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APPENDIX 2

ESSO GIPPSLAND SHELF NO. 1

THE MID-TERTIARY FORAMINIFERAL SEQUENCE

by

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CONTENTS

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Carter (1964) built up a composite sequence, consisting of both outcrop and bore material from the Longford, Bairnsdale, and Lakes Entrance areas. Carter's work is an application of his faunal unit scheme, which was based on the Aire Coast sections in Western Victoria (Carter, 1958). Wade (1964) has subsequently discussed the Tertiary planktonic foraminiferal zonation in southern Australia and has co-ordinated the work of Carter and Jenkins.

This previous work provided a firm basis on which to establish a foraminiferal sequence for the Gippsland Shelf No. 1 Well. However Carter, Jenkins, and Wade all use the first appearance of forms in evolutionary sequence. Theoretically this is the ideal approach as it is in the direction of evolution, that is "up-sequence". But subsurface sections are drilled "down-sequence". Where rotary cuttings have to be used for biostratigraphic determination, the first appearance of a species is the only reliable point in its range, because of rotary cutting contamination. This first appearance is in fact the level of extinction of the species in the section. Obviously the "up-sequence" schemes have to be adapted to a "down-sequence" approach.

The author has been working on this problem for several years, especially in regard to the onshore Gippsland Basin. A less empirical "down-sequence" approach has been tested by using the range and points of fragmentation and bifurcation in a number of linearly evolving species groups. The planktonic series discussed by Wade can be utilized by this approach. The classic Orbulina universa lineage poses difficulties in that the globular shape provides almost maximum buoyancy and may be constantly recirculated as a mud contaminant.

Uvigerinid and bolivinid forms are common in the Gippsland Shelf sequence, though they are not common onshore, apparently for environmental reasons. Vella (1964) has stressed the significance of linear development within these groups in the Tertiary of New Zealand. Similar, though not identical, lineages are recognized in the Gippsland Shelf sequence and these lineages have been detailed. It is thought that the bolivinid and uvigerinid lineages will be important factors in correlating subsequent Gippsland offshore sections.

Gippsland Shelf No. 1 Tertiary Foraminiferal Sequence

Vertical distribution of species groups will be discussed "down-sequence" with reference to summarized distribution of selected species as shown on Fig. 4.

(i) Planktonic species: Little change in the Globigerina spp. till 3400 feet where G. euapertura first appears coinciding with the virtual disappearance of G.woodi and G.apertura. G. euapertura clearly develops from G.ampliapertura and this latter form is present below 3700 feet. The apparent lineage is G.ampliapertura to G.euapertura to G.apertura (s.l.). Jenkins (1960) shows that G.woodi replaces G.euapertura, and he includes (pers. comm.) G.apertura (s.l.) within G.woodi. Wade (1964) does not recognize G.woodi and uses G.apertura. The author feels that the two species can be distinguished and that G.woodi is not in the direct G.ampliapertura to apertura lineage.

The closely related species G.linaperta and G.angipora appear in association below 3800 feet. In New Zealand the range of the latter extends higher than that of the former (Hornibrook, 1961).

Most members of Blow's (1956) Globigerinoides triloba - Orbulina universa bioseries are present in the sequence. Orbulina universa is present in Cores Nos 1 to 5, whilst O.suturalis is present in Cores Nos 6 and 7. Such a distribution would be anticipated.

A similar form, B. sp.9, with elongate ribs occurs below 2300 feet. These three species are within a definite linear development. The range overlap of species, though broad, is significant.

Below 3540 feet, the Bolivina pontis to B. anastomosa group is recognized. The former is clearly distinguished below 3800 feet. The development is similar to that described by Hornibrook (1961) and Vella (1964) from New Zealand. The highest appearange of B. anastomosa is stratigraphically lower than that recorded in New Zealand and slightly lower than other Gippsland Basin sections. Vella shows that B. affiliata is the descendant of B. anastomosa and that the lineage may be surviving as B. robusta. B. affiliata is not recognized in the Gippsland Shelf sequence, but the Bolivina sp.9 to B. sp.1 lineage exhibits similarities to B. robusta.

(iii) Uvigerinids: Vella (1961 and 1964) has made an extensive study of New Zealand uvigerinid lineages. Vella's approach is to place the species of one lineage within a distinct higher taxon. This has led to the erection of a number of new genera and sub-genera within the family Uvigerinidae. This is the modern taxonomic approach, yet Vella's proposed genera and sub-genera have not been generally accepted and probably require greater verification, especially with regard to apertural and internal chamber characteristics. Also Vella stresses the endemic nature of his species. For the above reasons, the author has refrained at this stage from using Vella's nomenclature. The author has generalized the generic concept of Uvigerina, but will attempt to place numbered species within Vella's lineages; that is within his proposed higher taxa.

The Hofkeruva (Trigonouva) group are common throughout most of the Tertiary section. The first form encountered, Uvigerina sp. 1, is elongate and moderately costate. Subsequent forms (down section) are U. sp.2, U. sp.4, and U. sp.8. The latter species is markedly triangular in cross-section and very similar to the New Zealand species "U". miozea. This form appears at 2300 feet and is still present at 3000 feet. The general shape and plate like costae of the large U. sp.9 suggests affinity with the New Zealand species "U". dorreeni. As U. sp.9 is present at 3080 feet and U. sp.8 persists to at least 3000 feet, then there is apparent disruption of Vella's (1961, Text fig. 3) proposed lineage if U. sp.8 equals "U". miozea and U. sp.9 equals "U". dorreeni.

U. sp.3, U. sp.7, and U. sp.10 are all hispid forms probably within the genus Neouvigerina as explained by Vella. The three Gippsland Shelf species do not appear related.

(iv) Gyroidinoides: A definite series of the G. zealandica group is recognized in New Zealand. G. sp.1 and G. sp.2 appear unrelated to this group. But below 2200 feet there is a form, G. sp.3, which resembles G. subzealandica, while below 3080 feet it is replaced by the more angular form G. sp.4 equalling G. zealandica (s.s). This is the New Zealand order of occurrence although Hornibrook (1961) shows that the ranges of the two species overlap considerably.

(v) Cibicides: Lineages within this group probably exist in the section but have not been studied. Common species down to 2700 feet include C. cygnorum, C. mediocris, C. subhaidingeri, and C. vortex. C. victoriensis is not recorded till 1500 feet and its presence below 3080 feet may be due to contamination. C. vortex probably forms a lineage group as a C. 'vortex form B' can be distinguished below 2400 feet. There is a marked change in the Cibicides fauna at 3080 feet, with the appearance of C. brevolalis, C. perforatus, and C. novozealandica. This change is anticipated from Carter's (1964) and other Gippsland sections.

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A significant feature of this zonule is the presence of worn Lepidocyclina sp., Gypsina sp., and Amphistegina sp., with decayed fragments of bryozoa. The sediment is a sandy one and is not comparable with the typical Victorian lepidocyclinal limestones (e.g. the Glencoe Limestone of Gippsland). Furthermore, Carter (1964) demonstrates that Orbulina suturalis appears above and not in association with Lepidocyclina sp. in Victoria. It is considered that these Lepidocyclina and other larger foraminifera are derived.

Zonules F and G are missing in this sequence. As already stated the Globigerinoides triloba to Orbulina universa bioseries is interrupted before the appearance of the mature form of G.triloba and is recommended with O.suturalis. The two significant missing events are the appearance ("up-sequence") of G.triloba and of G.bispherica. It is also noted that several bolivinid and uvigerinid lineages appear to be interrupted. Moreover, fresh specimens of Lepidocyclina sp. and other larger foraminifera are not present, although they would be expected immediately below O.suturalis.

The absence of the expected Zonules F and G indicates a hiatus within the sequence.

Zonule H - 3080 to 3400 feet: Despite contamination down to 3200 feet, the fauna is impressively different. Globigerina apertura, and G.woodi, are still present with immature and dubious specimens of Globigerinoides triloba. At the top of and within the zonule, such forms as Cibicides brevolalis, C.perforatus, C.novozealandica, Uvigerina sp. 9, U. sp.10, U. sp.11, Astrononion centroplax, and Anomalinoides vitrinoda occur. Arenaceous species are common with Textularia spp., Dorothia spp., Haplophragmoides spp., and Karreriella sp. The appearance of Karreriella sp. and Haplophragmoides rotundata within the unit may be biostratigraphic rather than a purely environmental feature, as these two species have not been noted at relatively higher levels in Gippsland sections.

Zonule I - 3400 to 3540 feet: Globigerina euapertura is positively identified at 3400 feet, and G.apertura and G. woodi are both extremely rare. Globorotalia opima opima and G.extans are rare though important elements of the planktonic fauna. The benthonic fauna is similar to that of Zonule H, except for the presence of Vaginulinopsis gippslandicus and the arenaceous Vulvulina sp. (probably referable to the New Zealand V.granulosa). There is a rich arenaceous fauna.

Zonule J - 3540 to 3800 feet: A strikingly different fauna because of the small size of specimens compared with the robust Zonule I fauna. The planktonic elements are similar to Zonule H apart from the presence of Globorotalia testarugosa and Chiloguembelina cubensis. There is a notable reduction in specimen size of the benthonic species which also occur in the two preceding zonules. Arenaceous species are rare. The highest occurrences of Bolivina anastomosa and the arenaceous Bolivinopsis cubensis are noted at 3540 feet.

Zonule K - 3800 feet to ? : Fauna generally similar to Zonule J, but mixtures of Globigerina euapertura with the ancestral form G.ampliapertura, and of Bolivina anastomosa with the ancestral form B.pontis, indicate specific fragmentation in these two lineages. This level also contains the highest appearance of the planktonic Globigerina angipora and G.linaperta as well as the rare occurrence of Guembelitria sp.

Below 3800 feet: No new species were found below this level and all cores were barren of foraminifera. Foraminifera were found sporadically in cutting samples below

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Zonule I - the highest appearance of Globorotalia extans and G.opima opima with the positive appearance of G.euapertura equates this with Jenkins' Globoquadrina dehiscens Zone (Zone 2). This is the equivalent of Faunal Unit 5, but Carter's main indicator, the adherent Victoriella conoidea is not present in this sequence.

Zonule J - Chiloguembelina cubensis without Globigerina linaperta is the planktonic criterion of Carter's Faunal Unit 4. Although Carter did not positively identify this unit in Gippsland, he suspected its presence and lately Hocking and Taylor (1964) have recognized it in limited areas. The highest appearance of Globorotalia testarugosa conforms with Jenkins lowest zone, but Zonule J probably represents a larger biostratigraphic interval than this zone. Jenkins recorded only five specimens of G.testarugosa at the base of his Lakes Entrance Oil Shaft sequence, suggesting that this was the extinction level of the species.

Zonule K - Carter's Faunal Unit 3 is at the top of the range of Globigerina linaperta so that Zonule K is probably at the top of Faunal Unit 3.

Correlation with Victorian Tertiary Stages

Carter (1964) has shown the relationship of his faunal units to a revised Victorian Tertiary Stage Classification. As the Gippsland Shelf sequence zonules are equated with Carter's faunal units, then the zonules are made to fit the classification, although the author does not consider them to have any significance in discussion or future correlation of the sequence. For instance, Carter differentiates the Mitchellian from the underlying Bairnsdalian on a faunal change which resulted from shallowing water. With regard to water depth, one would expect "facies step out" during mid-Tertiary times from the present onshore and offshore areas. As this is evident in the recognized Bairnsdalian (= Zonules D and ?C) it would be expected in the Mitchellian. Recognition of the Mitchellian can only be achieved by determining upper Miocene. Direct faunal correlation is not possible.

Crespin's (1943) stage classification for the Gippsland Basin appears to be a more workable one, but is dependent on facies without real biostratigraphic consideration. In the Gippsland Basin, Crespin's work did not suggest time-transgressive sedimentation, whilst an application of Carter's faunal unit scheme did, as shown by Hocking and Taylor (1964). It is evident that Crespin's scheme is in reality a rock-stratigraphic one and will be discussed later as such.

Intercontinental Correlation

The sequence can be discussed in terms of accepted world-wide division of the Tertiary period. Wade's (1964) thorough study of both the actual faunas and the massive literature, has placed the southern Australian planktonic sequence within the framework of the European Standard Stage Classification of the Tertiary. More recent overseas literature supports her contentions. Discussion on these matters will be limited to comment on the Gippsland Shelf sequence.

Following Wade's evidence, Zonule K is obviously at the top of the Eocene, Zonule J is lowermost Oligocene, whilst Zonule I occupies the rest of the Oligocene (Chattian). Glaessner (1959) and Wade (1964) both argue that Carter's Faunal Unit 6 can be correlated with the Aquitanian (lowermost Miocene) on its relative position in the planktonic sequence and thus the Oligocene-Miocene boundary is below the general emergence of the distinct "Globigerinoides form". Zonule H is considered as basal Miocene.

three samples with regard to the planktonic percentage. The results were: at 3560 to 3570 feet: 70%; at 3730 to 3740 feet: 83%; at 3805 to 3810 feet: 87%. Throughout the zonule the average size of specimens was less than 0.25 mm. The benthonic fauna consisted predominantly of uvigerinids and bolivinids with a small percentage of arenaceous forms.

Such a high percentage of planktonic forms would suggest an open ocean environment, whilst bolivinid and uvigerinid forms are fairly dominant benthonic constituents of outer shelf deposits. These conclusions do not account for the nature of the sediment, nor the abnormally small size of individual specimens. The explanation is probably that the faunas are "displaced", in that the tests have been washed into an alien environment. The sediments suggest shallow water, marginal marine conditions (lagoonal or swamp). If this environment were separated from the sea by a narrow barrier, then any marked sea-level rise (due to storms or abnormal tides) could cause flooding by marine waters. Strong onshore winds would bring in the oceanic plankton and could cause turbulence on the sea floor, suspending empty benthonic tests as described by Murray (1965). Under such conditions Murray shows size sorting operates on the foraminiferal tests, thus accounting for the small specimen size in the faunas. The sporadic distribution of the faunas within the interval indicates that the marine connections were not constant throughout the interval. This contention is supported by the lack of any obviously endemic fauna, which would not be established if sea water were diluted by coastal run-off, when the cause of marine flooding desisted. Such conditions exist today in the lagoons on the Gippsland seaboard.

It should be recorded that the delicate tests and the fairly homogeneous nature of the fauna do not indicate that it is reworked. The "displacement" is environmental and not stratigraphic, which is substantiated by previous discussions which show that the faunas are not misplaced in the Victorian Tertiary planktonic sequence.

Zonules I and H (upper Oligocene and lowest Miocene):

The sediment is a marl, glauconitic at the base, with a marked faunal change. Planktonic, arenaceous, and lagenid species with robust species of Cibicides are the dominant elements. Even at the base of the interval the arenaceous forms reflect an absence of quartz sand as their tests are composed of smaller particle size material. Fairly shallow water conditions, open to the ocean, are evident with slow sediment accumulation.

Zonule E (middle Miocene):

Calcareous sandstone with sparse arenaceous and miliolid faunas with occasional planktonic species. Obviously a shallow water, swiftly accumulating sediment.

Zonule D (middle to upper Miocene):

Sand content decreases up the section, with marls and limestones present above 2500 feet. With the decrease in sand the faunas are larger and the planktonic percentage increases. as does the percentage of uvigerinid and bolivinid forms. A deepening of the depositional environment is suspected.

Zonules C and B (middle to upper Miocene):

Faunas and sediments similar to that at the top of Zonule D. Shelf conditions are indicated.

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GEOLOGICAL SETTING WITHIN THE GIPPSLAND BASIN

Jenkins (1960) has demonstrated a continuous sequence from lower Oligocene to probably upper Miocene in the Lakes Entrance area. Hocking and Taylor (1964, summarized on figure 4) show that the initial marine Tertiary transgression was of a diachronous nature, being oldest in the then structurally deeper parts of the basin and becoming progressively younger up the flanks of structural "highs" (e.g. the "Baragwanath Anticline"). This transgression extended from the Eocene-Oligocene boundary to lowermost Miocene. Sedimentation on the "Baragwanath Anticline" probably took place only during lower Miocene and may not have covered the entire structure. In other parts of the Gippsland Basin marine sedimentation apparently continued uninterrupted till upper Miocene and even Pliocene times. Thus on the "Baragwanath Anticline", two hiati are evident in marine deposition. They are (i) a hiatus from uppermost Eocene throughout most of the Oligocene, and (ii) a post-lower Miocene hiatus.

The Gippsland Shelf No. 1 Well is drilled on the culmination of a seismic structure and the results of drilling do not alter any of the general interpretations. However, foraminiferal evidence shows that marine influence commenced in the upper Eocene and continued throughout the Oligocene. But there was a hiatus during the lower Miocene and then marine sedimentation resumed in the middle Miocene and continued to at least the upper Miocene.

The "Baragwanath Anticline" and the "Gippsland Shelf Structure" are roughly parallel with their axes some 30 miles apart, yet sedimentation took place on them at different times. For instance, lepidocyclinal limestones were deposited on the "Baragwanath Anticline"(as are seen at Brock's Quarry) at a time when a hiatus is evident on the "Gippsland Shelf Structure". Immediately following this, reworked lepidocyclinal limestone is present on the "Gippsland Shelf Structure" during a hiatus on the "Baragwanath Anticline". Other differences are illustrated on Fig. 5. It must be pointed out that this figure illustrates only the differences between the two structures and is not intended to imply these features in any other part of the Gippsland Basin. The depositional environment has been drawn relative to sea level on the basis of information discussed here and on unpublished work.

Envisaging these two structures as vertically moving blocks (as on Fig. 5), then the direction of movement must have been opposed throughout the period in order to account for differences in the Tertiary sequence on each structure.

With regard to lithological correlation within the Gippsland Basin, the following conclusion can be drawn on facies similarities.

The facies which contains Zonules K and J are almost identical to those of the sandy unit at the base of the Lakes Entrance Formation in the Lake Wellington Trough (Hocking and Taylor, 1964). This unit is the time equivalent of the Greensand and Colquhoun Gravel Members in the Lakes Entrance area, although the facies are slightly different due to thicker accumulations of glauconite in the latter, which the author regards as an "estuarine backwater".

The faunal elements of Zonules H and I are identical with those of Crespin's (1943) "Janjukian faunas" of the Gippsland Basin and especially of the Micaceous Marl Member of the Lakes Entrance Formation in the type sections. Crespin's "zonal" foraminifera of her "Janjukian" is Cyclammina incisa (= Haplophragmoides cf. incisa) and the fauna

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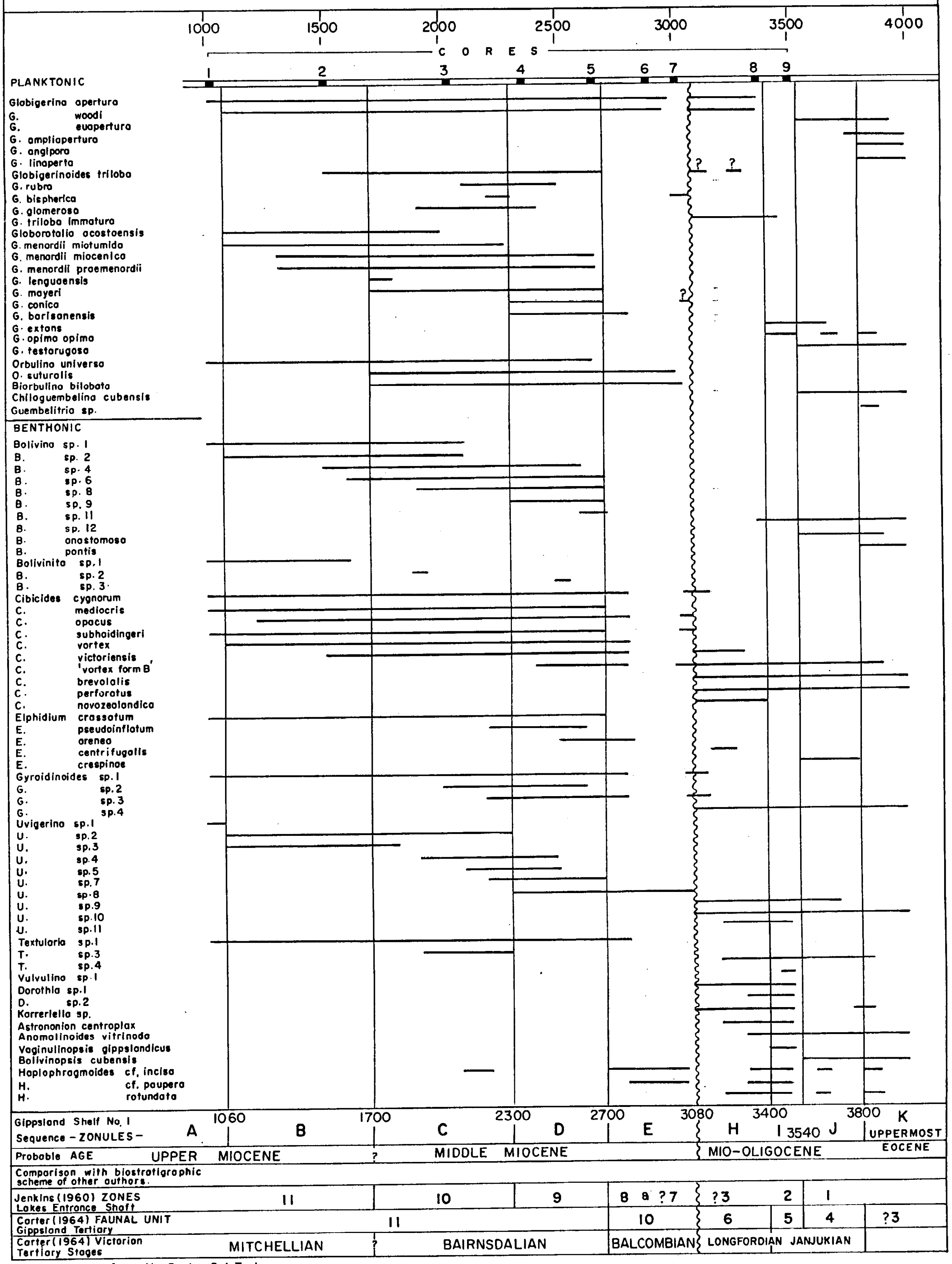
ENCLOSURE No 1.

Fig. 4

TERTIARY FORAMINIFERAL DISTRIBUTION
ESSO GIPPSLAND SHELF No I WELL
(Obvious contaminants and remanie forms eliminated)



To accompany Appendix 2 by D.J. Taylor