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FORAMINIFERAL SEQUENCE

FLOUNDER # 5

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SUMMARY

The FLOUNDER # 5 sample has proved to be vital in understanding the late Neogene foraminiferal sequence of the Gippsland Basin; both biostratigraphically and environmentally. This is the first section of deeper water sediments to be extensively shot with side wall cores above the 13³/₈" casing. As a result the two highest Zones of Taylor's (1966) scheme can be fragmented into five, or theoretically six Zones of greater biostratigraphic precision. This report summarizes the results, whilst more detailed discussion will appear in a complete revision of the Gippsland Basin biostratigraphic scheme in preparation.

The biostratigraphic sequence in FLOUNDER # 5 is summarized below:-

AGE	Minimal Depth Zone	Multi Association Zones	Depth in Flounder # 5	
			Top	Base
PLEISTOCENE		A-1	not sampled	
	A	A-2	?	to 889
PLIOCENE		A-3	1003 to 1860	
		A-4	1947 to 3266	
---	B	B-1	3372 to 3509	
LATE		B-2	3609 to 4347	
MIOCENE	C		4456 to 5614	
LATE	D	D-2	5714 to 6021	
MIOCENE	E	E-1	not sampled	
		E-2	6117 to 6117	
EARLY	F	F-1	6187 to 6187	
MIOCENE		F-2	not sampled or absent	
LATE	I	I-1-a	6268 to 6268	
OLIGOCENE				
MID to EARLY			6416 to 7332	
EOCENE				

INTRODUCTION

Seventy-four side wall cores were examined, with twenty-nine coming from between the 20" casing shoe and the 13³/₈" casing shoe. Side wall cores at 6278 and 6328 were barren of fauna, whilst those at 6416, 6717, 7173, 7278 and 7332 contained no planktonic foraminifera. No rotary cutting samples were examined.

Three sheets of Distribution Charts accompany this report.

Sheet 1 shows the distribution of planktonic foraminifera with the basis of biostratigraphic breakdown and a relative graph of fluctuations in water temperature during most of the Pliocene.

Sheet 2 shows distribution of benthonic foraminifera.

Sheet 3 gives an environmental summary with relative statistics.

Symbols on the charts are as follows:-

- o = 1 - 20 specimens
- I = over 20 specimens
- [?] or [I] = reworked planktonics or reworked or misplaced benthonics
- ? = dubious identification
- cf = similar but not identical

All depths cited in report and listed on charts are corrected depths in feet below datum of +30' M.S.L. Water depth to sea floor of 353' are included in this depth.

BIOSTRATIGRAPHY

Formal definition of newly erected zones will be established in a forthcoming report to Esso.

EARLY to MID EOCENE - 7332 to 6416:- The fauna within this interval is almost entirely composed of arenaceous foraminifera dominated by *Bathysiphon* spp. and *Haplophragmoides* spp. The age is based on *Truncorotaloides collacteus* which is the only diagnostic planktonic species which occurs only in the sample at 6877.

HIATUS:- The late Eocene and early Oligocene is apparently missing.

LATE OLIGOCENE - 6268:- The fauna dominated by *Globigerina euapertura*, *G. woodi woodi* and *Globoquadrina dehiscens* (S.L. plexus) is at the very top of the Zone of *G. euapertura* (= Zone I-1), probably constituting a further zonal fragmentation marking the association of the initial appearance of *Globoquadrina dehiscens* (S.L.) and *Globigerina woodi woodi* with the upper part of the range of *G. euapertura*. This Zone I-1-a is designated the Zone of *Globoquadrina dehiscens* (S.L.) and is probably the equivalent of the *G. dehiscens* Zone in New Zealand (Jenkins, 1975). It should be noted that the initial appearance of *G. dehiscens* (S.L.) is diachronous and this may explain the apparent hiatus of this Zone reported by Jenkins (l.c.) in D.S.D.P. Site 282 (west of Tasmania). This Zone in the Gippsland is one of association and range overlap, rather than based on a Datum Event.

LATE OLIGOCENE to EARLY MIOCENE HIATUS:- Although there is a sample gap of 81', it is assumed that the uppermost part of the Oligocene (= Zone H-2) and the two lowermost Miocene Zones H-1 and G are absent in this section.

EARLY MIOCENE - 6187 to 6117:- At 6187 the diagnostic features are the association of *Globigerinoides* spp; especially *G. trilobus*, *G. bisphericus* and *G. subquadratus* (= *G. rubra* of Carter, 1964 et. al.). *Globorotalia* spp. include *G. praemenardii*, *G. peripheroronda* and *G. miozea miozea* (S.S.). This association enables the splitting of Zone F into lower Zone F-2, the Zone of *G. bisphericus*, and upper Zone F-1, the Zone of *G. subquadratus*. The sample at 6187 represents Zone F-1. Zone F-2 may be present in the sequence but not sampled. Zone F-1 is the equivalent of Carter's (1964) onshore Gippsland

Faunal Unit 8 and Jenkins' (1960) *G. menardii praemenardii* Zone in the Lakes Entrance Oil Shaft.

The presence of the nominate species, *Praeorbulina glomerosa curva*, indicates Zone E-2 (= top of early Miocene) at 6117'.

LATE MIOCENE - 6021 to 5714:- The sample gap of 96' probably includes Zone E-1, the Zone of *Orbulina suturalis*.

Zone D-2, characterised by the association of *Globorotalia peripheronda*, *G. conica*, *G. mayeri mayeri* and *G. mayeri barisaensis* with *Orbulina universa* and *Globigerinoides* spp.

HIATUS within the LATE MIOCENE:- The usually thickly developed Zone D-1 (without *Globorotalia peripheronda* but with *G. mayeri barisaensis*) is absent in the sequence. Also, D-2 is apparently abbreviated. Evidence of the erosional nature of this hiatus is obtained from the presence of Zone D species of *Globorotalia* spp. within the Pliocene sequence. Examples of such reworking are *Globorotalia peripheronda*, *G. curva* and *G. mayeri mayeri*. There are also preservation differences in that the reworked specimens are dark coloured, which enables the distinction of two groups of *Orbulina universa*; a dark coloured group of larger, allochthonous specimens and a well preserved group of small, autochthonous specimens (see Distribution Chart, Sheet 1).

LATE MIOCENE - 5614 to 3609:- The interval between 5614 and 4456 contains *Globorotalia mayeri mayeri* without *G. mayeri barisaensis* and *G. conica*. *G. miotumida miotumida* and *G. miotumida conoidea* are well developed and *G. lenguanensis* appears at the top of the interval at 4456. The association is typical of Zone C, the Zone of *G. mayeri mayeri* as originally defined by Taylor (1966).

At and above 4347 the fauna is nondescript, dominated by *Globigerina* spp. The *miotumida* and *conoidea* morphotypes of *G. miotumida* intergrade, suggesting mixing of water masses in a deep water situation as expressed by Chaproniere (1973, text fig. 2). The association fits the original definition of Zone B (Taylor, 1966) but *G. miotumida miotumida* extends above 3609 and the initial appearance of *G. miotumida conomiozea* at 3509. Thus the Zone can be fragmented into a lower unit B-2, the Zone of *G. miotumida miotumida*, and an upper unit B-1, the Zone of *G. miotumida conomiozea* above the appearance of the dominant taxa. Thus, in Flounder # 5, Zone B-2 extends from 4347 to 3609 which is below the initiation of the *conomiozea* morphotype of *G. miotumida* (refer Chaproniere, 1973).

The top of Zone B-2 is assumed to correspond approximately with the Mio/Pliocene boundary of the Italian stratotype. A following discussion shows that the "traditional New Zealand" Mio/Pliocene boundary is higher than that accepted in the Mediterranean by Cita (1973), Cita & Ryan (1973) and Berggren & van Couvering (1974). However, exact correlation with the Mediterranean cannot be achieved because of the extra-tropical nature of the Flounder # 5 and other Gipsland sequences. Southwest Pacific correlation of Zone B-2 is shown on Table 1.

PLIOCENE and PLEISTOCENE - 3509 to 748 to ? :- This interval can be divided into two parts:-

- (2) The Minimal Layer Zone A above 3266 which is discussed later in detail.
- (1) The deeper water Zone B-1 from 3509 to 3372.

DEEPER WATER ZONE B-1

The base of this interval is marked by the initiation of *G. miotumida conomiozea* in the *G. miotumida miotumida* → *G. inflata* lineage of Chaproniere (1973) and Kennett & Watkins (1974). The earlier morphotypes of the lineage, *G. miotumida miotumida* and *G. miotumida conoidea* persist into the Zone. The rest of the *Globorotalia* fauna is nondescript and sporadic, probably because of the cold water influence during much of the Zone (refer Distribution Chart, Sheet 1).

The top of the Zone is immediately before the appearance of *G. puncticulata* morphotypes.

Because of the dominantly cold water masses, pan-tropical species, such as *G. margaritae*, are absent, making exact correlation impossible. In the Mediterranean, *G. margaritae* extends below *G. puncticulata*, and would thus be expected within this Zone. Thus, by extrapolation, Zone B-1 is placed within the basal Pliocene. Further discussion of this point is made under "Correlation of Minimal Layer Zone A".

MINIMAL LAYER ZONE A

The original definition of this Zone (Taylor, 1966) was a negative one, due to the total absence of diagnostic planktonic species in the shallow water Barracouta # 1 sequence. Later, Taylor (Esso Paleont. Rep. 1972/01) redefined the base as the initial appearance of *Globorotalia inflata* in the deeper water sequences. However, the interval above the 13³/₈" casing shoe was seldom sampled by conventional core or side wall core until the Flounder # 5 sequence was especially sampled with 30 side wall cores. Now it is realised that the species at the base of the Zone is, in fact, *G. puncticulata* which is the evolutionary precursor of *G. inflata* (Kennett, 1973 and Kennett & Watkins, 1974).

The diverse Flounder # 5 planktonic foraminiferal sequence contains members of the following evolutionary lineages:-

- 1) *Globorotalia miotumida miotumida* → *G. miotumida conomiozea* → *G. puncticulata sphericomiozea* → *G. puncticulata puncticulata* → *G. inflata*
(Kennett & Watkins, 1974 and Chaproniere, 1973).
- 2) *Globorotalia acostaensis* → *Neogloboquadrina humerosa* → *N. dutertrei*
(Lamb & Beard, 1972).
- 3) *Globorotalia tosaensis* → *G. truncatulinoides* (Kennett, 1973).
- 4) *Globorotalia aemiliana* → *G. crassacrottonensis* → *G. crassaformis*
(Lamb & Beard, 1972).

Lineage 1 is the most useful and allows correlation with the Southwest Pacific and New Zealand (Kennett, 1973, Kennett & Vella, 1975 and Jenkins, 1975), whilst fragmentation of the other lineages verify the reliability of the *G. inflata* lineage. From these lineages the broad Zone can be fragmented into three deep water Zones with a fourth Zone present but unsampled at the top of the sequence (i.e. above the 20" casing).

These Zones in descending order are:-

Zone A-1	The Zone of <i>GLOBOROTALIA TRUNCATULINOIDES</i>
Zone A-2	The Zone of <i>GLOBOROTALIA TOSAENSIS</i>
Zone A-3	The Zone of <i>GLOBOROTALIA INFLATA</i>
Zone A-4	The Zone of <i>GLOBOROTALIA PUNCTICULATA</i>

AGE *	offshore GIPPSLAND ZONES	NEW ZEALAND ZONES Jenkins, 1975	SOUTHWEST PACIFIC ZONES - Jenkins, 1975	TASMAN SEA cool sub-tropical Zones Kennett, 1973	TASMAN SEA informal Zones & N.Z. Stages - Kennett & Vella, 1975
PLEISTOCENE	A-1 <i>Globorotalia truncatulinoides</i>	<i>Globorotalia truncatulinoides</i>	<i>Globorotalia truncatulinoides</i>	<i>Globorotalia truncatulinoides</i> -----?-----?-----?-----? <i>G. truncatulinoides</i> <i>G. tosaensis</i> overlap	1 Hautawan
1.85 m.y.	A-2 <i>Globorotalia tosaensis</i> 889**	<i>Globorotalia inflata</i>	<i>Globorotalia inflata</i>	<i>Globorotalia tosaensis</i>	2
late PLIOCENE	A-3 <i>Globorotalia inflata</i> 1860**			<i>Globorotalia inflata</i>	Mangapanian Waipipian
? 3.2 m.y.	A-4 <i>Globorotalia puncticulata</i>	<i>Globorotalia puncticulata</i>	<i>Globorotalia puncticulata</i>	<i>Globorotalia crassaformis</i> -----?-----?-----?-----? <i>Globorotalia puncticulata</i>	3 Opoitian
4.3 m.y.	B-1 <i>Globorotalia conomiozea</i> 3509**	<i>Globorotalia miozea sphericomiozea</i>	<i>Globorotalia miozea conomiozea</i>	<i>Globorotalia conomiozea</i>	4 Kapitean
5 m.y.	-----?-----?-----?-----?	-----?-----?-----?-----?	-----?-----?-----?-----?	-----?-----?-----?-----?	-----?-----?-----?-----?
late MIOCENE	B-2 <i>Globorotalia miotumida</i>	<i>Globorotalia miotumida miotumida</i>	<i>Globorotalia miotumida miotumida</i>	<i>Globigerina nepenthes</i>	5 Tongaporutuan

TABLE 1. Correlation of offshore Gippsland late Neogene Zones with temperate Southwest Pacific Zonations.

* Paleomagnetic and radiometric time scale from Cita & Ryan (1973), Kennett & Watkins (1974) & Berggren & van

** Depth in feet of base of Zone in Flounder # 5.

Coupering (1974).

Zone A-4

The base of the Zone of *G. puncticulata* is marked by the initial appearance of the nominant species with an evolutionary transition from *G. miotumida conomiozea*. The latter species continues almost to the top of the Zone. The top of the Zone is immediately below the transition between *G. puncticulata* and *G. inflata*.

The associated species are similar to those of Zones A-3 and A-2, except for the following biostratigraphic events:-

G. crassaformis extends, sporadically, from just above the base of the Zone. *Neogloboquadrina humerosa* is not present in the Zone.

The initiation of *Globorotalia crassacrottonensis* is within the Zone, though its precursor, *G. aemiliana*, is either absent or too difficult to distinguish morphologically.

Neogloboquadrina pachyderma, though present sporadically higher in the sequence, is abundant at several intervals, but this is a paleohydrological effect rather than a biostratigraphic one.

The extinction of *Globigerina nepenthes*, *G. continuosa* and *Globoquadrina dehiscens* occurred within the Zone and they become most noticeable towards the base. *G. dehiscens* obviously has a diachronous extinction as suggested by Kennett & Watkins (1974) and not a sharp one of biostratigraphic and chronological significance as inferred by Berggren & van Couvering (1974, p.77).

Globorotalia tumida and *Sphaeroidinellopsis subdehiscens* were rare itinerant visitors from more tropical climes as they are associated with an abundance of sub-tropical species, such as *Globigerinella aequilateralis*, *Globigerina falconensis* and *Globigerinoides trilobus*.

The *sphericomiozea* morphotype of *Globorotalia puncticulata* is most distinct at the base of the Zone and becomes increasingly difficult to distinguish from *G. puncticulata* (S.S.) towards the top of the Zone.

A thick tested form resembling the morphology of *G. margaritae* occurs in the lower part of the interval (at and below 2423' in Flounder # 5). Associated with it is *G. cibaoensis*.

In Flounder # 5 small specimens of *Orbulina universa* are ubiquitous and distinct from the larger, dark coloured, frosted specimens of *O. universa* which were evidently reworked. Associated reworked species from Zone D-2 are *Globorotalia conica*, *G. mayeri* and *G. peripheroronda*. The presence of remane fossils may explain the anomalously fast deposition rate during Zone A-4. The mechanism which produced this rapid sedimentation was probably slumping and high energy bottom currents.

The designated standard section is in Flounder # 5 between side wall core at 3226' to side wall core at 1947'.

Zone A-3

The base of the Zone of *G. inflata* heralds the appearance of the nominant species which has developed from *G. puncticulata*. The initial evolutionary appearance of *Neogloboquadrina humerosa* apparently coincides with the base of the Zone.

The top of the Zone is immediately below the initial appearance of *G. tosaensis*. Associated species are the same as for Zone A-2 except for the gradual extinction of *G. puncticulata*, *G. crassacrottonensis* and *G. acostaensis*. The distribution of the latter three species is erratic but could be useful in identifying the Zone on rotary cuttings. *Neogloboquadrina humerosa* is present though some specimens blend with *Globorotalia acostaensis*. *G. woodi woodi* has a sharp extinction and *G. decoraperta* occupied its niche but the two species are unrelated.

The designated standard section is in Flounder # 5 from the side wall core at 1860' to side wall core at 1003'.

Zone A-2

The base of the Zone of *G. tosaensis* is represented by the initial appearance of the nominant species and the evolutionary transition of *Neogloboquadrina dutertrei* from *N. humerosa* (both present in basal part of Zone).

The top of the Zone is the evolutionary appearance of *Globorotalia truncatulinoides* and not the extinction of *G. tosaensis*.

Associated species are *G. inflata*, *G. crassaformis*, *Globigerina decoraperta* (often abundant), *G. bulloides*, *G. falconensis* and with occasional occurrences of *Orbulina universa*, *Globigerinoides trilobus*, *G. ruber* and *Globigerinella aequilateralis*.

The designated standard section for this Zone is in Flounder # 5 from side wall core at 889' upwards above the sampled interval in the sequence. A sample for the top of the Zone has yet to be designated, as discussed below for Zone A-1.

Zone A-1

The base of the Zone of *G. truncatulinoides* is marked by the initial appearance of the nominant species.

The top of the Zone is the present day assemblage on the Gippsland sea floor with *G. truncatulinoides* still present.

The Zone could be further subdivided as the basal part is characterised by the evolutionary transition between *G. truncatulinoides* and its ancestral form *G. tosaensis*. However, this has not been attempted because of a low

correlateable reliability due to the rarity of *G. tosaensis* and its gradual rather than sharp extinction. Associated species are *G. inflata*, *G. bulloides*, *G. falconensis*, *Neogloboquadrina dutertrei* and *N. pachyderma*. *Globorotalia crassaformis* may be present in the lower part of the Zone. At the top of the Zone the influx of warm water species is evident with the penetration of the East Australian Current but these influxes are sporadic both vertically and laterally and are of no stratigraphic significance. The warmer water species include *Orbulina universa*, *Pulleniatina obliquiloculata*, *Globigerinoides ruber*, *G. trilobus trilobus*, *G. trilobus sacculifer* and occasionally *Sphaeroidinella dehiscens*. In all examples *Globorotalia inflata* is the dominant species even in the modern Gippsland sea floor samples where the warm water element may comprise up to 20% of the planktonic fauna.

The standard section for this Zone has not, as yet, been designated and will probably be assigned to a cored interval in one of the foundation test wells. The example for the top one metre of the Zone is the gravity core San Pedro Bay-1 from 2,000 metres of water off the eastern extremity of Gippsland.

Correlation of Deep Water Zones which comprise Minimal Layer Zone A.

Taylor, 1966, originally regarded the base of this Zone as being on the Mio/Pliocene boundary but later (unpublished report to Esso) revised this, in light of the opinion of Blow (1969) that *Globorotalia inflata* originated in Zone N.17 which he regarded as late Miocene. Lately there has been much published discussion regarding the biostratigraphic significance of the evolution of *G. inflata* and its ancestral form *G. puncticulata*. The form referred to by Taylor as *G. inflata* in earlier reports is obviously *G. puncticulata*.

The fourfold division of Zone A is now in partial agreement with the biostratigraphic division of the cool sub-tropical region during the Plio/Pleistocene as proposed for the Tasman Sea by Kennett, (1973). The Gippsland zonation is in closer agreement with the revised scheme of Kennett & Vella (1975), in that *Globorotalia crassaformis* extends almost throughout the *G. puncticulata* Zone and does not characterise a separate Zone. Also, the division corresponds with that established by Jenkins for New Zealand and the ocean to the south (Leg 29), except that Jenkins' *G. puncticulata* Zone does not extend from the initial appearance of the nominant species. Comparison of the Southwest Pacific, New Zealand and Gippsland Zones for this biostratigraphic interval is shown on Table 1. The major difficulty in correlating

between the temperate areas and the warmer water sequences is the differences in fauna and different times of initial appearance of biostratigraphically important forms. For instance, in Kennett's (1973) warm sub-tropical zonation, the appearance of *G. puncticulata* is not an evolutionary one and it probably migrated north from the cooler waters of New Zealand and the Gippsland where the appearance is evolutionary (Kennett, l.c.). *G. margaritae* appears before *G. puncticulata* in warmer water, yet Kennett (1973) and Kennett & Watkins (1975) correlate the *G. margaritae* Zone with the basal part of the *G. puncticulata* Zone in cooler waters, where sporadic occurrences of *G. margaritae* correspond with the range of *G. puncticulata*. As Kennett (1973) points out, correlation of the Pliocene is difficult as in the tropics "*G. puncticulata* and *G. inflata* are virtually absent, while *G. tumida*, *S. dehiscens* and *P. primalis* increase even more in importance" in selecting the base of the Pliocene. The extinction of *Globoquadrina dehiscens* was given significance by Blow (1969) and Berggren & van Couvering (1974) but this must be regarded as a predominantly cold water species and tends to linger on in cooler waters, being reported from Zone A-4 in Flounder # 5.

Kennett & Watkins (1974) speak of the first appearance of *Globorotalia puncticulata sphericomiozea* marking the traditionally accepted Miocene/Pliocene boundary in New Zealand and find that this occurs at 4.3 ± 0.1 m.y. on the paleomagnetic time scale. However, what is "traditional Pliocene" in New Zealand, may well not correspond with the Pliocene stratotype in Italy. Berggren & van Couvering (1974) and Cita (1973) place the boundary between 4.9 and 5.1 m.y. Furthermore, Cita & Ryan (1973) place the first appearance of *G. puncticulata* in the Mediterranean at 4.2 m.y. which is within the scope of Kennett & Watkins' (1974) 4.3 ± 0.1 m.y. for this event in New Zealand. Also, Cita (1973) shows that *G. margaritae* occurs before *G. puncticulata*, but Kennett & Watkins (1974) dispute this on the grounds that there is no evidence that the appearance of *G. puncticulata* is an evolutionary one in the Mediterranean area. Despite Kennett & Watkins' assertions, the consistency of paleomagnetic dates between New Zealand and the Mediterranean suggests that the "traditional Pliocene in New Zealand" is above the base of the Pliocene stratotype. Therefore, the base of Gippsland Zone A-4 is within and not at the base of the Pliocene. This Zone probably corresponds with either Cita's (1973) *G. margaritae margaritae* or *G. margaritae evoluta* Zones and is not equivalent to her basal Pliocene Zone, the *Sphaeroidinellopsis* Acme-Zone. Confusion regarding the Mio/Pliocene boundary may be due to the fact that the concept of a synchronous flooding of the Mediterranean at the boundary is

apparently incorrect as the D.S.D.P. Leg 13 results show a diachronous transgression from west to east (Cita, l.c.).

Exact correlation with Lamb & Beard's (1972) scheme for the Caribbean, Gulf of Mexico and Italian stratotypes is as difficult as with other schemes based on tropical faunas, especially as they do not designate the range of *G. puncticulata*. However, the presence of and overlap between *G. crassacrotonensis* and *G. crassaformis* in Zone A-4 would indicate a position between the top of Beard & Lamb's *G. margaritae* and *P. obliquiloculata* Zone in the mid Pliocene. Tying in with Blow's zonation cannot be achieved but a position for Zone A-4 would be within N.19/N.20. Berggren's (1972) placement of the initiation of *G. puncticulata* at the base of the Pliocene (within N.18 at 5 m.y.) is, in all probability, too low.

The Zone of *G. inflata* (= A-3) and *G. tosaensis* corresponds to the same nominal zones in New Zealand and the Southwest Pacific (Kennett, 1973, Kennett & Vella, 1975 and Jenkins, 1975), although Kennett & Vella (1975) found that the sporadic appearance of *G. tosaensis* did not justify a separate zone for a cool temperate zonation. All the above authors accept the appearance of *G. truncatulinoides* (Zone A-4) as marking the Plio/Pleistocene boundary and corresponding with the base of Blow's (1969) Zone N.22, as is followed by Berggren & van Couvering (1974) who place this Datum Plane at 1.85 m.y. However, Lamb & Beard (1972) do not follow this convention and place the event within the Pleistocene, so that their *G. tosaensis* Sub Zone and the initial appearance of *Neogloboquadrina dutertrei* is within the Pleistocene; based on paleoclimatic reasons (Lamb & Beard, 1972, p.50, footnote). In this paper the convention is followed to coincide with opinions of New Zealand and Southwest Pacific workers so that the initiation of *G. truncatulinoides* corresponds with the Plio/Pleistocene boundary.

Thus:- Zone A-4 The Zone of *G. truncatulinoides* = Pleistocene to Recent
and Zone A-3 The Zone of *G. tosaensis* = late Pliocene

In conclusion, the Minimal Layer Zone A extends from early or mid Pliocene to the Recent, but not from the base of the Pliocene as inferred by Taylor (1966). Nicholls' (1968) "Faunal Unit 14" is characterised by *Globorotalia "inflata"* (in all probability in part = *G. puncticulata*) and *G. crassaformis*, so is the onshore Gippsland Basin equivalent of Zone A. An interpretation of Nicholls' work suggests that the "Kalimnan Stage" (stratotype - Lakes Entrance - Gippsland) and the underlying "Cheltenhamian Stage" (stratotype - Cheltenham, south of

Melbourne) are within Zone A though further fragmentation is impossible due to restricted, low diversity, planktonic faunas. Therefore, the base of the Cheltenhamian is above the Mio/Pliocene boundary but approximates the base of the "traditional New Zealand Pliocene" (Kennett & Watkins, 1974) as correctly inferred by Nicholls (1968). Zone A is above the highest Lakes Entrance Oil Shaft sample at 212' (Jenkins, 1960).

PALEOHYDROLOGY

The fauna in any one planktonic sample reflects all the water masses above the site at time of deposition. Thus a combination of warm and cold assemblages can be present in a single sample. Therefore a warmer water assemblage with a cool temperate assemblage can imply that a warm surface water mass penetrated into the region and does not necessarily imply that the whole water column or mass overlying the region was warm. For this reason, paleohydrology is used rather than paleoceanology, as paleohydrology infers more than one mass.

An attempt has been made to delineate the maximum water temperature, although only the relative designates "warm" and "cool" are used, as on Distribution Chart, Sheet 1.

The reliability of the assumptions decreases with time. During the Pleistocene and Pliocene, taxonomic criteria are used, whilst in older samples taxonomic diversity and generic or sub-generic occurrence are employed.

The late Oligocene hydrological column was obviously cool water without tropical forms. Initial occurrences are consistent with New Zealand, but not with region west of Tasmania (i.e. D.S.D.P. Site 282 and Nautilus # 1 in the Otway Basin) and suggest a circum-Tasman Sea current consistent with the reconstruction by Kennett et. al. (1975, fig. 10).

The uppermost early Miocene (Zones F-1 and E-2) in Flounder # 5 as in other Gippsland wells, shows increasing specific diversity and abundance of *Globigerinoides* spp. with *menardii* Group *Globorotalia*. These criteria, according to Jenkins (1968) and others, suggest warmer waters. Jenkins (l.c.) would place "the temperature peak" in Zone E-2. However, this "peak" in Flounder # 5 and other Gippsland sections is not reached till Zone D-2 in the late Miocene.

The base of the late Miocene (Zone D-2) demonstrates an increase in diversity and warm water supra-specific groups from the top of the early Miocene, but there is a decline in diversity and occurrence through D-2. This suggests that the "paleotemperature peak" or influx of warm water was most pronounced at the Zone D/Zone E boundary in Flounder # 5.

There is a distinct drop in temperature during Zone C and extending into Zone B-2, as is evident by decline in taxonomic diversity and rarity of *Globigerinoides* and *Globorotalia menardii* Group. Furthermore, *G. miotumida conoidea* is dominant whilst *G. miotumida miotumida* has a patchy distribution; a factor that suggests cool, deeper water by inference from Chaproniere (1973). Towards the top of Zone B-2, there is an increase in warm water, as evident from the dominance of *G. miotumida miotumida* over the *conoidea* morphotype.

Criteria used to determine temperature fluctuations during the Pliocene and Pleistocene are similar to those used by Kennett & Vella (1975) for D.S.D.P. Site 284 in the eastern Tasman Sea. These criteria include:-

- 1) Ratio of *Globigerina bulloides* to *G. falconensis*. Dominance of the latter is taken to infer warmer conditions.
- 2) High percentages of *Neogloboquadrina pachyderma* (both morphotypes) imply cooler conditions, though this criterion decreases, with time, in reliability (Kennett & Vella, i.c.).
- 3) Presence of *Globigerinoides* spp. and *Globigerinella aequalateralis* suggest warmer water.
- 4) There are at least two morphotypes of *Globorotalia inflata* off Gippsland today. The conical form inhabits warmer water, whilst the more abundant spherical form frequents the cooler Bass Strait water mass. Therefore, the ratio of the morphotypes should reflect fluctuating warm and cold water. This criterion was not applied by Kennett & Vella (1975).

From these criteria the relative water temperature graph on Distribution Chart Sheet 1 was constructed. Although similar criteria have been used, there is little correspondence between this graph and those for D.S.D.P. Site 284 (Kennett & Vella, i.c. and Shackleton & Kennett, 1975). In places the Flounder

5 graph is the reverse of those for Site 284. The major discrepancy is during Zone A-3, the Zone of *G. inflata*, where warm conditions are postulated in Flounder # 5, but marked cooling has been suggested for the equivalent level (= the Waipipian Stage) at Site 284 and in New Zealand (Kennett & Vella, 1975 and Shackleton & Kennett, 1975). This discrepancy has already been noted by Beu (1975) who postulates a warm Waipipian Stage in New Zealand on molluscan evidence. The explanation may be that Kennett & Vella (1975) are incorrect in assuming widespread warming and cooling at particular times, especially regarding spread of the Antarctic Sea ice. The Gippsland is a hydrologically transient region, dependent on the vagaries of the East Australian Current (Anon, 1975). It has been evident that there have been sporadic penetrations of a warm current into the Gippsland Basin during the Neogene and these warm influences were probably due to a proto-East Australian Current. The warm eddies of this proto-East Australian Current either did not reach or were dissipated by the time they reached Site 284.

ENVIRONMENT

Data relating to this environmental interpretation is shown on Distribution Chart Sheet 3.

The early to mid Eocene faunas, dominated by arenaceous forms, indicate an embayment or tidal marsh environment with anaerobic and polyhaline conditions prevailing. Sporadic planktonic faunas indicate occasional oceanic flooding.

The almost complete dominance of planktonic specimens in the one late Oligocene sample is evidence of a deep water, probably continental rise, deposition. This deep water environment persists on the other side of the late Oligocene to early Miocene hiatus in Flounder # 5. The deep water environment continues to the close of the late Miocene. The hiatus may be due to erosion or no deposition due to deep water boundary currents, similar to those postulated to explain the Oligocene unconformity in many D.S.D.P. sites in the Southwest Pacific (Kennett et. al., 1975).

The late Miocene section indicates physical disturbance on a steep continental slope. Slumping may have been responsible for the absence of much of Zone D

and continued instability and exposure of Zone D sediment is evident from the reworking of Zone D planktonic species into the Pliocene sediments.

Slumping, reworking and canyon activity is pronounced in the early Pliocene (Zones B-1 and A-4). Inner continental shelf species were misplaced into deeper water sediment, suggesting high energy current activity on the shelf edge. This high energy activity persisted through the late Pliocene into the Pleistocene where the sediment is rich in worn bryozoal fragments. There is a gradual progradation of the continental shelf throughout the Pliocene culminating in a mid-shelf environment, at the top of the Pliocene, analogous with the modern sea floor at the Flounder # 5 location.

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