China Sea, where sandy substrates dominate the inner shelf area (Azmi *et al*., 2020). Meanwhile, the other foraminifera groups, such as the miliolids and agglutinated taxa, were less common or even absent in the core samples. The agglutinated group did not exceed 10% relative abundance of the total assemblages, although the group was reported to reach > 40% in relative abundance in selected areas of the Straits of Malacca (Minhat *et al*., 2021).

This result is consistent with data from the long sediment core off Kedah (Minhat *et al*., 2019), which showed the disappearance of agglutinated taxa along the core. We believe that the combination of the type of species and taphonomic process within the area causes most agglutinated taxa to disaggregate in the sediment after they die (De Rijk & Troelstra, 1999; Murray & Alve, 1999). Meanwhile, the absence or extremely low abundance of the miliolids observed along the core was related to the naturally low abundance of the porcelaneous group from subtidal (< 2%) (Minhat *et al.,* 2020; 2021) and intertidal (~4%) (Malek *et al*., 2021) environments. Others have suggested that miliolids are less likely to be preserved compared to rotaliids (Corlis & Honjo, 1981). We believe that the low carbonate concentrations (< 2%) (Nurulnadia *et al*., 2023) together with hyposaline conditions of coastal water along the Straits of Malacca might have restricted the distribution of the miliolid group.

Thanatofacies and Foraminifera Preservation

Numerous studies have attempted to understand the preservation of intertidal foraminifera in both temperate (Murray & Alve, 1999; 2011) and tropical regions (Berkeley *et al*., 2008, Perry *et al*., 2008). The motivation for taphonomic study of the intertidal environment comes from the application of these assemblages in past sea-level reconstructions (Horton *et al*., 1999; Edwards & Hortons, 2006). This is because the intertidal foraminifera, especially those from salt marsh environments, have been recognized to occupy a specific vertical range with respect to the tidal range (Scott & Medioli, 1978; Horton *et al*., 1999). Hence, to reduce bias in the interpretation of past environments, many studies have tried to compare living and dead assemblages, different subsurface depth assemblages, and time-average preservation.

However, the changes in foraminiferal thanatofacies and their preservation in subsurface sediments from shallow tropical waters remain poorly understood. Unlike the intertidal environment, the subtidal foraminifera distributions are not subjected to high bioturbation activities, which are usually the main contributors to the foraminiferal test dissolution process (Berkeley *et al*., 2009). Based on the foraminiferal assemblages in this study, two thanatofacies (T1 and T2) were identified, both of which were dominated by the calcareous taxa, *A. pulchella*, the common taxa found within the Straits of Malacca (Minhat *et al*., 2021) and the Myanmar shelf (Panchang & Nigam, 2012). The extreme dominance of *A. pulchella* has been associated with the low salinity and fine-grained sediment found in the Myanmar shelf (Panchang & Nigarm, 2012) and the Bay of Bengal (Rao *et al*., 2013). Despite the coarser sediment in our core samples, *A. pulchella* was still the dominant taxon. It is possible that *A. pulchella* is endemic to the Sunda Shelf and Andaman Basin, explaining their high occurrence in the core and surface samples (Minhat *et al*., 2021). Although there were few differences in terms of sediment grain size and organic matter deposition between the two thanatofacies, we observed a relatively higher prevalence of *C. annectens* and *Discorbinella* spp. in T2. Both species have been reported to be common in tropical waters, with water depths ranging between 15 meters and 30 meters (Murray, 1991; Minhat *et al*., 2016).

Additionally, the agglutinated assemblages represented 3-10% of the total assemblages at 10-16 cm, the upper part of the core intervals. Overall, the *Textularia* spp. (average 4%) was abundant in the uppermost core intervals, which formed a major portion of thanatofacies T1; however, they were absent at the bottom of the core (T2). Other agglutinated species, such as *B. nodosaria,* exhibited the highest relative abundance (5%) at the bottom core intervals (28-30 cm). Meanwhile, despite being a common species (7-20%) in the < 20 m water depth along the Straits of Malacca, *Ammobaculites exiguus* was rare (< 2%) in the sub-surface samples. Additionally, many *A. exiguus* tests were severely damaged during the selection process. A comparison of the type of cement used for test construction in all the agglutinated species revealed that species such as *Textularia* spp., *B. nodosaria,* and *Cylindroclavulina bradyi* contained calcitic cement (Bender & Kaminski, 1995). The *A. exiguus* tests use organic cement for test construction (Bender & Kaminski, 1995).

We believe the organic cement would degrade upon the death of *A. exiguus*, thereby greatly reducing the number of this species in sub-surface fossil assemblages. In addition to weak cement, the prevalence of high flowing current within the study area may further contributed to the physical damage and fragmentation of the *A. exiguus* test (Berkeley *et al*., 2009). Other agglutinated taxa, such as *Textularia* spp., may also experience some potential losses compared to contemporary assemblages. Minhat *et al*. (2021) noticed that the *Textularia* spp. were relatively more abundant (13-24%) in northern sector of Straits of Malacca (> 50 m water depths). However, this study revealed that *Textularia* spp. was mostly absent or only made up 1% of the total assemblage, except in the uppermost core intervals, where they exhibited 4% of relative abundance. The test preservation of benthic foraminifera is affected by extrinsic and intrinsic factors (Berkeley *et al*., 2007). Extrinsic factors include temperature, sedimentation rate, and sediment oxygenation, which can affect organic matter degradation and the preservation potential of foraminiferal tests (Debeney *et al*., 2004; Berkeley *et al*., 2007). Intrinsic factors include the composition and structure of the foraminiferal tests which explain the selective preservation among species (Debenay *et al*., 2004; Hayward *et al*., 2004).

To understand how sediment type or organic matter can influence the preservation of the foraminifera test, we performed PCA. The results indicated that there is a small variation between the sediment and foraminifera distribution along the core. The test preservation of agglutinated and calcareous foraminifera species from the Malacca Straits does not show a significant correlation with organic matter. However, it is obvious that the uppermost core intervals have relatively higher occurrence of agglutinated test, especially the *Textularia* spp. Both *Textularia lancea* and *Textularia foliacea* still show good preservation numbers at the uppermost core intervals (10-18 cm) before becoming absent at the bottom of the core. One possible reason is that the agglutinated tests may have low preservation potential in tropical settings (Wang & Chappell, 2001; Woodroffe *et al*., 2005), which can result in their dissolution or destruction over time (Woodroffe *et al*., 2005; Berkeley *et al*., 2007).

Conclusion

The vertical distribution of foraminifera along the short core samples were dominated by rotaliids, such as *A. pulchella* (38-71%) and *C. annectens* (5-24%). Miliolids were rare or absent in the core samples. Meanwhile, the selected species from the agglutinated groups (*A. exiguus* and *Textularia* spp.) disappeared further down the core. In the subtidal environment along the Straits of Malacca, the stronger tests of the rotaliids were well preserved in the sediments. However, the agglutinated group exhibited a more complex test preservation pattern. The broken tests of *A. exiguus* may imply that species that use organic cement for test construction are less likely to be preserved. Overall, rotaliids with calcareous hyaline test walls exhibited a higher preservation potential than the agglutinated species in the shallow tropical waters of the Straits of Malacca. The loss of several agglutinated groups down the cores indicated that a more discreet approach to paleoenvironmental interpretation using benthic foraminifera assemblages should be adopted in this region to avoid bias in the interpretation.

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