Agglutinated Foraminifera from Miocene sediments of northwest Borneo

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ABSTRACT

Numerous (almost 250) outcrop and subsurface samples of Miocene-aged sediments from northwest Borneo (chiefly Brunei and the Malaysian territories of Sarawak and Labuan Island) have been studied with regard to their foraminiferal assemblages. Samples display variable recovery and are frequently dominated by abundant calcareous benthonic taxa, however some samples are often reasonably rich in agglutinating foraminifera, occasionally to the exclusion of other types. An iterative process of integrating the palynological, sedimentological and foraminiferal characteristics of each sample has permitted the recognition of assemblages of agglutinated foraminifera characteristic of various depositional environments. The process has also been aided by reference to studies of Recent foraminiferal distribution in similar depositional settings.

Palaeoenvironments so recognised include distal delta front, outer shelf/slope, middle shelf, inner shelf, estuary mouth (inner and outer), lagoon, tidal channel/tidal flat, upper estuarine/fluvial and mangrove-dominant/back-mangrove swamp. Taxa from the following genera were tentatively recognised: *Ammodiscus, Glomospira, Glomospirella?, Miliammina, Haplophragmoides, Trematophragmoides, Ammobaculites, Recurvoides, Cyclammina, Camurammina?, Trochammina, Arenobulimina?, Eggerella?, Karreriella, Martinotiella? and Textularia.* In addition some important forms not yet comparable with previously described taxa have also been recorded using informal nomenclature (i.e., *"Pseudoepistomina"*, *"Textukurnubia"*). At species level, the forms recognised mostly appear distinct from previously described taxa and are placed in open nomenclature pending further work. In total 34 individual taxa are recorded here. This study therefore represents the first practical attempt to utilise agglutinated foraminifera from northwest Borneo, previous studies having been limited by a tendency to name specimens in only one or two loose generic categories.

In northwest Borneo, interpretation of agglutinated foraminifera dominated assemblages has previously been problematic. Our precise palaeoenvironmental assessment of agglutinated foraminifera associations helps constrain the depositional modelling (and hence reservoir and sequence stratigraphic modelling) of sands associated with agglutinated foraminifera-rich shales and mudstones.

INTRODUCTION

Although agglutinated foraminifera are often very common in outcrop and subsurface samples of Miocene sediments from northwest Borneo, they remain poorly described and are hence of limited biostratigraphic and palaeoenvironmental utility. Specimens recovered are typically "lumped" into a few notional genera (i.e., *"Haplophragmoides"* spp., *"Trochammina"* spp.). It is our contention that if an attempt is made to speciate the agglutinated foraminifera from these sediments they will have value in making precise palaeoenvironmental determinations and also assist in stratigraphic and evolutionary studies. Herein we therefore present a first attempt to describe these agglutinated foraminifera in more detail and note their palaeoenvironmental application. By doing so, we hope to encourage the more rigorous use of agglutinating foraminifera in the study area and perhaps in other areas of the world and stratigraphic column where they may have also been under-utilised. Given that the stratigraphic interval under study in northwest Borneo is of great economic importance because it contains a series of hydrocarbon reservoirs, this work has both practical and academic value. This paper is an accompaniment to that of Simmons *et al.* (1999), which describes the applications in more detail.

The northwest Borneo area, particularly Brunei (i.e., the Baram Delta - see Figure 1), has an extensive history of oil and gas development dating back to the beginning of this century. The involvement of the Shell International oil company in the region has

In: Hart, M.B., Kaminski, M.A., & Smart, C.W. (eds) 2000. Proceedings of the Fifth International Workshop on Agglutinated Foraminifera. *Grzybowski Foundation Special Publication*, 7, 41–58.

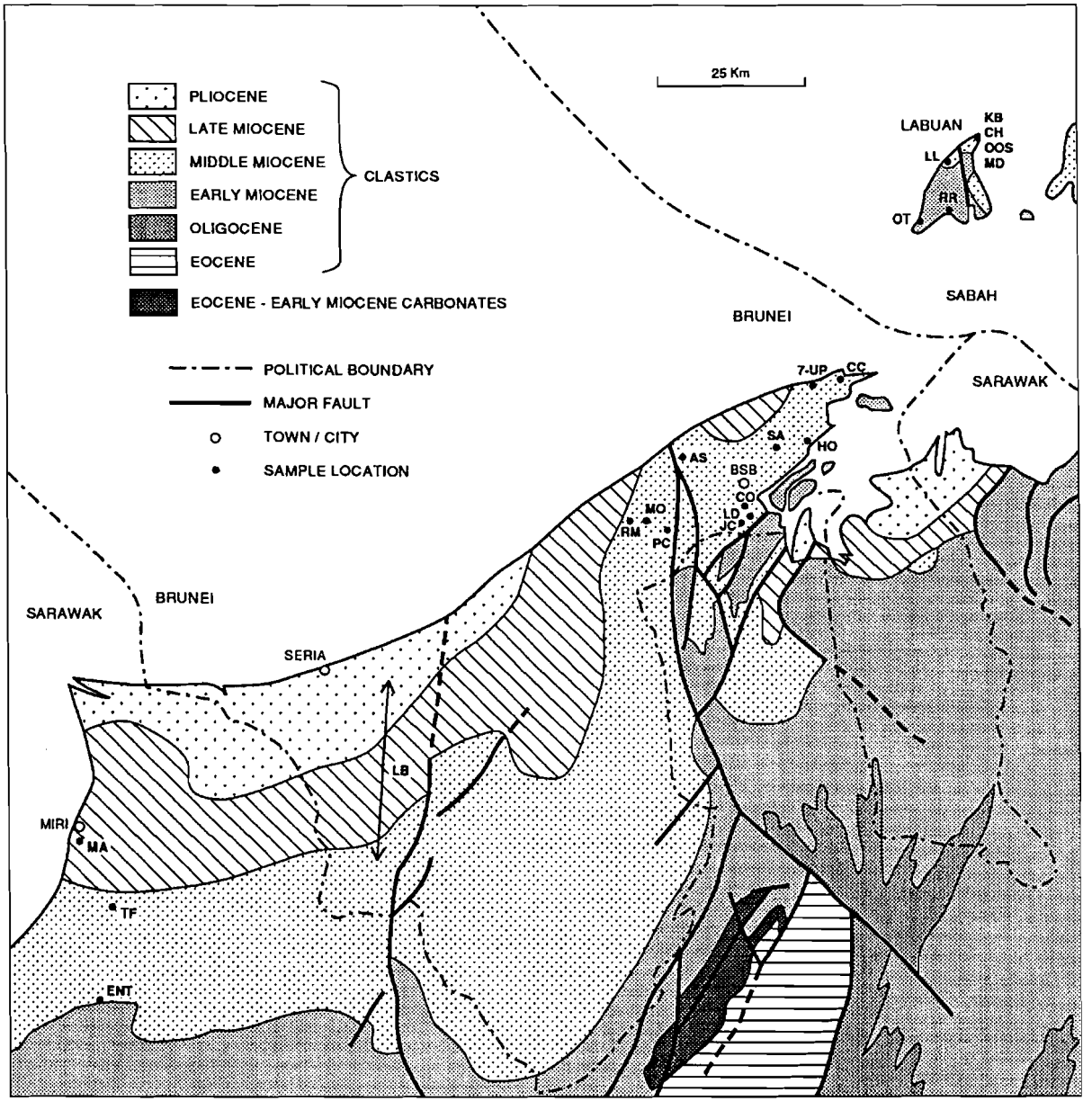

Figure 1. Simplified geological map of northwest Borneo showing position of outcrop localities studied.

been extensive, beginning in 1910 and subsequently all major hydrocarbon successes in Brunei have been achieved by Brunei Shell Petroleum (BSP).

Many of the offshore subsurface reservoirs are developed in topset clastic units of various shallow marine, deltaic and nearshore environments. The seismic expression of these reservoirs is unclear and the patterns obtained are characterised as "shingle". The reservoirs are typically composed of stacked sand units that, although relatively easy to discern using wireline log traces, are often difficult to assign to a specific depositional setting. This has important reservoir engineering implications, since the production strategies for reservoirs developed in, for example, channel sands and shoreface sands will be different. If the mudstone units bounding the sand bodies can be palaeoenvironmentally determined, then the nature of sand deposition can be established.

Similarly, the nature of sand deposition has important sequence stratigraphic implications. Sand bodies may be associated with highstand progradational deposits (shallow water) or with lowstand bypass into submarine fans (deep water). Understanding the precise depositional environment will often help unravel the sequence stratigraphic setting of sand bodies and hence assist in assessing their size, geometry and continuity and their prediction.

In order to understand the relationship between palaeoenvironment and biofacies, 204 samples from some 26 onshore localities, analogous to the subsurface sections, were examined using an integrated approach combining sedimentology/ facies analysis,

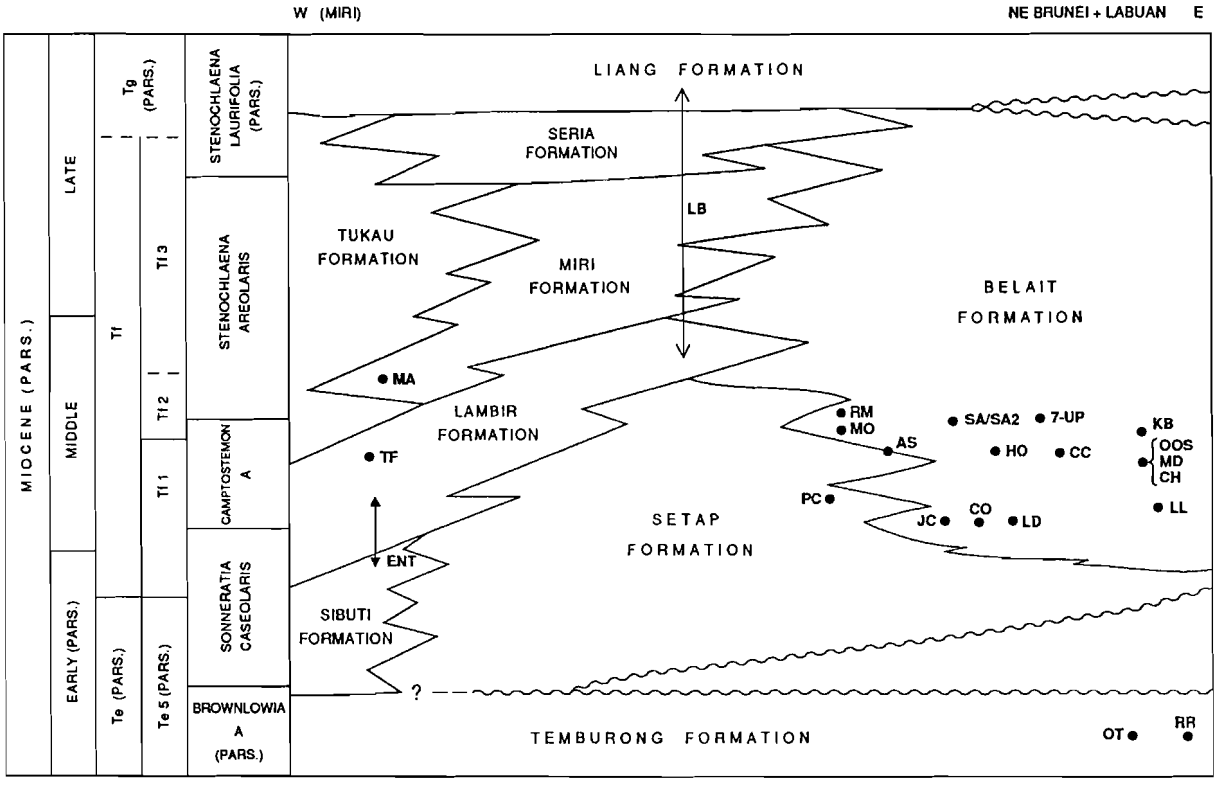

Figure 2. Schematic stratigraphic cross-section of the study area from Miri (Sarawak) to Labuan (Sabah) showing the stratigraphic position of outcrop localities studied.

micropalaeontology and palynology. Figure 1 shows the location of the sampled sections and Figure 2 summarises their stratigraphic position. Stratigraphic position is based on a combination of palynology, foraminiferal micropalaeontology and regional evidence. This is more fully discussed by Simmons *et al.* (1999), but it is worth noting that all the material described herein is of late Early Miocene to Late Miocene age. Stratigraphic precision within the sediments of this age in northwest Borneo is restrained by a lack of taxa of limited stratigraphic range, but the combined use of palynology and micropalaeontology enables the age assignments for samples locations illustrated in Figure 2.

In addition to the above samples, 38 ditch cuttings and sidewall core samples from Middle – Upper Miocene intervals from an offshore well (not named here for confidentiality reasons) drilled by Brunei Shell Petroleum were analysed for micropalaeontology. The majority of onshore sections are mainly representative of deposition under water depths no greater than inner shelf, whereas the offshore well samples represent somewhat deeper (outer shelf - slope) conditions.

All of the above samples, with the exception of the offshore well, were analysed for palynology by Patrice Brenac (see Simmons *et al.* 1999 for a more complete discussion of this palynological data), although this paper deals solely with the agglutinated foraminifera recovered from the material. It became apparent, however, that palynofloral assemblages from the majority of the sections studied showed a significant amount of material transported downslope from hinterland environments (see also Morley, 1991). Thus, environmental determinations based on the palynofloras were often shown to be from significantly shallower regimes than those suggested by micropalaeontology, ichnofacies, and sedimentology.

PREVIOUS WORK

As stated above, previous work on Miocene agglutinated foraminifera from northwest Borneo has been limited. James (1984) and Sandal (1996) have mentioned the occurrences of such forms from Brunei in a very general sense. Whittaker & Hodgkinson (1979) have studied coeval sediments close by from the eastern Sabah area of Malaysia although only a very minor component of the described microfaunas was agglutinated. There have also been some studies of Recent assemblages from the area (e.g., Dhillon, 1968; Brönnimann *et al.*, 1983; and Brönnimann & Keij, 1986) and some taxa recorded here are attributable to these previously described Recent taxa, thus extending their stratigraphic range.

In addition, other studies from the region (mainly the Indonesian Archipelago) record agglutinated foraminifera, although as a minor component of the assemblages: from the surrounding areas of the Banda Sea (Van Marle, 1991); from Irian Jaya and

Papua New Guinea (Belford, 1966); from Borneo, Sumatra and Java (LeRoy 1941a,b,c, 1944a,b); from Central Java (Boomgaart, 1949) and from Eastern Java (Saint-Marc & Suminta, 1979).

Depositional settings from coeval sediments to the north and east of the study area (i.e., northwest Sabah offshore) have been described by Rice-Oxley (1991) which are based, in part, on foraminiferal studies. However, no specific details of the foraminiferal assemblages were provided.

DEPOSITIONAL SETTING

In simple terms, during the Oligocene to Early Miocene, the northwest Borneo area represented a region of marine (deep shelf - bathyal) clay deposition (Setap Formation) which was subsequently covered by "deltaic" and associated deposits from two distinct sources during the Early to Late Miocene period (James, 1984; Sandal, 1996; Prosser & Carter, 1997). Although often referred to as deltas, the Miocene sediments of northwest Borneo actually comprise prograding clastic shelves of some complexity and of which deltas form only a part (Simmons *et al.* 1999; Lambiase *et al.* in press). The Brunei (or "Champion") "Delta" (Belait Formation) prograded north and somewhat westwards into the basin from the Brunei peninsula area. The Baram "Delta" (Lambir, Miri and Seria Formations) prograded northwards into the basin from the Baram/Belait area of southwest Brunei and "northern" Sarawak (Figure 2). These sequences consist of large thicknesses of interlayered non-uniform sands and shales deposited at rates in excess of 0.5 km/Ma, (Sandal, 1996).

In terms of a general depositional model for the studied sediments, analogy with parts of the coastline of modern-day northwest Borneo (e.g., Brunei Bay) is likely, as is analogy with the sub-Recent Baram Delta, which was flooded c. 5400 years BP (Caline & Huong, 1992). A coastline with variable wave, tidal and fluvial dominance (as in modern Brunei Bay) seems likely, into which major river systems were feeding. In times of falling relative sea-level these formed progradational deltas, at times of relative sea-level rise, large estuaries. Sub-environments within this setting would include distributary channels, lagoons, shorefaces, mangrove swamps, back-mangrove swamps and tidal flats. Using an iterative approach, combining sedimentological, ichnological, palynological and foraminiferal observations, we are able to recognise all these sub-environments in the material studied and inner and outer estuary deposits and inner through to outer shelf deposits. Assemblages of foraminifera (including agglutinated forms) together with palynology enables biofacies proxies to be defined to recognise these depositional settings in the absence of sedimentological data. This is further discussed by Simmons *et al.* (1999).

MICROFAUNAL ASSEMBLAGES

In addition to the agglutinatied taxa presented here, many of the samples also yield (and are often dominated by) diverse calcareous benthonic foraminifera of relatively shallow-water (i.e., shelf) aspect. Genera that are particularly abundant include *Ammonia*, *Asterorotalia*, *Pseudorotalia*, *Rotalia*, *Cellanthus*, *Bolivinita* and *Cibicidoides*.

Planktonic foraminifera are extremely rare in the samples studied (mainly *Globigerina* and *Globigerinoides*) - a reflection of the shallow water depths prevailing at the time and also of the freshwater plumes eggressing from the delta mouths which effectively lowered surface water salinities preventing planktonic foraminiferal presence (see below). This also explains the similar absence of marine dinocysts in the samples studied. Planktonic foraminifera are, however, more prevalent in the material from the offshore borehole.

PALAEOENVIRONMENTS

An iterative approach combining foraminiferal micropalaeontology, palynology, ichnology and sedimentology has enabled ten precise palaeoenvironments to be recognised in the material studied (Simmons *et al.*, 1999). These range from upper distributary channel to distal turbidite. The palaeoenvironmental determinations generally fit the known distribution patterns of the genera recognised and this work is further supported by the work of Brönnimann & Keij (1986) in reviewing the occurrence of modern agglutinated foraminifera in the estuaries and bays of Brunei. The work of Dhillon (1968) and Ho (1971) provides useful information on the modern distribution of all groups of foraminifera in northwest Borneo.

Distal Turbidite

Distal turbidite deposits of northwest Borneo contain microfossil assemblages which differ markedly from what might be expected from similar aged deposits from other parts of the world. Contrary to expectations, planktonic foraminifera and dinocysts are very rare or absent. This is thought to be due to the existence of considerable freshwater input into Brunei Bay via the Baram and "Champion" River systems during the Miocene that would have severely impacted upon the occurrence of stenohaline marine plankton such as planktonic foraminifera and most dinocysts. Brenac & Richards (in press) and Dunay *et al.* (1999) have described other examples of this phenomenon. Studies of Recent foraminiferal distribution patterns (Bidgood & Simmons, *in prep.*) suggests that this phenomenon was more pronounced during the Miocene than the present day.

Foraminiferal assemblages are rather distinctive, containing abundant agglutinated forms especially fine-grained and often deformed specimens of "*Trochammina/Recurvoides*". The fine-grained nature of the wall (individual agglutinated particles typically no more than 2-3 microns diameter) appears to

be particularly distinctive of deposition in a distal turbidite setting. The assemblages lack the diversity of more shallow water settings.

Proximal Turbidite
Foraminiferal assemblages are similar to those from a distal turbidite setting, containing abundant agglutinated foraminifera, especially fine-grained, deformed *"Trochammina/Recurvoides"*. Fine-grained and thin-walled *"Cyclammina"* and *Haplophragmoides* may also be present. Unlike the palynological assemblages (see Simmons *et al.*, 1999), reworking is not obvious, thus the use of both palynology and foraminiferal micropalaeontology is essential to recognise this depositional environment.

Open Shelf
Foraminiferal assemblages are rich and diverse. Calcareous benthonic foraminifera are common or abundant. Agglutinated forms are somewhat less common and include *"Recurvoides/Trochammina"* (with a white, sugary wall), *Martinotiella*?, *Karreriella*, *Textularia* and *Ammobaculites* sp. 1/1a. In some sections, for example, ENT, planktonic foraminifera are also common. The open shelf environment may be further subdivided on the basis on the relative proportion of certain calcareous benthonic taxa.

Open Shelf with Slumps
As might be expected, there are similarities between the microfossil assemblages recovered from sediments representing this depositional setting and those from "normal" open shelf settings. Palynological assemblages are very similar. The foraminiferal assemblage is, however, reasonably distinctive. The background fauna is dominated by agglutinated foraminifera including large and deformed *"Recurvoides"*, *"Trochammina/Recurvoides"* with a fine wall, *Bathysiphon*, glomospirids, and a distinctive, probably new form of agglutinating foraminifera referred to here as *"Textukurnubia"*. Overall the diversity of agglutinated forms is moderate. In addition to the agglutinated foraminifera, the sections with slumps contain abundant calcareous benthonic foraminifera. Also present in reasonable numbers are calcareous agglutinated forms such as *Textularia*. Planktonic foraminifera are rare.

Lower Shoreface
Lower shoreface deposits (down to storm wave-base) can be distinguished from open shelf deposits by the general absence of calcareous benthonics. They contain agglutinated foraminifera assemblages of moderate diversity and abundance, especially *Haplophragmoides*, *"Recurvoides"* and *"Trochammina"*, which have a white, sugary wall. *Ammobaculites* may also be present together with a distinctive form referred to here as *"Pseudoepistomina"*. *Glomospira glomerata* is also a characteristic component of this depositional setting, although it also occurs in open shelf sediments.

Upper Shoreface
Upper shoreface deposits (down to fair weather wave-base) are difficult to distinguish from the lower shoreface deposits, as described above, in terms of their microfossil assemblages. Foraminiferal assemblages are similar to those from lower shoreface deposits, consisting mainly of common and moderately diverse assemblages of agglutinated foraminifera, especially *"Trochammina"*, *"Recurvoides"* and *Haplophragmoides* with a white, sugary wall. A distinctive component is the presence of moderately common *Karreriella* and *Ammobaculites*.

Tidal Flat/Tidal Channel
Tidal flat/tidal channel deposits can be distinguished from many of the more open marine and more distal environments by their diverse palynological assemblages. Foraminiferal assemblages tend to be of low abundance but of moderate diversity and include coarse-grained *Trochammina* and *Recurvoides* (wall being coarser than in more distal settings), and occasional *Trematophragmoides* and *Ammobaculites* spp.

Lower Distributary Channel
Foraminiferal assemblages are of moderate diversity, consisting mainly of coarse-grained agglutinated forms such as *Trochammina* and *Trematophragmoides*. *"Pseudoepistomina"* which is common in lower shoreface deposits also occurs as rare specimens in sediments from this depositional setting.

Lagoon/Distributary Channel Margin
These settings occur where mangrove swamp vegetation is accumulating on windward or current protected edges of distributary channel mouths and where distributary channels are being infilled by mangrove swamps during falling sea-level or due to autocyclic channel shifting. Foraminiferal assemblages are almost monospecific, being dominated by either *Trematophragmoides* or *Miliammina fusca* although *Ammodiscus* and *Ammobaculites* are also recorded.

Upper Distributary Channel
Upper distributary channel deposits represent near-freshwater conditions and as such are typically barren of foraminifera. A summary chart of the distribution patterns of the taxa recorded in this study is shown in Table 1.

SYSTEMATICS
The agglutinated foraminifera presented here comprise at least 34 taxa although work remains to fully evaluate the assemblages. To avoid encumbering the literature with new nomenclature that may eventually prove to be superfluous, the taxa are herein

Table 1. Chart showing the patterns of distribution of the taxa recorded herein across the range of palaeoenvironments recognised from Miocene sediments of northwest Borneo.

Key x = rare xx = common xxx = abundant	PALAEOENVIRONMENT									
	Upper Distributary Channel	Lagoon/Distributary Channel Margin	Lower Distibutary Channel	Tidal Flat/Tidal Channel	Upper Shoreface	Lower Shoreface	Open Shelf with Slumps	Open Shelf	Proximal Turbidite	Distal Turbidite
Uncertain genus & species #1	Upper Distributry Channel typically barren of all foraminifera and defined by palynology						xx			
Uncertain genus & species #2							xx			
Ammodiscus cretaceus?		x	x	x						
Glomospira glomerata						x		xx		
Glomospira gordialis		xx	xx	xx				x		
Glomospirella? sp.1		x							x	x
Miliammina fusca		xx-xxx								
Haplophragmoides sp.1		xx	xx	xx						
Haplophragmoides spp.		xx	xx	xx	x	x	xx	xx	xx	xx
Trematophragmoides bruneiensis		xx-xxx								
Ammobaculites exiguus		x	x	x	xx	xx		xx		
Ammobaculites agglutinans		x	x	x	x	x		x		
Ammobaculites sp.1/1a		xx	x	x		xx		xx		
Ammobaculites? sp.		x								
Recurvoides spp.				xx	xx	xx	xx	xx	xx	xx
Cyclammina cancellata								xx	xx	
Cyclammina sp.1		x								
Cyclammina sp.2								xx	xx	
Cyclammina sp.3								xx	xx	
"Pseudoepistomina" sp.1			xx	xx						
Camurammina? sp.1				xx	?xx					
Trochammina amnicola				xx	?xx					
Trochammina sp.1								x		
Trochammina sp.2								x		
Trochammina sp.3		x	x							
Trochammina sp.4		x								
Trochammina spp.		xx	xx	xx	xx	xx	xx	xx	xx	xx
Arenobulimina? sp.		x								
Eggerella? sp.1									x	x
Eggerella? sp.2								xx		
Karreriella sp.				xx	xx	xx	xx	xx	xx	
Martinotiella? sp.1								xx	xx	xx
"Textukumubia" sp.1							xx-xxx		x	x
Textularia agglutinans				x	x	x		xx		
Textularia sp.1								xx		
Textularia sp.2								xx		
Textularia sp.3								xx		

partly described in open nomenclature. However, by providing this working nomenclature it means that the taxa can be used for practical purposes (e.g., palaeoenvironmental determination) whilst taxonomic studies are ongoing. Given the poor state of preservation of much of the material it is possible that some taxa can never be fully described in terms of conventional nomenclature. The authors believe that many of the taxa are currently undescribed. The taxa given contrived names (in inverted commas) are placed within the supra-generic classification (following Loeblich & Tappan, 1987) thought most applicable according to their morphology.

Order **FORAMINIFERIDA** Eichwald, 1830
Suborder **TEXTULARIINA** Delagé & Herouard, 1896
Superfamily **Ammodiscacea** Reuss, 1862

Uncertain genus and species no. 1

Plate 1, Fig. 1

Diagnosis. Test large (0.5 – 0.75mm), apparently comprising 1 or ?2 elongate ?tubular chambers laid down side by side with an elongated depressed central area.
Remarks. This taxon is placed within the Ammodiscacea because of its rather simple tubular coiling arrangement.
Distribution. This forms occurs from a limited number of samples within the PC outcrop which is from the upper part of the Setap Shale and of early Middle Miocene age. This part of the PC section is attributed to a marine (?deep) shelf setting although the associated assemblages are almost exclusively comprised of high diversity agglutinated forms suggesting bottom waters were dysaerobic.

Uncertain genus and species no. 2

Plate 1, Fig. 2

Diagnosis. Test large (0.5 – 0.75mm), nature of coiling uncertain, possibly a proloculus followed by perhaps one tubular chamber coiling randomly but in a linear direction. Wall very finely agglutinated.
Remarks. The highly uncertain and somewhat unusual chamber arrangement makes suprageneric assignment extremely difficult.
Distribution. This taxon has an almost identical distribution to that of Indeterminate genus no.1 above.

Family Ammodiscidae Reuss, 1862
Subfamily Ammovolummininae Chernykh, 1967
Ammodiscus Reuss, 1862

Ammodiscus cretaceus (Reuss)?

Plate 1, Figs 3, 4

Operculina cretacea Reuss 1845 p.35, pl.13, figs 61-63

Diagnosis. Test generally ovate, approximately planispiral, an enrolled tube coiled in a flattened plane.
Remarks. There is a high degree of variability in the rate of increase in tube diameter with coiling and overall test shape from broad-ovate (Pl. 1, Fig. 3) to elongate-ovate (Pl. 1, Fig. 4), although no specimens recorded herein display a wholly circular coiling mode. Jones & Charnock (1990) adopt a relatively loose concept of *Ammodiscus cretaceus* which would include forms like those described here. However pending detailed taxonomic study of the genus *Ammodiscus* the attribution of our specimens to *A.cretaceus* is regarded as questionable.
Distribution. Recorded rarely at 7UP, SA, SA2, SA3, HO, CC and JC. These sections represent largely marginal marine to brackish lagoonal deposits of the Belait Formation and are of late Early - Middle Miocene age.

Subfamily Ammovertellininae Saidova, 1981
Glomospira Rzehak, 1885

Glomospira glomerata Höglund

Plate 1, Figs 6, 7

Glomospira glomerata Höglund, p.130, pl.3, figs 8-10, text.fig. 104

Diagnosis. A "spherical" glomospirid with a proloculus followed by a more regularly coiled tubular chamber which appears to be laid down in a series of "folded loops".
Remarks. The coiled tube in this form (cf. *Glomospira gordialis* see below) appears to be laid down in a series of "folded loops" giving a somewhat overall more regular chamber shape. The pattern produced is not unlike that of the surface of a soccer ball. Jones & Wonders (this volume) have assigned this species to a new genus based on the peculiar coiling mode.
Distribution. Recorded moderately commonly in the uppermost PC section (marine shelf) and rarely in limited samples from MO and SA3 (marine shoreface). It is, however, commonly recorded from the offshore borehole material within marine shelf sequences of Middle to early Late Miocene age. *G.glomerata* appears to have preference for a more open marine environment then *Glomospira gordialis* (see below).

Glomospira gordialis (Jones & Parker)

Plate 1, Fig. 8

Trochammina squamata var. *gordialis* Jones & Parker, 1860, p.340

Diagnosis. A "spherical" glomospirid with a proloculus followed by a randomly coiled tubular chamber.
Remarks. Distinguished from other species of the genus by the random coiling mode.
Distribution. This species is recorded as moderately common from 7UP, SA and HO and rarely from RR, MD and PC sections. These sections are developed in the lower part of the Belait Formation (marginal marine - brackish lagoonal) although RR and PC are

located in the Setap Shale (open marine). These sections range from the Lower to Middle Miocene.

Glomospirella Plummer, 1945

Glomospirella? sp. 1

Plate 1, Fig. 9

Diagnosis. Initial proloculus followed by an irregularly coiled planispiral to streptospiral second tubular chamber.
Remarks. The coiling irregularly fluctuates above and below the equatorial plane of the test and positive generic assignment is difficult. Some similarity exists between this form and *Glomospira grzybowkii* Jurkiewicz recorded from the Palaeogene of northwest Europe by Charnock & Jones (1990).
Distribution. This taxon is recorded rarely from the lower 7UP and uppermost HO sections, both of which represent brackish lagoonal or mangrove deposits of the Belait Formation of northern Brunei. Other representatives of the genus are, however, recorded slightly more commonly from the RR, OT and LL sections (all on Labuan Island), which represents marine dysaerobic bathyal conditions. *Glomospirella* spp. are also recorded rarely, though consistently, within marine shelf deposits of Middle to early Late Miocene age from the offshore borehole.

Superfamily **Rzehakinacea** Cushman, 1933
Family Rzehakinidae Cushman, 1933
Miliammina Heron-Allen & Earland, 1930

Miliammina fusca (Brady)

Plate 1, Fig. 10

Quinqueloculina fusca Brady, 1870, p.47, pl.11, figs 2-3

Diagnosis. Test elongate with chambers in a "milioline" arrangement in a somewhat flattened plane. Aperture a terminal opening produced beyond the chamber margin.
Remarks. This distinctive taxon comes from a genus which has a wide environmental range (brackish-hypersaline marshes to upper bathyal; Murray, 1991) but *M. fusca* is a commonly recorded component of marsh and "fluviomarine" environments.
Distribution. *Miliammina fusca* is not commonly recorded in the samples studied here except from some in the HO section where it occurs with abundant mangrove palynomorphs.

Superfamily **Lituolacea** de Blainville, 1827
Family Lituolidae de Blainville, 1827
Subfamily Haplophragmoidinae Maync, 1952
Haplophragmoides Cushman, 1910

Haplophragmoides sp. 1

Plate 1, Fig. 11

Diagnosis. Test planispiral, biconvex, involute with c.6 chambers in the final whorl. The periphery is acute with a "pinched" appearance.
Remarks. This is a characteristic *Haplophragmoides* species which allows separate treatment here (see *Haplophragmoides* spp. below).
Distribution. Recorded rarely in limited samples from the MD, SA and HO sections, all of which are developed in brackish lagoonal or estuarine facies.

Haplophragmoides spp.

Plate 1, Figs 12,13

Remarks. A variety of generally involute planispiral forms with between 6-9 chambers attributable to this genus have been recorded from the study area. Most are deformed or flattened in some way and are difficult to evaluate and may indeed belong to other genera (e.g., *Trochammina* and *Recurvoides*). Due to poor preservation some forms attributed to *Trematophragmoides bruneiensis* herein may be referable to this taxonomic group and *vice versa*.
Distribution. Representatives of *Haplophragmoides* spp. are recorded, often very commonly, from nearly all the sections studied where agglutinated foraminifera were recorded. The sections cover a wide variety of environmental settings ranging from brackish lagoons and estuaries through to deep-water shelf and bathyal deposits.

Trematophragmoides Bronnimann & Keij, 1986

Trematophragmoides bruneiensis Brönnimann & Keij?

Plate 1, Figs 14, 15

Trematophragmoides bruneiensis Brönnimann & Keij, 1986, p.16, pl.1, figs 1-10, pl.2, figs 3-5, pl.10, figs 1-3, text-fig.1

Diagnosis. Test medium, compressed, apparently planispiral and somewhat evolute with 7-9 chambers in the final whorl. Periphery subacute, wall relatively coarse.
Remarks. The genus *Trematophragmoides* was defined (partly) as being similar to *Haplophragmoides* but with a supplementary aperture either side of the primary one, near the umbilical chamber tips and directed posteriorly. These cannot be clearly seen on the specimens figured here (which therefore may perhaps be better referred to as *Haplophragmoides* spp.) but the overall test shape is similar to that of *Trematophragmoides bruneiensis* Brönnimann & Keij (1986).
Distribution. In the study area most of the forms recorded are from the CC and SA sections from samples attributable to brackish (lagoonal, mangrove swamp or overbank) settings. These seem to correspond to Brönnimann & Keij's environmental data (depth 1.5 m, salinity between 24 and 18.9‰) for *T.bruneiensis*.

Subfamily Lituolinae de Blainville, 1827

Ammobaculites Plummer, 1932

Ammobaculites exiguus Cushman & Brönnimann

Plate 1, Fig. 5

Ammobaculites exiguus Cushman & Brönnimann, 1948, p.38, pl.7, figs 7-8

Diagnosis. Test elongate, an initial small compact planispiral portion becoming uncoiled and straight uniserial, uncoiling at 90° from the initial planispire. The uniserial chambers are axially compressed barrel-shaped and number 5-7.

Remarks. The general lack of lateral test compression distinguishes this form from other *Ammobaculites* spp. recorded here. Other *Ammobaculites* spp. also show the uncoiled portion uncoiling at an angle less than 90° from the initial planispire.

Distribution. This species has been recorded in moderate numbers from the MO, MD, SA, SA2 and AS sections and rarely from the PC section. It appears to have a preference for shallow marine and shoreface settings but has also been recorded from estuarine and (brackish?) lagoonal samples. It is commonly regarded throughout the area as a general "fluviomarine" indicator.

Ammobaculites agglutinans (d'Orbigny)

Plate 2, Fig. 3

Spirolina agglutinans d'Orbigny, 1846, p.137

Diagnosis. Test laterally compressed, planispiral portion with c.5 chambers and a depressed central area. Later uncoiled uniserial chambers uncoil almost perpendicularly to the initial coil. The agglutinating material is relatively coarse.

Remarks. This form is distinguished by the very laterally compressed test and the more "open" initial planispiral coil.

Distribution. *Ammobaculites agglutinans* has broadly the same distribution pattern as other *Ammobaculites* species recorded from northwest Borneo although it is recorded in much fewer numbers.

Ammobaculites sp. 1 / 1a

Plate 2, Figs 1, 2

Diagnosis. Test laterally compressed, planispiral portion with 5-6 chambers. Uncoiled portion up to 5 laterally compressed barrel-shaped chambers that uncoil somewhat tangentially. The agglutinated material is relatively coarse.

Remarks. These forms differ from *A.exiguus* and similar forms (e.g., *Ammobaculites agglutinans* (d'Orbigny)) in being more generally laterally compressed and uncoiling tangentially rather than perpendicular to the original planispire. *Ammobaculites* sp.1a (Pl. 2, Fig. 2) is a variety of *Ammobaculites* sp.1 in which the degree of lateral compression is much reduced.

Distribution. This taxon/a has been (often very commonly) recorded from the MD, CO and SA sections where it is often characteristic of estuarine or brackish lagoon/marsh type deposits. It is also recorded moderately commonly from the AS and MO sections from more shallow marine/shoreface deposits.

Ammobaculites? sp.

Plate 2, Fig. 4

Diagnosis. Test small, an apparently coiled initial portion followed by a straight, uncoiled, uniserial part. The agglutinated material is relatively very coarse.

Remarks. As the exact coiling nature of the initial portion is unclear the generic assignment is tentative.

Distribution. This form is only recorded (rarely) from the SA2 section.

Superfamily **Haplophragmiacea** Eimer & Fickert, 1899
Family Ammosphaeroidinidae Cushman, 1927
Subfamily Recurvoidinae Alekseychik-Mitskevitch, 1973
Recurvoides Earland, 1934

Recurvoides spp.

Plate 2, Figs 5, 6

Remarks. A variety of apparently streptospiral forms attributable to this genus have been recorded from the study area. Some (e.g., Pl. 2, Fig. 5) show the typical subglobular compact test shape, others tend to be more evolute in aspect.

Distribution. *Recurvoides* spp. are commonly recorded from a wide range of marine or estuarine palaeoenvironments although forms from deep marine settings tend to have finer wall structures (e.g., Pl. 2, Fig. 5) to those from nearshore environments.

Superfamily **Loftusiacea** Brady, 1884
Family Cyclamminidae Marie, 1941
Subfamily Cyclammininae Marie, 1941
Cyclammina Brady, 1879

Cyclammina cancellata Brady

Cyclammina cancellata Brady, 1879, p.62

Diagnosis. Test planispiral, involute, with a well-rounded periphery. Sutures straight, slightly depressed. Chambers number approximately 10-12 in the final chamber.

Remarks. *Cyclammina cancellata* is distinguished from other representatives of the genus recorded here by the larger number of chambers present in the final whorl.

Distribution. *Cyclammina cancellata* was recorded only from the offshore borehole material of Middle to Late Miocene age and of (broadly) shelfal-bathyal aspect.

Cyclammina sp. 1

Plate 2, Fig. 7

Diagnosis. Test planispiral, involute with c.8 chambers in the final whorl. Sutures straight, slightly

depressed. The periphery is somewhat rim-like being pinched approximately one-third of the chamber height in from the periphery edge.
Remarks. This form is characterised by the pinched peripheral rim. The alveolar nature of the wall distinguishes this species from *Haplophragmoides* sp.1, which also has a pinched periphery.
Distribution. The single specimen recorded here was obtained from sediments attributed to a lagoonal setting (CC). Like all specimens of *Cyclammina* recorded here, the apertural face is somewhat flattened with the aperture itself indistinct.

Cyclammina sp. 2

Plate 2, Figs 8, 9

Diagnosis. Test subglobose, medium to large, planispiral, involute with 7-8 chambers in the final whorl. The periphery is very well rounded, becoming only slightly subangular in the final 1 or 2 chambers. Apertural face flat.
Remarks. This form may represent the least laterally compressed end member of a plexus with *Cyclammina* sp. 3 (herein) at the other extreme (see below).
Distribution. Both *Cyclammina* sp. 2 and sp. 3 were recorded only from the offshore borehole material of Middle to Late Miocene age and of broadly shelfal aspect.

Cyclammina sp. 3

Plate 2, Figs 10, 11

Diagnosis. Test medium to large, planispiral, involute with 7-8 chambers in the final whorl. The umbilical area on both sides is indented resulting in a somewhat trapezoid-shaped cross section (e.g., Pl. 2 Fig. 10).
Remarks. These forms are more laterally compressed than *Cyclammina* sp. 2 and may represent the most laterally compressed end member of the plexus. This form (*Cyclammina* sp. 3) is not unlike the European Palaeogene form *Reticulophragmium amplectens* (Grzybowski) in overall shape. Plate 2, Figs 12 & 13 show forms that may be intermediate between the two end-members.
Distribution. Both *Cyclammina* sp. 2 and sp. 3 were recorded only from the offshore borehole material of Middle to Late Miocene age and of broadly shelfal aspect.

Superfamily **Trochamminacea** Schwager, 1877

"Pseudoepistomina" sp. 1

Plate 2, Figs 14, 15

Diagnosis. Test biconvex, apparently with a very low trochospiral (?almost planispiral) coiling arrangement. 7-9 chambers in the final whorl of which the surfaces are depressed away from the sutures and margins. The periphery is subangular and often "pinched" to a sharp petaloid rim. The wall is very finely agglutinated.
Remarks. The suprageneric affinities of this taxon are unclear. The contrived name is derived from the initial impression of the forms similarity to the calcareous rotaliid genus *Epistomina*.
Distribution. This taxon has been recorded in abundance in limited samples from the ENT section and less commonly from the JC, CC, MO and 7UP sections. At ENT and in the JC and CC samples it appears to be associated with estuarine and/or tidal flat deposits. Records from the MO and 7UP sections are extremely rare or questionable. The ENT, JJ and CC sections are of approximate late Early Miocene age.

Family Trochamminidae Schwager, 1877
Subfamily Trochammininae Schwager, 1877
Camurammina Brönnimann & Keij, 1986

Camurammina? sp. 1

Plate 3, Fig. 1

Diagnosis. Test a meduim-sized low trochospire with 5-6 chambers in the final whorl. The spiral side is only slightly convex with straight to slightly recurved sutures. The umbilical side is inflated convex with straight sutures. The apertural face (not shown clearly on photos) is flattened and has a somewhat depressed area around the aperture. The wall material is relatively coarse.
Remarks. The generic assignment is uncertain but the depressed apertural face may be related to *Camurammina* which has an "inward turned apertural border" (Brönnimann & Keij, 1986). Other possible generic assignments may be *Trochammina* Parker & Jones or *Pseudotrochammina* Frerichs.

Brönnimann & Keij (1986) describe a number of agglutinated taxa from Recent brackish waters in Brunei where material is of better preservational quality than that observed in this study. It is possible that this species is referable to one of their taxa though critical details (e.g., nature of aperture) are difficult to evaluate in our fossil material.
Distribution. This taxon is common in the CO section that represents a tidally influenced channels/shoreface setting.

Trochammina Parker & Jones, 1859

Trochammina amnicola Brönnimann & Keij?

Plate 3, Fig. 2

Trochammina amnicola Brönnimann & Keij, 1986, pp.22-24, pl.2, figs 1-2, pl.4, figs 1-13

Diagnosis. Test medium, a low trochospire with c.7 chambers in the final whorl. The final 2-3 chambers become more distinctly radially elongate. The spiral side is somewhat flattened with mainly straight or slightly recurved sutures. The umbilical side is inflated convex with straight sutures. The apertural face (not shown clearly on photos) is flattened and

has a somewhat depressed area around the aperture. The wall material is relatively coarse.
Remarks. The elongated final chambers together with more chambers in the final whorl distinguish this taxon from *Camurammina?* sp.1. This form is tentatively referred to *Trochammina amnicola* Brönnimann & Keij (Brönnimann & Keij, 1986; pl. 4, figs 1-13) which can also have elongated final chambers. However, the poor preservation does not allow a precise comparison (see above)
Distribution. This taxon, like *Camurammina* sp.1 above, is common in the CO section that represents a tidally influenced channels/shoreface setting.

Trochammina sp. 1

Plate 3, Figs 5, 6

Diagnosis. Test medium sized, a low trochospire with a subrounded periphery and 5-6/7 chambers in the final whorl (2 whorls visible). Sutures are depressed and straight although becoming recurved in specimens with more than 6 chambers.
Remarks. A variety of trochamminids occur in the studied material although none appear referable to taxa common in the literature. Pending more detailed taxonomic work they are placed in open nomenclature. *Trochammina* sp. 2 is smaller and has few chambers though the possibility that the two taxa are variations on the same cannot be excluded.
Distribution. Recorded rarely from the ENT section that is a marine shelf deposit.

Trochammina sp. 2

Plate 3, Figs 7, 8

Diagnosis. Test a small low trochospire with a subrounded periphery and 4-5/6 chambers in the final whorl (2 whorls visible).
Remarks. This taxon is similar to but smaller than *Trochammina* sp. 1 and also has fewer chambers.
Distribution. Recorded rarely from the ENT section that is a marine shelf deposit.

Trochammina sp. 3

Plate 3, Fig. 9

Diagnosis. Test small, a low trochospire with 5 globular chambers in the final whorl. Umbilicus open, periphery well rounded and distinctly lobate.
Remarks. This form distinctly resembles a planktonic foraminifer in chamber arrangement.
Distribution. Recorded from the CO section only from marginal marine (lagoonal or estuary-mouth) deposits.

Trochammina sp. 4

Plate 3, Figs 3, 4

Diagnosis. Test a low trochospire with a high umbilical side. On the spiral side the chambers (ca. 4 per whorl) are evolutely coiled and somewhat "sausage" shaped. Sutures slightly depressed and recurved. The central part is excavated but this may be a preservational feature. The umbilical side is domed and involute with sutures only very slightly depressed or flush. The apertural face is flat and the umbilicus is closed.
Remarks. This taxon, though rare, is highly distinctive having a "spirilinid" appearance in spiral view.
Distribution. This form has been recorded (rarely) from lagoonal sediments of the 7UP section.

Superfamily **Ataxophragmiacea** Schwager, 1877
Family Ataxophragmiidae Schwager, 1877
Subfamily Ataxophragmiinae Schwager, 1877
Arenobulimina Cushman, 1927

Arenobulimina? sp.

Plate 3, Fig. 10

Diagnosis. Test fairly coarse, a relatively drawn out trochospire with c.4 or more chambers per whorl. The aperture is indistinct.
Remarks. Poor preservation prevents exact generic assignment.
Distribution. Recorded rarely from the 7UP section in ?brackish lagoonal deposits.

Superfamily **Textulariacea** Ehrenberg, 1838
Family Eggerellidae Cushman, 1937
Subfamily Eggerellinae Cushman, 1937
Eggerella Cushman, 1935

Eggerella? sp. 1

Plate 3, Fig. 12

Diagnosis. Test a sub-ovate trochospire. Number of chambers in early part unclear but ca. 3 chambers per whorl in later stage. Chambers broadly inflated. Wall relatively finely agglutinated.
Remarks. *Eggerella?* sp. 2 has a more elongate test shape. Like much of the material studied herein, the exact generic assignment is unclear because of the poor preservation often encountered, particularly in the nature of the aperture. These forms (species 1 and 2) may be referred to *Eggerella* Cushman (areal aperture) or *Verneuilinulla* Saidova (interio-marginal aperture).
Distribution. So far recorded only from deep-water settings in the offshore borehole

Eggerella? sp. 2

Plate 3, Fig. 11

Diagnosis. Test elongate, trochospiral, slightly inflated chambers, ca. 3 per whorl, increasing regularly in size. Wall finely agglutinated.
Remarks. This taxon is distinguished from *Eggerella* sp. 1 by its more elongate and cone-like test shape.
Distribution. It has only been recorded so far from marine shelf environments (PC section).
Karreriella Cushman, 1933

Karreriella **sp.**

Plate 3, Fig. 13

Diagnosis. Test elongate, triserial becoming twisted biserial in later stages. Subglobular chambers increasing slowly in size.
Remarks. Forms with a finely agglutinating wall are recorded from the ENT sections (shallow marine) and the offshore borehole (deep marine). Forms with a coarser wall structure recorded from tidal channels / shoreface sediments of the CO section.
Distribution. This form appears to have a wide marine distribution from deep-water settings (e.g., the offshore borehole and ENT sections) to tidal/ shoreface environments of the CO section.

Martinotiella Cushman, 1933

Martinotiella? **sp. 1**

Plate 4, Fig. 6

Diagnosis. Test initially quadri- or triserial followed by a short uniserial portion of 2-4 barrel-shaped chambers. The final chamber is distinctly more globular with a terminal aperture. Wall finely agglutinated.
Remarks. The generic assignment is uncertain due to the indistinct nature of the initial coil.
Distribution. This taxon is recorded from marine shelf (ENT section) to slope deposits (offshore borehole) in the study area.

Family Textulariidae Ehrenberg, 1838

"Textukurnubia" **sp. 1**

Plate 4, Figs 1-5

Diagnosis. Test elongate, cigar-shaped. The chamber arrangement in external view appears to be buliminid but on a few well preserved specimens can be shown to be biserial. This is confirmed by thin-section observation (Pl. 4, Figs 4-5). The wall surface is characteristically rough and interval longitudinal ?alveolae / partitions can be seen although these are obscured on coated SEM specimens. In thin section, the test appears wholly biserial with a relatively large initial proloculus and large siliceous grains making up the test wall construction.
Remarks. The contrived given name is related to the first impressions of a vague similarity with the Mesozoic genus *Kurnubia*. No definite internal alveolar wall structures were observed in the thin sectioned specimens (Pl. 4, Figs 4 & 5) or broken specimens under the SEM (Pl. 4, Fig. 3) suggesting that the partitions observed in whole specimens are caused by some other feature, perhaps the relatively large quartz grains used in the wall construction. Whatever their origins, they are visibly distinct and are useful to characterise this particular taxon. The biserial chamber arrangement was established by both external and thin-section observations.
Distribution. The specimens are recorded mainly from the PC section that represents a deep-shelf marine setting. However, the associated microfossils are relatively diverse agglutinated foraminifera. Specimens have also been recorded from the deeper marine (shelf/slope) offshore well.

Subfamily Textulariinae Ehrenberg, 1838
Textularia Defrance, 1824

Textularia agglutinans d'Orbigny

Plate 4, Fig. 7

Textularia agglutinans d'Orbigny, 1839, p.144, pl.1 figs 17, 18, 32-34

Diagnosis. Test biserial, slender, elongate with subglobular chambers increasing slowly in size.
Distribution. Apart from rare occurrences in the CO section, which is interpreted as a tidally influenced channel/shoreface deposit, this taxon - like the other *Textularia* spp. recorded here - is found mainly in open marine shelf deposits (e.g., PC) of the Setap Shale.

Textularia **sp. 1**

Plate 4, Fig. 8

Diagnosis. Test biserial, robust, elongate with subglobular chambers increasing relatively rapidly in size.
Remarks. Differs from *Textularia agglutinans* by the more rapid chamber size increase.
Distribution. Recorded from the PC section; Setap Shale (marine).

Textularia **sp. 2**

Plate 4, Fig. 9

Diagnosis. Test biserial, blade-like with a subangular periphery. The chambers are low and elongated and distinctly backward pointing.
Remarks. The kite-shaped, or blade-like appearance of the test is characteristic and is possibly referable to *Vulvulina* although there is no obvious planispiral early portion. It is somewhat similar to *Textularia pseudogramen* Chapman & Parr although that species displays a much more overall flaring-triangular test shape rather than blade-like as in this taxon.
Distribution. Recorded from the PC section; Setap Shale (marine).

Textularia **sp. 3**

Plate 4, Fig. 10

Diagnosis. Test biserial, slightly compressed, chambers somewhat spherical with later chambers showing irregular development with expanded lower parts partially enveloping previous chambers.
Remarks. The later chambers take on a vaguely "melted" appearance to assume the effect of partially enveloping previous chambers.

Distribution. Recorded from the PC section; Setap Shale (marine).

CONCLUSIONS

Agglutinated foraminifera form a significant and in many cases diverse proportion of the total microfossil assemblages from Miocene sediments of northwest Borneo. Herein we have briefly described 34 discrete taxa to provide a practical tool for the recognition of ten precise palaeoenvironments. These taxa may also have as yet unexploited biostratigraphic value. However, it is recognised that those taxa presented here represent initial results and further material needs to be examined to complete a full taxonomic analysis.

Although a range of analytical techniques (e.g., palynology, sedimentology, ichnology etc.) is required, the distribution of agglutinated foraminifera is often critical when determining palaeoenvironments - especially in shallow-water facies or under certain physio-chemical conditions where calcareous foraminifera may be rare or absent. The use of such detailed palaeoenvironmental reconstruction is crucial to the understanding of shale-bounded sand body deposition (and hence geometry) and the consequent reservoir-development strategies employed to exploit their hydrocarbon potential.

ACKNOWLEDGEMENTS

The authors would like to gratefully thank Dr. Shirley van Heck of Brunei Shell Petroleum for the subsurface data and for funding the study. In addition, Patrice Brenac (Brenac Stratigraphy International) for analysis of the palynofloras and discussions of their significance, Prof. Joe Lambiase and Dr. Paul Crevello (University of Brunei) for help with field work, Dr. Bob Jones (BP) for some taxonomic assistance, Dr. John Whittaker and Richard Hodgkinson of the Natural History Museum, London for thin-section production of some of the specimens and John Still & Walter Ritchie (University of Aberdeen) for SEM assistance, photo-developing and plate production. CT would like to acknowledge N.E.R.C. for research studentship funds.

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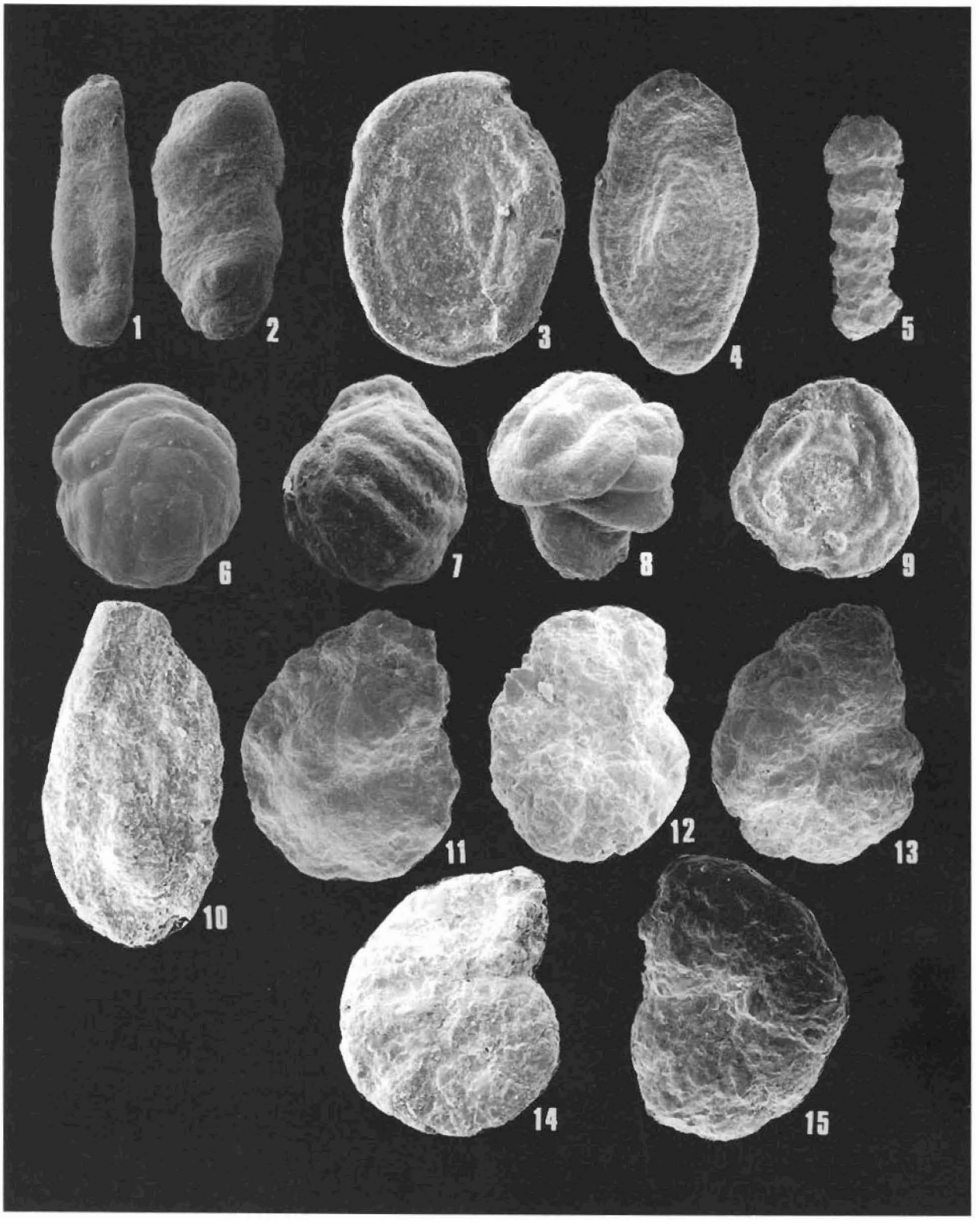

PLATE 1. **1**. Uncertain genus and species no. 1 (PC-4; x60; 0020); **2**. Uncertain genus and species no. 2 (PC-4; x100; 0018); **3**. *Ammodiscus cretaceus* (Reuss)?: broad-ovate form (7UP 58.75; x200; 4001); **4**. *Ammodiscus cretaceus* (Reuss)?: elongate-ovate form (CC 0.0; x100; 5012); **5**. *Ammobaculites exiguus* (Cushman & Brönnimann) (PC-8; x55; 0001); **6**. *Glomospira glomerata* Höglund (offshore borehole; x100; 2017); **7**. *Glomospira glomerata* Höglund (PC-11; x120; 1007); **8**. *Glomospira gordialis* (Jones & Parker) (7UP 24.8; x150; 4006); **9**. *Glomospirella* sp. 1 (7UP 45.0; x150; 3015); **10**. *Miliammina fusca* (Brady) (HO 45.0; x50); **11**. *Haplophragmoides* sp.1 (SA 10.5; x150; 5004); **12**. *Haplophragmoides* spp. (HO-0.3; x200; 5005); **13**. *Haplophragmoides* spp. (SA 58.0; x150; 4014); **14**. *Trematophragmoides bruneiensis* Brönnimann & Keij? (CC 0.0; x150; 5009); **15**. *Trematophragmoides bruneiensis* Brönnimann & Keij? (SA 58.0; x200; 4013)

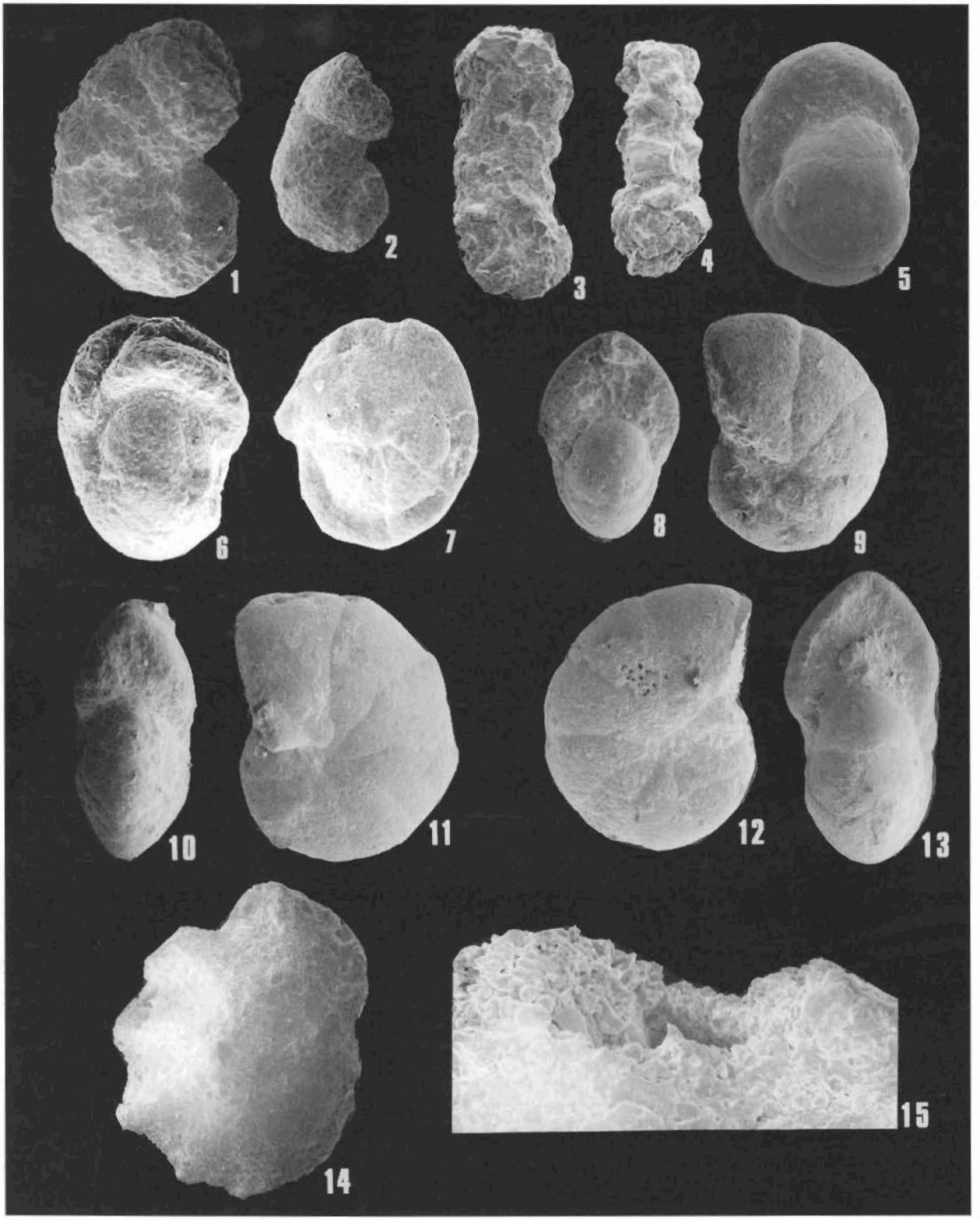

PLATE 2. 1.*Ammobaculites* sp.1/1a: laterally compressed form (SA 63.0; x150; 4015); 2. *Ammobaculites* sp.1/1a (CO 2; x100; 0011); 3. *Ammobaculites agglutinans* (d'Orbigny) (SA 58.0; x150; 3007); 4. *Ammobaculites*? sp. (SA2 58.0; x150; 3006); 5. *Recurvoides* spp.: subglobular form with fine wall structure (offshore borehole; x200; 4001); 6. *Recurvoides* spp. (CC -5.0; x150; 5008); 7. *Cyclammina* sp. 1: note "pinched" rim (CC -5.0; x100; 5007); 8. *Cyclammina* sp. 2: apertural view (offshore borehole; x63; 2034); 9. *Cyclammina* sp. 2: lateral view (offshore borehole; x70; 2033); 10. *Cyclammina* sp. 3: apertural view (offshore borehole; x50; 2032); 11. *Cyclammina* sp. 3: lateral view (offshore borehole; x50; 2031); 12. *Cyclammina* ex inter. sp.2/3: lateral view (offshore borehole; x45; 2036); 13. *Cyclammina* ex inter. sp. 2/3: apertural view (offshore borehole; x50; 2035); 14. *"Pseudoepistomina"* sp.1 (ENT (Miri-9); x50); 15. *"Pseudoepistomina"* sp.1: close up of broken wall demonstrating agglutinating nature (ENT (Miri-9); x600; 3003)

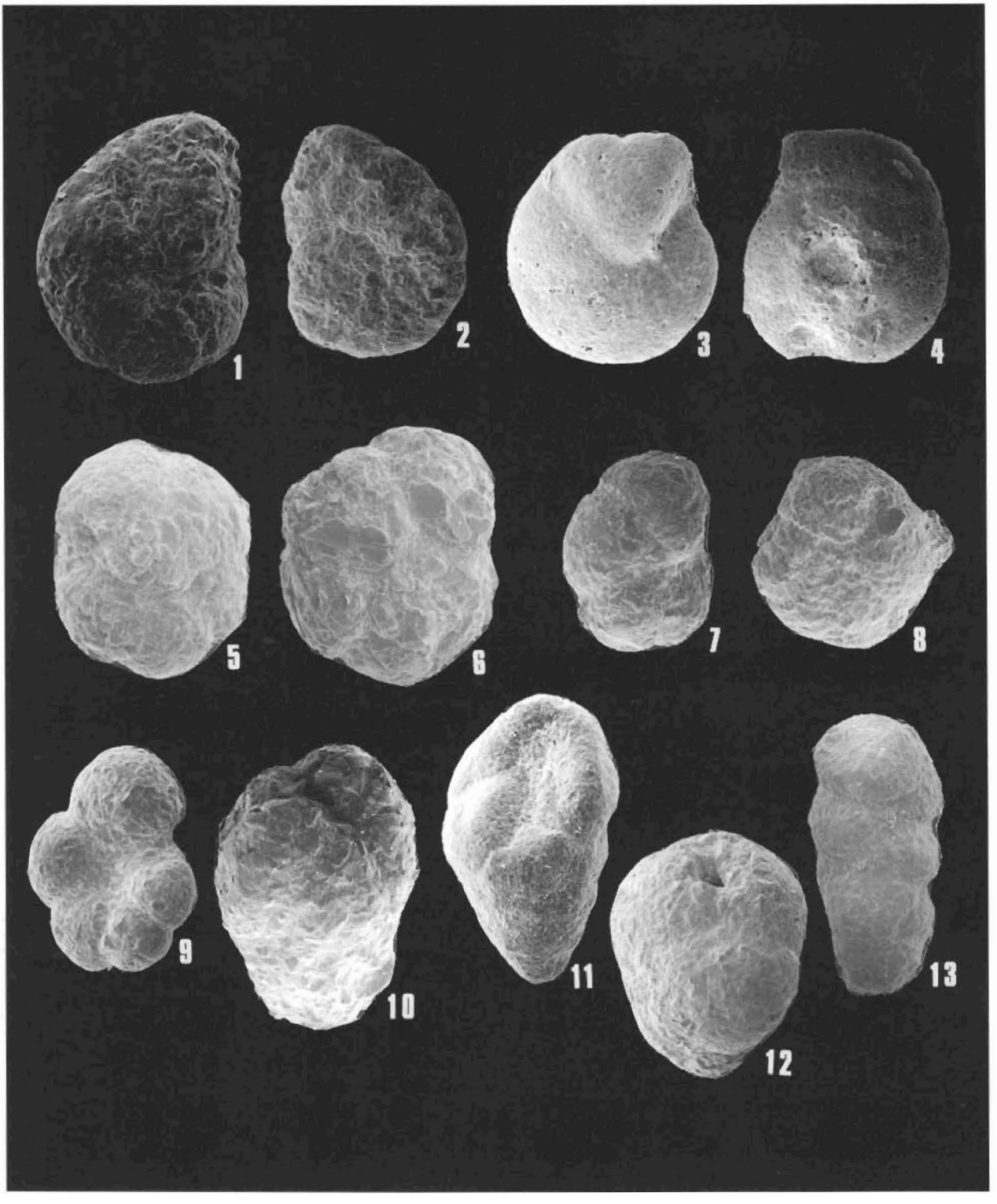

PLATE 3. 1. *Camurammina*? sp. 1 (CO 2; x180; 0003); 2. *Trochammina amnicola* Brönnimann & Keij? (CO 2; x120; 0001); 3. *Trochammina* sp. 4: umbilical view (7UP 235.0; x150; 4002); 4. *Trochammina* sp. 4: spiral side view (7UP 235.0; x150; 4003); 5. *Trochammina* sp.1: umbilical view (ENT (Miri-17); x200; 2014); 6. *Trochammina* sp. 1: spiral side view (ENT (Miri-17); x200; 3001); 7. *Trochammina* sp. 2: umbilical view (ENT (Miri-17); x200; 3009); 8. *Trochammina* sp. 2: spiral side view (ENT (Miri-17); x200; 3010); 9. *Trochammina* sp. 3 (CO 2; x140; 0010); 10. *Arenobulimina*? sp. (7UP 235.0; x150; 4010); 11. *Eggerella*? sp. 2 (PC-11; x120; 0031); 12. *Eggerella*? sp. 1 (offshore borehole; x100; 2014); 13. *Karreriella* sp. (ENT (Miri-9); x150; 2013)

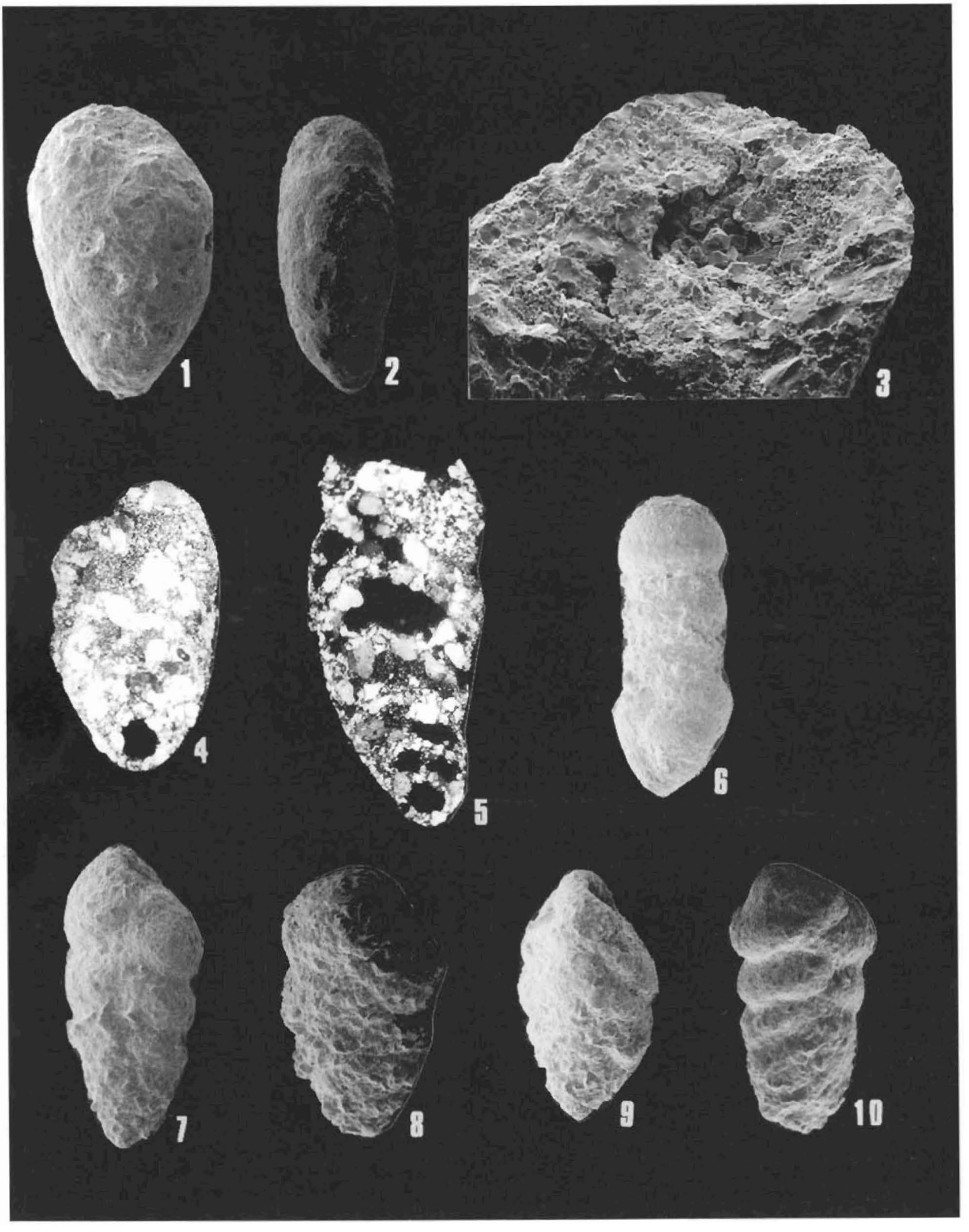

PLATE 4. 1. *"Textukurnubia"* sp.: external view - compact ovoid form (PC-4; x70; 0015); 2. *"Textukurnubia"* sp.: external view - elongate ovoid form (PC-4; x60; 0017); 3. *"Textukurnubia"* sp.: close up of broken wall structure demonstrating agglutinating nature - apertural end (PC-11; x190; 0003); 4. *"Textukurnubia"* sp.: transmitted light view (PC-11; x70); 5. *"Textukurnubia"* sp.: transmitted light view (PC-11; x70); 6. *Martinotiella*? sp.1 (offshore borehole; x100; 2028); 7. *Textularia agglutinans* d'Orbigny (PC-8; x90; 0025); 8. *Textularia* sp. 1 (PC-8; x100; 0023); 9. *Textularia* sp. 2 (PC-8; x100; 0022); 10. *Textularia* sp. 3 (PC-10; x110; 1011).