LATE CRETACEOUS FORAMINIFERAL BIOFACIES OF THE NORTHEASTERN INDIAN OCEAN REGION

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VOLUME 1.

TEXT

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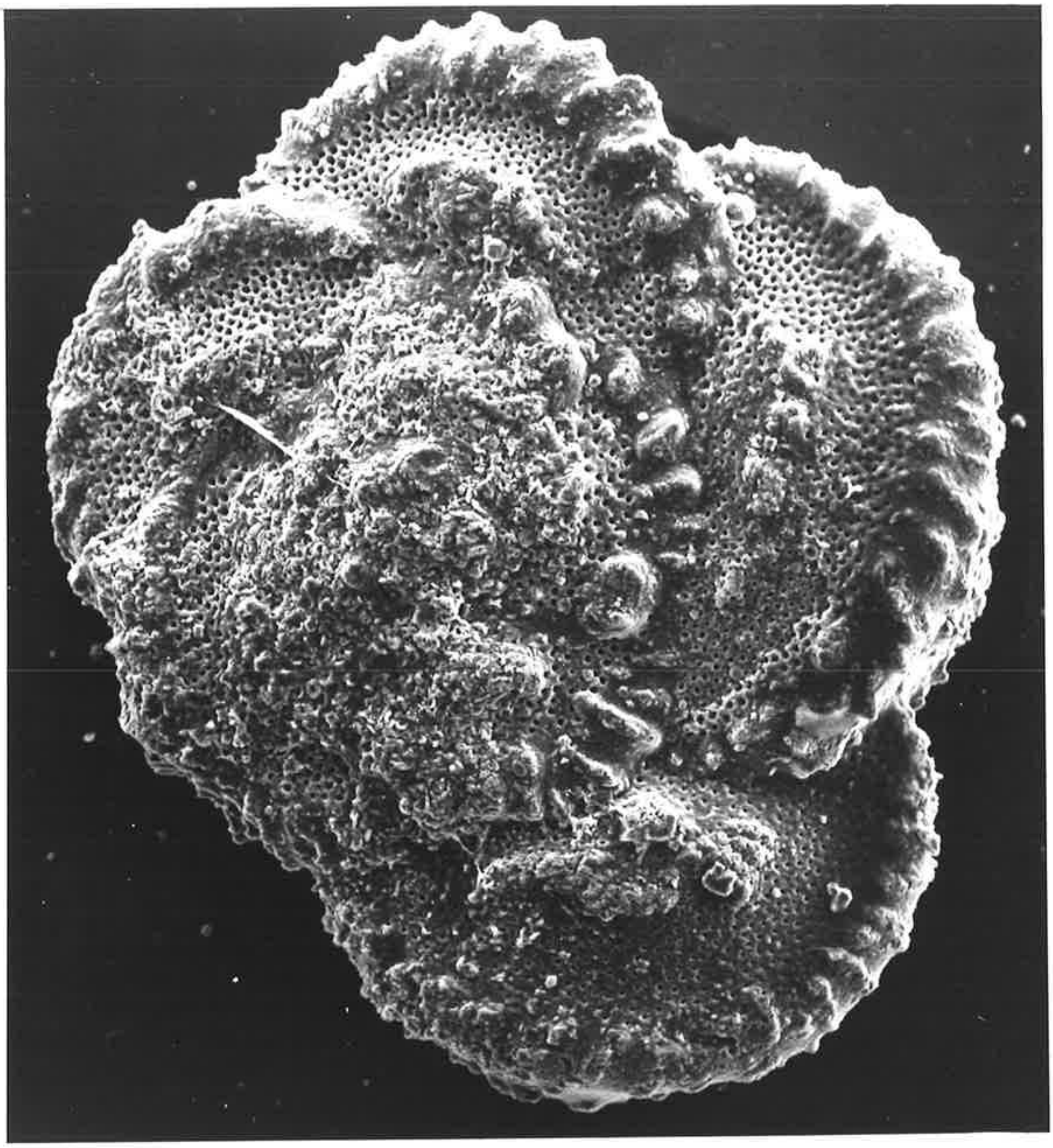
FRONTISPIECE : *GLOBOTRUNCANELLA MAYAROENSIS*



This thesis contains no material which has been accepted for the award of any other degree or diploma in any university and, to the best of my knowledge and belief, no material previously published or written by any other person except where duly acknowledged.

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SUMMARY

The foraminiferal content of ten sections representing a time span of Late Campanian to latest Maastrichtian have been examined. Nine sections are from the Northeastern Indian Ocean region and represent facies from active margin, passive margin and oceanic settings. The final section, from the Ontong-Java plateau was used for comparative purposes only.

Using a simple counting technique, a "biofacies profile" was constructed for each section allowing a number of non-phyletic or biofacies events to be recognised. The biofacies events can be identified in several sections; therefore, once calibrated by conventional biostratigraphy, they become available as additional correlation tools. The biostratigraphic framework produced by combining the conventional biostratigraphic events with the biofacies events enables a more refined chronological correlation of the sections than has previously been possible. Such a framework is especially useful in those sections which suffer a dearth of biostratigraphically useful species.

Apart from the biostratigraphic significance of the various shifts in the biofacies profile, consideration of their causes is important. The major biofacies events are a series of five peaks in the number of agglutinated forms which appear to be due to shallowing. They are ocean-wide in their distribution; their number suggests eustatic oscillations at a higher frequency than the Transgression/Regression cycles documented by Kauffman, (1979b).

Superimposed on the agglutinated peaks from the mid-Maastrichtian onward, is a trend towards high praebuliminid numbers. This trend can be recognised in all sections of the appropriate age. Higher praebuliminid numbers are directly attributable to dysaerobic conditions.

The changes in foraminiferal assemblages recognised in the biofacies profiles can be viewed as secondary precursor events to the terminal Cretaceous event. The concept of a long build-up to the boundary is at odds with the now popular catastrophic models, however, the profiles offer some support to the ecological approach used by Kauffman, (1979a).

The situation at oceanic Site 217 on the Ninetyeast Ridge is unusual in two respects. Firstly in regard to biofacies events, Site 217 for much of the Maastrichtian acts in concert with the neritic sections of the Western Australian margin. This suggests that the site was not as deep as its mid-ocean position would indicate. Secondly the majority of globotruncanid species do not appear at Site 217 until after *Globotruncanella mayaroensis;* (McGowran, 1974, Pessagno and Michael, 1974); thus only the final Late Maastrichtian zone can be recognised. It is therefore suggested that the late development of keeled forms was due to the site moving from an extratropical to a tropical situation as it drifted northward with the Indian plate.

INTRODUCTION

INTRODUCTION

One of the major preoccupations of palaeoceanography has been the construction of various profiles in time. After processing large amounts of data from lengthy time intervals, curves such as changing sea level, fluctuations of the carbonate compensation depth and changes in hiatus density have been successfully produced.

Recently, however, there has been a move away from the documentation of long-term trends to a more "event-oriented" approach; that is, to a detailed analysis of shifts or events which take place on a fine time scale. Thierstein and Berger, (1978), for example, discuss what they consider to be the major palaeoceanographic events of the last 100 million years; included are the mid-Cretaceous anoxic events, the Cretaceous and Eocene terminations, and the Messinian event. The signals used in the analysis of these events are largely micropalaeontological.

The new "event-oriented" approach is also reflected in a renewed interest in the Cretaceous/Tertiary boundary problem. (See for example Christensen and Birkelund, 1979 and Birkelund and Bromley, 1979, and references therein.) The search for a satisfactory model to explain this event has generated an enormous amount of literature without coming to any consensus of views. Most authors, when dealing with the boundary problem, are content to document changes that occurred across the boundary. Very few workers have examined the possibility of changes in oceanic conditions which may have occurred prior to, but linked with, the boundary event. Such changes should manifest themselves in the fossil record by shifts in the make-up of the foraminiferal assemblages. Hence an "event-oriented" analysis of foraminiferal assemblages over a restricted time interval preceding the Cretaceous/Tertiary boundary is one of the main aims of this work.

To this end, several sections from the Northeastern Indian Ocean with a composite time span of Late Campanian to latest Maastrichtian have been examined. The sections were chosen to represent a variety of facies in passive margin, active margin and oceanic settings. Documentation of assemblages was carried out using simple counts so as to produce, for each section, a biofacies profile to reflect any shifts in oceanic conditions. Analysis of any biofacies events recognised in the profiles should therefore lead to a fuller understanding of the Cretaceous/Tertiary boundary event.

The global significance of the biofacies events is another important consideration. That is: are any of these events related in any way to the long-term trends mentioned at the outset? Of particular interest in this context are the global sea level curves.

One problem with all the sections studied is the dearth of biostratigraphically useful species. However, biofacies events, once calibrated by conventional biostratigraphy, become available as additional correlation tools in much the same way as changes in coiling direction are used during the Tertiary. The construction of a combined biostratigraphic framework using both conventional biostratigraphic events and biofacies events is therefore central to this work. Once constructed, such a framework provides the means of determining accurately the timing of the fluctuations in biofacies profiles.

Chapter One of this thesis documents the sections used, including location, age and any pertinent biostratigraphic information. Details of construction and analysis of the biofacies profiles takes up Chapters Two and Three.

The unusual foraminiferal distribution at Site 217 has been recorded elsewhere, (McGowran 1974, Pessagno and Michael, 1974) but is documented in greater detail using biofacies profiles and discussed fully in Chapter Four.

The systematics has been reduced to checklist form at the end of the thesis. All species recognised during this study have been illustrated and these plates are bound as a separate atlas.

CHAPTER ONE

DESCRIPTIONS OF SECTIONS

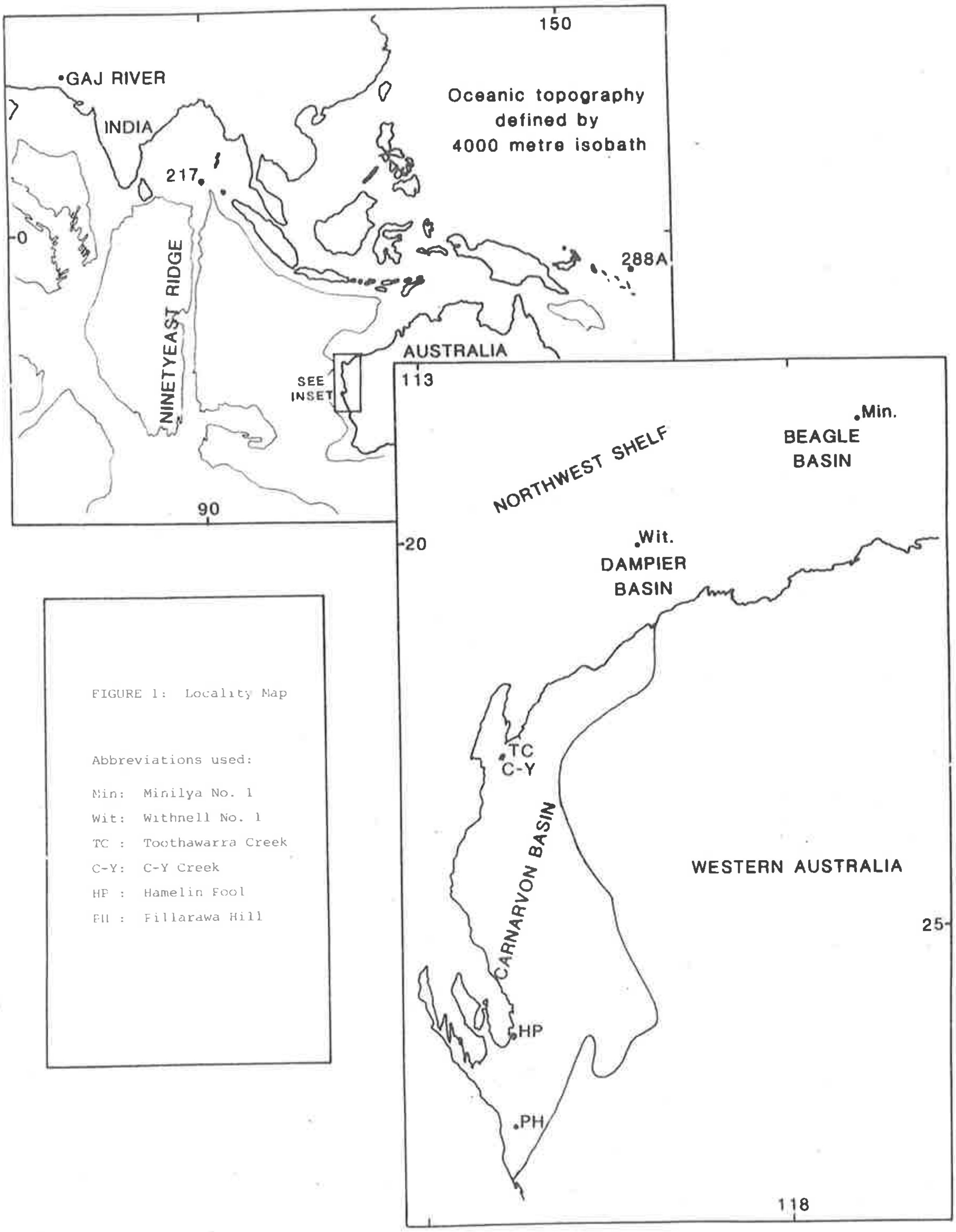


FIGURE 1: Locality Map

Abbreviations used:

Min:	Minilya No. 1
Wit:	Withnell No. 1
TC :	Toothawarra Creek
C-Y:	C-Y Creek
HP :	Hamelin Pool
PH :	Pillarawa Hill

SOURCES OF MATERIAL

The samples used for this study come from sections representing three contrasting environments:

1. Oceanic conditions

The Deep Sea Drilling Project (Chief Scientist at the time, Dr. D.G. Moore) provided samples from Sites 217 and 288A. The location of these and all other sections studied are shown in Figure 1. Similarly, lists of the samples examined and their depths are provided for all sections in Figures 16 to 22 at the back of this thesis.

Sample nomenclature for Sites 217 and 288A is in accordance with standard DSDP procedure. That is, 9.5 metre cores are cut into 1.5 metre sections numbered downwards from 1. The symbol CC refers to the core catcher located at the bottom of each core. Hence a sample numbered 217-23-3(119-121) indicates:

217	- Site Number
23	- Core Number
3	- Section Number
(119-121)	- Position of sample below top of section, measured in centimetres.

2. Active Margin Sediments

Samples from the Gaj River section in Pakistan, on what was India's active margin during the Late Cretaceous, were provided by Prof. M.F. Glaessner and Dr. B. McGowran; they were supplied by Mr. E.B. Fritz of the Tidewater Oil Company in 1960. These samples are numbered according to their collecting station (26 to 31, up-section) followed, in brackets, by an interval number.

3. Passive Margin Sediments

Two groups of samples from the passive margin of Western Australia have been examined. One group comes from five sections through the Late Cretaceous units of the Carnarvon Basin. These were provided by Dr. D. Belford of the Bureau of Mineral Resources, Canberra. Individual samples are referred to by the numbers assigned by Dr. Belford. Three distinct lithological units are recognised: the Toolonga Calcilutite (sample numbers 0036 to 0049 and 0412 to 0418), Korojon Calcarenite (sample numbers 0121 to 0152) and the Miria Marl (sample numbers 0153 to 0155 and 0161 to 0163).

The second group of samples comes from two wells on the offshore Northwest Shelf, Withnell No. 1 and Minilya No. 1. Sidewall core material was provided by Ms M. Apthorpe and Woodside Offshore Petroleum Pty. Ltd. The samples are referred to by their sub-bottom depth preceded by a W or M as appropriate.

BIOSTRATIGRAPHIC FRAMEWORK

The sections studied contain a paucity of the biostratigraphic events commonly used in generalized zonal schemes (see van Hinte, 1976 and reference therein). This means that an authoritative reassessment of these zonal schemes is beyond the scope of the material. In this work van Hinte's,(1976) scheme is used with two important modifications.

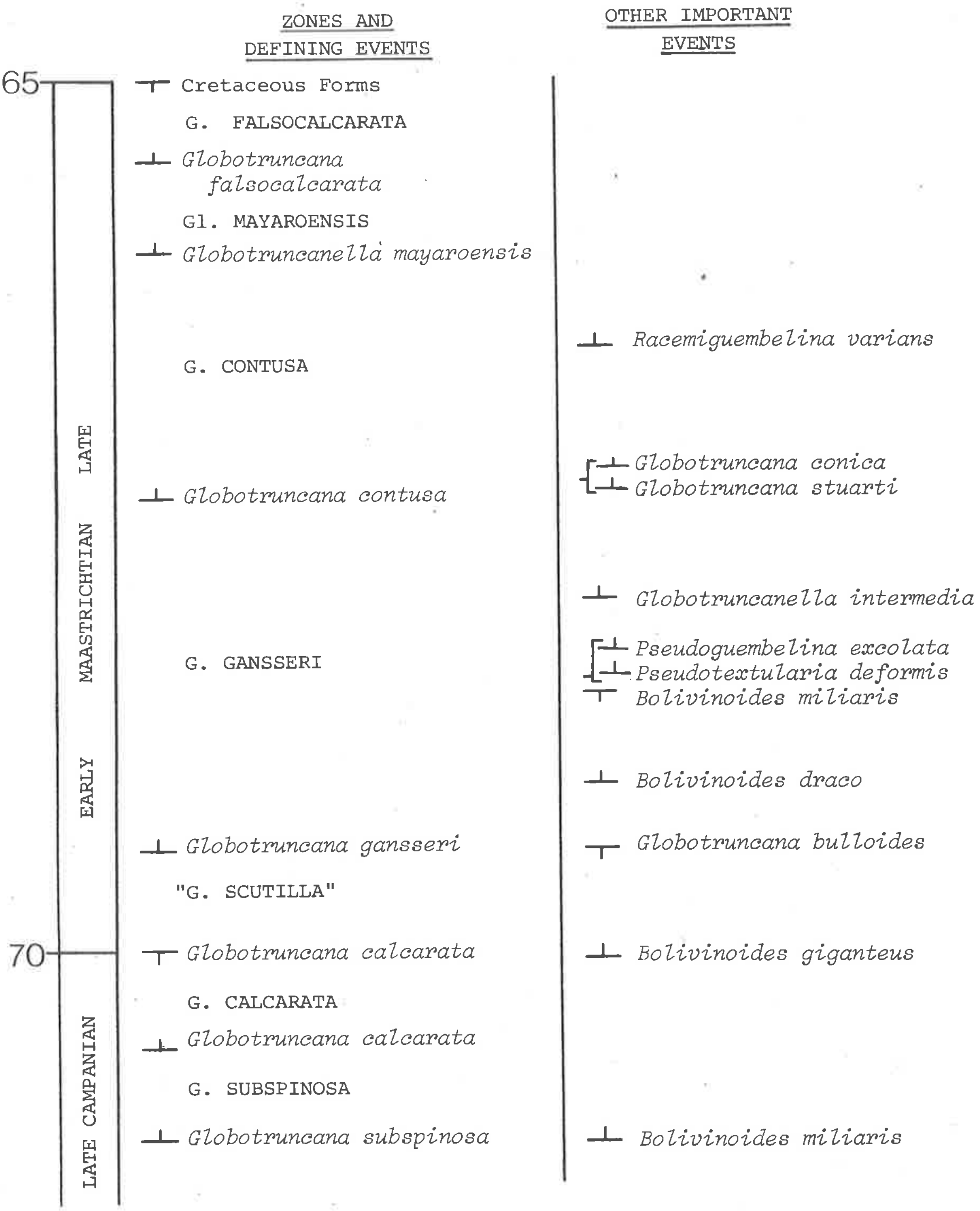


FIGURE 2: Biostratigraphic framework. Sources for zones and defining events, van Hinte 1976, McGowran 1978, and Kassab 1978, other events, van Hinte 1976, Barr 1976, McGowran 1976, and Masters 1977.

(1) A Late Cretaceous sub-zone (the *Globotruncana falsocalcarata* sub-zone) is recognised. It is defined as the interval between the appearance of the eponymous species and the final extinction of Cretaceous planktonic forms. There is some uncertainty as to the relationship between the first appearances of *G. falsocalcarata* and *Globotruncanella mayaroensis*, since the two species appear to be almost mutually exclusive. Masters, (1977) suggests that the species appear synchronously; however, Kassab, (1978), who asserts that *G. falsocalcarata* appears significantly after *Gl. mayaroensis*, is followed in this study.

(2) McGowran, (1978) suggested that van Hinte, (1976) ascribed too short a range to *Globotruncana contusa*, and that at least in the Indian Ocean area this species appears before *Globotruncana stuarti*. Confirmation of this cannot be provided here. However, in Site 288A, specimens of *G. contusa* have been found within the *Lithraphites quadratus* nannofossil zone (Shafik, 1975) somewhat earlier than is shown by van Hinte, (1976), indicating that on the balance of probabilities, McGowran is correct. Therefore the *G. contusa* zone, as recognised here, is approximately equivalent to the combined *G. stuarti* and *G. contusa* zones of van Hinte.

Figure 2 shows this modified zonal scheme along with other useful biostratigraphic events and together they provide the biostratigraphic framework for the following discussion.

INTERVAL Cores and Sub-Bottom Depth	LITHOLOGY
Cores 17-22 (421-480 M)	Nannofossil chalk
Cores 23-35 (480-600 M)	Micarb chalk, partly shelly, becoming cherty down hole.
Cores 36-37 (600-614.5 M)	Dolarenite, chert, claystone with some shelly micarb chalk in upper part.

From Sclater, von der Borch and others, 1974.

TABLE 1: LITHOSTRATIGRAPHIC UNITS DSDP SITE 217

OCEANIC SEDIMENTS

DSDP SITE 217

Introduction

Site 217 was drilled by the D/V Glomar Challenger in about three kilometres of water on the northernmost extremity of the Ninetyeast Ridge (8° 56' N, 90° 32' E). The ridge is the major submarine topographic feature of the Eastern Indian Ocean, running North/South along ninety degrees east of longitude for a distance of about 4,500 kilometres. It consists of an elongate pile of extrusive material which sits on the Indian plate a little to the west of the former transform fault between the Indian and Australian plates. Its age and depth increase from south to north. Sclater, von der Borch and others, (1974), and Sclater and Fischer, (1974) suggest that the ridge was formed by a magmatic source near the spreading centre, "leaking" material onto the newly formed oceanic crust of the Indian plate as it moved northwards.

Thirty-seven cores were taken in all, with Cretaceous sediments occupying cores 17 to 37 inclusive. Sclater, von der Borch and others, (1974) divided the Cretaceous section into the three informal lithostratigraphic units shown in Table 1.

Biostratigraphy

Macrofossils: Sponge spicules are common in cores 37 to 30. The Cretaceous pelecypod *Inoceramus* is also common in these cores, but it continues above core 30. After a sharp

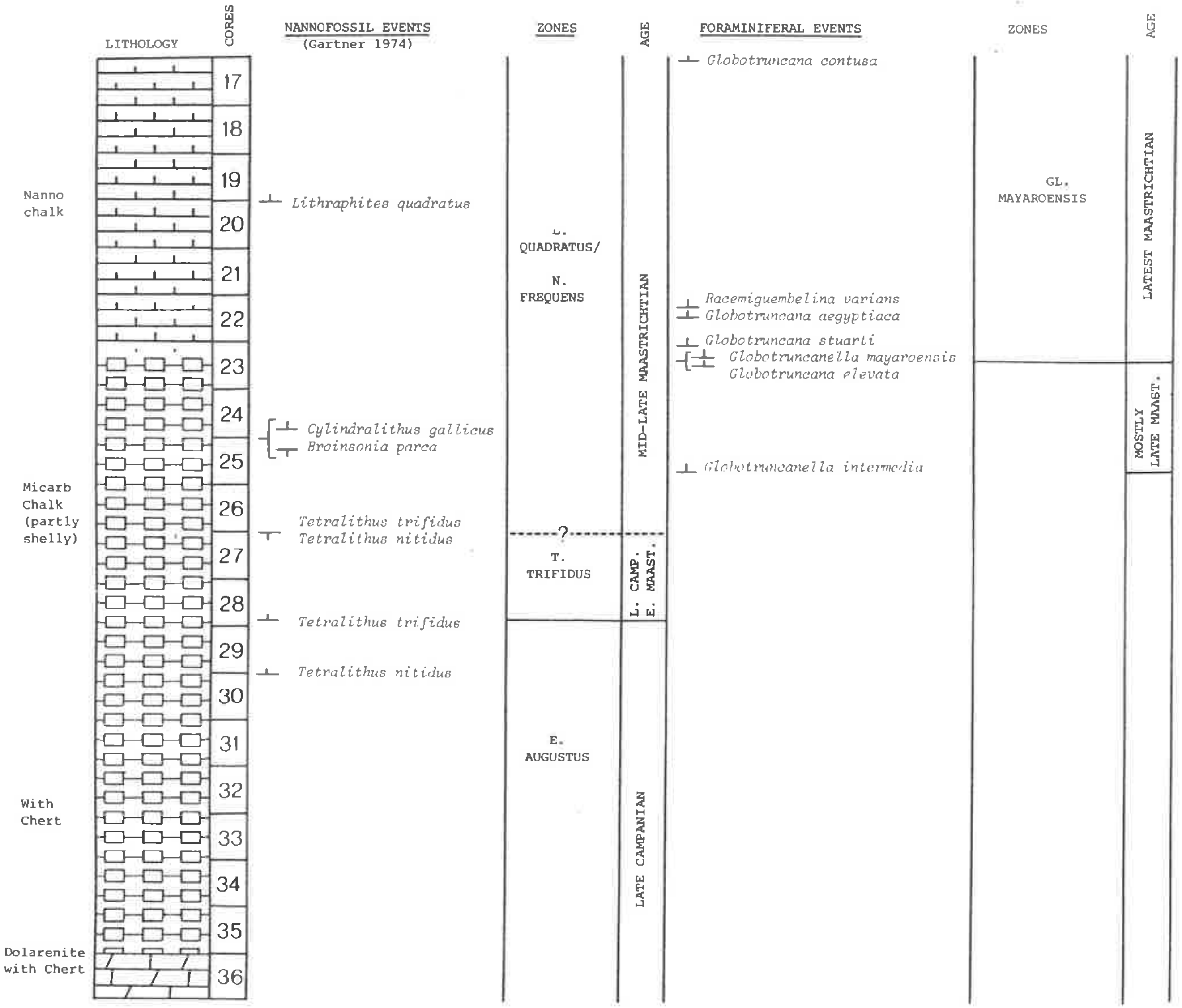


FIGURE 3: Foraminiferal and nannofossil biostratigraphy, DSDP Site 217. Lithology simplified from Sclater, von der Borch and Others, 1974.

peak in abundance in core 28, it too fades away up-section.

Using these macrofossil distributions and the lithological units listed in Table 1, McGowran (1974) recognised a series of facies which indicate that Site 217 underwent rapid sinking soon after formation. Pimm and others (1974) extended this work, recognising these facies at each site drilled along the crest of the ridge. They then showed their diachronous nature from north to south, thus supporting the model of ridge formation outlined above.

Nannofossils: Nannofossil determinations were carried out by Gartner (1974) and Bukry (1974). Although each worker produced an essentially similar zonation for the site, Gartner's is more complete, and with one change, is included here (Fig. 3). The modification is the shortening of the *Tetralithus trifidus* zone which Gartner had extended up to the top of core 25. This resulted in its overlapping with the range of *Globotruncanella intermedia* which is unlikely (van Hinte, 1976). It is not clear from the data published by Gartner (1974) why the decision was made to place the top of the zone in this position. Gartner has defined the top of the zone as the first appearance of *Lithraphites quadratus* and in Site 217 this species' first appearance is in core 19, within the *Gl. mayaroensis* zone. In this study the top of the *T. trifidus* zone is tentatively placed at the last appearance of the name species, considered by many authors to be equivalent to the first appearance of *L. quadratus*, at the base of core 26, so avoiding the overlap with *Gl. intermedia*.

CORES	AGE	DOMINANT PLANKTONIC FORMS	
17	LATEST MAASTRICHTIAN	GLOBOTRUNCANIDS: PEAK IN ABUNDANCE AND DIVERSITY OF HETEROHELICIDS.	
18			
19			
20			
21			
22			
23	MOSTLY LATE MAASTRICHTIAN		
24		GLOBIGERINIDS: DOMINANTLY HIGH TROCHOSPIRAL FORMS *(Rugoglobigerina)*	
25			
26			
27	LATE CAMP. EARLY MAAST.		
28			
29	LATE CAMPANIAN		LOW/HIGH TROCHOSPIRAL OVERTURN
30		GLOBIGERINIDS: DOMINANTLY LOW TROCHOSPIRAL FORMS *(Rugoglobigerina = Archaeoglobigerina* McGowran, 1974*)*.	
31			
32			
33			
34			
35			
36		GLOBIGERINIDS: PLANISPIRAL FORMS *(Globigerinelloides)*	PLANISPIRAL/LOW TROCHOSPIRAL OVERTURN

TABLE 2: Major planktonic overturns DSDP Site 217.

Foraminifera: Foraminifera are common in all cores except 37 where they are absent. Their preservation is variable: in the lower cores (36-28) their tests are silicified and poorly preserved. Up-section of core 28, preservation generally improves until core 23, above which there is a sharp increase in the numbers of tests showing dissolution. Tests become corroded, thin walls are punctured, and the whole sample takes on a pink-brown tint. At the same time foraminiferal numbers decrease. Within cores 17, 18 and 19, there is a spectacular reduction in the number of planktonic forms. Although high plankton numbers return in the final part of core 17, preservation does not improve.

Investigations of the foraminiferal content of Site 217 were carried out by Pessagno and Michael (1974) and McGowran (1974, 1977). All workers record a striking pattern of keeled planktonic assemblage changes; a brief qualitative outline of all plankton changes is provided in Table 2.

It is the late development of a diverse keeled (Globotruncanid) assemblage that is of the most interest here. The Globotruncanids are the mainstay of most Late Cretaceous zonal schemes; the unusually late development of a diverse keeled assemblage means that most important keeled species are not found until after the first occurrence of *Gl. mayaroensis* in core 22, so that only the final Maastrichtian zone can be recognised (Fig. 3). The significance of the other changes in planktonic assemblages listed in Table 2 is unclear but these changes appear to be correlative with sections from Western Australia and the North West Shelf, hence their exact age is important. At Site 217 both occur before the first appearance of *T. trifidus* (Gartner, 1974) indicating a minimum age of Late Campanian. At this stage, an assertion that both planktonic overturns occur post the first occurrence of *B. miliaris*, restricting their age to Late Campanian, will have to suffice. Evidence for this is contained in Chapter Two.

The only other biostratigraphically useful event is the non-evolutionary appearance of *Gl. intermedia* at the base of Core 25. This event dates the sediments above as mostly Late Maastrichtian. Nannofossil dates indicate a Late Campanian - Early Maastrichtian age for core 27. Thus the entire middle Maastrichtian must be compressed into core 26 (Fig. 3). It is more likely that a major hiatus, representing most of that interval, is present in the section just below the first appearance of *Gl. intermedia*.

Cretaceous/Tertiary Boundary

The Cretaceous/Tertiary Boundary lies between cores 16 and 17 (McGowran, 1974). A change from nannofossil chalk to a clay and foraminifera rich nannofossil chalk has been recorded at this level (Sclater, von der Borch and others, 1974). An increase in bioturbation is also recorded. On foraminiferal evidence core 16 section 6 is assigned to zone P1.b and the core catcher to zone P1.a (McGowran, 1974), indicating a slight micropalaeontological break. Data from nannofossils also suggests that the earliest Danian is missing on the Ninetyeast Ridge (Gartner, 1974).

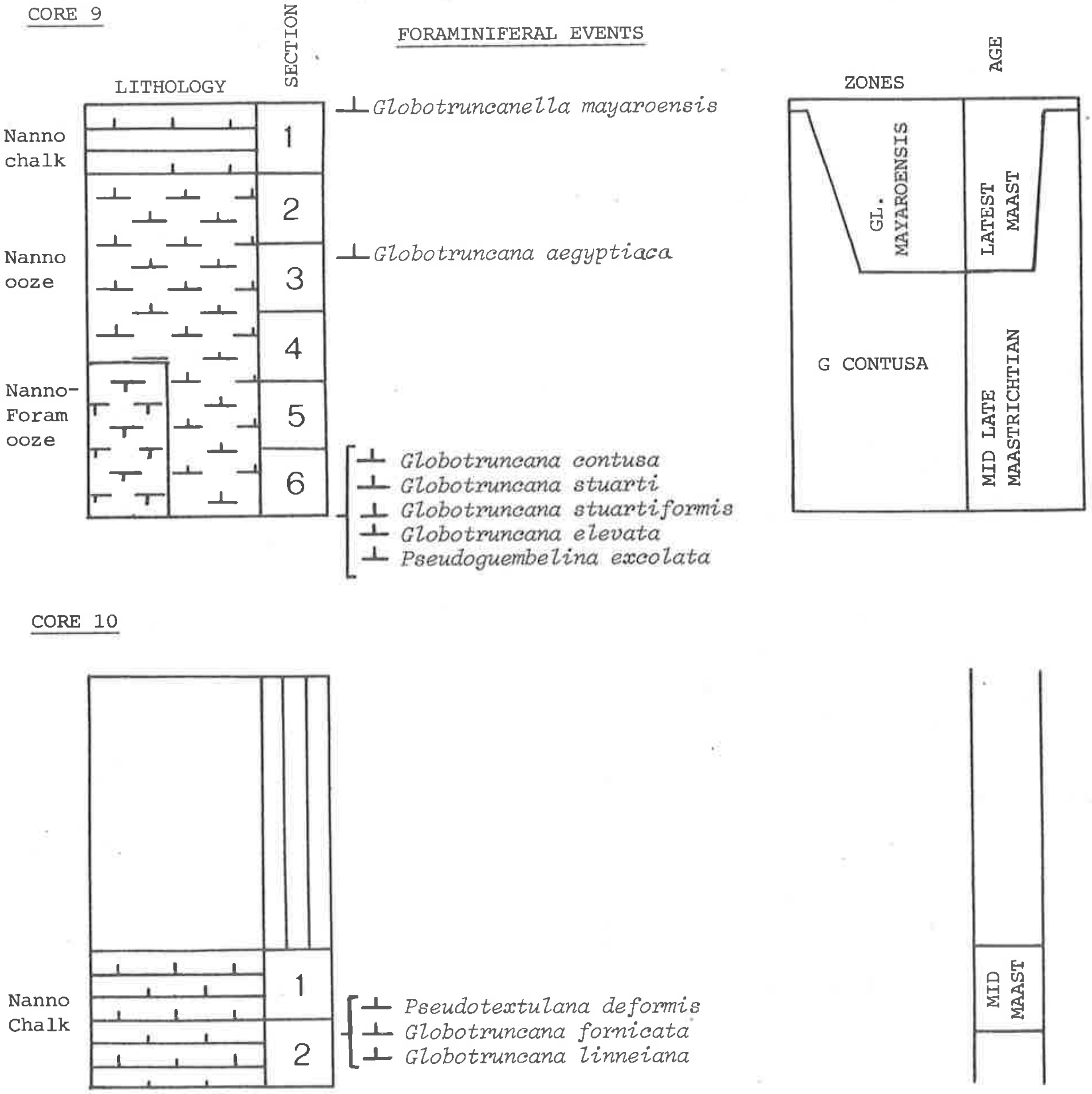


FIGURE 4: Foraminiferal biostratigraphy, Cores 9 and 10, DSDP Site 288A. Simplified lithology from Andrews, Packham and Others, 1975.

DSDP SITE 288A

Introduction

For comparative purposes, a small suite of samples from the Maastrichtian of Site 288A (cores 9 and 10) has been examined.

Site 288A was drilled to a depth of 288.5 metres in about three kilometres of water. It is situated on the south-eastern flank of the Ontong-Java Plateau, South West Pacific Ocean, 5° 53.35'S, 161°44.53'E (Andrews, Parkham and others, 1975).

Biostratigraphy

In both cores the foraminiferal assemblage is dominated by planktonic species. The few benthonic forms were not considered.

Core 10 contains a somewhat impoverished fauna made up of almost equal numbers of *Globigerinelloides* species, biserial Heterohelicids and double keeled *Globotruncana* species (*G. linneiana* and *G. fornicata*). The presence of *Pseudotextularia deformis* in core 10 section 2 indicates a maximum age of middle Maastrichtian (Fig. 4).

Core 9 on the other hand, contains a large, diverse, beautifully-preserved fauna dominated by single keeled *Globotruncana* species (*G. stuarti*, *G. stuartiformis* and *G. elevata*). Multiserial forms of the Heterohelicids are present in considerable numbers, especially *Planoglobulina acervulinoides*. Oddly, *Racemiguembelina varians* is absent.

Most of the core can be assigned to the *Globotruncana contusa* zone (Fig. 4) (mid - Late Maastrichtian). The zonal species is first found in core 9CC. Saito (1975) assigns the core to the *G. gansseri* zone, but this species has not been found. It is possible that Saito confused juvenile *Bucherina sandidgi* with *G. gansseri*.

The topmost sample in core 9 contains *Gl. mayaroensis*, albeit rare, providing a solid latest Maastrichtian age.

Cretaceous/Tertiary Boundary

The boundary falls somewhere within 30 metres of uncored section between cores 8 and 9. The earliest Tertiary dated (core 8CC) is Danian zone P1.c.

ACTIVE MARGIN SEDIMENTS

GAJ RIVER SECTION, PAKISTAN

Introduction

The sediments exposed by the Gaj River range in age from Late Cretaceous in the West to Early Miocene in the East. A suite of samples from the Cretaceous Korara shale (Kureshy, 1978) has been examined.

Biostratigraphy

The Gaj River section falls into two halves with the first appearance of *G. falsocalcarata* occurring at the midpoint. Samples from the lower half of the section produce an abundant fauna, the preservation of which is poor but

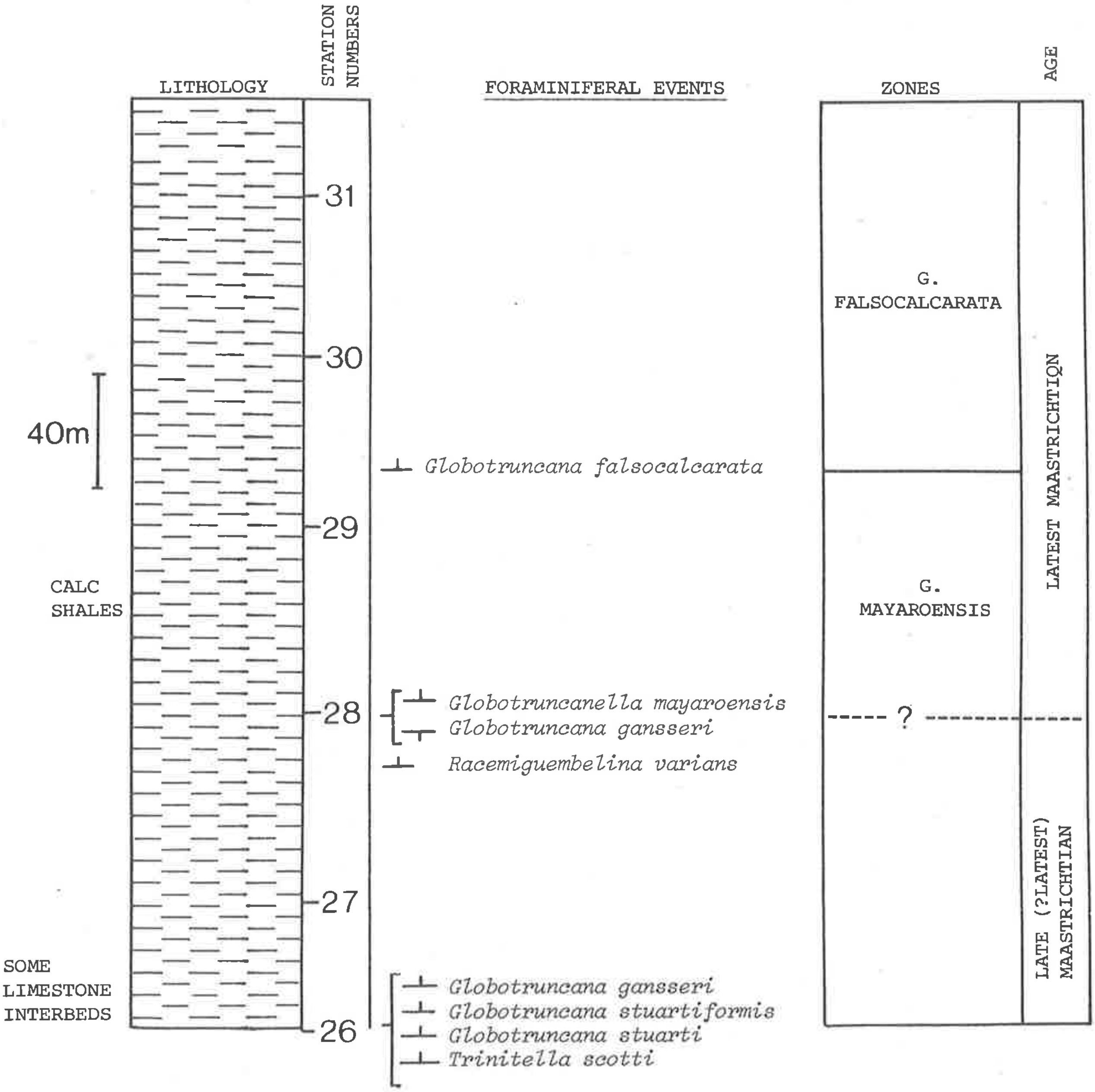


FIGURE 5: Foraminiferal biostratigraphy Gaj River Section. Simplified lithology from strip log provided by Mr E.P. Fritz.

adequate, a result of recrystallization. The large numbers of planktonic forms are dominated by single keeled globotruncanids (*G. stuarti, G. elevata* and *G. conica*).

Above the first appearance of *G. falsocalcarata,* foraminiferal numbers drop sharply, especially the benthonic forms. Preservation deteriorates but again it is the benthonics which suffer most. The benthonic assemblage is dominated by a flood of praebuliminids, the planktonic assemblage by *G. falsocalcarata.*

As well as heralding a period of deteriorating preservation, the first appearance of *G. falsocalcarata* also marks the base of the latest Maastrichtian subzone (Fig. 5). In that portion of the section below the subzone, there are few foraminiferal events to provide an age.

A single, but excellent specimen of *Gl. mayaroensis* from sample 27 (20-30), fairly low in the section, extends the Late Maastrichtian age downwards. The lowest sample contains *Trinitella scotti.* Both Masters (1977) and Postuma (1962) attribute to this species the same range as *Gl. mayaroensis* which would result in the assignment of the entire section to the *Gl. mayaroensis* zone. (Kureshy, 1979, has suggested this.) On the other hand, Pessagno (1967) and Smith and Pessagno (1973), show *T. scotti* as appearing slightly before the zone species. Nevertheless, a Late Maastrichtian age for the Korara shales cannot be doubted.

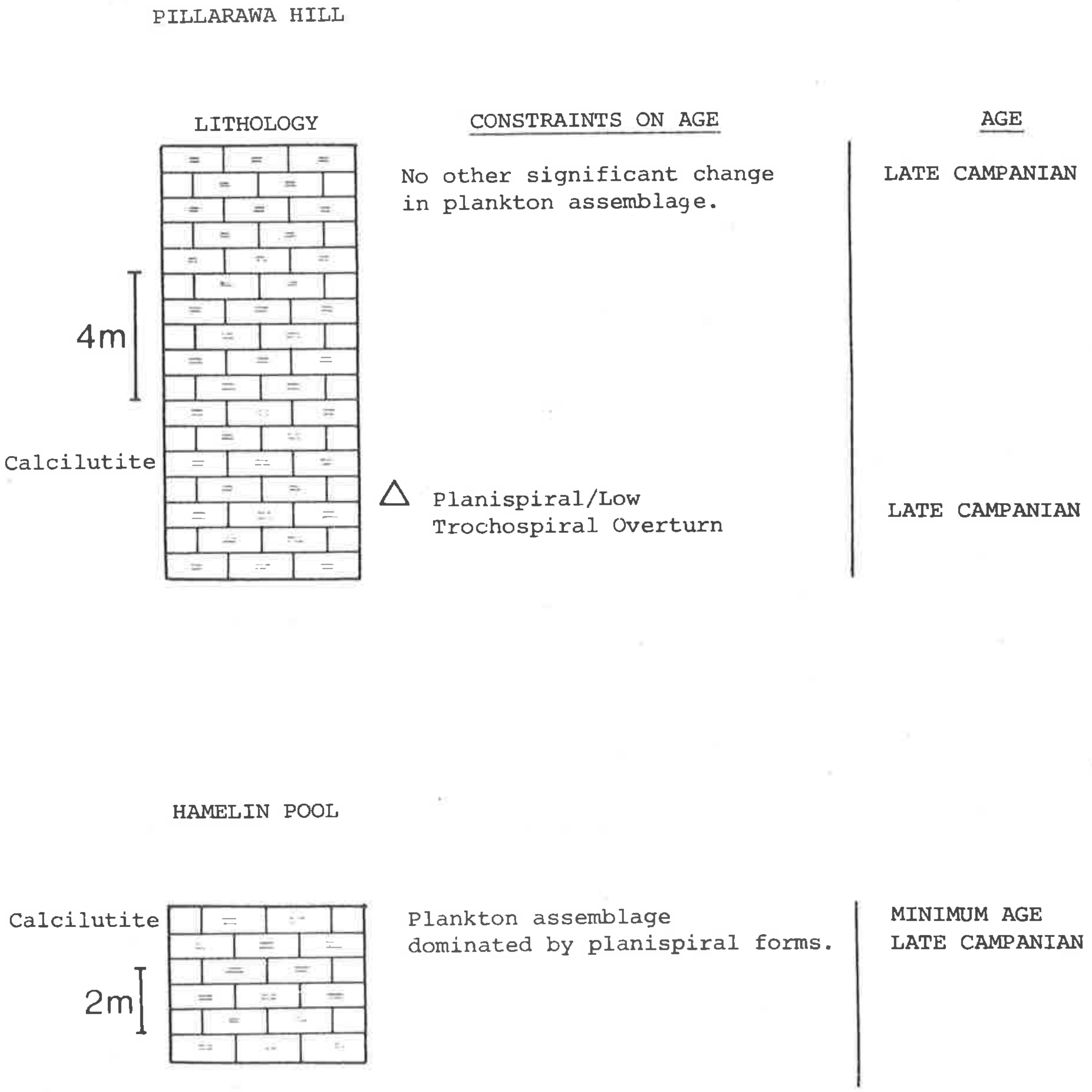
Cretaceous/Tertiary Boundary

The Cretaceous/Tertiary contact at Gaj River occurs within a lithologically continuous sequence (McGowran, 1968; Dorreen, 1974). Dorreen (p. 186) in fact states that the contact "cannot be picked in the field". It has been suggested that the lack of a lithological break is reflected in there being no significant faunal break (Dorreen, 1974; Kureshy, 1970). That is, both the latest Maastrichtian and the earliest Danian are present. Certainly the latest Maastrichtian is present. However, the appearance of *Planorotalites compressa* in the earliest Tertiary sample (McGowran, 1978; Dorreen, 1974, and confirmed in this study) indicates that most, if not all, the Danian is missing. Thus, despite a lithologically continuous section, a major faunal break is evident.

PASSIVE MARGIN SEDIMENTS

ONSHORE SECTIONS - CARNARVON BASIN

Uncertainty surrounds the exact stratigraphic location and precise age of the three Late Cretaceous units from the Carnarvon Basin. Various authors have placed the Korojon Calcarenite both above and below the Toolonga Calcilutite (Playford and others, 1975; Quilty, 1977). The reported age of the thin Miria Marl varies from Late Campanian - Early Maastrichtian (Brunnschweiler, 1966, determination based on Ammonites), to Middle Maastrichtian (Edgell, 1957; Belford, 1959; Foraminifera) to latest Maastrichtian (McGowran, 1968; Foraminifera). The sections studied here can go some way towards resolving the problem.



No other significant change in plankton assemblage.

Plankton assemblage dominated by planispiral forms.

Figure 6: Constraints and age of the Toolonga Calcilutite. Simplified lithology from Playford and others, 1975.

TOOLONGA CALCILUTITE

Introduction

Two sections through the Toolonga Calcilutite were studied. One, from Pillarawa Hill where the section is about 14 m thick, the other is thinner (about 5 m thick) and comes from Hamelin Pool. Quilty (1977) records the lithology of the unit as being ". . . greenish calcilutite often massive and leached in outcrop to give the appearance of white chalk."

Biostratigraphy

All samples yielded abundant, well preserved foraminifera, however, both sections lack any biostratigraphically useful species. Fortunately the Pillarawa Hill section contains a plankton overturn comparable to one at Site 217.

Samples from the bottom of the section (numbers 0036 to 0038) contain a planktonic fauna dominated by non-keeled planispiral forms (*Globigerinelloides* spp.). The rest of the section yields a plankton assemblage comprising mainly non-keeled low trochospiral forms (*Hedbergella bulbosa*) (Fig. 6). The same planispiral/low trochospiral overturn at Site 217 is dated as Late Campanian (Table 2). The lack of an assemblage dominated by non-keeled, high trochospiral forms confirms that the topmost part of the section can be no younger than Late Campanian.

The entire planktonic assemblage from the Hamelin Pool section is composed mainly of non-keeled planispiral forms

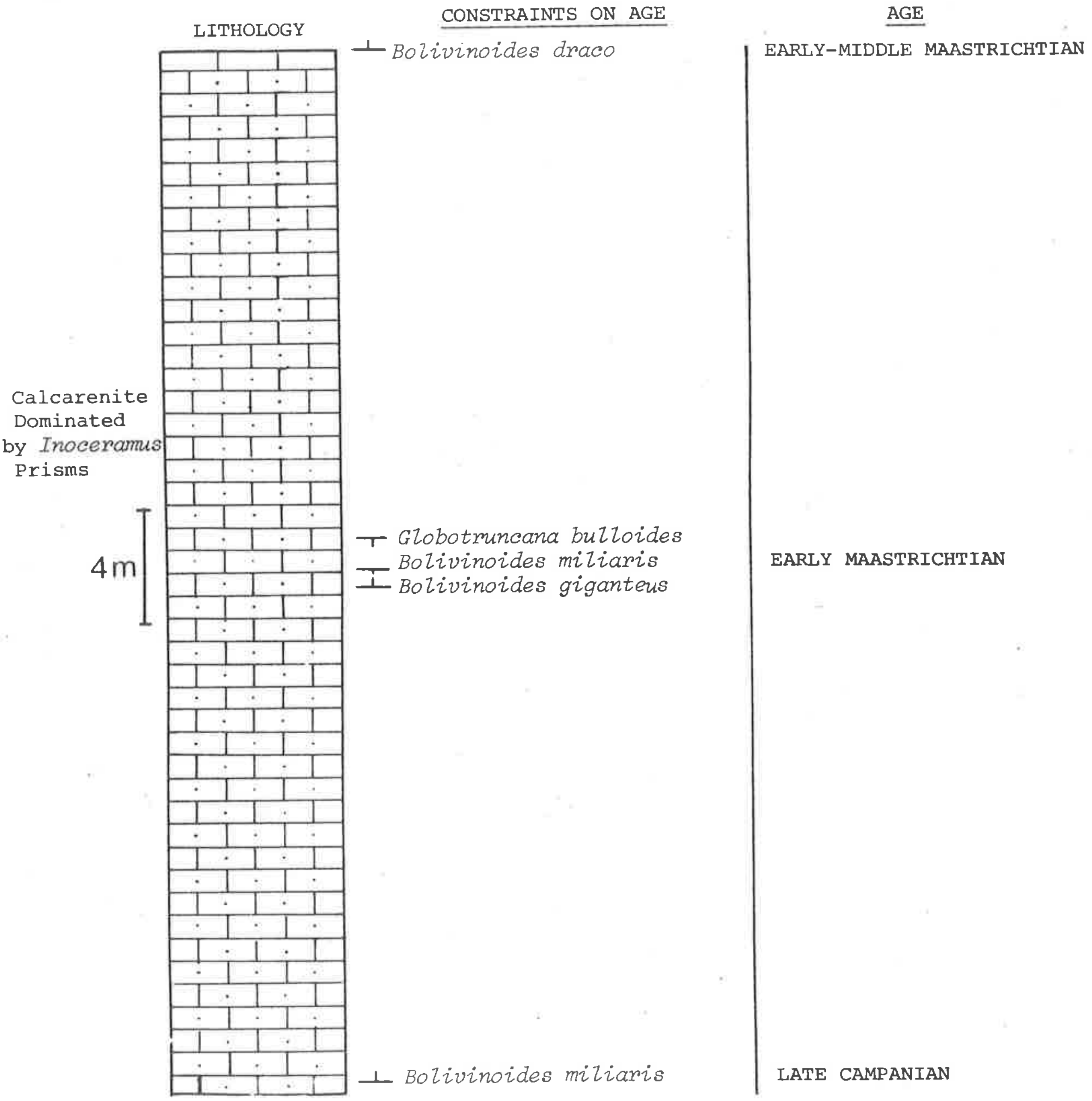


Figure 7: Constraints and age of the Korojon Calcarenite. Simplified lithology from Playford and others, 1975.

indicating that this section is stratigraphically below and/or equivalent to the base of that from Pillarawa Hill.

KOROJON CALCARENITE

Introduction

Thirty-two samples from the type section of the Korojon Calcarenite in C-Y Creek have been used in this study. These represent a thickness of about 39 metres.

The lithology of the C-Y Creek section is described in great detail by Condon and others (1956). As pointed out by Quilty (1977), its lithology is the same as the Toolonga Calcilutite except for the addition of huge amounts of *Inoceramus* prisms.

Biostratigraphy

As with the Toolonga Calcilutite, all samples produced a large, well preserved foraminiferal assemblage. There is some evidence of reworking; stained specimens are found in samples which otherwise show no staining and *vice versa*. However, in each case the reworked material constituted such a small proportion of the fauna which was recovered that it was considered negligible.

No standard zonal species have been found, nor have any planktonic overturns useful in dating the Toolonga Calcilutite; the assemblage contains instead an equal mix of low and high trochospiral forms.

Despite the dearth of standard zonal species a number of constraints can be placed on the age of the section (Fig. 7):

(i) The appearance of *Bolivinoides miliaris* near the base of the section provides a maximum age of Late Campanian.

(ii) The overlap of the ranges of *B. miliaris* and *Bolivinoides giganteus* in samples 0138 and 0139, half-way through the section is indicative of an Early Maastrichtian age. This is confirmed by the last occurrence of *G. bulloides* in sample 0140.

(iii) The final sample (0152) contains *Bolivinoides draco*, again suggestive of an Early Maastrichtian age.

In summary, the Korojon Calcarenite from C-Y Creek ranged in age from ?Late Campanian to Early Maastrichtian.

MIRIA MARL

Introduction

The top of the Korojon Calcarenite marks the close of the first phase of shelf carbonate sedimentation in the Carnarvon Basin. A second very brief but widespread phase is marked by the Miria Marl. It is a thin (0.6 - 2.1 m thick, Playford and others, 1975) unit consisting of "calcarenite and light greenish-grey marl".

Two sections were used: one from Toothawarra Creek (type section) where the unit is about 1.2 m thick, and the other from the C-Y Creek where a thickness of 1 m is recorded.

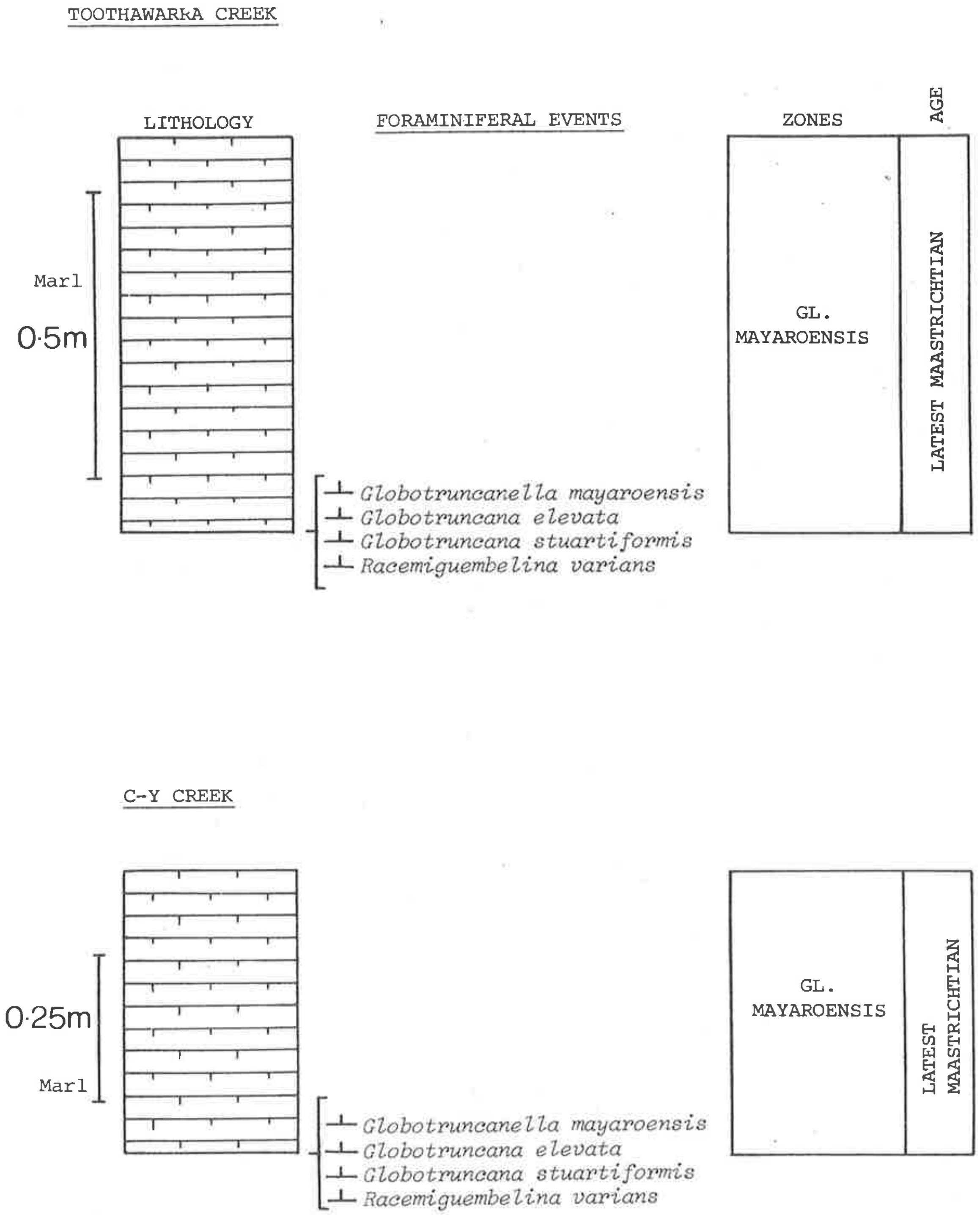


Figure 8: Constraints and age of the Miria Marl. Simplified lithology from Playford and others, 1975.

Biostratigraphy

Each sample produced a diverse and well preserved microfauna. The two sections are identical and can be treated together.

Plankton diversity in the Miria Marl is higher than in the underlying Korojon Calcarenite. Multiserial heterohelicids and both single and double keeled globotruncanids are found. One member of this latter group notable for its absence is *G. contusa*. A form referred to here as *G.* cf. *contusa* has a similar overall shape, but, as suggested in the systematics section, it may be more closely related to *G. arca* than *G. contusa*.

Estimates of the age of the Miria Marl vary from author to author, depending upon the fossil groups used. The variation is due largely to the non-recognition of standard zonal species. During this study, however, *Gl. mayaroensis* has proved to be reasonably common in every sample examined (Fig. 8), indicating conclusively a latest Maastrichtian age for the unit.

Cretaceous/Tertiary Boundary

The Miria Marl is disconformably overlain by the Middle Paleocene Boongerooda Greensand (McGowran, 1978), indicating a significant hiatus across the boundary.

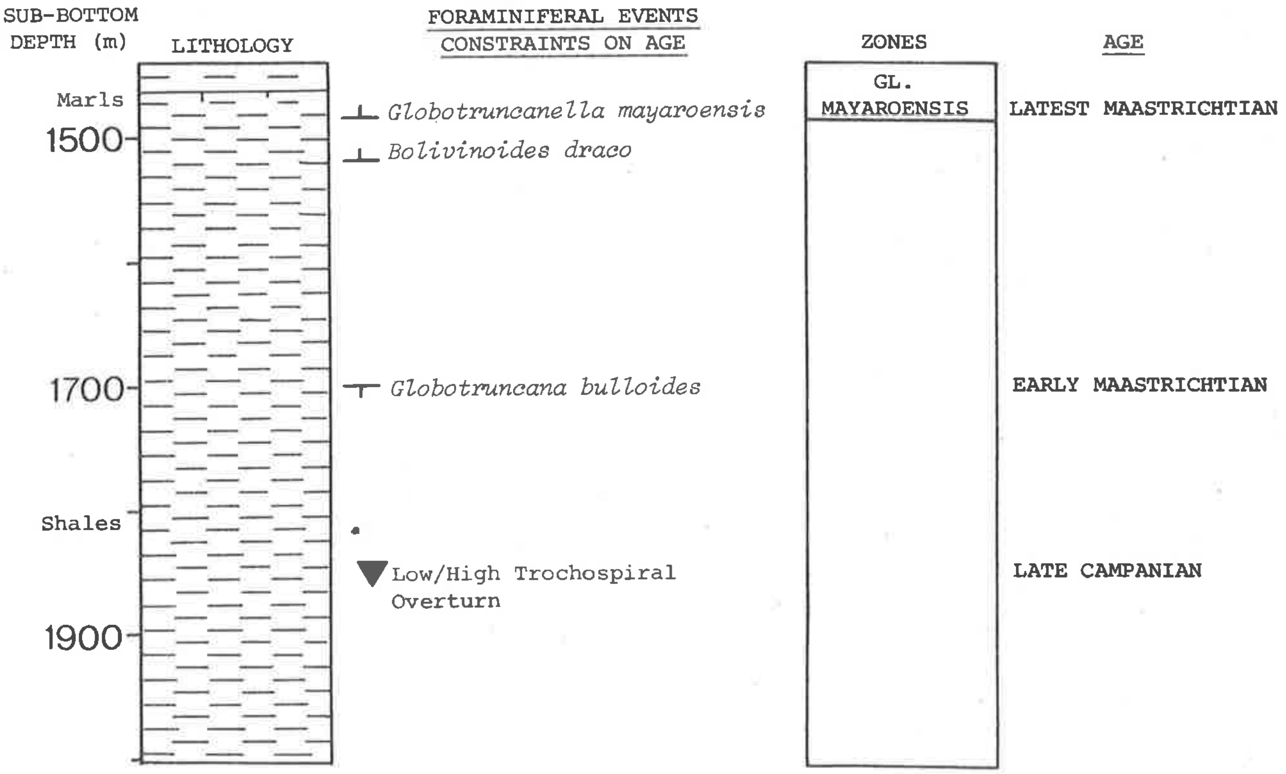


Figure 9: Constraints and age of Withnell No. 1. Simplified lithology from Apthorpe, 1979.

OFF SHORE SEDIMENTS - NORTHWEST SHELF

Material from two wells on the Northwest Shelf has been examined. A summary of the lithology and estimates of the ages of the sections has been published by Apthorpe (1979).

WITHNELL NO. 1

Introduction

This well is located in the Dampier sub-basin (20°01'12"S, 115°48'15"E). The section studied lies between 1440 m and 2010 m sub-bottom depth.

Biostratigraphy

Samples yielded varying numbers of foraminifera with very low plankton numbers occasionally being recorded. Preservation is in general poor.

In common with the Carnarvon Basin material, a major problem in these two wells is the lack of solid biostratigraphic control, since standard zonal species are rare. The top three samples of the section (W1485, W1460, W1440) contain *Gl. mayaroensis*, fixing their age as latest Maastrichtian, equivalent in part at least to the Miria Marl. Below sample W1485 it is difficult to do more than place the following constraints on the age of the section (Fig. 9):

(i) Between samples W1950 and W1799, towards the base of the section, a low trochospiral - dominated plankton assemblage gives way to a high trochospiral assemblage. The same overturn occurs in the late Campanian of Site 217 (Table 2).

(ii) Sample W1700, about half-way through the section, contains the last occurrence of *G. bulloides*, providing a minimum age of early Maastrichtian.

(iii) The first occurrence of *B. draco* in W1519 dates it as early Maastrichtian.

Apthorpe (1979) has suggested that the middle Maastrichtian is missing at this site. The ages deduced above would support this. Sample W1519 is dated as early Maastrichtian; thirty-five metres above it, sample W1485 contains well developed *Gl. mayaroensis* (latest Maastrichtian). Therefore all the middle and some of the Late Maastrichtian has to be accommodated in that thirty-four metres. There is one sample in this contentious interval (W1505) which contains so few planktonic foraminifera that it is impossible to rule out the possibility that it too is part of the *Gl. mayaroensis* zone. If this is the case, the likelihood of a hiatus is increased.

The situation then is exactly analogous to the relationship between the Korojon Calcarenite and the Miria Marl; it is also very similar to Site 217.

Cretaceous Tertiary Boundary

Sample W1350 is dated as zone P.1c-d and represents the oldest Tertiary sample recovered and accurately dated. An

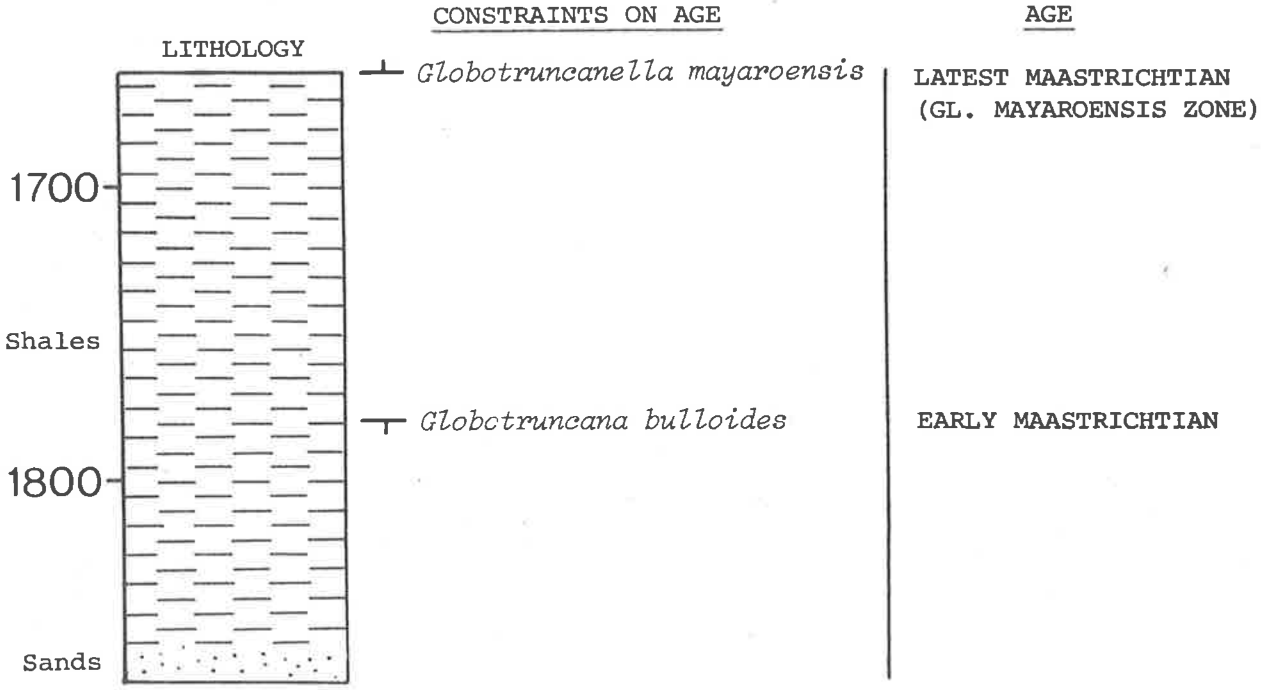


Figure 10: Constraints and age of Minilya No. 1. Simplified lithology from Apthorpe, 1979.

impoverished benthonic fauna does continue below this to 1430 m (R. Heath, pers. comm., 1981).

MINILYA NO. 1

Introduction

The second well (Minilya No. 1) is situated about 360 kilometres to the north-east of Withnell No. 1 in the Outer Beagle sub-basin (180°10'28"S, 118°48'56"E). The section studied lies between 1868 m and 1686 m sub-bottom depth.

Biostratigraphy

The bottom part of the section (samples M1868 and M1841)contained little or no foraminifera. The remaining samples produced slightly higher numbers of specimens than Withnell No. 1. In common with that site preservation is poor.

There is very little information which can be used to deduce the age of the section (Fig. 10).

G. bulloides makes its first and last appearance in sample M1779, indicating that the sample is no younger than Early Maastrichtian. *Gl. mayaroensis* is common in the top sample, providing the only firm date in this section: latest Maastrichtian.

Apthorpe (1979) has suggested that this section too has a middle Maastrichtian hiatus similar to that discussed in the previous section. *B. draco*, so useful in defining the hiatus in Withnell No. 1, first appears in Minilya No. 1 at the same time as *Gl. mayaroensis*. There is no biostratigraphic event in Minilya No. 1 that can be used to determine the presence or absence of a hiatus.

Cretaceous Tertiary Boundary

The oldest dated Tertiary sample is in sample 1678.5 and is assigned to zone P.1d (R. Heath, pers. comm., 1981).

CHAPTER TWO

FORAMINIFERAL BIOFACIES PROFILES

INTRODUCTION

Processing of large amounts of palaeoceanographic data has been successfully used in the construction of various profiles in time. These include the records of fluctuations in carbonate compensation depth (van Andel, 1975) and the sea level curves of Vail and others (1977) and Kauffman (1979a). Recently, however, the emphasis has changed to the detailed analysis of short term events and shifts such as δC^{13} and δO^{18} fluctuations (Scholle and Arthur, 1980; Vincent and others, 1981) and the change from the salinity dominated Cretaceous ocean to the thermohaline controlled modern ocean.

It is understandable then that the Cretaceous-Tertiary boundary event has generated a great deal of discussion (Christensen and Birkelund, 1979,and references therein). However, there have been very few attempts to document in detail any oceanic perturbations that possibly occurred prior to the boundary event and may be reflected in the marine micropalaeontological record. One such attempt can be found in the work of Percival and Fischer (1977). These workers quantified nannofossil assemblage changes in a few metres of section each side of the boundary at Zumaya, Spain. Their excellent work, however, was on a very small scale.

In this study, changes in foraminiferal assemblages in each section have been quantified (Site 288A was omitted because of its lack of continuous coring), and assembled into a foraminiferal biofacies profile (Figs. 15 to 22).

The sections used in this study cover a time span of Late Campanian to Latest Maastrichtian. Their geographic location offers a good coverage of the North-Eastern Indian Ocean region.

METHODS

In each section, three counts were undertaken. The first ascertained the relative proportions of planktonic and benthonic forms in each sample, largely to give some indication of depositional depth. The second count split the planktonic fraction into three large groups:

(A) Globotruncanids (keeled forms)

genera included: *Globotruncana*
Globotruncanella

(B) Globigerinids (non-keeled forms)

genera included: *Bucherina*
Globigerinelloides
Hedbergella
Rugoglobigerina
Trinitella

(C) Heterohelicids

genera included: *Gublerina*
Heterohelix
Planoglobulina
Pseudoguembelina
Pseudotextularia
Racemiguembelina
Ventilabrella

In addition, where present, *Guembelitria cretacea* was counted separately.

These groups do not constitute formal taxa, but the genera included in each do possess a natural unity. Also their being defined in this way allowed easy recognition and the counting process could be carried out quickly and accurately. The aim of this count was firstly to document any gross changes in the planktonic assemblage, and secondly to use the abundance of keeled forms to give some indication of the tropical or extratropical nature of the environment of deposition.

The final count was a profiling of the changes in benthonic assemblages. More groups were used; consequently, the profile is more refined. However, unlike the plankton count, the same groups were not used in each section, selection depending upon which genera were present and their abundance. No preferred taxonomic level was used, some "groups" consisting of single genera or species.

The contents of other, larger groups require some explanation:

(A) Agglutinated: all agglutinated forms, mainly *Spiroplectammina*, *Marssonella*, *Dorothia* and *Gaudryina*.

(B) Uvigerinids: Includes two genera only, *Eouvigerina* and *Pseudouvigerina*. Occasionally, however, these were counted separately.

(C) Cibicidids: Comprises *Cibicides*, all members of the Anomalinidae and, when not counted separately, *Gyroidinoides*. *Angulogavelinella bettenstaedti* and *Karreria* were occasionally treated separately. *Angulogavelinella rakauroana* was always considered a separate group.

(D) Nodosarids: Nodosariacea.

(E) Others: All remaining genera; composition is very variable.

The results of all counts are plotted against sub-bottom depth or section thickness (Figs. 16 to 22). These figures also show a complete listing of the benthonic groups used and the total number of foraminifera counted. The final piece of information included is a select range chart, plotted on the same scale as the profiles and showing the occurrence of the more important species.

The method of counting was the same for all sections. However, only the samples from the Northwest Shelf were small enough to allow a complete count. In all other cases, a sub-sample was obtained and a great deal of care devoted to avoiding bias. In each sample an attempt was made to count at least 1,000 individuals; usually this was exceeded. Occasional samples yielded only very small numbers of specimens; only if the total number of specimens counted exceeded thirty was the data plotted.

RESULTS

The biofacies profiles document changes in foraminiferal assemblages through time. Some changes are common to several sections and can be regarded as non-phyletic events in the same way as changes in direction of coiling are used in the Tertiary.

These events are summarised in Figures 23 and 24. In these figures, selected curves have been abstracted from the

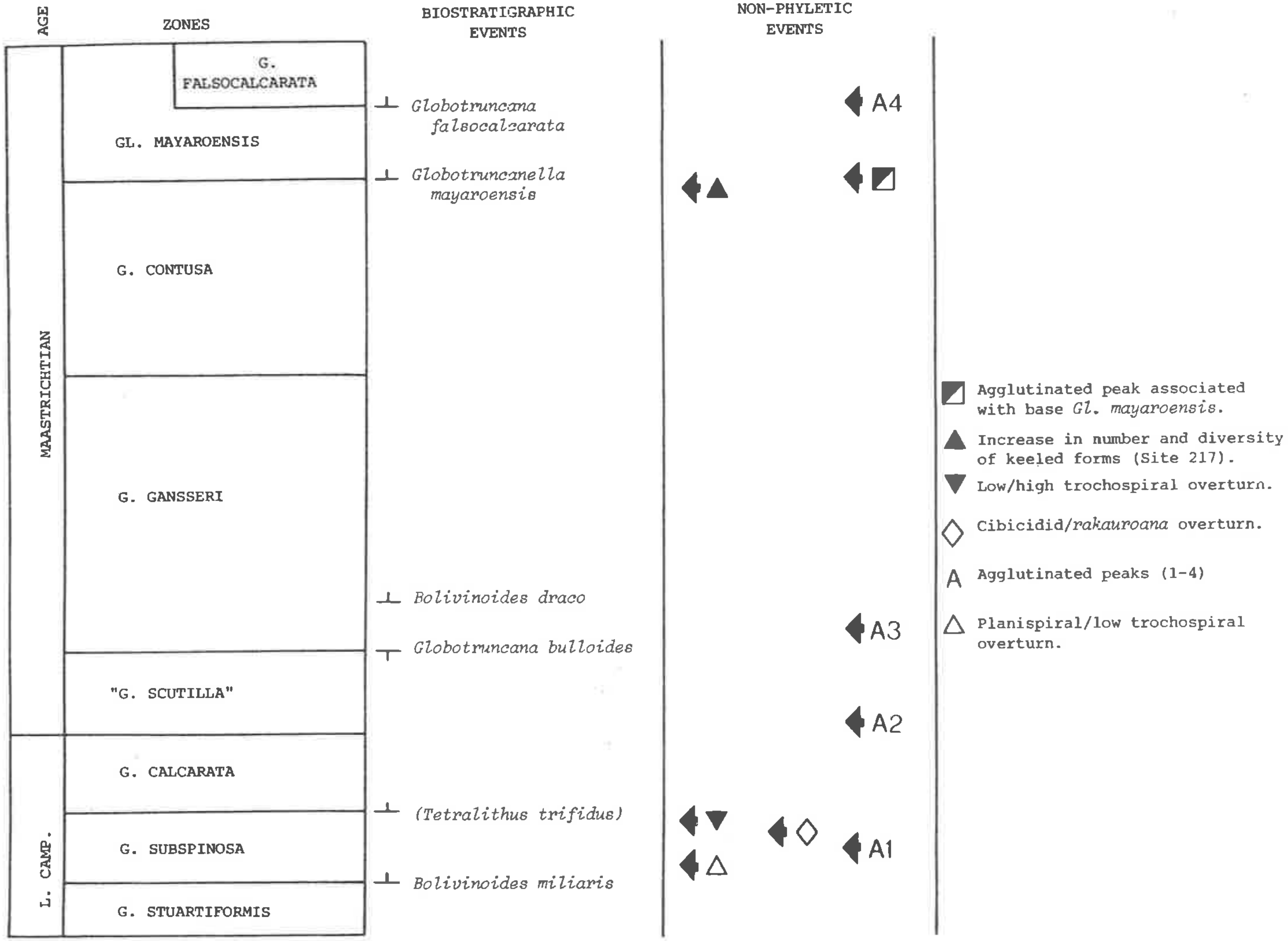


FIGURE 11: Calibration of the biofacies events by conventional biostratigraphy.

complete plots of results. Figure 23 tabulates, for each section, the percentage of plankton plus the curves of the agglutinated forms and praebuliminids from the benthonic split. Figure 24 presents the cibicidid and the *A. rakauroana* curves for selected sections. Both figures also show limited biostratigraphic data.

The most obvious feature of the biofacies profiles are the sharp fluctuations in the numbers of agglutinated forms. Figure 23 shows that five peaks in these forms have been recognised in the Late Campanian - Maastrichtian. The composition of the agglutinated peaks varies from section to section depending upon the assemblage present (see range charts). In most cases the peaks are accompanied by a drop in plankton numbers.

The oldest peak, A1, is found in Site 217, where it occurs after the planispiral/low trochospiral overturn and before the first appearance of the nannofossil species *T. trifidus* (Gartner, 1974). The recognition of A1 in the Korojon Calcarenite after the first appearance of *B. miliaris* fixes its age as Late Campanian, within the *G. subspinosa* zone. (Figure 11 shows the complete biostratigraphic framework alongside the estimated age of the non-phyletic events.) This agglutinated peak is also found at the base of Withnell No. 1, but this occurrence does not refine the date any further.

The Pillarawa Hill section of the Toolonga Calcilutite contains no clear peak. However, just above the planispiral/ low trochospiral overturn, there is a sharp reduction in agglutinated numbers and A1 is placed a little before the drop. Supporting this placement, just above A1 in some sections, is the next major non-phyletic event, the cibicidid/*rakauroana* overturn. Illustrated in Figure 24, it is the replacement of *A. rakauroana* with cibicidids. The overturn is clearly found in Site 217, Korojon Calcarenite and the Pillarawa Hill section of the Toolonga Calcilutite. *A. rakauroana* is very rare in Withnell No. 1, however, and the overturn can still be recognised on the basis of a sudden increase in cibicidids. Whenever found, this overturn always closely follows A1, or in the case of the Pillarawa Hill section of the Toolonga Calcilutite, the estimated position of A1.

Immediately above the cibicidid/*rakauroana* overturn in Withnell No. 1 and Site 217 is the low/high trochospiral event which, in the latter section, occurs before the first appearance of *T. trifidus* (Gartner, 1974). This ordering indicates that the cibicidid/*rakauroana* overturn lies within the *G. subspinosa* zone and is of Late Campanian age.

The sharp drop in numbers of *A. rakauroana* associated with the cibicidid/*rakauroana* overturn does not mark the extinction of this species. Instead the species fades slowly away up section, just reaching the Early Maastrichtian in the Korojon Calcarenite where its last appearance is coincident with the last appearance of *Globotruncana bulloides*, but extending to within the *Gl. mayaroensis* zone at Site 217.

The appearance of large numbers of *A. rakauroana* in the Late Campanian and its depletion in younger sediments, as recorded here,is at odds with data from New Zealand where the species was originally described.

There, Stevens (1978) reports that the species is a prominent part of Late Haumurian microfaunas (approximately equivalent to the Maastrichtian); it has also been recorded as high as the Paleocene (Webb, 1971).

Agglutinated peak A2 (Fig. 23) is restricted to Withnell No. 1 where it occurs in one sample only. Dating of the peak can only be described as loose. It is bracketed by the low/high trochospiral overturn and the last appearance of *G. bulloides*, indicating a broad Late Campanian/Early Maastrichtian age.

The bottom part of the section at Minilya No. 1 is notable for its lack of foraminifera (so few in fact that it is omitted from Figure23) and a sandy lithology. As far as can be determined from conventional biostratigraphy, A2 correlates with this portion of Minilya No. 1.

The next agglutinated peak, A3, is found clearly and unambiguously in every section containing sediments of the appropriate age: Site 217, Withnell No. 1, Minilya No. 1, and the Korojon Calcarenite. In all sections except Minilya No. 1, it is preceded by a peak in *Bolivinoides* numbers. Peak A3 is always followed by a rapid increase in praebuliminids (Fig. 23). The age of A3 can be determined with a fair degree of precision since it falls between the last occurrence of *G. bulloides* and the first appearance of *Bolivinoides draco*, thus indicating an Early Maastrichtian age (basal *G. gansseri* zone).

The high *Praebulimina* numbers which occur after A3 continue to the top of each section except where further agglutinated peaks occur. Site 217 is slightly more complex in that high *Praebulimina* counts have been recorded prior to A3. However, these early increases are only transitory.

The foreshortening of several species' ranges at Site 217 is a result of the late development of a keeled assemblage. The sudden increase in the number of globotruncanids which occurred at this time (Late Maastrichtian) is clearly shown in the biofacies profile for that site, and is represented symbolically in Figure 23.

The next agglutinated peak is difficult to "pin down" in time and consequently is shown in Figure 23 as a symbol rather than a time line. Both sections of the Miria Marl have a large agglutinated content (50-60%) suggesting a peak associated with *Gl. mayaroensis*. An agglutinated peak does occur just before this species' first occurrence in Withnell No. 1 and in Gaj River. In both sections there is no evidence to suggest that this peak does not fall within the *Gl. mayaroensis* zone.

At Withnell No. 1, plankton numbers are very low at the time of the peak, hence accurate age determination is impossible. The presence of *T. scotti* in the lowest sample of the Gaj River section indicates that the entire section is possibly within the *Gl. mayaroensis* zone. All this evidence suggests the presence of an agglutinated peak at or near the base of the *Gl. mayaroensis* zone.

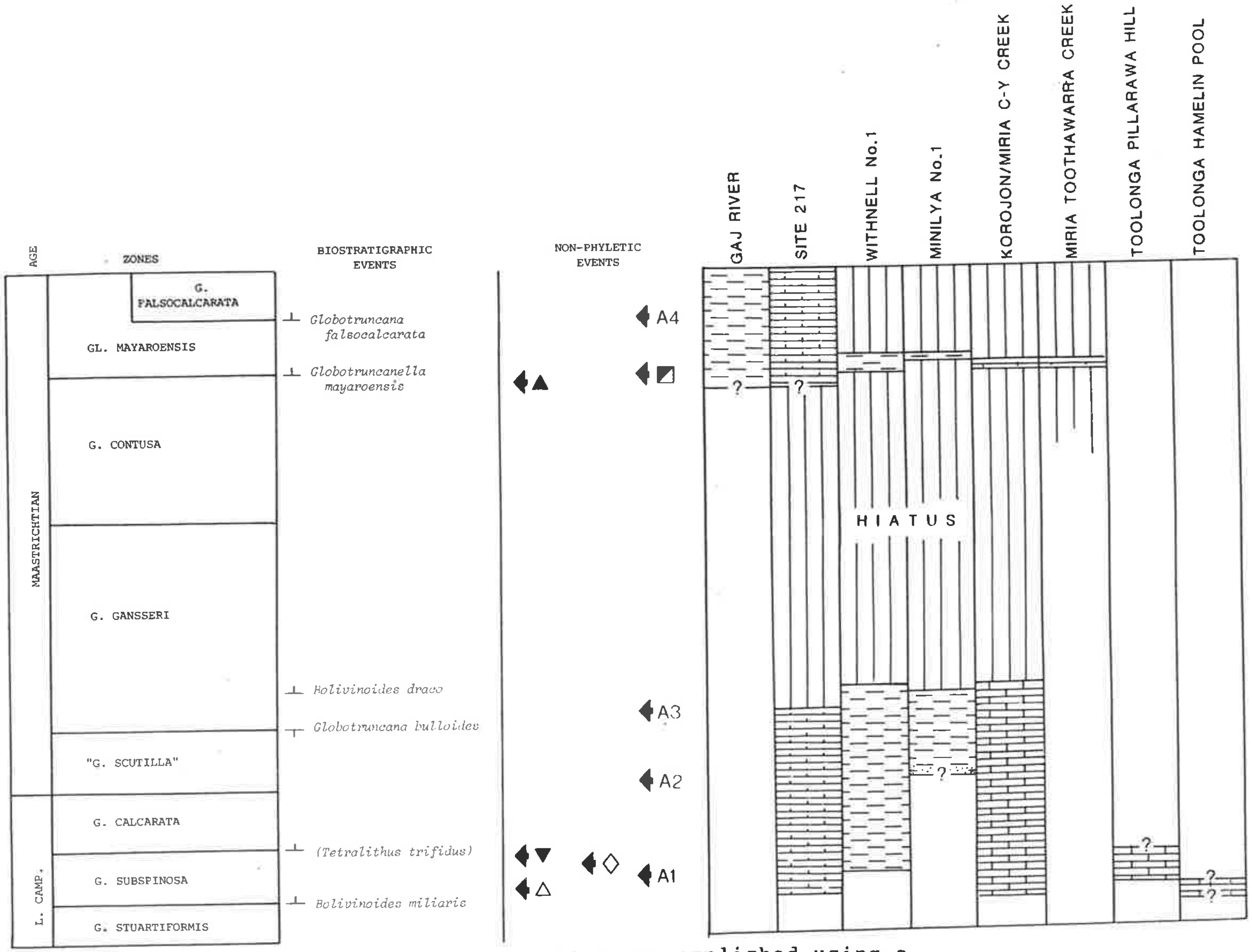


FIGURE 12: Correlations accomplished using a combination of conventional biostratigraphic events and the biofacies events. Simplified lithology from various sources.

The final agglutinated peak certainly lies within the *Gl. mayaroensis* zone as is evident in Site 217. It is also recognised in Gaj River where it occurs simultaneously with the first appearance of *G. falsocalcarata.* The peak in this section is followed by a further increase in *Praebulimina* numbers. Prior to A4, numbers of this genera are already at the elevated, post A3 level of the Western Australian sections; after A4, *Praebulimina* numbers explode, at times reaching 60% of the benthonic fraction.

At Site 217, spectacular fluctuations in Plankton numbers occur following A4.

CORRELATIONS AND HIATUSES

The events discussed above once calibrated by "classical" biostratigraphy, become available as additional tools for use in correlation. Figure 12 shows the pattern of sediment distribution obtained when the non-phyletic events and biostratigraphic framework are used in conjunction. The lower boundaries shown represent the lowest samples studied, not necessarily the bottom of the unit or well.

The basic pattern of two phases of carbonate sedimentation separated by a hiatus has long been known from the Carnarvon basin (Playford and others, 1975). Apthorpe (1979) recorded the hiatus in Withnell No. 1 and suspected its presence in Minilya No. 1. What is new here is the accurate dating of the hiatus' duration and its recognition on the Ninetyeast Ridge.

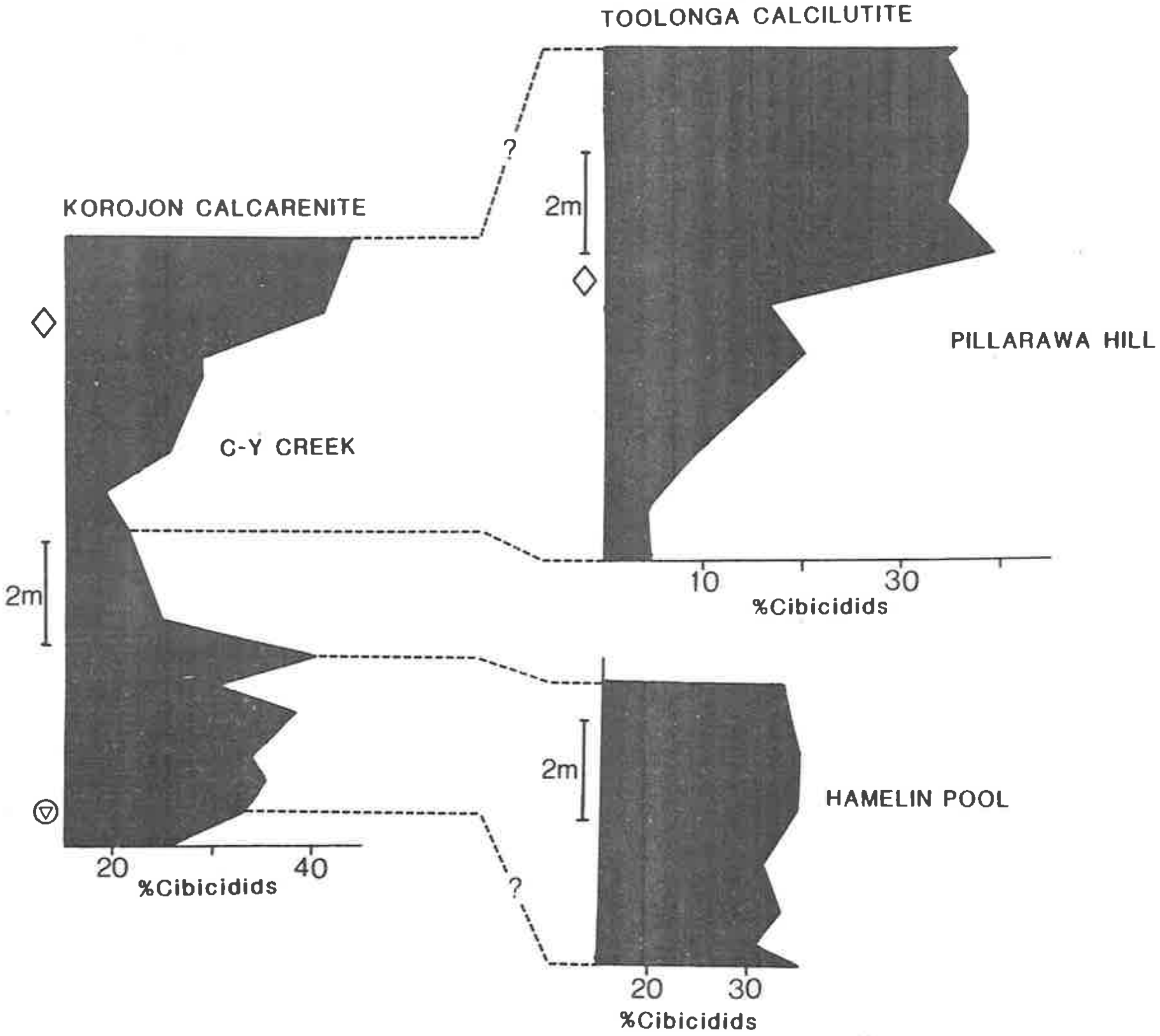


FIGURE 13: Correlation of the Korojon Calcarenite and the Toolonga Calcilutite using cibicidid numbers.

Data from the biofacies profiles can also sort out the stratigraphic relationship of the Korojon Calcarenite and the Toolonga Calcilutite. Some authors argue that the Korojon Calcarenite lies mostly stratigraphically above the Toolonga Calcilutite, whilst others assert the reverse.

The cibicidid curve for each section of the Toolonga Calcilutite and the basal part of the Korojon Calcarenite are shown in Figure 13. The curve for the latter section shows three distinct stages: a basal section with high cibicidid numbers, followed by a section with a low proportion of cibicidids which then passes upwards into an interval with a high count of cibicidids. This increase is associated with the cibicidid/*rakauroana* overturn.

Comparison of this pattern with the curves obtained from the two Toolonga Calcilutite sections reveals a similar pattern: the Hamelin Pool section has high cibicidid numbers, equivalent to the basal stage of the Korojon Calcarenite. The Pillarawa Hill section, on the other hand, begins with low cibicidid numbers which rapidly increase again in association with the cibicidid/*rakauroana* overturn. The implication is that both sections of the Toolonga Calcilutite are equivalent to the basal part of the Korojon Calcarenite. Further, the possibility of the Hamelin Pool section extending some way below the Korojon Calcarenite cannot be entirely discounted.

This correlation also finally confirms the age of the planispiral/low trochospiral overturn. The overturn is present in the Pillarawa Hill section of Toolonga Calcilutite; this section is equivalent to a portion of the Korojon Calcarenite above the first appearance of *B. miliaris*, which in turn equals the base of the *G. subspinosa* zone. The fact that the overturn occurs before the agglutinated peak A1 further restricts its age to the lower part of the *G. subspinosa* zone.

Figure 12 shows the lowest sample from the Korojon Calcarenite as being approximately equivalent to the lowest part of the section from Site 217, about the base of the *G. subspinosa* zone. The slight discrepancy is due to the lack of *B. miliaris* in the basal part of Site 217.

The section studied from Withnell No. 1 starts just prior to A1, whereas the section from Minilya No. 1 starts with the low foraminiferal interval equivalent to agglutinated peak A2.

The hiatus in Site 217, inferred from nannofossil data and the first appearance of *Gl. intermedia*, occurs during Core 26. It is no coincidence that this core also contains the agglutinated peak A3. On the Western Australian margin, however, A3 does not mark the beginning of the hiatus. In both Withnell No. 1 and the Korojon Calcarenite, sedimentation continues until the first appearance of *Bolivinoides draco*. Depending on exactly how close A3 is to the first occurrence of this species, the "lag-time" may be very small. It is during this time that the numbers of *Praebulimina* begin to increase.

The recognition of A3 in Minilya No. 1 confirms the presence of the hiatus there. A3 occurs in sample M1750 providing an Early Maastrichtian age for the sample. The highest sample in the section (M1686) contains the latest Maastrichtian zonal species *Gl. mayaroensis*. Data from the other shelf sections suggests that at least some of the sediments above A3 would also be Early Maastrichtian in age, leaving very little room for the middle Maastrichtian. In Figure 12, the hiatus is shown as starting a little earlier in Minilya No. 1 than in the other Western Australian sections, due to the late appearance of *B. draco* in this section.

The end of the hiatus in all sections occurs at approximately the same time as the first appearance of *Gl. mayaroensis*, and the agglutinated peak associated with it. In detail, the hiatus termination at Site 217 occurs before this event, based on the presence of *Gl. intermedia* in several samples without *Gl. mayaroensis*.

The lowest sample from the Gaj River section is considered synchronous with the base of Site 217, due to the recognition of the agglutinated peak associated with basal *Gl. mayaroensis* zone. In the Western Australian sections, this peak, where present, marks the end of the hiatus, and at Gaj River it is found a few metres above the bottom of the section. The absence of this agglutinated peak in Minilya No. 1 is thought to be a result of the hiatus extending higher in the section.

Deposition of the Miria Marl begins and ends within this agglutinated peak, whereas on the Northwest Shelf some Late Cretaceous record exists above. However, sections from

Minilya No. 1 and Withnell No. 1 finish well before the end of the Cretaceous. However, the sections from Site 217 and Gaj River appear to extend right up to the Cretaceous/ Tertiary boundary.

Agglutinated peak A4 is uniquely defined by its association with the first appearance of *G. falsocalcarata*. Its recognition in Site 217 is more equivocal, there being three peaks which are possible correlatives. However, the oldest and most prominent peak is used. The recognition of A4 in both the Gaj River section and Site 217, (a) confirms that the *G. falsocalcarata* subzone is equivalent to the upper portion of the *Gl. mayaroensis* zone, and (b) emphasises the synchronism of the deterioration in the sections.

Having used these non-phyletic events to correlate in this way, the next step is to give some consideration to their paleoenvironmental significance. This is the thrust of the next chapter.

CHAPTER THREE

THE BIOFACIES EVENTS
THEIR CAUSES AND SIGNIFICANCE

INTRODUCTION

The non-phyletic events recognised from the biofacies profiles have proved to be useful adjuncts to conventional biostratigraphy. The correlations carried out in the previous chapter were, however, accomplished without any reference to the cause of these events. The aim of this chapter is to discuss the causes of the agglutinated peaks and the sudden increase of praebuliminids. An assessment is then made of their significance in relation to the Terminal Cretaceous Event.

CAUSES OF THE BIOFACIES EVENTS

Figure 23 shows that an agglutinated peak often occurs simultaneously with a sharp reduction in plankton numbers. This association is clearly seen in Withnell No. 1, Minilya No. 1 and the Korojon Calcarenite during agglutinated peak A4. The reduction of planktonic numbers suggests that the agglutinated peaks occur during periods of regression. The correlations carried out in the previous chapter offer support for this hypothesis by systematically linking the agglutinated peaks with other significant events.

As far as can be ascertained from conventional biostratigraphy, the agglutinated peak A2 at Withnell No. 1 occurs synchronously with an interval which is almost devoid of foraminifera on Minilya No. 1, possibly representing a regressive phase. At Site 217, agglutinated peak A3 coincides with a major break in the section. On the Western

Australian margin the same peak may be very close in time to the beginning of the same middle Maastrichtian hiatus. The start of the transgresion which terminates the hiatus is marked in many sections by an agglutinated peak (see Figure 12). The association of the agglutinated peaks with these features supports the hypothesis that high agglutinated numbers are linked with shallow water, due to either a regression or the beginning of a transgression.

Above A3, praebuliminid numbers increase dramatically and they maintain their high numbers until the end of the Cretaceous. During the agglutinated peaks, however, their numbers fall (see, for example, the Miria Marl and Withnell No. 1 in Figure 23). The reciprocity of the two groups may be a result of depth fluctuations. That is, if high agglutinated numbers are due to shallow water, the high praebuliminid numbers may represent deeper water. However, this does not appear to be the case; the basal part of the Korojon Calcarenite has high plankton numbers but a low praebuliminid count, whereas the top of the section has a similar abundance of plankton and is accompanied by high *Praebulimina* numbers. Obviously there must be some factor other than water depth involved.

Praebulimina numbers reach a maximum in the upper part of the Gaj River section after the first appearance of *G. falsocalcarata*. Prior to this event, praebuliminid numbers are about the same as those recorded on the Western Australian margin, that is, roughly 20% of the benthonic fraction. However, in Gaj River, after the first occurrence of *G. falsocalcarata* they occasionally comprise up to 60% of the benthonic fraction.

Four species are involved, *Praebulimina carseyae*, *P. reussi*, *P. laevis* and *P. kickapooensis*. The fourth species is the most important, as at the top of the section it is the only member of *Praebulimina* present.

A number of other physical and biological changes pivot around the first occurrence of *G. falsocalcarata:*

(1) There is a sudden increase in pyrite content in the samples: from rare or absent below *G. falsocalcarata* to abundant above. An exception to this is a single sample near the top of the section (31 (40-50)) which, in contrast to samples on either side, contains only rare pyrite.

(2) *Inoceramus* prisms are confined to the *G. falsocalcarata* subzone.

(3) There is a sharp decrease in foraminiferal numbers up-section, especially benthonic forms which maintain their numbers relative to the plankton (Fig. 15) only by the increase in praebuliminids. The only other benthonic species to increase its numbers at this time is *Loxostomoides cushmani*.

(4) Accompanying this drop in abundance is a similar decrease in faunal diversity. Once again this is most noticeable amongst the benthonics, where the number of species drops from a maximum of approximately forty to ten.

(5) The quality of preservation of all forms decreases into the *G. falsocalcarata* subzone. As with the other changes

listed here, it is the preservation of the benthonics which deteriorates the most. They undergo a conspicuous reduction in size and become infilled with pyrite. Preservation becomes so poor that individual species of the Cibicididae and Anomalinidae cannot be recognised.

These changes indicate that the microfauna is responding to some form of ecological stress, clearly affecting the benthonic forms more than the planktonics. The praebuliminids (and to some extent, *L. cushmani*) appear to be opportunistic species which flourish while other species, for example the cibicidids, become reduced in size and numbers.

The lithology of the section - dark grey shales, coupled with the large amounts of pyrite - indicates that strong reducing conditions prevailed during deposition of the upper portion of the Gaj River section. This suggests that the changes associated with first appearance of *G. falsocalcarata* are due to the development of a fairly intense oxygen minimum zone near the sediment/water interface.

Since there are some changes within the planktonic assemblage, it must be assumed that although the oxygen minimum is most intense near the bottom of the water column, the dysaerobic conditions extend at least a little way up through the water column.

The appearance of *Inoceramus* above *G. falsocalcarata* offers limited support to this hypothesis. Eicher and Worstell (1977), Thiede and van Andel (1977) and Frerichs and Dring (1981) have all documented what they considered to be oxygen minimum situations and in all cases noted an increase in the *Inoceramus* content of their samples.

The association of low oxygen conditions and elevated praebuliminid numbers in the upper portion of the Gaj River section provides a model for the post A3 increase of these forms. That is, after A3 the water mass over the shelves and Site 217 stagnated, resulting in a significant depletion of its oxygen content. Obviously this reduction in available oxygen was not as severe as occurred after A4 in the Gaj River section; there is, for example, no pyrite in any of the Western Australian sections studied. Nevertheless, the dysaerobic conditions produced a significant fractionation of the benthonic fauna; the praebuliminids flourished.

Agglutinated peaks aside, high praebuliminid numbers continue up to the top of every section studied, except Site 217. Here, after A4, praebuliminid numbers fall. This site presents its own special problems which are examined in greater detail in Chapter Four.

The lowered oxygen content of the water in the Late Cretaceous Indian Ocean is the "missing factor" in explaining the reciprocity between the praebuliminids and the agglutinated forms.

The agglutinated peaks represent periods of shallowing, times when one would expect the entire water column over the shelves to be well oxygenated by direct diffusion, resulting in a low *Praebulimina* count. As water depth increases, agglutinated numbers drop. At this point, only the top part of the water column can be supplied with oxygen by direct diffusion. If circulation is sluggish, very little oxygen will reach the benthonic organisms. These organisms quickly use up any available oxygen thus resulting in an oxygen depletion of the bottom waters and an increase in praebuliminids. Estuarine circulation can then carry this oxygen depleted water out beyond the shelves, forming a mid-water oxygen minimum zone (Jenkyns, 1980).

As pointed out by Demaison and Moore (1980) much fundamental research needs to be carried out before a full understanding of the interaction between benthonic foraminiferal assemblages and oxygen minima can be achieved. Studies that have been completed generally involve Recent or Quaternary species, and often describe the modification of benthonic assemblages around sewerage outfalls (areas of high organic carbon, low oxygen). However, the literature does bear out the major points of the above discussion.

The association of reduced oxygen levels and low benthonic numbers is now well established. Several authors (Bates and Spencer, 1979 and references therein) note a significant drop in benthonic numbers, or even a "dead zone" near sewerage outfalls. Saidova (1971) carried out an analysis of the biomass of Recent benthonic foraminifera across a section of the shelf/slope off the Pacific coast of South America; she recorded that between the depths of 150 metres and 250 metres the oxygen content of the water drops significantly. At the same time the benthonic biomass is reduced to virtually nothing.

The fractionation of the benthonic assemblage by low oxygen conditions has also been recognised. As early as 1968, Seiglie listed several genera which increased numerically in low oxygen conditions near a sewerage outfall. Included were a number of genera belonging to the Buliminidae (*Bulimina*, *Buliminella*, *Uvigerina* and *Bolivina*). He also noted that most species of the listed genera have a toothplate and thin walls.

In her study, Saidova (1971) found that when the benthonic biomass was very low due to the decreased oxygen supply, the individuals present were predominantly members of the genus *Brizalina*. During a review of Quaternary deep sea benthonics, Schnitker (1980) noted that periods of high organic carbon preservation (which requires low oxygen conditions) coincide with high *Uvigerina* numbers. The large number of genera belonging to the Buliminidae which thrive in oxygen minimum conditions supports the notion that high *Praebulimina* numbers are an indication of such conditions in the Cretaceous.

However, low oxygen conditions and associated foraminiferal changes from the Cretaceous have generally received only scant attention, despite the proven importance of these conditions as a factor in hydrocarbon production (Demaison and Moore, 1980). A number of authors have recorded oxygen minima from the sediments deposited in the Cretaceous epicontinental sea which ran North/South across Western North America (Frush and Eicher, 1975; Eicher and Worstell, 1970; and Frerichs and Dring, 1981). These low oxygen events are recorded by huge increases in the relative number of planktonics due to the almost total absence of benthonics. However, there have been no previous attempts at a detailed analysis of changes in Cretaceous benthonic assemblages due to an oxygen minimum.

The Cretaceous ocean was vastly different from the Tertiary ocean; lengthy periods of stagnation and widespread oxygen minimum conditions were not unusual (Jenkyns, 1980). The lack of a large temperature differential between the equator and the poles resulted in the absence of temperature driven deep water currents, hence circulation was sluggish and the ocean poorly mixed (Kauffman, 1979a). Occasionally, the entire ocean stratified which resulted in the development of strongly dysaerobic conditions on a global scale, as evidenced by the deposition of black, organic rich shales in marine sections throughout the world. Several such Oceanic Anoxic Events (OAE's) have been documented during the Cretaceous (Jenkyns, 1980). All have a global nature and the largest (the Abbian-Aptian OAE) lasted about 18 million years. All OAE's are closely linked with transgressive periods.

In contrast to the long time span of some OAE's, the stagnation recorded during this study is a fairly short, sharp event. From the initial increase in praebuliminids to the end of the Cretaceous is only 3-4 million years;the peak of low oxygen conditions at Gaj River lasted significantly less than 1 million years. Neither is this last stagnation as intense as the previous OAE's, at least in its initial stages. However, in common with other OAE's,the start of dysaerobic conditions is linked with transgression.

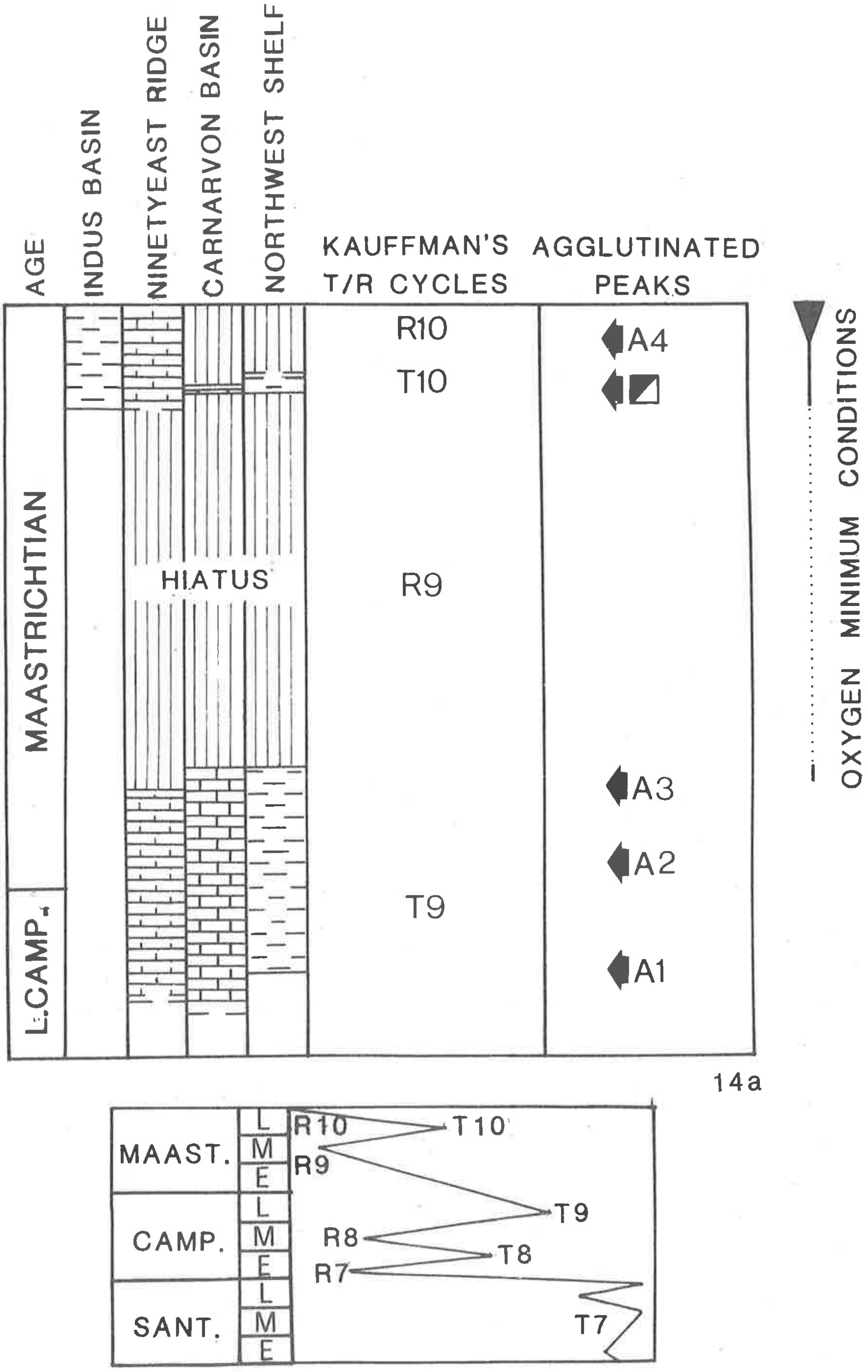


FIGURE 14(a): Comparison of Kauffman's (1979b) Transgression/Regression cycles with the biofacies events. (b): Kauffman's Transgression/Regression cycles.

RELATIONSHIP OF THE BIOFACIES EVENTS WITH THE CRETACEOUS/ TERTIARY BOUNDARY

The events recognised in the biofacies profiles imply large scale fluctuations prior to the Cretaceous/Tertiary boundary. These events are recognised ocean-wide and in a variety of facies. Their basic framework is a series of agglutinated peaks representing shallow water conditions. Although these peaks are more frequent than the transgressive/ regressive cycles plotted by Kauffman (1979a), both are probably due to the same cause.

Figure 14 is an attempt at fitting Kauffman's (1979a) transgression/regression cycles to the sedimentary deposition pattern obtained earlier. To highlight the more rapid nature of the shallowing events, the agglutinated peaks are shown. The figures also indicates an increasingly intense oxygen minimum situation, starting in the Early Maastrichtian and peaking just prior to the boundary. Interestingly, while the beginning of dysaerobic conditions is linked to a deepening or transgressive phase, the most intense oxygen depletion occurs during a generally regressive phase, just prior to the boundary.

This pattern of long term fluctuations prior to some form of deterioration is not unknown in the fossil record. McGowran (1978) documents two such patterns in the Tertiary. These are the late Middle to Late Eocene fluctuations before the earliest Oligocene crash, and the late Early and Middle Miocene perturbations prior to the deterioration in the Late Miocene.

The signals differ: the fluctuations documented by McGowran are biogeographic, extratropical excursions of larger foraminifera, whereas in the latest Cretaceous the perturbations are largely due to fluctuating sea levels. Nevertheless, they are analogous. A full discussion of the Terminal Cretaceous Event is beyond the scope of this thesis. However, the association of the oceanic fluctuations recorded above with this major discontinuity in the fossil record necessitates some comment.

Attempts to provide a model for the boundary event can be split into two categories: those that postulate a catastrophic end to the Cretaceous, and others which use a gradualistic approach. Into the catastrophic category falls the "asteroid impact" hypothesis (Alvarez and others, 1980) and the "Arctic spillover" model (Gartner and Keany, 1978; Thierstein and Berger, 1978).

The impact model suggests that the extinctions were triggered by the collision of a large extraterrestrial body with the Earth. This model is based almost solely on the discovery of large amounts of Iridium concentrated at the boundary which its proponents argue must have an extraterrestrial source.

The "Arctic spillover" model requires that an isolated, freshwater Arctic Ocean be suddenly reconnected with the world ocean. The freshwater flows out forming a low salinity lid on the dense, saline world ocean thus dampening circulation and acting as a trigger for both the extinctions and major climatic fluctuations.

Both models, whatever their success in explaining the extinctions and other changes that occur at the boundary, cannot explain the presence of perturbations which, although linked with the boundary event, start well before it. To include these precursor events requires a more gradualistic approach such as that used by Kauffman (1979b).

Firstly, he argues that the catastrophic nature of extinctions is more apparent than real, as a result of the presence in many sections of a hiatus at the boundary. He also states that many Maastrichtian forms which finally became extinct at the boundary actually underwent significant restrictions in both number and diversity well before that time. Finally Kauffman notes that the species which became extinct represent no single ecological grouping, hence no single ecological change could have brought about their demise.

In brief, the model suggests that the faunas were caught in a three-way ecological squeeze. The changing ecological parameters are documented as:

(1) The development of an oxygen minimum during the last Cretaceous transgression (T.10, Middle-Late Maastrichtian, Kauffmann, 1979a), which intensifies up to the end of the Cretaceous.

(2) A decline in temperature as the oceans move into a Late Maastrichtian regressive phase (R.10 - the terminal Cretaceous regression, Kauffman, 1979a).

(3) The destruction of shelf habitats, also due to the regression.

The ecological squeeze results in a sequential series of extinctions which start in the Middle Maastrichtian coeval with the development of the oxygen minimum, and climax at the end of the Cretaceous, coincident with peak ecological stress.

Although this model was developed using material from the northern hemisphere, the parallels with events documented in the Indian Ocean region are striking. One notable instance is the occurrence of the most intense oxygen minimum conditions just prior to the end of the Cretaceous, a regressive, cooler interval when better circulation and hence better oxygenation of the water column would be expected. Problems with Kauffman's model include the lack of an explanation for the terrestrial extinctions. Nevertheless, it would appear that the gradualistic approach offers the most hope for a solution to the boundary problem.

CHAPTER FOUR

FORAMINIFERAL DISTRIBUTION

SITE 217

PLANKTON DISTRIBUTION: SITE 217

Site 217 contains so many unique problems that a separate discussion of them is warranted. The analysis centres around the plankton distribution of the site, as shown in Figure 17. The planktonic/benthonic curve in this figure falls into two distinct parts. The larger of the two (cores 36 to basal core 19) is a straightforward documentation of a sinking section; in the basal cores,plankton numbers make up approximately 70-80% of the sample,increasing to over 90% above core 27. The section slips below the lysocline during deposition of core 22, where evidence of dissolution is first observed. Corroded specimens continue to be found to the top of the section.

In the last part of the curve(cores 19 to 17) the situation changes dramatically. Plankton numbers tumble from over 90% to between 20-30%. These low numbers continue to the top of core 17 when they suddenly return to about 90% of the sample.

While a gradual overall increase in plankton numbers is recorded during cores 36 to basal core 19, the graph of the plankton split reveals that significant changes were taking place within the planktonic assemblage (Fig. 17). These changes are due to the increase in the number of keeled forms. The late development of a keeled assemblage causes a sharp increase in globotruncanid numbers and diversity just prior to the first appearance of *Gl. mayaroensis*. However, a closer examination of the data shows an earlier jump in keeled numbers in core 32. Diversity, however, remains the same across this jump. Douglas and Savin (1978) have clearly demonstrated that Cretaceous foraminifera were stratified according to depth, and that the globotruncanids occupied the lowest levels in the water column. This, combined with a sinking section, probably caused the initial increase in keeled forms. The low diversity over the jump is attributable to the site's extratropical position at the time.

The second jump in keeled numbers occurs in Core 23 and is more complex. The plankton consistently make up over 90% of the sample, so rapid depth changes can be ruled out as a factor influencing this jump. There is also a parallel increase in diversity as discussed in the first chapter; that is, a diverse keeled assemblage does not appear until after the first appearance of *Gl. mayaroensis*. Pessagno and Michael (1974) suggested that the unusual distribution of keeled forms was due to their being reworked into younger sediments. In support of this hypothesis, they list a number of species which they considered reworked. These can be divided into three groups:

(1) *Pseudotextularia elegans, Bolivinoides draco*.

Pessagno and Michael claim that both species are reworked into the *Gl. mayaroensis* zone, yet it is generally accepted that the species range up to and include that zone (Masters, 1977 and references therein). It would be very difficult to prove conclusively that they were reworked.

(2) *Globotruncana linneiana, Globotruncana ventricosa.*

By applying standard Gulf Coast ranges to these species it would appear that they too are reworked. A case can be made, however, for an extension of their ranges. They are both found in the Gaj River section, within the *Gl. mayaroensis* zone. *G. linneiana* is found in Site 288A, again within the *Gl. mayaroensis* zone, as is *G. ventricosa* in Minilya No. 1 and Withnell No. 1. Douglas (1973) noted a similar extension of the range of *G. linneiana* in the North Pacific. At Site 167 this species disappears just before the *Gl. mayaroensis* zone, while at Site 171, *G. linneiana obliquus* ranges almost to the end of the Maastrichtian. It seems unlikely that all these appearances are due to reworking.

(3) *Globotruncana calcarata.*

The recognition of this species in the highest Cretaceous sample at Site 217 would doubtless indicate that serious reworking has occurred. McGowran (1977) has suggested that what actually may have been found was a juvenile specimen of *Globotruncana falsocalcarata.* Neither species has been found during this study.

If reworking has occurred, it has been extremely selective as the nanofossils show no indication of it (Gartner, 1974). One of the strongest arguments against reworking is the recognition of the non-phyletic events described above; these would be unrecognisable if significant reworking had occurred.

McGowran (1974, 1977) also rejected the reworking hypothesis and instead suggested that the increase in globotruncanid numbers and diversity was due to a change in water mass over the site, from one of extratropical to tropical aspect. Bandy (1967) noted that an assemblage dominated by keeled forms is indicative of tropical conditions. The simultaneous increase in diversity of the heterohelicids and benthonics (see range charts: Figs. 27 and 28) is also consistent with such a change. In addition, the final Late Cretaceous nannofossil zone was not recognised and it has been suggested that this is due to the zonal species being extratropical. The evidence for a Late Maastrichtian cooling is now fairly convincing (Kauffman, 1979a), hence the change to a tropical aspect is due to the site moving into the tropics rather than an expansion of the tropical climatic belts.

The top part of the section (top Core 19 to Core 17) is marked by large scale perturbations in the number of planktonics contained in each sample. There is also a significant rearrangement of the planktonic assemblage, with the heterohelicids becoming the dominant forms while plankton numbers are low. At the top of core 17, when plankton numbers return to their former high value, the globotruncanids again resume their dominance, largely at the expense of the globigerinids. The return to high plankton numbers is also accompanied by a peak in the agglutinated forms.

Selective dissolution may preferentially remove the planktonics producing the initial reduction in numbers.

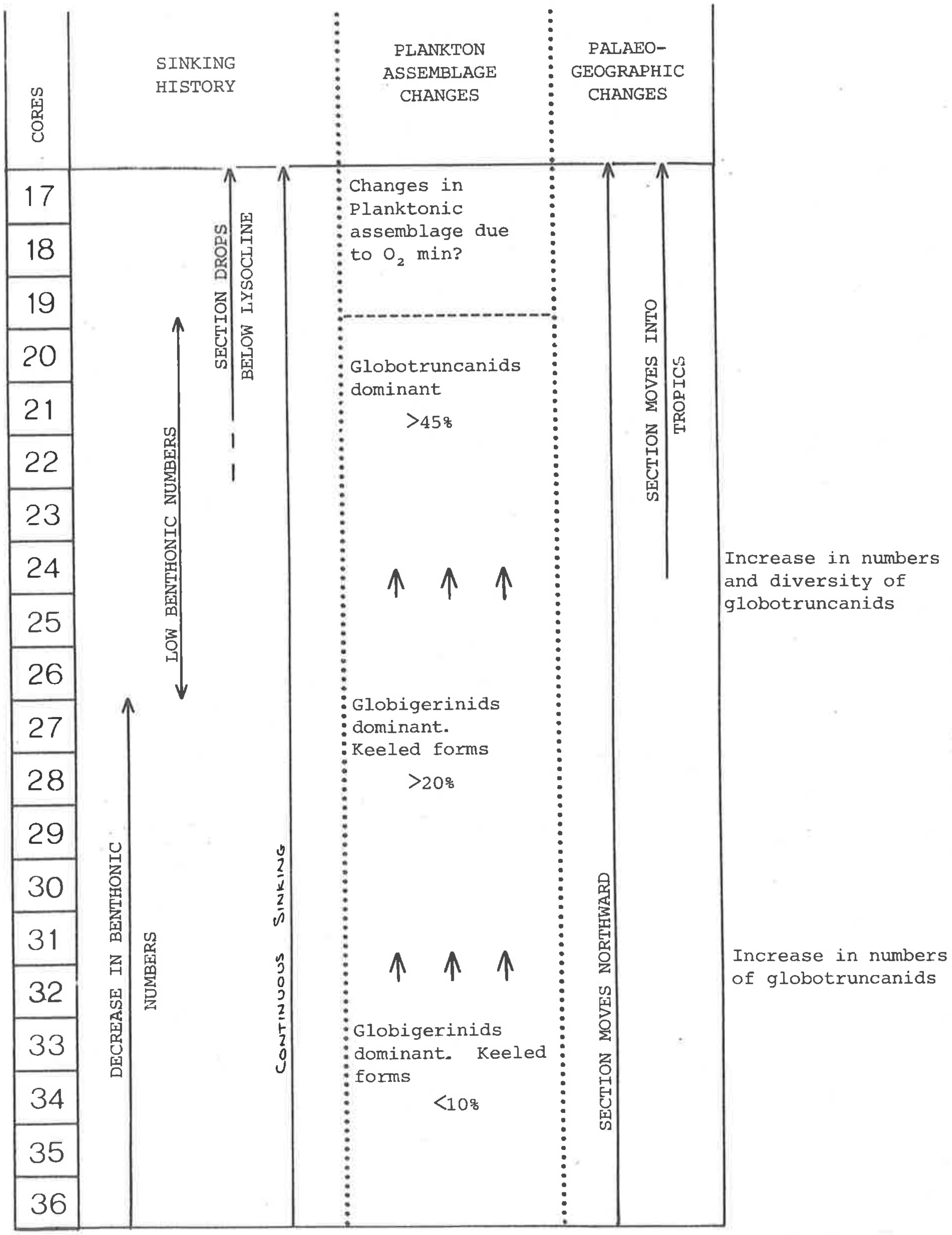


FIGURE 15: Model for plankton distribution DSDP Site 217.

However, indications of strengthening dissolution continue right up until the end of the section, and it is difficult to see how continued dissolution could cause an increase in planktonic numbers.

At the same time as these perturbations at Site 217, the Gaj River section records its strongest oxygen minimum. It is probable that these two events are related. That is, if Site 217 did drop below the oxygen minimum zone above A4 and hence out of its influence, as evidenced by the reduced numbers of praebuliminids, it is possible that the zone of lowered oxygen tension then affected the plankton. By analogy with the benthonics, this could result in the lowered plankton numbers and the rearrangement of the assemblage, with the heterohelicids taking on the role of *Praebulimina*. The increase in plankton in the latter part of core 17 would be due to the waning of the low oxygen conditions; the coincident high agglutinated peak is consistent with an increase in available oxygen. Figure 15 summarises the above discussion.

SITE 217 AS A NERITIC SECTION

Prior to Core 27, the section at Site 217 is remarkable for its close parallels with the sections on the Western Australian margin. Most of the benthonic species recorded in Site 217 are also recorded in these neritic sections and a significant number of non-phyletic events are common to both. (Fig. 11).

Even more interesting is the almost coeval hiatus which occurs in Site 217 and the Shelf sections. According to Berger's (1970) shelf-basin fractionation model, a hiatus on the shelves should result in improved preservation in oceanic carbonate sections; conversely, deposition of large amounts of carbonate on the shelves should cause poor preservation and/or a hiatus in oceanic sections.

However, there is only a slight offset in time between the hiatus in the ocean and that on the shelves; the model does not apply here. Either the differences between the Cretaceous and the Tertiary oceans makes the model inappropriate, or, despite its mid-ocean position, Site 217 remained fairly shallow during the Late Campanian - Middle Maastrichtian. The palaeobathymetric curves of Sclater, Abbott and Thieve (1977) which show the site as being at less than 1,000 metres water depth at 70 million years b.p. support this latter alternative, and the tolerances in back tracking allow that the site could have been substantially shallower.

GLOBOTRUNCANA A BENTHONIC FORM?

A quantitative analysis of the Cretaceous of Western Australia was made by Edgell (1957). Changes in abundance of major faunal groups from a single section of the Korojon Calcarenite were documented, and although the counting was not carried out in great detail, it did produce some interesting results.

Edgell noted that there was an inverse relationship between total plankton numbers and *Globotruncana* numbers, which suggested to him that *Globotruncana* were benthonic forms with a planktonic phase in their life-cycle.

This same relationship between *Globotruncana* and total plankton numbers has been documented in more detail during this study. The curves for globotruncanid numbers and total plankton are mirror images of each other, not only in the Korojon Calcarenite but also in Withnell No. 1, Minilya No. 1 and, most clearly, the bottom half of the section at Site 217 (Figures 18, 19, 21).

It is the recognition of this pattern at Site 217 which is of the greatest interest. There, the inverse relationship only occurs prior to the second jump in keeled numbers (Core 23), that is, whilst the site is extratropical and globotruncanid diversity and numbers are low. This restricted occurrence suggests that the relationship between the globotruncanids and total plankton numbers is more complex than Edgell thought. There is still no clear explanation for this phenomenon. However, it is certain that Edgell's benthonic model is incorrect.

CONCLUSIONS

The construction of biofacies profiles carried out in this study allows the first detailed comparisons to be made of changes in foraminiferal assemblages prior to the Cretaceous/Tertiary boundary. The profiles (Figures 16 to 22) contain a number of biofacies events which appear to be both useful for correlation and significant in regard to an understanding of the Cretaceous/Tertiary boundary. These biofacies events are summarised in Figures 23 and 24.

CORRELATIONS

A combined biostratigraphic framework can be built by calibrating the biofacies events with conventional biostratigraphy (Figure 11). Use of such a framework results in a more precise correlation of the sections studied than has previously been available (Figure 12). One important outcome of this strategy is the recognition of the widespread nature of the mid-Maastrichtian hiatus which separates the Korojon Calcarenite and the Miria Marl in the Carnarvon Basin. Its presence can now be confirmed both on the Northwest Shelf and the Ninetyeast Ridge. The recognition of this hiatus in the supposedly deep water Site 217, and the neritic sections of the Western Australian passive margin is just one indication of the close links between these two areas during the Late Campanian/Early Maastrichtian. Many of the other biofacies events recognised in the profiles are also common to both areas. The most likely explanation for this linkage is that, despite its mid-ocean position, Site 217 remained very shallow during the Cretaceous.

SITE 217

The late development of a diverse keeled plankton assemblage at Site 217 means that only the final Late Maastrichtian zone can be recognised. Detailed examination of the biofacies profile for the site (Figure 17) reveals that the sudden increase in both number and diversity of keeled forms which accompanies the first appearance of *Gl. mayaroensis* is the second major fluctuation in the keeled assemblage. The earlier Late Campanian jump involves an increase in the number of keeled forms but not diversity and is due to a combination of subsiding section and depth stratification of globotruncanids in an extratropical situation. The later jump is attributable to the site itself moving into the tropics.

SIGNIFICANCE

Perhaps the most important outcome of this work is a better understanding of the relationship between the biofacies events and the terminal Cretaceous event. The basic framework is provided by a series of five peaks in agglutinated numbers, each of which represents a shallowing episode. As seen in Figure 14, these shallowing episodes occur considerably faster than the Transgression/Regression cycles plotted by Kauffman (1979a).

Overprinting the agglutinated peaks, from the Early Maastrichtian onwards, is a rapid increase in numbers of praebuliminids which reach a maximum in the upper half of the Gaj River section (*G. falsocalcarata* subzone), where they are accompanied by other indications of a strong oxygen minimum situation. This association of *Praebulimina* and low oxygen conditions suggests that from the Early Maastrichtian onwards, the Northeastern Indian Ocean was prone to stagnation and hence dysaerobic conditions.

There are two situations during this time interval where low *Praebulimina* numbers indicate periods of improved oxygenation : firstly while agglutinated numbers are high signifying that the water column was shallow enough to allow direct diffusion of oxygen to the benthos, and secondly, at the top of Site 217, somewhat paradoxically coeval with the most intense oxygen depletion on the shelf at Gaj River. The decrease in this case is probably due to the Site sinking below the oxygen minimum zone. Dramatic fluctuations in plankton abundance at Site 217 which occur at the same time, may be a result of dysaerobic water affecting the planktonic assemblages.

McGowran(1978) recognises a series of oceanic perturbations occurring prior to two major deteriorations in the Tertiary. The biogeographic signals used by McGowran document these perturbations are analagous with the biofacies events recorded here. That is, the biofacies events represent major fluctuations in the ocean prior to the terminal Cretaceous event.

This pattern of a long term build-up to the boundary is inconsistent with the now popular catastrophic models which rely on a short, sharp shock at the end of the Maastrichtian. These precursor events are, however, compatible with the model outlined by Kauffman (1979a) which suggests that the extinctions at the boundary are the result of an ecological squeeze which has its origins in the mid-Maastrichtian.

The parallels between Kauffman's model and the events documented here are striking. The association of low oxygen conditions and the terminal Cretaceous regression still poses a problem for the model. However, the analysis of precursor events seems to offer the greatest hope for a solution to this perplexing problem.

SYSTEMATICS

INTRODUCTION

During this study approximately three hundred species were recognised. A detailed discussion of their classification, however, is beyond the scope of this thesis, hence the systematics has been abbreviated to checklist form.

The classification used here is that of Loeblich and Tappan, 1964, as modified in 1974, accepting that this scheme appears to be at times forced and artificial.

For species to which a name has been found, references are given to its initial author, other important works and a fuller synonomy. Often, however, a species name could not be found in which case its distinctive features are noted. Remarks on individual species have been kept to an absolute minimum.

LATE CRETACEOUS BENTHONIC FORAMINIFERA

Suborder TEXTULARIINA Delage and Herouard, 1896
Superfamily AMMODISCACEA Reuss, 1862
Family ASTRORHIZIDAE Brady, 1881
Subfamily RHIZAMMININAE Rhumbler, 1895

Genus *Bathysiphon* M. Sars in G.O. Sars, 1872

Type species: *Bathysiphon filiformis* M. Sars in G.O. Sars, 1872.

Remarks: Several forms belonging to this genus are common in the lower half of the section at Withnell No. 1 and throughout Minilya No. 1. No attempt has been made to assign these to species. Plate 1, Figures 1-2, show examples of the forms found.

Family SACCAMMINIDAE Brady, 1884
Subfamily SACCAMMININAE Brady, 1884

Genus *Pelosina* Brady, 1879

Type species: *Pelosina variabilis* Cushman, 1910.

Pelosina sp. 1
(Pl. 1, Fig. 3)

Description: Medium sized ovid test, finely agglutinated. Apertures, at either end of the test, are produced on the end of short necks.

Distribution: Very rare, Withnell No. 1, Minilya No. 1.

Family AMMODISCIDAE Reuss, 1862

Subfamily AMMODISCINAE Reuss, 1862

Genus *Ammodiscus* Reuss, 1862

Type species: *Ammodiscus informus* Bornemann, 1874

Ammodiscus? cretaceus (Reuss), 1845

(Pl. 1, Fig. 4)

Operculina cretacea REUSS, 1845, p. 35, pl. 13, figs. 64-65.

Ammodiscus cretaceus (Reuss), SLITER, 1968, p. 42, pl. 1, fig. 8.

Remarks: The identification is tentative only. Sliter's (1968) specimens show less whorls than those found here. The recognition of this species also represents a significant extension of its range into the Latest Maastrichtian.

Distribution: Fairly common in Gaj River, Withnell No. 1, Korojon Calcarenite and the Toolonga Calcilutite. Rare in Minilya No. 1.

Ammodiscus sp. 1

(Pl. 1, Fig. 5)

Description: Distinguished from *A. cretaceus* by its very small compressed test with numerous whorls and fine agglutination.

Distribution: Rare, Withnell No. 1 and Minilya No. 1.

Genus *Glomospira* Rzehak, 1885

Type species: *Trochammina squamata* Jones and Parker, *var gordialis* Jones and Parker, 1860.

Glomospira gordialis (Jones and Parker),1860

(Pl. 1, Fig. 6)

Trochammina squamata var *gordialis* JONES AND PARKER, 1860

Glomospira gordialis (Jones and Parker), DUPEUBLE, 1979, pl. 4, figs. 5-6 (illustration only).

Distribution: Rare, at the base of the Korojon Calcarenite.

Glomospira pileolus Subbotina, 1960

(Pl. 1, Figs. 7-8)

Glomospira pileolus Subbotina, 1960, pp. 179-180, pl. 1, figs. 13a-c, 14a-c (seen in Ellis and Messina, 1940)

Remarks: Identical to the Oligo-Miocene species figured by Subbotina, 1960. Similar to *Glomospira charoides* (Parker and Jones) as figured by Hornibrook and Hay (1978), but differs in being more regularly coiled.

Distribution: Rare Withnell No. 1 and Minilya No. 1.

Superfamily LITUOLACEA de Blainville, 1825

Family LITUOLIDAE de Blainville, 1825

Subfamily HAPLOPHRAGMOIDINAE Maync, 1952

Genus *Haplophragmoides* Cushman, 1910

Type species: *Nonionina canariensis* d'Orbigny, 1839

Haplophragmoides Sp. 1

(Pl. 1, Figs. 9-10)

Description: Two species are assigned to this genus. The first is distinguished by its large size, coarse agglutination, and relatively small number of chambers.

Distribution: Common, Withnell No. 1, Minilya No. 1.

Haplophragmoides Sp. 2

(Pl. 1, Figs. 11-12)

Description: Test large, distinguished from *H. Sp. 1* by possessing a larger number of chambers and finer agglutination.

Distribution: Rare, Withnell No. 1, Minilya No. 1.

Subfamily LITUOLINAE de Blainville, 1825

Genus *Lituola* Lamarck, 1804

Type species: *Lituola nautiloidea* Lamarck, 1804

Lituola grandis (Reuss), 1854

(Pl. 1, Fig. 13)

Spirolina grandis REUSS, 1854, p. 69, pl. 25, fig. 14.

Lituola grandis (Reuss), BARTENSTEIN, 1952, p. 322, pl. 1, fig. 9; pl. 4, figs. 7-13.

Distribution: Miria Marl (common) and Gaj River (rare).

Genus *Ammobaculites* Cushman, 1910

Type species: *Spirolina agglutinaus* d'Orbigny, 1846.

Ammobaculites Sp. 1

(Pl. 1, Fig. 14)

Description: Test compressed, coarsely agglutinated. Initial planispiral section very large with lobate periphery and large number of chambers, uniserial section short. Aperture terminal, simple.

Distribution: Rare in Gaj River section.

Subfamily PLACOPSILININAE Rhumbler, 1913

Genus *Placopsilina* d'Orbigny, 1850

Type species: *Placopsilina cenomana* Cushman, 1920.

Placopsilina Sp. 1

(Pl. 1, Figs. 15-16)

Description: Test medium sized, attached and irregularly coiled. Aperture at the end of a phialine neck. Unattached side of test covered with raised reticulate pattern.

Distribution: Common in the Korojon Calcarenite, rare in the Miria Marl.

Family TEXTULARIIDAE Ehrenberg, 1838

Subfamily SPIROPLECTAMMININAE Cushman, 1927

Genus *Spiroplectammina* Cushman, 1927

Type species: *Textularia agglutinans* d'Orbigny var *biformis* Parker and Jones, 1865.

Spiroplectammina grzybowskii Frizzell, 1943

(Pl. 1, Figs. 17-18)

Spiroplectammina grzybowskii FRIZZELL, 1943, p. 337, figs. 12a-b, 13; BELFORD, 1960, p. 7, pl. 1, figs. 4-6.

Remarks: Two distinct forms of this species are illustrated. Plate 1, figure 17 is the megalospheric generation; figure 18 is the microspheric.

Distribution: Common in all sections.

Spiroplectammina laevis (Roemer), 1841

(Pl. 1, Fig. 19)

Textularia laevis ROEMER, 1841, p. 97, pl. 15, fig. 17.

Spiroplectammina laevis (Roemer), CUSHMAN, 1932, p. 87, pl. 11, fig. 2; SLITER, 1968, p. 46, pl. 2, fig. 9.

Distribution: Common in all sections except Site 217 and the Miria Marl.

Spiroplectammina paula Belford, 1960

(Pl. 1, Fig. 20)

Spiroplectammina paula BELFORD, 1960, p. 8, pl. 1, figs. 11-13.

Distribution: Common in Toolonga Calcilutite, Korojon Calcarenite, Withnell No. 1, and Minilya No. 1.

Subfamily TEXTULARIINAE Ehrenberg, 1838

Genus *Textularia* Defrance in de Blainville 1824

Type species: *Textularia sagittula* Defrance in de Blainville, 1824.

Textularia Sp. 1

(Pl. 2, Fig. 1)

Description: Test medium in size, very elongate chambers increasing slowly in size becoming more compressed with age. Sutures depressed, distinct. Agglutination fine. Similar to *S. paula* but lacks initial coiled section.

Distribution: Rare in Gaj River.

Textularia Sp. 2

(Pl. 2, Fig. 2)

Description: Test small, flaring. Chambers increasing rapidly in size, globular. Sutures distinct, depressed, agglutination very coarse.

Distribution: Rare Miria Marl.

Family TROCHAMMINIDAE Schwager, 1877

Subfamily TROCHAMMININAE Schwager, 1877

Genus *Trochammina* Parker and Jones, 1859

Type species: *Nautilus inflatus* Montagu, 1808

Trochammina cf. *boehmi* Franke, 1928

(Pl. 2, Figs. 3-4)

Trochammina boehmi FRANKE, 1928, p. 174, pl. 15, fig. 24; SLITER, 1968, p. 46, pl. 2, fig. 10.

Remarks: This species, with its four distinct chambers in the final whorl is very similar to *T. boehmi*. However, the species illustrated here is higher spired.

Distribution: Very rare, Site 217.

Trochammina Sp. 1

(Pl. 2, Figs. 5-6)

Description: Test small, smooth walled, fine agglutination. Convex spiral side, concave umbilical side. Sutures very distinct, chambers crescentic with six per whorl.

Distribution: Rare, Miria Marl.

Family ATAXOPHRAGMIIDAE Schwager, 1877

Subfamily VERNEUILININAE Cushman, 1911

Genus *Verneuilina* d'Orbigny in de la Sagra, 1839

Type species: *Verneuilina tricarinata* d'Orbigny, 1840.

Verneuilina parri Cushman, 1936

(Pl. 2, Figs. 7-8)

Verneuilina parri CUSHMAN, 1936, p. 2, pl. 1, figs. 3a-b; BELFORD, 1960, pp. 9-10, pl. 1, figs. 14-19.

Distribution: Common in Withnell No. 1, Minilya No. 1, Korojon Calcarenite, Toolonga Calcilutite, and the Miria Marl.

Verneuilina aff. *tricarinata* d'Orbigny, 1840

(Pl. 2, Figs. 9-10)

Verneuilina tricarinata d'ORBIGNY, 1840, p. 39, pl. 4, figs. 3-4. (Seen in Ellis and Messina, 1940)

Remarks: *V. tricarinata*, as redrawn by Loeblich and Tappan (1964) possesses narrow extensions of its chambers extending down over the previous chambers at each corner of the triangular test. The specimens illustrated here do not have such extensions.

Distribution: Common in the Korojon Calcarenite.

Genus *Gaudryina* d'Orbigny in de la Sagra, 1839

Type species: *Gaudryina rugosa* d'Orbigny, 1840.

Gaudryina australis Belford, 1960

(Pl. 2, Figs. 11-12)

Gaudryina australis BELFORD, 1960, pp. 11-12, pl. 2, figs. 8-14.

Distribution: Rare Toolonga Calcilutite.

Gaudryina healyi Finlay, 1939

(Pl. 2, Figs. 13-14)

Gaudryina healyi FINLAY, 1939, p. 311, pl. 25, figs. 34, 35; BECKMANN, 1978, p. 766, pl. 1, fig. 8.

?*Gaudryina rugosa* d'Orbigny, BELFORD, 1960, p. 13, pl. 2, figs. 17-20.

Distribution: Common in Withnell No. 1, Minilya No. 1, Miria Marl, Korojon Calcarenite and the Toolonga Calcilutite.

Gaudryina laevigata Franke, 1914

(Pl. 2, Figs. 15-16)

Gaudryina laevigata FRANKE, 1914, p. 431, pl. 27, figs. 1-2; SLITER, 1968, p. 48, pl. 3, fig. 8 (synonomy); SLITER, 1977, pl. 1, fig. 8.

Remarks: Similar to *G. healyi* but differs by possessing more angular margin to the test.

Distribution: Common in Gaj River Section.

Gaudryina aff. pulvina Belford, 1960

(Pl. 2, Figs. 17-19)

Gaudryina pulvina BELFORD, 1960, pp. 10-11, pl. 2, figs. 1-7.

Remarks: Similar to Belford's *G. pulvina* in the angular nature of its test. It differs, however, by its sutures being less depressed and the biserial section less lobate. The test is smooth being composed entirely coccolith plates (Pl. 2, Fig. 19).

Distribution: Rare, Site 217.

Gaudryina pyramidata Cushman, 1926 a

(Pl. 3, Figs. 1-2)

Gaudryina laevigata Franke, var *pyramidata* CUSHMAN, 1926a, p. 587, pl. 16, fig. 8.

Gaudryina pyramidata Cushman, GRAHAM AND CLARK, 1961, p. 109, fig. 2,1; SLITER, 1968, p. 48, pl. 3, fig. 9 (synonomy); SLITER, 1977, pl. 2, fig. 9.

Distribution: Rare in Site 217, Gaj River, and Toolonga Calcilutite.

Gaudryina Sp. 1

(Pl. 3, Figs. 3-4)

Description: A distinctive form, narrow, with a very elongate angular triserial section and usually with a short biserial portion. Agglutination coarse.

Distribution: Common in Withnell No. 1, Minilya No. 1, Korojon Calcarenite, Toolonga Calcilutite and the Miria Marl.

Genus *Spiroplectinata* Cushman, 1927

Type species: *Textularia annectens* Parker and Jones, 1863.

Spiroplectinata compressiuscula (Chapman), 1917

(Pl. 3, Fig. 5)

Bigenerina compressiuscula CHAPMAN, 1917, p. 19, pl. 2, figs. 13-14.

Spiroplectinata compressiuscula (Chapman) BELFORD, 1960, pp. 15-16, pl. 3, figs. 9-19.

Distribution: Common in the Toolonga Calcilutite.

Genus *Pseudoclavulina* Cushman, 1936

Type species: *Clavulina clavata* Cushman, 1926a.

Loeblich and Tappan (1964) place this genus in synonomy with *Clavulina*. However, the species illustrated here lacks the valvular tooth indicative of that genus.

Pseudoclavulina cf. *gaultina* Morozova, 1948

(Pl. 3, Figs. 6-7)

Pseudoclavulina gaultina MOROZOVA, 1948, p. 36, pl. 1, fig. 4.

Tritaxia gaultina (Morozova) SLITER, 1977, p. 676, pl. 3, figs. 5,6; DEPEUBLE, 1979, pl. 2, fig. 16.

Remarks: Specimens very similar to those illustrated by Depeuble (1979).

Distribution: Basal Site 217, Gaj River. Rare in both sections.

Genus *Tritaxia* Reuss, 1860

Type species: *Textularia tricarinata* Reuss, 1844.

Tritaxia aspera (Cushman), 1926a

(Pl. 3, Fig. 8)

Clavulina trilatera Cushman var *aspera* CUSHMAN, 1926a

Tritaxia aspera (Cushman) SLITER, 1977, p. 676, pl. 3, fig. 2, 4.

Distribution: Site 217, Toolonga Calcilutite. Common in both sections.

Tritaxia trifidus (Belford), 1960

(Pl. 3, Fig. 9)

Clavulinoides trifidus BELFORD, 1960, p. 13, pl. 3, figs. 1-4.

Distribution: Common in Toolonga Calcilutite.

Tritaxia Sp. 1

(Pl. 3, Fig. 10-11)

Description: Test small fine agglutination, initially triserial then uniserial. Cross section triangular throughout. Edge of the test strongly thickened. Aperture simple opening at the end of the uniserial section.

Remarks: Similar to *T. barakai* Said and Kenway 1956, however, this species lacks the distinctive thickened edges.

Distribution: Restricted to Gaj River, common.

Subfamily GLOBOTEXTULARIINAE Cushman, 1927

Genus *Dorothia* Plummer, 1931

Type species: *Gaudryina bulletta* Carsey, 1926.

Dorothia biformis Finlay, 1939

(Pl. 3, Figs. 12-13)

Dorothia biformis FINLAY, 1939, p. 313, pl. 25, figs. 26-28; BELFORD, 1960, pp. 19-20, pl. 4, figs. 14-18.

Distribution: Found in all sections except Site 288A, common.

Dorothia bulletta (Carsey), 1926

(Pl. 3, Figs. 14-15)

Gaudryina bulletta CARSEY, 1926, p. 28, pl. 4, fig. 4.

Dorothia bulletta (Carsey) PLUMMER, 1931, p. 132, pl. 8, figs. 13-17; BELFORD, 1960, p. 18, pl. 4, figs. 8-10.

Distribution: Common in all sections except Site 288A and the Miria Marl.

Dorothia pupa (Reuss), 1860

(Pl. 3, Figs. 16-17)

Textularia pupa REUSS, 1860, p. 232, pl. 13, figs. 4a-b.

Dorothia pupa (Reuss) CUSHMAN, 1937, p. 78, pl. 8, figs. 20-24; BELFORD, 1960, p. 19, pl. 4, figs. 11-13.

Distribution: Reasonably common in the Miria Marl, the Korojon Calcarenite, Toolonga Calcilutite, and Site 217.

Genus *Marssonella* Cushman, 1933

Type species: *Gaudryina oxycona* Reuss, 1860.

Marssonella ellisorae Cushman, 1936

(Pl. 3, Figs. 18-19)

Marssonella ellisorae CUSHMAN, 1936, p. 44, pl. 4, figs. 11a-b; BELFORD, 1960, pp. 17-18, pl. 4, figs. 4-7.

Distribution: Common in Withnell No. 1, Korojon Calcarenite, Toolonga Calcilutite, and the Miria Marl.

Marssonella oxycona (Reuss), 1860

(Pl. 3, Figs. 20-21)

Gaudryina oxycona REUSS, 1860, p. 229, pl. 12, fig. 3.

Marssonella oxycona (Reuss) CUSHMAN, 1933, p. 36, pl. 4, figs. 13a-b; BELFORD, 1960, pp. 16-17, pl. 4, figs. 1-3.

Distribution: Abundant in all sections except Site 288A.

Genus *Eggerella* Cushman, 1933

Type species: *Verneuilina bradyi* Cushman, 1911.

Eggerella ? trochoides (Reuss), 1845

(Pl. 3, Fig. 22)

Globigerina trochoides REUSS, 1845, p. 36, pl. 12, fig. 22.

Eggerella trochoides (Reuss), CUSHMAN, 1937, p. 46, pl. 5, figs. 1-2; CUSHMAN, 1946, p. 43, pl. 12, fig. 2.

Distribution: Common in the Korojon Calcarenite, rare in Site 217.

Subfamily VALVULININAE Berthelin, 1880

Genus *Goesella* Cushman, 1933

Type species: *Clavulina rotundata* Cushman, 1913.

Goesella chapmani Cushman, 1936a

(Pl. 4, Figs. 1-2)

Goesella chapmani CUSHMAN, 1936a, p. 33, pl. 5, figs. 61-b; BELFORD, 1960, pp. 21-22, pl. 5, figs. 14-18.

Distribution: Rare in the Korojon Calcarenite and Toolonga Calcilutite.

Suborder MILIOLINA Delage and Herouard, 1896

Two species of Miliolid were recognised, however, neither were assigned to genera.

Miliolid sp. 1

(Pl. 4, Figs. 3-4)

Description: Elongate form which in adult specimens has distinct longitudinal ridges (Pl. 4, Fig. 4) and in juvenile forms has a large amount of adventitious material in the centre of the test (Pl. 4, Fig. 5).

Distribution: Rare in the Toolonga Calcilutite common in the Korojon Calcarenite, Withnell No. 1, and Minilya No. 1.

Miliolid sp. 2

(Pl. 4, Fig. 5)

Description: Distinguished from *Miliolid sp. 1* by its short, squat form.

Distribution: Rare in the Korojon Calcarenite.

Suborder ROTALIINA Delage and Herouard, 1896

Superfamily NODOSARIACEA Ehrenberg, 1838

Family NODOSARIIDAE Ehrenberg, 1838

Subfamily NODOSARIINAE Ehrenberg, 1838

Genus *Nodosaria* Lamarck, 1812

Type species: *Nautilus radicula* Linne, 1758.

Nodosaria intercostata Reuss, 1860
(Pl. 4, Figs. 6-7)

Nodosaria intercostata REUSS, 1860, p.179, pl.1, fig. 179. (Seen in Ellis and Messina, 1940)

Distribution: Common in the Miria Marl, Korojon Calcarenite, Toolonga Calcilutite and Withnell No. 1. Rare in the Gaj River section.

Nodosaria limbata d'Orbigny, 1840
(Pl. 4, Fig. 8)

Nodosaria limbata d'ORBIGNY, 1840, p.12, pl. 1, fig.1; SLITER, 1968, p.53, pl.4, fig. 15.

Distribution: Common in the Korojon Calcarenite and Toolonga Calcilutite. Rare in the Miria Marl and Withnell No. 1.

Nodosaria cf. proboscidea Reuss, 1851
(Pl. 4, Fig. 9)

Nodosaria proboscidea REUSS, 1851, p.7, pl.1, fig. 6; SLITER, 1968, p. 54, pl. 4, figs. 12-13.

Distribution: Basal part of Site 217 only, rare.

Nodosaria ?velascoensis Cushman, 1926
(Pl. 4, Fig. 10)

Nodosaria fontannesi Berthelin var *velascoensis* CUSHMAN, 1926, p. 504, pl. 18, fig. 12.

Nodosaria velascoensis Cushman. CUSHMAN AND CAMPBELL, 1935, p. 72, pl. 11, fig. 3; SLITER, 1968, p. 54, pl. 4, fig. 17.

Distribution: Rare, Gaj River and Site 217.

Nodosaria Sp. 1

(Pl. 4, Fig. 11)

Description: Test small, distinguished by its very elongate chambers, depressed sutures, and smooth wall.

Distribution: Rare in the Miria Marl.

Nodosaria Sp. 2

(Pl. 4, Fig. 12)

Description: Squat test with depressed sutures, chambers more inflated than *N. Sp. 1* increasing slowly in size.

Distribution: Rare in basal Site 217.

Nodosaria Sp. 3

(Pl. 4, Fig. 13)

Description: Very similar to *N. Sp. 1*, however, its chambers are slightly more inflated and not as elongate.

Distribution: Rare in basal Site 217.

Genus *Astacolus* de Montfort, 1808

Type species: *Astacolus crepidulatus* de Montfort, 1808
= *Nautilus crepidulus* Fichtel and Moll, 1798.

Astacolus Sp. 1

(Pl. 4, Fig. 14)

Description: Fragment only. Smooth walled, small initial coil, uniserial portion of test with distinctive triangular cross section.

Distribution: Rare in Gaj River.

Astacolus Sp. 2

(Pl. 4, Fig. 15)

Description: Fragment of uniserial portion of test only. Test covered by distinctive striae.

Distribution: Rare, Korojon Calcarenite.

Astacolus Sp. 3

(Pl. 4 Fig. 16)

Description: Test smooth with rounded cross section, small initial coil and large uniserial portion.

Distribution: Found at Site 217 (rare) and questionably, Toolonga Calcilutite.

Genus *Citharina* d'Orbigny in de la Sagra, 1839

Type species: *Vaginulina (Citharina) strigillata* Reuss, 1846.

Citharina geisendoerferi (Franke), 1928

(Pl. 4, Fig. 17)

Vaginulina geisendörferi Franke, 1928, p. 80, pl. 7, figs. 18a-5.

Citharina geisendörferi (Franke), FRIZZELL, 1954, p. 94, pl. 11, figs. 5a-b; BELFORD, 1960, p. 40, pl. 11, figs. 14-15.

Remarks: Differs slightly from specimens figured by Belford in lacking steeply inclined sutures.

Distribution: Rare, Korojon Calcarenite, Toolonga Calcilutite.

Genus *Dentalina* Risso, 1826

Type species: *Nodosaria (Dentaline) cuvieri* d'Orbigny, 1826.

Dentalina basiplanata Cushman, 1938

(Pl. 4, Fig. 18)

Dentalina basiplanata CUSHMAN, 1938a,p. 38, pl. 6, figs. 6-8; SLITER, 1968, p. 57, pl. 5, figs. 8-11.

Distribution: Common in all Western Australian sections except Minilya No. 1 and the Toolonga Calcilutite where it is rare.

Dentalina ?catenula Reuss, 1860

(Pl. 4, Fig. 19)

Dentalina catenula REUSS, 1860, p. 185, pl. 3, figs. 6; SLITER, 1968, p. 57, pl. 5, fig. 14.

Remarks: Specimens found are finer than those figures by Belford (1960) hence the tentative identification.

Distribution: Korojon Calcarenite, Withnell No. 1, rare.

Dentalina cylindroides Reuss, 1860

(Pl. 4, Fig. 20)

Dentalina cylindroides REUSS, 1860, p. 185, pl. 1, fig. 8; BELFORD, 1960,pp.26-27,pl. 7, figs. 8-12.

Distribution: Rare, Gaj River, Withnell No. 1, Minilya No. 1.

Dentalina delicatula Cushman, 1938

(Pl. 4, Fig. 21)

Dentalina delicatula CUSHMAN, 1938a,p. 40, pl. 6, figs. 19-20; Cushman, 1946, p. 70, pl. 25, figs. 1-6.

Distribution: Rare Toolonga Calcilutite.

Dentalina luma Belford, 1960

(Pl. 4, Fig. 22)

Dentalina luma BELFORD, 1960, p. 34, pl. 10, figs. 6-11.

Distribution: Found in small numbers in all sections except Sites 217 and 288A.

Dentalina marcki Reuss, 1860

(Pl. 4, Fig. 24)

Dentalina marcki REUSS, 1860, p. 188, pl. 2, fig. 7; SLITER, 1968, p. 58, pl. 5, fig. 19.

Distribution: Rare, Toolonga Calcilutite.

Dentalina megalopolitana Reuss 1855

(Pl. 4, Fig. 23)

Dentalina megalopolitana REUSS, 1855, p. 267, pl. 8, fig. 10; BELFORD, 1960, p. 26, pl. 7, figs. 6-7.

Distribution: Rare in all Carnarvon Basin sections.

Dentalina pertinens Cushman, 1938 a

(Pl. 4, Fig. 25)

Dentalina pertinens CUSHMAN, 1938a, p. 40, pl. 6, figs. 15-18; BELFORD, 1960, p. 28, pl. 8, figs. 5-7.

Distribution: Rare in the Korojon Calcarenite and Miria Marl.

Dentalina solvata Cushman, 1938 a

(Pl. 4, Fig. 26)

Dentalina solvata CUSHMAN, 1938a, p. 39, pl. 6, figs. 9-14; SLITER, 1968, p. 58, pl. 5, figs. 20-21.

Distribution: Rare specimens from Withnell No. 1.

Dentalina Sp. 1

(Pl. 4, Fig. 27)

Description: Elongate form, smooth walled. Very similar to *D. luma* but lacks the inverted "V's" down the side of the test.

Distribution: Rare in both Site 217 and Toolonga Calcilutite.

Genus *Frondicularia* Defrance in d'Orbigny, 1826

Type species: *Renulina complanata* Defrance, 1824.

Frondicularia archiaciana d'Orbigny, 1840

(Pl. 5, Fig. 1)

Frondicularia archiaciana d'ORBIGNY, 1840, p. 20, pl. 1, figs. 34-36; SLITER, 1968, pp. 59-60, pl. 6, fig. 2.

Distribution: Common in the Toolonga Calcilutite and Korojon Calcarenite. Rare in the basal part of Site 217 and in the Gaj River section.

Frondicularia bulla Belford, 1960

(Pl. 5, Fig. 2)

Frondicularia bulla BELFORD, 1960, p. 49, pl. 13, figs. 9-11.

Distribution: Toolonga Calcilutite, rare.

Frondicularia cf. *bulla* Belford, 1960

(Pl. 5, Fig. 3)

Remarks: Similar to *F. bulla*, however, its initial chamber not as inflated and is covered with distinct short costae.

Distribution: Korojon Calcarenite, rare.

Frondicularia costulifera Belford, 1960

(Pl. 5, Fig. 4)

Frondicularia costulifera BELFORD, 1960, pp. 51-52, pl. 14, figs. 1-3.

Distribution: Rare in the Toolonga Calcilutite.

Frondicularis?disjuncta Belford 1960

(Pl. 5, Fig. 5)

Frondicularia disjuncta BELFORD, 1960, pp. 50-51, pl. 13, figs. 12-15.

Distribution: Rare in the Toolonga Calcilutite.

Frondicularia mucronata Reuss, 1845

(Pl. 5, Fig. 6)

Frondicularia mucronata REUSS, 1845, p. 31, pl. 13, figs. 43-44; SLITER, 1968, p. 62, pl. 6, fig. 7.

Distribution: Reasonably common in Site 217, Gaj River, the Korojon Calcarenite and the Miria Marl.

Frondicularia planifolium Chapman, 1894

(Pl. 5, Fig. 7)

Frondicularia planifolium CHAPMAN, 1894, p. 158, pl. 4, figs. 1a-b; BELFORD, 1960, pp. 46-47, pl. 12, figs. 12-13.

Distribution: Rare specimens from the Toolonga Calcilutite.

Frondicularia teuria Finlay, 1939

(Pl. 5, Fig. 8)

Frondicularia teuria FINLAY, 1939, p. 316, pl. 26, figs. 60-61; BELFORD, 1960, p. 47, pl. 13, figs. 1-2.

Distribution: Common in the Korojon Calcarenite, Toolonga Calcilutite, and a single specimen in the Miria Marl.

Frondicularia Sp. 1

(Pl. 5, Fig. 9)

Description: Test broad, fan shaped, initial chamber small with a few distinct costae. Sutures strongly raised with pustulose ornamentation between.

Distribution: Korojon Calcarenite, rare.

Frondicularia Sp. 2

(Pl. 5, Fig. 10)

Description: Test small, elongate. Large initial chamber followed by only a few uniserial chambers. Surface of test covered with distinctive reticulate pattern.

Distribution: Minilya No. 1, rare.

Frondicularia Sp. 3

(Pl. 5, Fig. 11)

Description: Test elongate, small initial chamber. Other chambers slowly increasing in size. Sutures depressed, edge of test carinate. Covered with discontinuous costae.

Distribution: Rare, Miria Marl.

Genus *Lagena* Walker and Jacob in Kanmacher, 1798

Type species: *Serpula (Lagena) sulcata* Walker and Jacob, 1798.

Lagena hexagona (Williamson), 1848

(Pl. 5, Fig. 12)

Entoselenia squamosa (Montagu) var *hexagona* WILLIAMSON, 1848, p. 20, pl. 3, fig. 23.

Lagena hexagona (Williamson) BELFORD, 1960, p. 55, pl. 14, figs. 14-15.

Distribution: Common in the Miria Marl.

Lagena hispida Reuss, 1863

(Pl. 5, Fig. 13)

Lagena hispida REUSS, 1863, p. 355, pl. 6, figs. 77-79; SLITER, 1968, p. 64, pl. 6, fig. 21.

Distribution: Minilya No. 1, rare, Gaj River, common.

Lagena ?stavensis Bandy, 1949

(Pl. 5, Fig. 14)

Lagena laevis (Montagu) var *stavensis* BANDY, 1949, p. 56, pl. 7, fig. 15.

Lagena stavensis Bandy; SLITER, 1968, p. 65, pl. 7, fig. 1.

Distribution: Rare in Gaj River, Withnell No. 1 and the Miria Marl.

Lagena sulcata Walker and Jacob, 1798

(Pl. 5, Fig. 15)

Serpula (Lagena) sulcata WALKER AND JACOB, 1798, pl. 14, fig. 5.

Lagena sulcata Walker and Jacob, BELFORD, 1960, p. 55, pl. 14, figs. 12-13.

Distribution: Common in the Miria Marl.

Genus *Lenticulina* Lamarck, 1804

Type species: *Lenticulina* **rotulata** Lamarck, 1804.

Lenticulina muensteri (Roemer), 1839

(Pl. 5, Fig. 16)

Robulina münsteri ROEMER, 1839, p. 48, pl. 22, fig. 29.

Lenticulina muensteri (Roemer) SLITER, 1968, p. 66, pl. 7, figs. 9, 13.

Distribution: Abundant in all sections except Minilya No. 1 where it is common, Site 217 where it is rare and Site 288A where it is absent.

Lenticulina cf. *muensteri* (Roemer), 1839

(Pl. 5, Fig. 17)

Remarks: A variant of *L. muensteri* with a larger, more rounded, apertural face.

Distribution: Rare in the Korojon Calcarenite.

Lenticulina pondi (Cushman), 1931a

(Pl. 5, Fig. 18)

Robulus pondi CUSHMAN, 1931a, p. 25, pl. 2, fig. 9.

Lenticulina pondi (Cushman), SLITER, 1968, p. 67, pl. 7, fig. 10.

Distribution: Common in the Toolonga Calcilutite, rare in the Korojon Calcarenite.

Lenticulina sublatus (Reuss) 1854

(Pl. 5, Fig. 19)

Cristellana sublata REUSS, 1854, p. 68, pl. 25, fig. 13.

Robulus sublatus (Reuss) Cushman and Jarvis, CUSHMAN, 1946, p. 55, pl. 18, figs. 7, 8.

Lenticulina Sp. 1

(Pl. 5, Fig. 20)

Description: Species distinguished by its very short apertural face and a well developed flange around the margin of the test.

Distribution: Common in the Korojon Calcarenite. Rare in the Toolonga Calcilutite, Miria Marl, Site 217, and Gaj River.

Lenticulina Sp. 2

(Pl. 5, Fig. 21)

Description: Test small worn. Readily distinguished by the raised sutures on the later portion of the test.

Distribution: Rare, Korojon Calcarenite and Toolonga Calcilutite.

Lenticulina Sp. 3

(Pl. 6, Fig. 1)

Description: Test large, very similar to *L. muensteri* but with a large flange around edge of the test.

Distribution: Species common in the Toolonga Calcilutite.

Genus *Marginulina* d'Orbigny, 1826

Type species: *Marginulina raphanus* d'Orbigny, 1826

Marginulina ?jarvisi Cushman

(Pl. 6, Fig. 2)

Marginulina jarvisi CUSHMAN, 1938, p. 35, pl. 5, figs. 17, 18; CUSHMAN, 1946, p. 63, pl. 22, figs. 18-20.

Distribution: Miria Marl (Rare), Korojon Calcarenite (common).

Marginulina Sp. 1

(Pl. 6, Fig. 3)

Description: Test elongate, smooth. Rectilinear portion of the test consists of 3-4 inflated chambers, sutures depressed.

Distribution: Korojon Calcarenite, rare.

Marginulina Sp. 2

(Pl. 6, Fig. 4)

Description: Test small with initial striations. Rectilinear portion small, generally smooth. Sutures flush to slightly depressed. Chambers increasing only slowly in size.

Distribution: Common in the Korojon Calcarenite, rare in Minilya No. 1.

Marginulina Sp. 3

(Pl. 6, Fig. 5)

Description: Test small, similar to *M. Sp. 2* but lacks initial striations and final chamber more inflated.

Distribution: Withnell No. 1, rare.

Marginulina Sp. 4

(Pl. 6, Fig. 6)

Description: Similar to *M. jarvisi* but differs by being more rounded, and final chambers are not as inflated.

Distribution: Site 217, Toolonga Calcilutite, rare in both sections.

Genus *Marginulinopsis* A. Silvesteri, 1904

Type species: *Marginulinopsis densicostata* Thalmann, 1937.

Marginulinopsis texasensis (Cushman), 1938

(Pl. 6, Fig. 7)

Marginulina texasensis CUSHMAN, 1938, p. 95.

Marginulinopsis texasensis (Cushman), SLITER, 1968, p. 71, pl. 8, figs. 12-13.

Distribution: Gaj River only, where it is common.

Marginulinopsis Sp. 1

(Pl. 6, Fig. 8)

Description: Test medium to large distinguished by the straight rectilinear portion of the test and striations which cover it. Chambers inflated, sutures slightly depressed.

Distribution: Site 217 and Toolonga Calcilutite, common in both sections.

Genus *Neoflabellina* Bartenstein, 1948

Type species: *Flabellina rugosa* d'Orbigny 1840.

Neoflabellina praereticulata Hiltermann, 1953

(Pl. 6, Fig. 9)

Neoflabellina praereticulata HILTERMANN, 1953, p. 53, text-fig. 3, fig. 37; BELFORD, 1960, pp. 43-44, pl. 12, figs. 7-8, text-fig. 2.

Distribution: Korojon Calcarenite, rare.

Neoflabellina reticulata (Reuss), 1851

(Pl. 6, Fig. 10)

Flabellina reticulata REUSS, 1851, p. 30, pl. 1, fig. 22.

Neoflabellina reticulata (Reuss), POZARYSKA, 1957, p. 162, pl. 26, fig. 6; VILLAIN, 1977, pp.49-50, pl. 4, fig. 12.

Distribution: Single specimen from the top-most Korojon Calcarenite. Rare in the Miria Marl.

Neoflabellina rugosa (d'Orbigny), 1840

(Pl. 6, Fig. 11)

Flabellina rugosa d'ORBIGNY, 1840, p. 23, pl. 2, figs. 4-5,7.

Neoflabellina rugosa (d'Orbigny), LOEBLICH AND TAPPAN, 1964, p. C522, fig. 407,6; SLITER, 1968, pp. 71-72, pl. 8, fig.21.

Distribution: Common in the Miria Marl, Gaj River, Minilya No. 1 and Toolonga Calcilutite.

Genus *Palmula* Lea, 1833

Type species: *Palmula sagittaria* Lea, 1833.

Palmula pilulata Cushman, 1938

(Pl. 6, Fig. 12)

Palmula pilulata CUSHMAN, 1938, p. 37, pl. 6, fig. 2; CUSHMAN, 1946, p. 84, pl. 32, figs. 18-21.

Palmula Sp. aff. *P. pilulata*, BELFORD, 1960, pp. 42-43, pl. 12, figs. 4-6.

Distribution: Rare, Toolonga Calcilutite.

Genus *Planularia* Defrance in de Blainville, 1826

Type species: *Peneropolis auris* Defrance in de Blainville, 1826.

Planularia Sp. 1

(Pl. 6, Fig. 13)

Description: Test small, ovoid. Large initial whorl and short multiserial section with carinate margin. Sutures raised, surface of test pustulose and initially covered with short discontinuous costae.

Distribution: Korojon Calcarenite, rare.

Planularia Sp. 2

(Pl. 6, Fig. 14)

Description: Test large, elongate, possesses a very well developed carinate uniserial section. Sutures slightly raised, test smooth.

Distribution: Korojon Calcarenite, common.

Planularia Sp. 3

(Pl. 6, Fig. 15)

Description: Test small, ovate, similar to *Pl. Sp. 1* but differs by (a) being more angular, (b) possessing depressed sutures, and (c) lacking costae. Surface of test pustulose.

Distribution: Common in the Toolonga Calcilutite and questionable occurrences Site 217.

Genus *Pseudonodosaria* Boomgaart, 1949

Type species: *Glandulina discreta* Reuss, 1850.

Pseudonodosaria manifesta (Reuss) 1851

(Pl. 6, Fig. 16)

Glandulina manifesta REUSS, 1851, p. 22, pl. 1, fig. 4.

Pseudonodosaria manifesta (Reuss), SLITER, 1968, p. 72, pl. 8, fig.18.

Distribution: Rare, Toolonga Calcilutite.

Genus *Saracenaria* Defrance in de Blainville 1824

Type species: *Saracenaria italica* Defrance, 1824

Saracenaria aff. *colei* Srinvasan, 1966

(Pl. 6, Fig. 17)

Saracenaria colei SRINVASAN, 1966, p. 238, pl. 2, figs. 10,13.

Description: Test small close coiled with small initial whorl apertural face wide, concave with a distinct flange around the edge of the test. Similar to *S. colei* but differs by having fewer chambers, a distinct keel and closer coiling.

Distribution: Common in the Toolonga Calcilutite, rare in Withnell No. 1.

Saracenaria triangularis (d'Orbigny) 1840

(Pl. 6, Fig. 18)

Cristellaria triangularis d'ORBIGNY, 1840, p. 27, pl. 2, figs. 21-22.

Saracenaria triangularis (d'Orbigny), CUSHMAN, 1946, p. 58, pl. 28, figs. 1-3; SLITER, 1968, p. 74, pl. 9, figs. 3-4.

Distribution: Common in Toolonga Calcilutite, less so in Withnell No. 1.

Saracenaria Sp. 1

(Pl. 6, Fig. 19)

Description: Test small, elongate, with long narrow uniserial section.

Distribution: Rare, Korojon Calcarenite.

Genus *Vaginulina* d'Orbigny, 1826

Type species: *Nautilus legumen* Linne, 1758.

Vaginulina cretacea Plummer, 1927

(Pl. 6, Fig. 20)

Vaginulina gracilis Plummer var *cretacea* PLUMMER, 1927, p. 172, pl. 2, fig. 8.

Vaginulina cretacea Plummer, CUSHMAN, 1946, p. 80, pl. 30, figs. 11-14.

Distribution: Gaj River, rare.

Genus *Vaginulinopsis* Silvestri 1904

Type species: *Vaginulina soluta* Silvestri var *carinata* Silvestri, 1898.

Vaginulinopsis Sp. 1

(Pl. 6, Fig. 21)

Description: Test large, robust. Smooth walled. Initially coiled then uniserial. Sutures initially flush then slightly raised. Similar to *Vaginulinopsis directa* (Cushman) but differs by its possessing raised instead of depressed sutures.

Distribution: Rare in the Korojon Calcarenite.

Family POLYMORPHINIDAE d'Orbigny, 1839

Subfamily POLYMORPHININAE d'Orbigny, 1839

Genus *Globulina* d'Orbigny in de la Sagra, 1839

Type species: *Polymorphina (Globuline) gibba* d'Orbigny, 1826.

Globulina lacrima (Reuss) 1845

(Pl. 6, Fig. 22)

Polymorphina (Globulina) lacrima REUSS, 1845, p. 40, pl. 12, fig. 6; pl. 13, fig. 83.

Globulina lacrima Reuss, CUSHMAN, 1946, p. 96, pl. 40, figs. 11-12.

Globulina lacrima (Reuss), SLITER, 1968, p. 77, pl. 9, fig. 17; pl. 10, fig. 1.

Globulina lacrima lacrima Reuss, BECKMANN, 1978, p. 766, pl. 1, fig. 28.

Distribution: Common in the Korojon Calcarenite.

Globulina lacrima horrida Reuss 1845

(Pl. 6, Fig. 23)

Globulina horrida REUSS, 1845, p. 110, pl. 43, fig. 14.

Globulina lacrima Reuss var *horrida* CUSHMAN AND OZAWA, 1930, p. 79, pl. 19, fig. 3; CUSHMAN, 1946, p. 97, pl. 40, fig. 14.

Globulina lacrima horrida Reuss BECKMANN, 1978, p. 766, pl. 3, figs. 27-28.

Distribution: Rare in the Korojon Calcarenite.

Genus *Guttulina* d'Orbigny in de la Sagra, 1839

Type species: *Polymorphina (Guttuline) communis* d'Orbigny, 1826.

Guttulina Sp. 1

(Pl. 7, Fig. 1)

Distribution: Rare in both the Korojon Calcarenite and Withnell No. 1.

Guttulina Sp. 2

(Pl. 7, Fig. 2)

Remarks: The two species are distinguished in the overall test shape; *G. Sp. 1* is globular, *G. Sp. 2* is elongate.

Distribution: Rare, Withnell No. 1.

Subfamily RAMULININAE Brady, 1884

Genus *Ramulina* Jones in Wright 1875

Type species: *Ramulina laevis* Jones 1875.

Ramulina pseudoaculeata (Olsson), 1960

(Pl. 7, Fig. 4)

Dentalina aculeata (d'Orbigny), CUSHMAN, 1946, p.67, pl. 26, figs. 17-18.

Dentalina pseudoaculeata OLSSON, 1960, p. 14, pl. 3, figs. 1-2.

Ramulina pseudoaculeata (Olsson), SLITER, 1968, p. 79, pl. 10, fig. 8.

Distribution: Common in the Miria Marl, and Korojon Calcarenite, rare in the Toolonga Calcilutite.

Family GLANDULINIDAE Reuss, 1860

Subfamily GLANDULININAE Reuss, 1860

Genus *Tristix* Macfadyen 1941

Type species: *Rhabdogonium liasinum* Berthelin, 1879.

Tristix sp. 1

(Pl. 7, Fig. 4)

Description: Test small featureless, uniserial throughout with triangular cross-section.

Distribution: Rare, top of Site 217.

Subfamily OOLININAE Loeblich and Tappan, 1961

Genus *Fissurina* Reuss, 1850

Type species: *Fissurina laevigata* Reuss, 1850

Fissurina cf. *orbignyana* Seguenza 1862

(Pl. 7, Fig. 5)

Fissurina orbignyana SEGUENZA, 1862, p. 66, pl. 2, figs. 25-26; SLITER, 1968, p. 82, pl. 11, fig. 3.

Remarks: Similar to *F. orbignyana* possessing narrow bordering keels. However, the specimens show no clear flange around the outside of the test and the aperture is a slit rather than being presented on the end of a short neck.

Distribution: Rare, Miria Marl, Korojon Clacarenite and Gaj River.

Fissurina Sp. 1

(Pl. 7, Fig. 6)

Description: Same shape and size as *F.* cf. *orbignyana* but differs in having both sides of the test decorated by costae.

Distribution: Miria Marl and Minilya No. 1, rare in both cases.

Superfamily BULIMINACEA Jones, 1875

Family TURRILINIDAE Cushman, 1927

Subfamily TURRILININAE Cushman, 1927

Genus *Praebulimina* Hofker, 1953

Type species: *Bulimina ovulum* Reuss, 1844.

Praebulimina carseyae (Plummer) 1931

(Pl. 7, Fig. 7)

Bulminella carseyae PLUMMER, 1931, p. 179, pl.8, fig. 9

Praebulimina carseyae (Plummer), HOFKER, 1957, p. 192, figs. 235-237; SLITER, 1968, p. 83, pl. 11, fig. 16.

Distribution: Common in all sections except Gaj River where it is rare, and Site 288A where it is absent.

Praebulimina kickapooensis (Cole), 1938

(Pl. 7, Fig. 8)

Bulimina kickapooensis COLE, 1938, p. 45, pl. 3, fig. 5.

Praebulimina kickapooensis (Cole), HOFKER, 1957, p. 190, figs. 233-234; SLITER, 1968, p. 84, pl. 11, figs. 17-19.

Distribution: Very common Gaj River, rare Minilya No. 1.

Praebulimina laevis (Beissel), 1891

(Pl. 7, Fig. 9)

Bulimina laevis BEISSEL, 1891, p. 66, pl. 12, figs. 39-43.

Praebulimina laevis (Beissel), HOFKER, 1956, p. 71, fig. 51.

Distribution: Common in all sections except Sites 217 and 288A where it is absent.

Praebulimina reussi (Morrow), 1934

(Pl. 7, Figs. 10-11)

Bulimina reussi MORROW, 1934, p. 195, pl. 29, fig. 12.

Praebulimina reussi (Morrow) HOFKER, 1957, p. 187, fig. 227; SLITER, 1968, p. 85, pl. 12, fig. 1 (not fig. 2); SLITER, 1977, p. 675, pl. 4, figs. 9-10.

Remarks: Two forms of this species are figured. Specimens from the Carnarvon Basin (pl. 7, fig. 11) show a sharper initial section than elsewhere.

Distribution: Common in Gaj River, the Korojon Calcarenite, Miria Marl. Rare in the Toolonga Calcilutite and Minilya No.1.

Praebulimina Sp. 1

(Pl. 7, Fig. 12)

?Praebulimina reussi (Morrow) SLITER, 1968, p. 85, pl. 12, fig. 2 (Not Fig. 1).

Remarks: Possibly a variant of *P. reussi*. Distinguished from this latter species by this more ovate test and shorter apertural face which results in the curved aperture very close to the top of the test.

Distribution: Site 217 only, rare.

Praebulimina Sp. 2

(Pl. 7, Fig. 13)

Remarks: Easily distinguished from other members of this genus by its large size and the lobate edges of its chambers.

Distribution: Single specimen from Site 217.

Family BOLIVINITIDAE Cushman, 1927

Genus *Bolivina* d'Orbigny, 1839

Type species: *Bolivina plicata* Cushman, 1911.

Bolivina incrassata Reuss, 1851

(Pl. 7, Fig. 14)

Bolivina incrassata REUSS, 1851, p. 29, pl. 5, fig. 13; SLITER, 1968, p. 88, pl. 12, fig. 14; SLITER, 1977, p. 674, pl. 5, fig. 1.

Distribution: Common in all sections except Toolonga Calcilutite and Site 288A where it is absent.

Bolivina incrassata gigantea Wicher, 1949

(Pl. 7, Fig. 15)

Bolivina incrassata Reuss forma *gigantea* WICHER, 1949, p. 85, pl. 5, figs. 2-3.

Bolivina incrassata gigantea Wicher, BETTENSTAEDT AND WICHER, 1955, p. 502, pl. 2, fig. 19; SLITER, 1968, p. 88, pl. 12, fig. 15.

Distribution: Common in Site 217, Minilya No.1 and Gaj River.

Genus *Bolivinoides* Cushman, 1927

Type species: *Bolivina draco* Marsson, 1878.

Bolivinoides cf. *culverensis* Barr, 1967

(Pl. 7, Fig. 16)

Bolivinoides hiltermanni BARR, 1966, pp. 229-231, pl. 36, figs. 7, 8; pl. 37, figs. 1-3.

Bolivinoides culverensis BARR, 1967, p. 136; PETTERS, 1977, pp. 1031-1032, pl. 1, figs. 10-12.

Remarks: Similar to specimens figured by Petters but differs in the sharper initial angle of test. *B. culverensis* s.s. is restricted to the Late Santonian - Early Campanian (Barr 1966, Petters 1977).

Distribution: Common at the top of Site 217, rare questionable appearance in Withnell No. 1.

Bolivinoides draco (Marsson), 1878

(Pl. 7, Fig. 17)

Bolivina draco MARSSON, 1878, p. 157, pl. 3, fig. 25.
Bolivinoides draco draco (Marsson), HILTERMANN AND KOCH, 1950, p. 598, fig. 1, 72-73, 2-4, 52-54, 58-60, 5, 53, 69-70; SLITER, 1968, p. 88, pl. 12, fig. 17. (Synonomy)
Bolivinoides draco (Marsson) MONTANARO GALLITELLI, 1957, p. 145, pl. 33, figs. 14-16; BARR, 1970, p. 646, pl. 99, figs. 2,3; PETTERS, 1977, p. 1033, pl. 1, fig. 1.
Distribution: Found in varying numbers in all sections except Toolonga Calcilutite and Site 288A.

Bolivinoides giganteus Hiltermann and Koch, 1950

(Pl. 7, Fig. 18)

Bolivinoides decorata gigantea HILTERMANN AND KOCH, 1950, pp. 610-612, text, fig. 2-4, no. 49, 51, 63; text fig. 5, No. 50.
Bolivinoides decorata (Jones) *australis* EDGELL, 1954, pp. 71-72, pl. 13, figs. 5, 6; pl. 14, figs. 5,6.
Bolivinoides giganteus Hiltermann and Koch, HOFKER, 1957, p. 267, text fig. 320; PETTERS, 1977, pp. 1032-1033, pl. 1, fig. 6.
Distribution: Miria Marl, Korojon Calcarenite (very common in both sections), Withnell No. 1, Minilya No. 1 (less common).

Bolivinoides ?giganteus Hiltermann and Koch, 1950

(Pl. 7, Fig. 19)

Remarks: Two small fragmentary specimens found. Test ovate, inflated, covered with continuous reteral processes as in *B. giganteus*. The two specimens are tentatively assigned to this species.

Distribution: Rare, top of Site 217.

Bolivinoides miliaris Hiltermann and Koch, 1950

(Pl. 7, Fig. 20)

Bolivinoides draco (Marsson) *miliaris* HILTERMANN AND KOCH, 1950, pp. 604-606, text figs. 2-4, no. 32-34 (?), 39-41, 46-48; text fig. 5, no. 39a-c.

Bolivinoides miliaris Hiltermann and Koch, BARR, 1966, pp. 234-235, pl. 35, figs. 4-5; PETTERS, 1977, p. 1034, pl. 1, fig. 3.

Distribution: Rare in Site 217 and the Korojon Calcarenite.

?Bolivinoides Sp. 1

(Pl. 8, Fig. 1)

Remarks: Test small, biserial with an acute periphery. Early chambers indistinct lacking reteral processes. Final chambers distinct, reniform with a single process extending to the mid-line of the test.

Distribution: Common in the top part of the section at Site 217.

Genus *Loxostomoides* Reiss, 1957

Type species: *Bolivina applini* Plummer, 1927.

Loxostomoides cushmani Wickenden 1932

(Pl. 8, Fig. 2)

Loxostomoides cushmani WICKENDEN, 1932, p. 91, pl. 1, figs. a-b; CUSHMAN, 1946, p. 129, pl. 53, figs. 24-31.

Distribution: Very common in the upper half of the Gaj River section.

Family EOUVIGERINIDAE Cushman, 1927

Genus *Eouvigerina* Cushman, 1926b

Type species: *Eouvigerina americana* Cushman, 1926

Eouvigerina americana Cushman, 1926

(Pl. 8, Fig. 3)

Eouvigerina americana CUSHMAN, 1926, p. 4, pl. 1, figs. 1a-c; BELFORD, 1960, pp. 63-64, pl. 16, figs. 3-6.

Distribution: Miria Marl (common), Withnell No.1, Minilya No. 1 (less so).

Eouvigerina gracilis (Reuss) 1851

(Pl. 8, Fig. 4)

Uvigerina gracilis REUSS, 1851, p. 77, pl. 5, fig. 39a-b.

Eouvigerina gracilis (Reuss), CUSHMAN, 1946, p. 115, pl. 49, fig. 6;VILLAIN, 1977 p. 70, pl. 5, fig. 11.

Distribution: Rare Site 217, Gaj River and Miria Marl.

Genus *Stilostomella* Guppy, 1894

Type species: *Stilostomella rugosa* Guppy, 1894.

Stilostomella aspera (Reuss), 1845

(Pl. 8, Fig. 5)

Nodosaria aspera REUSS, 1845, p. 26, pl.13, figs. 14-15.

Stilostomella aspera (Reuss), BELFORD, 1960, p. 69, pl. 19, figs. 1-2.

Distribution: Miria Marl (rare) and Korojon Calcarenite (common).

Stilostomella ?sagrinensis (Bagg), 1912

(Pl. 8, Fig. 6)

Nodosaria sagrinensis BAGG, 1912 (seen in Ellis and Messina 1940).

Stilostomella sagrinensis (Bagg) VILLAIN, 1977, p.47, pl.4, fig.11.

Remarks: Identical to the description given by Bagg, 1912 which Villain (1977) records from the type Maastrichtian.

Distribution: Top of Site 217 only, common.

Family BULIMINIDAE Jones, 1875

Subfamily BULIMININAE Jones, 1875

Genus *Bulimina* d'Orbigny, 1826

Type species: *Bulimina marginata* Cushman, 1911.

Bulimina prolixa Cushman and Parker, 1935

(Pl. 8, Fig. 7)

Bulimina prolixa CUSHMAN and PARKER, 1935, p.98, pl. 15, fig. 5.

Reussella prolixa (Cushman and Parker) HOFKER, 1957, p. 209, fig. 255-256.

Pyramidina prolixa (Cushman and Parker) SLITER, 1968, p. 86, pl. 12, figs. 7-8.

Distribution: Common, Miria Marl, Korojon Calcarenite and Withnell No. 1, less common in Minilya No. 1.

Bulimina pseuodspinulosa (Troelsen), 1945

(Pl. 8, Fig. 8)

Reussella pseudospinulosa TROELSEN, 1945, p. 261; SLITER, 1977, pl. 5, figs. 8, 11.

Remarks: Tentative identification only from specimens figured by Sliter, 1977.

Distribution: Site 217 only, very common.

Bulimina Sp. 1

(Pl. 8, Fig. 9)

Description: Test small, rapidly flaring. Thicker than *B. prolixa*, also lacks the twisted arrangement of chambers which is common in that species. Chambers globular, sutures depressed. Surface of the test occasionally roughened as if recrystallization has obscured ornamentation.

Distribution: Gaj River only, common.

Bulimina Sp. 2

(Pl. 8, Fig. 10)

Description: Test squat, small, triserial throughout. Later chambers more distinct with slightly depressed sutures. Initial portion of the test blunt, heavily ornamented with reticulate costae and pustules. Final chambers partly covered by vernicular ornamentation.

Remarks: Similar to *B. arkadelphiana*, Cushman and Parker, however, the difference in ornamentation style and initial test shape distinguishes it from this species.

Distribution: Common in the Miria Marl, less so in Withnell No. 1 and Minilya No. 1.

Subfamily PAVONININAE Eimer and Fickert, 1899

Genus *Reussella* Galloway, 1933

Type species: *Verneuilina spinulosa* Reuss, 1850.

Reussella szajnochae (Grzybowski), 1896

(Pl. 8, Fig. 11)

Verneuilina szajnochae GRZYBOWSKI, 1896, p. 287, pl. 9, fig.19.

Pyramidina szajnochae (Grzybowski) SLITER, 1968, p. 87, pl. 12, fig. 13.

Reussella szajnochae (Grzybowski) subspp. BELFORD, 1960, pp.66-69, pl. 16, figs. 16-19.

Reussella szajnochae (Grzybowski) SLITER, 1977, p. 684, pl. 5, figs. 9-10; BECKMANN, 1978, pl. 2, figs. 16-17.

Distribution: Found in varying numbers in all sections except Site 288A.

Family UVIGERINIDAE Haeckel, 1894

Genus *Pseudouvigerina* Cushman, 1927

Type species: *Uvigerina cristata* Marsson, 1878.

Pseudouvigerina plummerae Cushman, 1927

(Pl. 8, Fig. 12)

Pseudouvigerina plummerae CUSHMAN, 1927a, p. 115, pl. 23, fig. 8; SLITER, 1968, p. 91, pl. 13, fig. 11.

Distribution: Reasonably common in Gaj River, the Korojon Calcarenite, Withnell No.1 and Minilya No. 1.

Superfamily DISCORBACEA Ehrenberg, 1838

Family GLABRATELLIDAE Loeblich and Tappan 1964

Genus *Heronallenia* Chapman and Parr, 1931

Type Species: *Discorbina wilsoni* Heron-Allen and Earland, 1922

Heronallenia Sp. 1

(Pl. 8, Figs. 13-15)

Description: Test small, highly compressed. Umbilical side concave, spiral convex. Chambers strongly crescentic with thickened translucent rim. Umbilical side of chamber marked with large lobe extending back over previous chamber.

Remarks: Very similar to the specimen figured by Sliter (1968) as *Pseudopatellinella minuta* but this species lacks the thickened rim indicative of the Western Australian material.

Distribution: Rare, Korojon Calcarenite.

Family EPISTOMARIIDAE Hofker, 1954

Genus *Nuttallinella* Belford, 1959

Type species: *Nuttallina coronula* Belford, 1958.

Nuttallinella coronula (Belford) 1958

(Pl. 8, Figs. 16-18)

Nuttalina coronula BELFORD, 1958, p. 97, pl. 19, figs. 1-14; test fig. 4.

Nuttalinella coronula (Belford), 1960, p.84,pl.23, figs.7-12.

Distribution: Rare basal Site 217 and the Toolonga Calcilutite.

?Nuttallinella Sp. 1

(Pl. 8, Figs. 19-21)

Description: Similar to *N. coronula* but lacks large peripheral flange. Chambers smaller, more numerous. Test biconvex but with very high spiral side. Final chamber of final whorl drops below plane of coiling. Dissection shows same toothplate structure as *N. coronula*. Specimens from 217 tend to be thicker and more robust than in Gaj River.

Distribution: Gaj River and top of Site 217, common.

Genus *Nuttallides* Finlay, 1939

Type species: *Eponides trumpyi* Nuttall, 1930.

Nuttallides cf. *galiciensis* Fisher, 1969

(Pl. 8, Figs. 22-24)

Nuttallides galiciensis FISHER, 1969, pp. 194-195, text fig. 1a-c.

Description: Test large, equally biconvex with a thickened rim around its periphery. Umbilical side involute with the umbilicus blocked by a small plug. Sutures radial. Central portion covered with a secondary thickening. Spiral side

evolute, with numerous small crescentic chambers. Initially sutures flush, eventually they become slightly depressed. Aperture a long slit at base of final chamber. Differs from *Nt. galiciensis* by possessing less numerous, more crescentic chambers and straight sutures on the umbilical side. Its small umbilical boss separates it from *Nt. trumpyi* (Nuttall).
Distribution: Site 217 only, common.

Family EPONIDIDAE Hofker 1951

Genus *Eponides* de Montfort, 1808

Type species: *Nautilus repandus* Fichel and Moll, 1798.

Eponides ?concinna Brotzen 1936

(Pl. 9, Figs. 1-3)

Eponides concinna BROTZEN, 1936, p. 167, pl. 12, figs. 4a-c; BELFORD, 1960, p. 83, pl. 23, figs. 1-6.
Distribution: Common in the Toolonga Calcilutite.

Eponides aff. *concinna* Brotzen, 1936

(Pl. 9, Figs. 4-6)

Remarks: Differs from Belford's (1960) figures by having deeper umbilical side and larger chambers in the final whorl.
Distribution: Gaj River only, where it is common.

Eponides ?diversus Belford, 1960

(Pl. 9, Figs. 7-9)

Eponides diversus BELFORD, 1960, pp. 82-83, pl. 22, figs. 11-26.

Remarks: This species is possibly synonomous with *Eponides beisseli* Schijfsma.

Distribution: All Western Australian sections, common.

Eponides simplex (White) 1928a

(Pl. 9, Figs. 10-12)

Gyroidina simplex WHITE, 1928a, p. 290, pl. 40, fig. 7.

Eponides simplex (White) CUSHMAN, 1946, p. 142, pl. 57, fig. 15.

Distribution: Common in Site 217, Gaj River, Withnell No. 1, and Minilya No. 1.

Family CIBICIDIDAE Cushman, 1927

Subfamily CIBICIDINAE, Cushman, 1927

Genus *Cibicides* de Montfort, 1808

Type species: *Cibicides refulgens* de Montfort, 1808.

Cibicides bembix (Marsson)

(Pl. 9, Figs. 13-15)

Discorbina bembix MARSSON, 1878, p. 167, pl. 5, fig. 37.

Cibicides bembix (Marsson) MARIE, 1941, p. 248, pl. 137, fig. 350.

Gavelinopsis bembix (Marsson) HOFKER, 1957,p. 330, text figs. 380-384.

Distribution: Miria Marl, Korojon Calcarenite, Withnell No. 1, Minilya No. 1. Abundant, in all sections.

Cibicides monterelensis (Marie) 1941

(Pl. 9, Figs. 19-21)

Anomalina monterelensis MARIE, 1941, p. 243, pl. 37, fig. 342.

Gavelinopsis monterelensis (Marie) HOFKER, 1966, p. 29, pl. 3, fig. 60; VILLAIN, 1977, p. 59, pl. 7, figs. 1-3.

Distribution: Common in Gaj River section, Site 217, and in the Korojon Calcarenite.

Cibicides stellula (Belford), 1960.

(Pl. 9, Figs. 16-18)

Gavelinella stellula BELFORD, 1960, p. 110, pl. 33, figs. 11-18.

Distribution: Common in the Toolonga Calcilutite.

Cibicides voltziana (d'Orbigny) 1840

(Pl. 10, Figs. 1-3)

Rotalina voltziana d'ORBIGNY, 1840, p. 31, pl. 2, figs. 32-34.

Cibicides voltziana (d'Orbigny) MARIE, 1941, p. 247, pl. 37, figs. 345-347.

Gavelinopsis voltziana (d'Orbigny) VILLAIN, 1977, pp. 59-60, pl. 7, figs. 4-6.

Distribution: Common to abundant in all sections.

?Cibicides Sp. 1

(Pl. 10, Fig. 4-6)

Description: Test medium in size, almost planispiral. Aperture at the base of final chamber one side evolute. Sutures initially flush, finally slightly depressed other side with sutures strongly thickened and raised with some secondary thickening in the centre of the test.

Distribution: Common in Gaj River.

Family PLANORBULINIDAE Schwager, 1877

Genus *Planorbulina* d'Orbigny, 1826

Type species: *Planorbulina mediterranensis* Cushman, 1915.

Planorbulina Sp. 1

(Pl. 10, Figs. 7-8)

Description: Test large, flattened, and attached. Chambers initially spirally coiled, later irregularly arranged. Flat on attached side, inflated on the other, coarsely perforate.

Distribution: Rare, Korojon Calcarenite.

Family HOMOTREMATIDAE Cushman, 1927

Subfamily VICTORIELLINAE Chapman and Crespin, 1930

Genus *Carpenteria* Grey, 1858

Type species: *Carpenteria balaniformis* Grey, 1858.

Carpenteria conica (Belford), 1960

(Pl. 10, Figs. 9-11)

Haerella conica BELFORD, 1960, p. 115, pl. 35, figs. 1-12.

Distribution: Common Toolonga Calcilutite.

Carpenteria globosa (Belford), 1960

(Pl. 10, Figs. 12-14)

Haerella globosa BELFORD, 1960, p. 116, pl. 35, figs. 13-20.

Distribution: Common Toolonga Calcilutite.

Superfamily CASSIDULINACEA d'Orbigny, 1839

Family PLEUROSTOMELLIDAE Reuss, 1860

Subfamily PLEUROSTOMELLINAE Reuss, 1860

Genus *Pleurostomella* Reuss,1860

Type species: *Dentalina subnodosa* Reuss, 1851.

Pleurostomella subnodosa Reuss, 1860

(Pl. 10, Figs. 15-16)

Pleurostomella subnodosa REUSS, 1860, p. 204, pl. 8, figs. 2a-b; BELFORD, 1960, p. 70, pl. 19, figs. 3-4; (Synonomy), DUPEUBLE, 1979, pl. 3, figs. 3-4.

Distribution: Common in the Korojon Calcarenite, rare in the Toolonga Calcilutite.

Pleurostomella torta Cushman, 1926

(Pl. 10, Figs. 17-18)

Pleurostomella torta CUSHMAN, 1926c, p. 18, pl. 2, fig. 7; CUSHMAN, 1946, p. 133, pl. 55, fig. 11.

Remarks: Specimens from the Korojon Calcarenite possibly represent a different species. The initial part of their test is narrow but expands rapidly.

Distribution: Site 217, Withnell No. 1 and the Korojon Calcarenite. Rare in all three sections.

Genus *Ellipsoidella* Heron-Allen and Earland, 1910

Type species: *Ellipsoidella pleurostomelloides* Heron-Allen and Earland, 1910.

Ellipsoidella Sp. 1

(Pl. 10, Figs. 19-20)

Description: Distinguished by its small size and low numbers of inflated chambers, aperture a wide crescent with a prominent hood.

Distribution: Site 217, Gaj River, and Minilya No. 1, rare in all these sections.

Ellipsoidella Sp. 2

(Pl. 10, Figs. 21-22)

Description: Test very large, smooth, chambers rapidly expanding in size. Aperture a small deep slit at the top of the final chamber covered with a hook shaped flap.

Distribution: Site 217 only, rare.

Ellipsoidella Sp. 3

(Pl. 10, Figs. 23-24)

Description: Only a single fragment found. Test smooth, narrow with a similar aperture to *E. sp. 1*.

Distribution: Rare in Withnell No. 1 only.

Family LOXOSTOMIDAE Loeblich and Tappan, 1962

Genus *Loxostomum* Ehrenberg 1854

Type species: *Loxostomum subrostratum* Cushman, 1927.

Loxostomum eleyi (Cushman) 1927

(Pl. 10, Figs. 25-26)

Bolivinita eleyi CUSHMAN, 1927b, p. 91, pl. 12, fig. 11.

Loxostomum eleyi (Cushman) LOEBLICH AND TAPPAN, 1964, p. C736, fig. 603, 2-5; SLITER, 1968, p. 112, pl. 20, fig. 2.

Remarks: The specimen figured is from the Korojon Calcarenite and, with its initial irregular raised sutures may represent a new species.

Distribution: Top part of Site 217, Miria Marl and Korojon Calcarenite, common.

Genus *Aragonia* Finlay 1939

Type species: *Aragonia zelandica* Finlay, 1939.

Aragonia velascoensis (Cushman) 1925

(Pl. 10, Fig. 27)

Textularia velascoensis CUSHMAN, 1925, p. 18, pl. 3, figs. 1a-c.

Aragonia velascoensis (Cushman) SLITER, 1977, pl. 7, fig. 11.

Distribution: Rare in Site 217.

Superfamily NONIONACEA Schultze, 1854

Family NONIONIDAE Schultze, 1854

Subfamily CHILOSTOMELLINAE Brady, 1881

Genus *Quadrimorphina* Finlay, 1939

Type species: *Valvulina allomorphinoides* Reuss, 1860.

Quadrimorphina allomorphinoides (Reuss), 1860

(Pl. 10, Figs. 28-29)

Valvulineria allomorphinoides REUSS, 1860, p. 223, pl. 11, fig. 6.

Quadrimorphina allomorphinoides (Reuss) TRUJILLO, 1960, p. 330, pl. 47, fig. 15; SLITER, 1968, p. 114, pl. 20, fig. 7.
Distribution: Site 217, Gaj River, Korojon Calcarenite and the Toolonga Calcilutite. Common in all four sections.

Subfamily NONIONINAE Schultze, 1854

Genus *Pullenia*, Parker and Jones in Carpenter, Parker and Jones, 1862

Type species: *Nonionina bulloides* d'Orbigny, 1846.

Pullenia ?americana Cushman, 1936 b

(Pl. 11, Figs. 5-6)

Pullenia americana CUSHMAN, 1936b, p. 76, pl. 13, figs. 4a-b, 5a-b; BELFORD, 1960, p. 89, pl. 24, figs. 16-18.
Distribution: Common in all sites containing benthonic forms.

Pullenia coryelli White, 1929

(Pl. 11, Figs. 1-2)

Pullenia coryelli WHITE, 1929, p. 56, pl. 5, fig. 22; CUSHMAN, 1946, p. 147, pl. 60, figs. 10, 11; BECKMANN, 1978, pl. 3, fig. 21.
Distribution: Common in Site 217, the Korojon Calcarenite, the Toolonga Calcilutite, Withnell No. 1, and Minilya No. 1.

Pullenia cretacea Cushman, 1936

(Pl. 11, Figs. 3-4)

Pullenia cretacea CUSHMAN, 1936b, p. 75, pl. 13, fig. 8; SLITER, 1968, p. 115, pl. 21, fig. 2.

Distribution: Common in Site 217, Gaj River and questionably the Korojon Calcarenite.

Family ALABAMINIDAE Hofker, 1951

Genus *Alabamina* Toulmin, 1941

Type species; *Alabamina wilcoxensis* Toulmin, 1941.

Alabamina australis Belford, 1960

(Pl. 11, Figs. 7-9)

Alabamina australis australis BELFORD, 1960, pp. 84-85, pl. 23, figs. 13-20; text figs. 4,5 (1-4).

Alabamina australis obscura BELFORD, 1960, pp. 86-87, pl. 24, figs. 1-8; text fig. 5 (5-7).

Distribution: Restricted to the Toolonga Calcilutite, rare.

Alabamina dorsoplana (Brotzen), 1940

(Pl. 11, Figs. 10-12)

Eponides dorsoplana BROTZEN, 1940, p. 31, fig. 8:2.

Alabamina dorsoplana (Brotzen), BROTZEN, 1948, p. 102, pl. 16, fig. 3, text - figs. 25-27.

Distribution: Miria Marl, Korojon Calcarenite, Toolonga Calcilutite, and Withnell No. 1, rare in all four sections.

Family OSANGULARIIDAE Loeblich and Tappan, 1964

Genus *Osangularia* Brotzen, 1940

Type species: *Osangularia lens*, Brotzen, 1940.

Osangularia Sp. 1

(Pl. 11, Figs. 13-15)

Description: Test large, biconvex, with a thickened rim around its periphery. Spiral side evolute and marked by secondary apertures on each chamber. Increasing in size with age. Other side of test smooth, involute, with the aperture a bent opening at the base of the final chamber.

Distribution: Common Site 217.

Osangularia Sp. 2

(Pl. 11, Figs. 16-18)

Remarks: Distinguished from *O. Sp. 1* by its smaller almost featureless test. The height of the spiral side is very variable.

Distribution: Common in Withnell No. 1 and Minilya No. 1.

Genus *Globorotalites* Brotzen, 1942

Type species: *Globorotalia multisepta* Brotzen, 1936.

Globorotalites michelinianus (d'Orbigny), 1840

(Pl. 11, Figs. 19-21)

Rotalina micheliniana d'ORBIGNY, 1840, p. 31, pl. 3, figs.1-3.

Globorotalites micheliniana (d'Orbigny), VILLAIN, 1977, p. 56, pl. 9, figs. 4-6.

Globorotalites michelinianus (d'Orbigny) SLITER, 1968, p. 119, pl. 22, fig. 1.

Distribution: Common in Gaj River, the Korojon Calcarenite and the Toolonga Calcilutite. Rare in Withnell No. 1 and Minilya No. 1.

Globorotalites Sp. 1

(Pl. 11, Figs. 22-24)

Description: Test very small. Relatively flat spiral side, central portion slightly raised and a raised angular shoulder runs around the periphery. Coiling evolute. Deep u-shaped umbilical side with a distinct umbilicus. Aperture an elongate slit at the base of the final chamber.

Distribution: Gaj River, Withnell No. 1, Minilya No. 1. Rare in all three sections.

Genus *Gyroidinoides* Brotzen, 1942

Type species: *Rotalina nitida* Reuss, 1844.

Gyroidinoides girardana (Reuss), 1851

(Pl. 12, Figs. 10-12)

Rotalina girardana REUSS, 1851, p. 73, pl. 5, fig. 34a-c.

Gyroidinoides girardana, VILLAIN, 1977, p. 57, pl. 9, figs. 10-12.

Distribution: Common in all sections except Site 288A.

Gyroidinoides nitida (Reuss) 1844

(Pl. 12, Figs. 1-3)

Rotalina nitida REUSS, 1844, (in Ellis and Messina, 1973).

Gyroidinoides nitida (Reuss), VILLAIN, 1977, pp. 56-57, pl. 10. figs. 1-3.

Distribution: Common in all sections except Site 288A.

Gyroidinoides aff. *pontoni* Brotzen 1948

(Pl. 12, Figs. 4-6)

Gyroidinoides pontoni BROTZEN, 1948, p. 76, pl. 11, figs. 4,5.

Remarks: Similar to *Gy. pontoni* from the Paleocene of Europe. Also shows a strong resemblance to *Gy. umbilicata* (d'Orbigny).

Distribution: Found in all sections except Gaj River and 288A, common.

Gyroidinoides umbilicata (d'Orbigny), 1840

(Pl. 23, Figs. 7-9)

Rotalina umbilicata d'ORBIGNY, 1840, p. 32, pl. 3, figs. 4-6.

Gyroidinoides umbilicata (d'Orbigny), VILLAIN, 1977, p. 57, pl. 10, figs. 4-6.

Distribution: Gaj River (common), Site 217 (rare).

Family ANOMALINIDAE Cushman, 1927

Subfamily ANOMALININAE Cushman, 1927

Genus *Anomalinoides* Brotzen, 1942

Type species: *Anomalinoides plummerae* Brotzen, 1942.

Anomalinoides ?henbesti (Plummer), 1936

(Pl. 12, Figs. 13-15)

Anomalina henbesti PLUMMER, 1936, p. 290, pl. 5, figs. 7-10.

Gavelinella henbesti (Plummer) SLITER, 1968, pp. 123-124, pl. 23, fig. 2.

Distribution: Common in all sections except Site 288A, Gaj River and Toolonga Calcilutite where it is absent.

Anomalinoides insculpta (Belford), 1960

(Pl. 12, Figs. 16-18)

Gavelinella insculpta BELFORD, 1960, p. 109, pl. 33, figs. 1-10.

Distribution: Restricted to the Toolonga Calcilutite where it is common.

Anomalinoides aff. *pinguis* (Jennings), 1936

(Pl. 12, Figs. 19-21)

Anomalina pinguis JENNINGS, 1936, p. 37, pl. 5, fig. 1.

Anomalinoides pinguis (Jennings) OLSSON, 1977, pl. IV, figs. F-G.

Remarks: Differs somewhat from the specimens figured by Olsson by possessing a finer more compressed test.

Distribution: Common in Site 217, Miria Marl, Korojon Calcarenite, Withnell No. 1, and Minilya No. 1.

Anomalinoides murchisonensis Belford, 1960

(Pl. 13, Figs. 1-3)

Anomalinoides murchisonensis BELFORD, 1960,pp.107-109, pl. 32, figs. 12-22. Text fig. 12 (1-6).

Distribution: Rare in the basal part of Toolonga Calcilutite.

Anomalinoides velascoensis (Cushman), 1925

(Pl. 13, Figs. 4-6)

Anomalina velascoensis CUSHMAN, 1925, p. 21, pl. 3, figs. 3a-c; CUSHMAN, 1946, p. 156, pl. 64, fig. 7.

Gavelinella velascoensis (Cushman) SLITER, 1977, pl. 13, fig.1.

Gavelinella cf. *velascoensis* (Cushman) BECKMANN, 1978, p. 766, pl. 5, figs. 19-22.

Distribution: Site 217, Korojon Calcarenite, Withnell No. 1, and Gaj River. Common in each section.

Anomalinoides Sp. 1

(Pl. 13, Figs. 7-9)

Description: Test large, almost planispiral, involute. Coarsely perforate especially on spiral side. Aperture a slit at the base of the final chamber. Species distinguished by an irregular secondary thickening in the centre of the spiral side.

Distribution: Abundant in both the Korojon Calcarenite and Miria Marl.

Anomalinoides Sp. 2

(Pl. 13, Figs. 10-12)

Description: Test large, strongly compressed, almost planispiral, numerous chambers per whorl, sutures initially flush, finally thickened and raised. Both sides of test perforate but with an imperforate periphery. Aperture a low slit at the base of the final chamber with a slight lip.

Distribution: Common in the Miria Marl and basal part of the Korojon Calcarenite. Abundant in the upper part of the Korojon Calcarenite.

Genus *Angulogavelinella* Hofker, 1957

Type species: *Discorbina gracilis* Marsson, 1878.

Angulogavelinella aff. *bettenstaedti* Hofker, 1957

(Pl. 13, Figs. 13-15)

Angulogavelinella bettenstaedti HOFKER, 1957, p. 367, figs. 421-422.

Remarks: Hofker's figures indicate a simple smooth umbilical side whereas the specimens found here show a complex radial arrangement of grooves centred on the umbilicus. Coarse perforation is restricted to the spiral side.

Distribution: Abundant in Site 217 and the Miria Marl. Common in Withnell No. 1, and Minilya No. 1.

?*Angulogavelinella cayeuxi* (deLapparent), 1918

(Pl. 13, Figs. 16-18)

Rotalina cayeuxi deLAPPARENT, 1918, p. 89, pl. 9, figs. 1-3, 6, text. figs. 25-26.

Distribution: Common in the Korojon Calcarenite, less so in Withnell No. 1 and Minilya No. 1.

Angulogavelinella rakauroana (Finlay), 1939

(Pl. 13, Figs. 19-21)

Planulina rakauroana FINLAY, 1939, p. 326, pl. 29, figs. 154-156.

Distribution: Common in the basal portions of Site 217, Toolonga Calcilutite, and Korojon Calcarenite. Rare in Withnell No. 1 and Minilya No. 1.

Genus *Coleites* Plummer, 1934

Type species: *Pulvinulina reticulosa* Plummer, 1927.

Coleites Sp. 1

(Pl. 14, Figs. 1-3)

Description: Test small, equally biconvex. Spiral side evolute with large crescentic chambers and distinct, raised sutures. Coarsely perforate final chambers. Centre of test ornamented with reticulate pattern. Other side involute with only the final whorl showing. Sutures initially flush, later deeply indented. Aperture a narrow slit at the base of the final chamber.

Distribution: Reasonably common in the Korojon Calcarenite and Miria Marl.

Genus *Karreria* Rzehak, 1891

Type species: *Karreria fallax* Rzehak 1891.

Karreria aff. *beaumontiana* (d'Orbigny)

(Pl. 14, Figs. 4-6)

Cibicides beaumontiana (d'Orbigny) HOFKER, 1957, p. 94, fig. 98.

Distribution: Common in the Korojon Calcarenite and Toolonga Calcilutite, less so in Site 217, Minilya No. 1 and Gaj River.

Karreria Sp. 1

(Pl. 14, Figs. 7-9)

Description: Test medium in size, attached. Distinguished from *K* aff. *beaumontiana* by its initially planoconvex, regularly coiled test, which is followed by a single whorl of highly inflated chambers.

Distribution: Common in Miria Marl, rare in Korojon Calcarenite.

Genus *Stensioeina* Brotzen, 1936

Type species: *Rotalia exsculpta* Reuss, 1860.

Stensioenia pommerana Brotzen, 1936

(Pl. 14, Figs. 10-12)

Stensioenia pommerana BROTZEN, 1936, p. 166; VILLAIN, 1977, pp. 58-59, pl. 11, figs. 10-12.

Distribution: Common in Gaj River, Site 217, Korojon Calcarenite, Withnell No. 1 and Minilya No. 1.

?Stensioenia Sp. 1

(Pl. 14, Figs. 13-15)

Description: Test small, planoconvex. Spiral side flat, evolute, with slightly raised sutures. Other side involute, sutures slightly depressed, possesses radial ornamentation in centre of test, and large pores similar to those on *A. bettenstaedti*.

Distribution: Restricted to Gaj River where it is common.

Superfamily ROBERTINACEA Reuss, 1850

Family CERATOBULIMINIDAE Cushman, 1927

Subfamily CERATOBULIMININAE Cushman, 1927

Genus *Ceratolamarckina* Troelsen, 1954

Type species: *Ceratobulimina tuberculata* Brotzen, 1948

Ceratolamarckina Sp. 1

(Pl. 14, Figs. 16-18)

Description: Test small, almost planispiral. Spiral side slightly evolute, sutures depressed. Large open umbilicus filled with pustulose ornament into which the aperture opens. The aperture also continues round the base of the final chamber almost into the spiral side.

Distribution: Rare, Korojon Calcarenite.

LATE CRETACEOUS PLANKTONIC FORAMINIFERA

Superfamily GLOBIGERINACEA Carpenter, Parker and Jones, 1862

Family HETEROHELICIDAE Cushman, 1927

Genus *Heterohelix* Ehrenberg, 1843.

Type species: *Spiroplecta americana* Ehrenberg, 1844.

Heterohelix glabrans (Cushman), 1938b

(Pl. 15, Figs. 1-2)

Guembelina glabrans CUSHMAN, 1938b,p. 15, pl. 3, figs. 1a-b, 2.

Heterohelix glabrans (Cushman), OLSSON, 1960, pp. 26-67, pl. 4, fig. 4; MASTERS, 1977, p. 343, pl. 1, figs. 6, 7.

Remarks: Faint striae have been found on the initial portion of the test of some specimens. Pore mounds such as recorded by Masters (1977) are absent.

Distribution: Present in varying numbers in all sections except Site 217.

Heterohelix moremani (Cushman), 1938 b

(Pl. 15, Figs. 3-4)

Guembelina moremani CUSHMAN, 1938 b, p. 10, pl. 2, figs. 15-17.

Heterohelix moremani (Cushman), MASTERS, 1977, pp. 346-347, pl. 2, fig. 1, (Synonomy), PETTERS, 1977, pl. 1, fig. 10.

Distribution: Base of Site 217, rare.

Heterohelix planata (Cushman), 1938 b

(Pl. 15, Figs. 5-6)

Guembelina planata CUSHMAN, 1938b, p. 12, fig. 13, 14.

Heterohelix planata (Cushman), OLSSON, 1960, p. 27, pl. 4, fig. 6; PESSAGNO, 1967, pp. 261-262, pl. 86, figs. 3, 4; pl. 89, figs. 6, 7. (Synonomy) PETTERS, 1977, pl. 1, fig. 9.

Remarks: A single specimen from high in the section of Gaj River appears identical to that figures by Petters (1977).

Distribution: Very rare Gaj River.

Heterohelix ***pulchra*** (Brotzen), 1936

(Pl. 16, Figs. 7-8)

Guembelina ***pulchra*** BROTZEN, 1936, p. 121, pl. 9, figs. 3a-b, not figs. 2a-2b.

Heterohelix *pulchra* (Brotzen), MONTANARO GALLETTELLI, 1957, p. 137, pl. 31, fig. 20; PESSAGNO, 1967, p. 262, pl. 87, fig. 4.

Distribution: Common in the Korojon Calcarenite, Minilya No. 1, Withnell No. 1 and in the basal part of Site 217, rare in the Miria Marl, Toolonga Calcilutite and Gaj River.

Heterohelix ? punctulata (Cushman), 1938

(Pl. 15, Fig. 9-10)

Guembelina punctulata CUSHMAN, 1938b, p. 13, pl. 2, figs. 15, 16; *Heterohelix punctulata* (Cushman), PESSAGNO, 1962, p. 358, pl. 1, fig. 11; PESSAGNO, 1967, pp. 262-263, pl. 86, figs. 9-10.

Remarks: Under light microscopy this specimen seemed to have the typical punctate wall texture expected of *H. punctulata*, however, on the SEM, the wall ornamentation was revealed as being short discontinuous costae, and the specimen then looked like a variant of *H. ultimatumida*. Further work is required to sort out the relationship between these two species.

Distribution: Single specimen from the Korojon Calcarenite.

Heterohelix striata (Ehrenberg) 1840

(Pl. 15, Figs. 11-12)

Textularia striata EHRENBERG, 1840, p. 135, pl. 4, figs. 1alpha, 1alpha prime, 2alpha, not fig. 9alpha.

Heterohelix striata (Ehrenberg), PESSAGNO, 1962, p. 358, pl. 1, fig. 5; MASTERS, 1977, pp. 356-358, pl. 3, figs. 2, 3.

Distribution: Ubiquitous in sections studied.

Heterohelix ultimatumida (White) 1929

(Pl. 15, Figs. 13-14)

Guembelina ultimatumida WHITE, 1929, p. 39, pl. 4, figs. 13a-b.

Heterohelix ultimatumida (White) GOVINDAN, 1972, p. 168, pl. 1, figs. 3-4.

Heterohelix robusta STENESTAD, 1969, p. 658, pl. 1, figs. 17-19; pl. 2, fig. 3a-b; text fig. 13a-c.

Distribution: Common in Sites 217 and 288A, less so in the Miria Marl, Korojon and Minilya No. 1.

Heterohelix Sp. 1

(Pl. 15, Figs. 15-16)

Description: Test medium to large. Chambers strongly inflated, slightly reniform. Later chambers with small extensions interlocking down the mid-line of the test, sutures strongly depressed producing a "serrated edge" in adult specimens. Sides of the test flattened. Aperture a high interomarginal arch at the base of the final chamber. Strongly striated.

Remarks: The interlocking extensions are not flaps covering supplementary apertures as in *Pseudoguembelina*.

Distribution: Rare in Gaj River and Site 288A.

Genus *Gublerina* Kikoine, 1948

Type species: *Gublerina cuvillieri* Kikoine, 1948.

Gublerina cuvillieri Kikoine, 1948

(Pl. 15, Fig. 17)

Gublerina cuvillieri KIKOINE, 1948, p. 26, pl. 2, fig. 10. BROWN, 1969, pp. 57-58, pl. 2, fig. 7; pl. 3, fig. 5; pl. 4, fig. 5.

Gublerina rajagopalani GOVINDAN, 1972, p. 170, pl. 2, figs. 1-5.

Distribution: Common in all sections.

Gublerina reniformis (Marie), 1941

(Pl. 15, Fig. 18)

Ventilabrella reniformis MARIE, 1941, p.185, pl.28, figs.277a-c.

Gublerina reniformis (Marie), MASTERS, 1977, pp.334-336.

Distribution: Reasonably common in Gaj River, Sites 217, 288A, the Miria Marl and the Korojon Calcarenite.

Genus *Pseudoguembelina* Bronnimann and Brown, 1953

Type species: *Guembelina excolata* Cushman, 1926.

Pseudoguembelina is distinguished from *Heterohelix* by the presence of flaps covering supplementary apertures down the midline of the test (Pessagno, 1967).

Pseudoguembelina costulata (Cushman), 1938b

(Pl. 15, Figs. 19-21)

Guembelina costulata CUSHMAN, 1938b, pp. 16-17, pl. 3, figs. 7a-b, 8, 9.

Pseudoguembelina costulata (Cushman), BRONNIMANN AND BROWN, 1953, pp.153-154, text. fig 5; SMITH AND PESSAGNO, 1973, pp.24-25, pl.6, figs. 1-3, 4-5.

Distribution: Found in every section except the Korojon Calcarenite.

Pseudoguembelina excolata (Cushman), 1926c

(Pl. 16, Figs. 1-3)

Guembelina excolata CUSHMAN, 1926c, p.20, pl.2, fig. 9

Pseudoguembelina excolata (Cushman), BRONNIMANN AND BROWN, 1953, p.153, text figs. 1,2,3,4; SMITH AND PESSAGNO, 1973, pp. 25-26, pl. 6, figs. 6-10.

Distribution: Common in the Miria Marl, the Korojon Calcarenite, Site 288A and Gaj River.

Pseudoguembelina kempensis Esker, 1968

(Pl. 16, Figs. 4-5)

Pseudoguembelina kempensis ESKER, 1968, pp. 168-169, text figs. 1-5; SMITH AND PESSAGNO, 1973, pp. 26-27, pl. 7, figs. 1-9, pl. 8, figs. 1-4.

Distribution: Rare, Gaj River.

Pseudoguembelina Sp. 1

(Pl. 16, Figs. 6-8)

Description: Possibly a variation of *P. costulata*, however, *P. Sp. 1* has a wider, more wedge shaped test.

Distribution: Rare in the Korojon Calcarenite.

Genus *Ventilabrella* Cushman, 1928

Type species: *Ventilabrella eggeri* Cushman, 1928.

Of all the genera comprising the Heterohelicidae, the trio *Ventilabrella*, *Planoglobulina* and *Racemiguembelina* have been the most confused taxonomically (Brown 1963, Martin 1972, Masters 1976, 1977 and Smith 1978). A review of the reasons for the confusion is given in the above references. Valid arguments for the recognition of these three genera as separate taxonomic entities are to be found in Martin (1972) and Smith (1978).

Ventilabrella multicamerata de Klasz, 1953

(Pl. 16, Fig. 9)

Ventilabrella multicamerata De KLASZ, 1953, p. 230, pl. 5, figs. 1a-b. MARTIN, 1972, p. 88, pl. 3, figs. 1, 2.

Ventilabrella manuelensis MARTIN, 1972, pp. 87-88. pl. 2, figs. 5-8.

Distribution: Common in Sites 217 and 288A and Gaj River.

Genus *Pseudotextularia* Rzehak, 1891

Type species: *Cuneolina elegans* Rzehak,

Pseudotextularia deformis (Kikoine), 1948

(Pl. 16, Figs. 10-11)

Guembelina striata (Ehrenberg) *var. deformis* KIKOINE, 1948, p. 20, pl. 1, figs. 8a-c.

Pseudotextularia deformis (Kikoine) PESSAGNO, 1967, p. 269,pl.90, fig, 16, pl. 92, figs. 19-21, pl. 97, figs. 16-17, pl. 98, figs. 15, 17, 18; SMITH AND PESSAGNO, 1973, pp. 29-30, pl. 9, figs. 1-4; pl. 10, fig. 1

Distribution: Reasonably common in all sections except Korojon.

Pseudotextularia elegans (Rzehak) 1891

(Pl. 16, Figs. 12-13)

Cuneolina elegans RZEHAK, 1891, p. 4.

Pseudotextularia elegans (Rzehak) MONTANARO GALLEITELLI 1957, pp. 138-189, pl. 33, figs. 6a-b; SMITH AND PESSAGNO, 1973, pp. 30-32, pl. 9, figs. 5-15; pl. 10, figs. 2-6.

Distribution: All sections, common.

Genus *Planoglobulina* Cushman, 1927

Type species: *Guembelina acervulinoides* Egger, 1899.

Planoglobulina acervulinoides (Egger), 1899

(Pl. 16, Fig. 14)

Planoglobulina acervulinoides (Egger), MARTIN, 1972, pp. 81-82, pl. 3, figs. 3-6 (neotype erected).

Distribution: Rare in all sections except Korojon, where it is absent.

Genus *Racemiguembelina* Montanaro Gallitelli, 1957

Type species: *Guembelina fructicosa* Egger, 1899 (= *Pseudotextularia varians* Rzehak, 1895).

Racemiguembelina varians (Rzehak) 1895

(Pl. 16, Figs. 15-17)

Pseudotextularia varians RZEHAK, 1895, p. 217, pl. 7, figs. 2-3, not figs. 1a-b.

Racemiguembelina fructicosa (Egger), MONTANARO GALLITELLI, 1957, pp. 142-143, pl. 32, figs. 14a-b, 15a-b, PESSAGNO, 1967, pp. 270-271, pl.90, figs.14-15 (Synonomy).

Racemiguembelina varians (Rzehak), SMITH, 1978, pp. 315-316.

Planoglobulina varians (Rzehak), MASTERS, 1977, p. 321.

Distribution: Common in all sections except the Korojon Calcarenite and Site 288A.

Family PLANOMALINIDAE Bolli, Loeblich and Tappan, 1957

Genus *Globigerinelloides* Cushman and ten Dam, 1948

Type species: *Globigerinelloides algeriana* Cushman and ten Dam, 1948.

There seems to be only three distinct forms of this genus in the sections studied. Two are assigned to *Globigerinelloides multispinatus* and *Gl. subcarinata.* The third, for reasons given below is not given a formal species name but is labelled *Gl. Sp. 1.*

Globigerinelloides multispinatus (Lalicker), 1948

(Pl. 16, Figs. 17-21)

Biglobigerinella multispina LALICKER, 1948, p. 624, pl. 92, figs. 1a-c, 2a-b, 3a-c.

Globigerinelloides multispina (Lalicker) PESSAGNO, 1967, pp.276-277, pl.70, pl. 70, figs. 1-2; pl. 87, figs.10-11; pl.91, figs. 1-2; SMITH AND PESSAGNO, 1973, pp.38-39, pl.13, figs. 1-11.

Distribution: Common in all sections.

Globigerinelloides subcarinata (Bronnimann), 1952

(Pl. 17, Figs. 1-2)

Globigerinella messinae subsp. *subcarinata* BRONNIMANN, 1952, pp. 44-45, pl. 1, figs. 1a-m.

Globigerinelloides subcarinatus (Bronnimann) PESSAGNO, 1967, p. 278, pl. 62, figs. 12, 13. SMITH AND PESSAGNO, 1973, pp. 40-41, pl. 16, figs. 10-12.

Remarks: Possibly the most distinctive of all species of *Globigerinelloides.* The unique imperferate band may indicate the necessity of its transferral to a new genus.

Distribution: Common in all sections except the Korojon Calcarenite.

Globigerinelloides Sp. 1

(Pl. 17, Figs. 3-4)

Description: Test small planispiral, biumbilicate evolute, 8-9 chambers per whorl. Aperture a high interomarginal arch with a lip at the base of the final chamber. Relict lips visible in umbilici, surface occasionally pustulose.

Remarks: *Gl. Sp. 1* differs from *Gl. multispinata* by (a) being more evolute, (b) possessing a larger number of chambers per whorl, (c) never showing bifurcation of aperture.

This species is almost certainly part of a plexus of froms lumped by Masters (1977) into *Gl. ultramicra* (Subbotina). This also includes *Gl. aspera* (Ehrenberg) and *Gl. bolli* Pessagno. The specimen figured by Smith and Pessagno 1973 as *G. Sp. A* is very similar, as is *Gl. impensus* Sliter. This latter species, is, however, slightly different in being consistently larger with more numerous chambers per whorl. Further work would be required on the types of all these species to sort out relationships before even a tentative identification can be made.

Distribution: Abundant in all sections except the Miria Marl.

Family HEDBERGELLIDAE Loeblich and Tappan, 1961

Genus *Hedbergella* Bronnimann and Brown, 1958

Type species: *Anomalina lorneiana* d'Orbigny, var *trochoidea* Gandolfi, 1942.

Hedbergella cf. *bulbosa* (Belford), 1960

(Pl. 17, Figs. 5-7)

Rugoglobigerina (Rugoglobigerina) bulbosa BELFORD, 1960, pp. 94-95, pl. 26, figs. 1-10; text fig. 7 (1-8).

Remarks: Very similar to specimens figured by Belford, 1960. However, he reported that the species has four, rarely five, chambers in the final whorl. The specimens found in this study are more varied with five to six chambers not being uncommon.

Distribution: Restricted to Toolonga Calcilutite, common.

Family GLOBOTRUNCANIDAE Brotzen, 1942

Subfamily GLOBOTRUNCANINAE Brotzen, 1942

Genus *Globotruncana* Cushman, 1927

Type species: *Pulvinulina arca* Cushman, 1926.

Globotruncana aegyptiaca Nakkady, 1950

(Pl. 17, Figs. 8-10)

Globotruncana aegyptiaca NAKKADY, 1950, p. 690, pl. 90, figs. 20-22; SMITH AND PESSAGNO, 1973, pp. 42-43, pl. 17, figs. 1-7.

Distribution: Common in Gaj River, rare in Sites 288A and 217, single questionable appearance in Miria Marl.

Globotruncana arca (Cushman), 1926

(Pl. 17, Figs. 11-13)

Pulvinulina arca CUSHMAN, 1926c,p. 23, pl. 3, figs. 1a-c.

Globotruncana arca (Cushman) CUSHMAN, 1927c, p. 169, pl. 28, figs. 15a-c; MASTERS, 1977, pp. 536-540, pl. 23, figs. 1,2,4.

Distribution: Abundant - common in all sections.

Globotruncana cf. *arca* (Cushman), 1926c

(Pl. 17, Figs. 14-16)

Remarks: This species differs from *G. arca* by possessing a narrower double heel and a higher umbilical side.

Distribution: Common in the base of the Gaj River section.

Globotruncana bulloides Vogler, 1941

(Pl. 17, Figs. 17-19)

Globotruncana linnei (d'Orbigny) subsp. *bulloides* VOGLER, 1941, p. 287, pl. 23, figs. 32-39.

Globotruncana bulloides Vogler, PESSAGNO, 1967, pp. 324-326, pl. 64, figs. 15-17; pl. 67, figs. 1-3; pl. 73, figs, 9, 10; pl. 75, figs. 4-8; pl. 97, figs. 14, 15.

Distribution: Reasonably common in Site 217, the Korojon Calcarenite, Withnell No. 1, Minilya No. 1.

Globotruncana conica White, 1928b

(Pl. 18, Figs. 13-15)

Globotruncana conica WHITE, 1928b, p. 285, pl. 38, figs. 7a-c; MASTERS, 1977, p. 545.

Distribution: Common in Gaj River section, single questionable appearance in Site 288A.

Globotruncana contusa (Cushman), 1926c
(Pl. 18, Figs. 1-9)

Pulvinulina arca var *contusa* CUSHMAN, 1926c, p. 23.

Globotruncana contusa (Cushman), CITA, 1948, pp. 150-151, pl. 3, figs. 6a-c; SMITH AND PESSAGNO, 1977, pp. 45-46, pl. 21, figs. 1-5.

Remarks: *G. contusa* is easily recognised by its strongly angular cross section and its crescentic, plicate chambers which are always arranged in a quadrate pattern. Plate 19, Figures 1-9 indicates, however, that within these constraints the species is highly variable especially in the height of the spiral side.

Distribution: Common in Gaj River and Site 288A. Rare in Site 217.

Globotruncana cf. *contusa* (Cushman), 1926c
(Pl. 18, Figs. 10-12)

Remarks: *G.* cf. *contusa* possesses a more rounder cross section than *G. contusa*, the periphery of the test being circular not quadrate. It also possesses small non plicate chambers reminiscent of *G. arca*.

The referral of this species to *G. patelliformis* by Wright and Apthorpe (1976) is incorrect since it lacks the larger crescentic chambers of that species. Wright and Apthorpe also record a continuum of forms between *G.* cf. *contusa* and *G. contusa ss*. No such continuum has been found here. In fact, despite similarities to *G. contusa* it is possible that this species has closer ties with *G. arca.*

Distribution: Relatively common in Miria Marl, Withnell No. 1, Minilya No. 1, rare at top of Site 217.

Globotruncana cretacea (d'Orbigny), 1840

(Pl. 18, Figs. 16-18)

Globigerina cretacea d'ORBIGNY, 1840, p. 34, pl. 3, figs. 12-14.

Globotruncana cretacea (d'Orbigny) BANNER AND BLOW, 1960, pp. 8-10, pl. 7, figs. 1a-c; MASTERS, 1977, pp. 551-555, pl. 41, figs. 3, 4; pl. 43, fig. 1.

Distribution: Single specimen from the Korojon Calcarenite.

Globotruncana elevata (Brotzen) 1934

(Pl. 19, Figs. 1-3)

Rotalia elevata BROTZEN, 1934, p. 66, pl. 3, fig. c.

Globotruncana elevata elevata (Brotzen) DALBIEZ, 1955, p. 169, text figs. 9a-c.

Globotruncana elevata (Brotzen) MASTERS, 1977, pp. 557-559, pl. 42, figs. 2-4.

Remarks: Many specimens which can otherwise be referred to this species with great confidence possess a marginal imperferate band, occasionally accompanied by a weak second keel just below the periphery of the test. (Pl. 19, Fig. 2)

Distribution: Common in all sections except Korojon and Withnell No. 1.

Globotruncana falsocalcarata Kerdany and Abdelsalam, 1969

(Pl. 19, Figs. 4-6)

Globotruncana falsocalcarata KERDANY AND ABDELSALAM, 1969, pp. 261-263, pl. 1, fig. 1-4; pl. 2, fig. 1-2; DORREEN, 1974, p.178, pl.1, fig. IIIe; KASSAB, 1975, pp.346-348, pl. 1. figs 1-7; pl.2, **figs.** 1-4.

Distribution: Restricted to Gaj River where it is abundant in the upper half of the section.

Globotruncana fornicata Plummer, 1931

(Pl. 19, Figs. 7-9)

Globotruncana fornicata PLUMMER, 1931, pp. 198-199, pl. 13, figs. 4a-b; MASTERS, 1977, pp. 564-566, pl. 44, figs. 4-6.

Distribution: Occurs commonly in Site 288A, Korojon, Withnell No. 1 and Gaj River section.

Globotruncana gansseri Bolli, 1951

(Pl. 19, Figs. 10-12)

Globotruncana gansseri BOLLI, 1951, pp. 196-197, pl. 35, figs. 1-3; MASTERS, 1977, pp. 566-569, pl. 45, figs. 1-3.

Distribution: Common in Gaj River. Single very questionable appearance in Minilya No. 1.

Globotruncana linneiana (d'Orbigny), 1839

(Pl. 19, Figs. 13-15)

Rosalina linneiana d'ORBIGNY, 1839, p. 106, pl. 5, figs. 10-12.

Pulvinulina tricarinata QUEREAU, 1893, p. 89, pl. 5, figs. 3a.

Globotruncana linneiana (d'Orbigny) CUSHMAN, 1931b, p. 90; MASTERS, 1977, pp. 583-585, pl. 46, figs. 3, 5, 6 (Synonomy).

Globotruncana lapparenti BROTZEN, 1936, pp. 175-176, text figs. 2m (NOT 1a, c, 2ac, ef, L-J).

Remarks: It is impossible to separate the plexus of forms variously referred to as *G. linneiana*, *G. lapparenti* and *G. tricarinata* without resorting to some form of arbitrary demarcation. Here they are grouped under one species (*G. linneiana* by priority).

Distribution: Common in Sites 288A, 217, the Korojon Calcarenite, Withnell No. 1, Minilya No. 1 and the Gaj River section.

Globotruncana patelliformis Gandolfi, 1955

(Pl. 19, Figs. 16-18)

Globotruncana contusa patelliformis GANDOLFI, 1955, pp. 54-55, pl.4, figs. 2a-c.

Globotruncana patelliformis Gandolfi, SMITH AND PESSAGNO, 1974, pp. 50-51, pl. 21, figs. 6-8.

Remarks: Although *G. patelliformis* is clearly linked to *G. fornicata* and *G. contusa* it differs from both; its non-plicate crescentic chambers sets it apart from *G. contusa*, the height of its spiral side separates it from *G. fornicata* Its circular periphery differs from both *G. contusa* and *G. fornicata*.

Distribution: Found only in Site 288A where it is reasonably common.

Globotruncana stuarti (de Lapparent) 1918

(Pl. 20, Figs. 1-3)

Rosalina stuarti de LAPPARENT, 1918, pp. 11-12, text fig. 4, pl. 1. figs. 5-7.

Globotruncana stuarti (de Lapparent), GLAESSNER, 1937, pp. 39-40, pl. 1, figs. 13a-c; MASTERS, 1977, pp. 607-609, pl. 53, figs. 2-3, pl. 54, fig. 1.

Distribution: Rare, Site 217, common Site 288A and abundant in Gaj River.

Globotruncana stuartiformis Dalbiez, 1955

(Pl. 20, Figs. 4-6)

Globotruncana (Globotruncana) elevata stuartiformis DALBIEZ, 1955, p. 169, text figs.10a-c.

Globotruncana stuartiformis Dalbiez, PESSAGNO, 1967, pp. 357-359, pl. 80, figs- 3-6; pl. 92, figs. 1-3, pl. 93, figs. 6-7, text figs, 43-44; 17, SMITH AND PESSAGNO, 1973, pp. 52-54, pl. 19, figs. 10-12.

Distribution: Found in every section except Korojon Calcarenite, Withnell No. 1 and Minilya No. 1.

Globotruncana trinidadensis Gandolfi, 1955

(Pl. 20, Figs. 7-9)

Globotruncana caliciformis trinidadensis GANDOLFI, 1955, p. 47, pl. 3, figs. 2a-c.

Globotruncana trinidadensis Gandolfi, PESSAGNO, 1967, pp. 359-362, pl. 84, figs. 4-12; pl. 90, figs. 9-13; pl. 96, figs. 1-2; text figs. 57a-c; SMITH AND PESSAGNO, 1973, p. 54, pl. 18, figs. 11-13.

Distribution : Site 288A only.

Globotruncana ventricosa White, 1928b

(Pl. 20, Figs. 10-12)

Globotruncana canaliculata var *ventricosa* WHITE, 1928b, p. 284, pl. 38, figs. 5a-c.

Globotruncana ventricosa White, CUSHMAN, 1946, p. 150, pl. 62, figs. 3a-c; MASTERS, 1977, pp. 614-615, pl. 55, figs. 1-3.

Distribution: Common Gaj River, DSDP Site 217, Withnell No. 1, Minilya No. 1.

Globotruncana Sp. 1

(Pl. 20, Figs. 13-15)

Description: Test large compressed almost equally biconvex. Five large cresentic chambers in final whorl. Very narrow double keels border the test.

Distribution: Rare, Gaj River.

Globotruncana Sp. 2

(Pl. 20, Figs. 16-18)

Description: Test medium, coarsely perforate biconvex. The aperture opens into a large open umbilicus. Sutures very thickened. In the final few chambers, they reflex round the acute periphery of the test without forming a continuous keel.

Distribution: Rare, Site 288A.

Genus *Bucherina* Bronnimann and Brown, 1956

Type species: *Bucherina sandidgi* Bronnimann and Brown, 1956.

Bucherina sandidgi Bronnimann and Brown, 1956

(Pl. 21, Figs. 1-3)

Bucherina sandidgi BRONNIMANN AND BROWN, 1956, p. 577, pl. 22, fig. 19; pl. 22, figs. 19-21.

Distribution: Common in Site 288A, rare at top of Site 217.

Genus *Rugoglobigerina* Bronnimann, 1952

Type species: *Globigerina rugosa* Plummer, 1927.

Rugoglobigerina hexacamerata Bronnimann, 1952

(Pl. 21, Figs. 4-6)

Rugoglobigerina reicheli hexacamerata BRONNIMANN, 1952, pp. 23-25, pl. 2, figs. 10-12, text fig. 8a-m.

Rugoglobigerina hexacamerata Bronnimann, PESSAGNO, 1967, pp.364-365, pl.74, fig. 4; pl.91, figs. 5-7; MASTERS, 1977, pp.618-620, pl. 56, figs. 2,3.

Distribution: Gaj River only, common.

Rugoglobigerina macrocephala Bronnimann, 1952

(Pl. 21, Figs. 7-9)

Rugoglobigerina macrocephala macrocephala BRONNIMANN, 1952, pp. 25-27, pl. 2, figs. 1-3, text figs. 9a-s.

Rugoglobigerina macrocephala Bronnimann, SMITH AND PESSAGNO, 1973, pp. 55-56, pl. 23, figs. 1-3, 7-10.

Distribution: Single specimen in Site 288A.

Rugoglobigerina rugosa (Plummer), 1927

(Pl. 21, Figs. 10-21)

Globigerina rugosa PLUMMER, 1927, pp. 38-39, pl. 2, figs. 10a-d.

Rugoglobigerina rugosa rugosa (Plummer) BRONNIMANN, 1952, pp. 28-33, text figs. 11a-i, 12a-i, 13a-i.

Rugoglobigerina rugosa (Plummer) BOLLI AND OTHERS, 1957, pp. 43-44, pl. 11, figs. 2a-c; SMITH AND PESSAGNO, 1973, pp. 58-60, pl. 25, figs. 1-4.

Rugoglobigerina (Rugoglobigerina) pilula BELFORD, 1960, p. 92, pl. 25, figs. 7-13, text fig. 6 (1-6).

Rugoglobigerina (Rugoglobigerina) plana BELFORD, 1960, pp. 95-96, pl. 27, figs. 1-5, text fig. 8 (1-6).

Remarks: This species as recognised here shows enormous variation and it is possible that further work would split it into two or more distinct species. Plate 21, Figures 10-21, gives some indication of the degree of variation involved. The characters which vary most are the number of chambers per whorl and spiral height (compare figs. 3a-c and 3d-f). The degree of alignment of rugosites is very variable.

Distribution: Found in all sections.

Genus *Trinitella* Bronnimann, 1952

Type species: *Trinitella scotti* Bronnimann, 1952.

Distinguished from *Rugoglobigerina* by the possession of flattened final chambers and imperforate margin.

Trinitella scotti Bronnimann, 1952

(Pl. 22, Figs. 1-3)

Trinitella scotti BRONNIMANN, 1952, p. 57, pl. 4, figs. 4-6, text figs. 30a-m: MASTERS, 1977, pp. 629-630, pl. 58, figs. 2, 4.

Distribution: Common in Gaj River.

Subfamily GLOBOTRUNCANELLINAE Maslakova, 1964

Genus *Globotruncanella* Reiss, 1957

Type species: *Globotruncana citae* Bolli 1951 (= *Globotruncana havanensis* Voorwijk, 1937).

Many authors suppress this genus as a junior synonym of *Globotruncana*. Here van Hinte (1963) is followed, that is: it is considered a valid genus and a senior synonym of *Abathomphalus*.

Globotruncanella havanensis (Voorwijk) 1937

(Pl. 22, Figs. 4-6)

Globotruncana havanensis VOORWIJK, 1937, p. 195, pl. 1, figs. 25, 26, 29; MASTERS, 1977, pp. 569-572, pl. 45, figs. 4-6.

Globotruncana citae BOLLI, 1951, p. 197, pl. 35, figs. 4-6.

Globotruncanella havanensis (Voorwijk), SEIGLIE, 1958, pp. 73-74, pl. 4, figs. 3a-5c.

Distribution: Sites 288A, 217, Miria Marl, Korojon Calcarenite, Minilya No. 1, Gaj River Section. Common in all six sections.

Globotruncanella intermedia (Bolli) 1951

(Pl. 22, Figs. 7-9)

Globotruncana intermedia BOLLI, 1951, p. 197, pl. 35, figs. 7-9; MASTERS, 1977, pp. 576-578 (Synonomy).

Distribution: Common in Sites 288A, 217 and Miria Marl.

Globotruncanella mayaroensis (Bolli) 1951

(Pl. 22, Figs. 10-12)

Globotruncana mayaroensis BOLLI, 1951, p. 25, pl. 35, figs. 10-12; MASTERS, 1977, pp. 591-593, pl. 48, figs. 1-5.

Distribution: Sites 288A, 217, Miria Marl, Withnell No. 1, Minilya No. 1, Gaj River, common in each section.

Family GLOBIGERINIDAE Carpenter, Parker and Jones, 1862

Genus *Guembelitria* Cushman, 1933

Type species: *Guembelitria cretacea*

Guembelitria cretacea Cushman

(Pl. 22, Figs. 13-14)

Guembelitria cretacea CUSHMAN, 1933, pp. 37-38, pl. 4, figs. 12a-b; SMITH AND PESSAGNO, 1973, pp. 15-16, pl. 1, figs. 1-8.

Distribution: Abundant in the Miria Marl, Korojon Calcarenite, Withnell No. 1 and Minilya No. 1.

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