

## DSDP Site 594, Chatham Rise, New Zealand – Late Neogene planktonic foraminiferal biostratigraphy revised

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**ABSTRACT** - A restudy of the planktonic foraminifera at DSDP Leg 90, Site 594, has been made and consequently a revised scheme of late Neogene zones has been necessary. The *Globorotalia sphericomiozea* Zone (including *G. conomiozea*) is contracted to occupy a much smaller interval just below the Miocene/Pliocene boundary and the *G. puncticulata*, *G. inflata* and *G. truncatulinoides* Zones have been expanded. In the uppermost Miocene and Lower Pliocene, the standard regional planktonic foraminiferal datums provide a good correlation with DSDP Leg 29 Hole 284, DSDP Leg 90 Hole 593 and with New Zealand on-land palaeomagnetically-zoned sequences. They do not, however, correlate with the magnetostratigraphy adopted in the Leg 90 Initial Reports for this interval in Hole 594 in which Chrons 4–6 are offset downwards against the foraminiferal datums. It is possible that there are unrecognized hiatuses in the Plio-Pleistocene.

Higher in the Pliocene, very low species diversity of the cold-water faunas, scarcity of warm-water foraminiferal zonal species, and their much later appearance in Hole 594, contribute to a recognition that the Subtropical Convergence has been an effective barrier against the southwards penetration of most warmer water planktonic species.

*Neocarinina blowi* Thompson and *Globorotalia crozetensis* Thompson, are recorded from the New Zealand area for the first time. *J. Micropalaeontol.*, 13(2): 93–101, December 1994.

### INTRODUCTION

DSDP Leg 90, Holes 594, 594a and 594b, were sited in the Bounty Trough on the southern edge of the Chatham Rise, due east of Oamaru at Lat. 45°31.41'S, Long. 179°56.88'E, in a water depth of 1204 m (Fig. 1).

The primary scientific objectives were to obtain a high resolution stratigraphic sequence from the Quaternary to the late Palaeogene using the hydraulic piston corer and extended core barrel. The location, south of the Subtropical Convergence, is well placed to record oscillating glacial and interglacial episodes accompanied by alternating Subantarctic and cool subtropical assemblages of the fossil planktonic microfauna and microflora (Fig. 1). Hole 594, drilled to a subbottom depth of 1716.9 m, recovered a late Early Miocene to Holocene sequence and Holes 594a and 594b were drilled to depths of 1851.3 m and 1255.1 m respectively to recover intervals of poor recovery from cores 17, 22, 32 and 33.

The initial reports of DSDP Leg 90 recorded that many zonal indicators of the calcareous nannoplankton were very rare or absent and the zonation adopted had to rely on auxiliary species. Reworking of nannofossils from older deposits was common and their preservation was generally poor. The Miocene/Pliocene zonal boundary could only be approximately located and the Pliocene Zones NN18, NN17, NN13 and the NN8/NN7 boundary could not be identified (Lohman, 1985). Siliceous microfossils, radiolarians, diatoms and silicoflagellates occur throughout the cored sequence, but the stratigraphic correlation of the Neogene

radiolaria was difficult because they were very scarce and much diluted by terrigenous material and lacked warm-water species in the Pliocene (Caulet, 1985). Diatom assemblages present throughout the hole enabled recognition of 11 of 14 zones in the Middle Miocene to Quaternary Southern Ocean diatom zonation (Ciesielski, 1985).

Silicoflagellates were present in sufficient numbers to recognize 6 zones, somewhat modified for the cold-water character of the assemblages (Locker & Martini, 1985). Study of the Upper Miocene silicoflagellates from Site 594 by Bukry (1985) showed that large abundances of *Mesocena* and *Distephanus* between 180 m and 290 m indicated very cool conditions compared to their occurrence in more northern Leg 90 Pacific sites.

Jenkins & Srinivasan (1985) produced a shipboard-report on the planktonic foraminiferal biostratigraphy, dividing the sequence into 10 zones, being a modification of the zonal scheme of Jenkins (1966, 1967, 1975) for the cool subtropical seas, adapted to the considerably less diverse Subantarctic assemblages. Their zonation of the uppermost Miocene and Lower Pliocene showed an anomalously long *Globorotalia sphericomiozea* Zone extending from Core 20(3) 90–91 cm to Core 9(3) 90–91 cm, compared to more northern sequences in DSDP Holes 284 and 593 (Hornibrook, 1982; Jenkins & Srinivasan, 1985; Hoskins, 1990) and also to on-land sequences in Blind River and Mangapoike River (Kennett & Watkins, 1974; Hornibrook, 1984).

Recognizing that a revision of the foraminiferal biostratigraphy of this interval was necessary the authors re-examined shipboard splits of Cores 1–23 from Hole 594.

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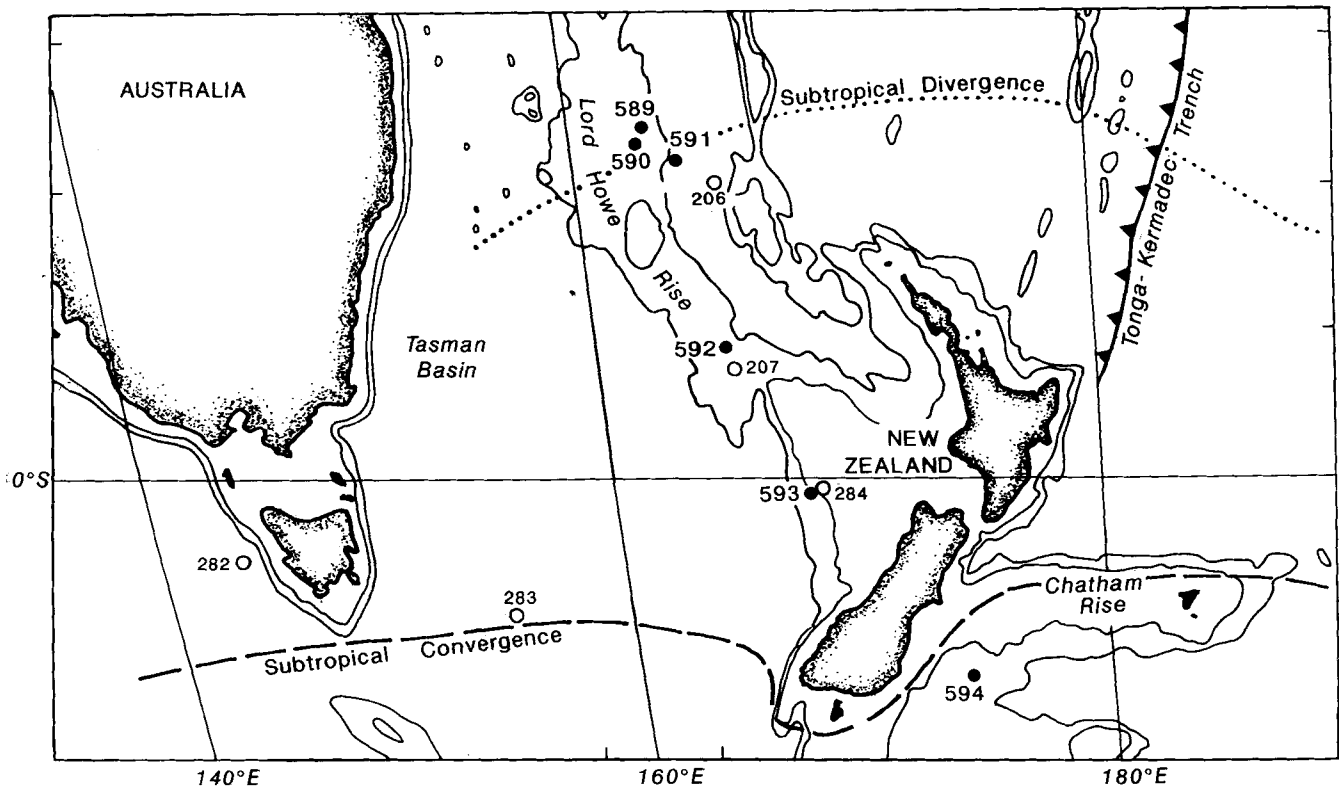


Fig. 1. Location of sites drilled during Leg 90 (solid circles) and other DSDP drill sites (open circles) in the southwest Pacific.

The spacing of the available samples is not as close as the authors would have preferred as a basis for a more detailed revision, and the assemblages are sparse in some intervals. However, they have provided a basis sufficient to allow a much improved record of the foraminiferal ranges. The resulting amended biostratigraphy (Table 1 and Plates 1 & 2) incorporates some revised and some new species identifications. The range of *Globorotalia sphericomiozea*, which had been combined with *G. puncticulata puncticuloides* by Jenkins & Srinivasan (1985), is shortened and confined to the interval from Core 20(4) 91–92 cm to Core 20(2) 90 cm. *Globorotalia juanai*, which is a new record, becomes extinct in Core 20(2) 90–92 cm. *Globorotalia crassaformis* is recorded only in Core 19(4) 90–92 cm and in Core 15 cc; the upper part of its range, as initially recorded in Core 9 cc to Core 4(5) cc, in the Leg 90 Initial Reports (p. 828, table 16A), is referred to *G. crassarina* Scott *et al.* (1990). The entry of *G. crassula* is recorded in Core 9 cc, and *G. truncatulinoides* is recorded earlier, from Core 7(2)

90–92 cm upwards; the first typical population with a wide open umbilicus is recorded in Core 3 cc. The range of *Globorotalia inflata* is extended downwards to Core 15 cc. *Globorotalia crozetensis*, and *Neoacarinina blowi* are recorded from the Southwest Pacific for the first time.

Compared to DSDP Leg 90 Initial Reports (p. 828, table 16A; Jenkins & Srinivasan, 1985), this revision has resulted in a contraction of the *G. sphericomiozea* Zone, the upper part of which is included in the *G. puncticulata* Zone, and an expansion of the *G. inflata* and *G. truncatulinoides* Zones.

#### CORRELATION OF PLANKTONIC FORAMINIFERAL ZONES AND DATUMS

With the revised ranges of planktonic foraminifera from Hole 594, it is possible to correlate the Upper Miocene and Lower Pliocene part of the sequence with onshore New Zealand stages and also with DSDP Holes 284, 284A and 593 in the Tasman Sea (Figs 2, 3).

The *Globorotalia miotumida* Zone, present in Cores 23 cc

#### Explanation of Plate 1

**Figs 1–3.** *Globorotalia miotumida* Jenkins: fig. 1, umbilical view,  $\times 90$ ; fig. 2, spiral side,  $\times 90$ ; fig. 3, lateral view,  $\times 90$ , 594, 21 cc. **Fig. 4.** *Globorotalia conomiozea* Kennett, lateral view,  $\times 90$ , 594, 20 cc. **Figs 5, 6.** *Globorotalia sphericomiozea* Walters: fig. 5, umbilical view,  $\times 90$ ; fig. 6, lateral view,  $\times 100$ , 594, 16 cc. **Figs 7, 8.** *Globorotalia margaritae* Bolli & Bermudez: fig. 7, umbilical view,  $\times 110$ ; fig. 8, spiral side,  $\times 110$ , 594, 21–3–90. **Figs 9–11.** *Globorotalia juanai* Bermudez & Bolli: fig. 9, umbilical view,  $\times 100$ ; fig. 10, spiral side,  $\times 100$ ; fig. 11, lateral view,  $\times 100$ , 594, 23 cc. **Figs 12–14.** *Globorotalia puncticulata* (Deshays): fig. 12, lateral view,  $\times 90$ ; fig. 13, umbilical view,  $\times 80$ ; fig. 14, spiral side,  $\times 95$ , 594, 19 cc. **Figs 15–17.** *Globorotalia puncticulata puncticuloides* Hornibrook: fig. 15, umbilical view,  $\times 70$ ; fig. 16, spiral side,  $\times 75$ ; fig. 17, lateral view,  $\times 65$ , 594, 16 cc.



Plate 1

DSDP Leg 90 Site 594 Samples		25 cc	21 cc	20 cc	19 cc	18 cc	16 cc	15 cc	14 cc	13 cc	12 cc	11 cc	10 cc	9 cc	8 cc	7 cc	6 cc	5 cc	4 cc	3 cc	2 cc	1 cc
<b>PLANKTONIC FORAMINIFERA</b>																						
<i>Globorotalia juanai</i>		■	■	■	■																	
<i>Globorotalia cf. juanai</i>				■																		
<i>Globigerina woodi decoraperta</i>		■	●	●				■	□													
<i>Globigerinoides? sp.</i>		■			■	■																
<i>Globorotalia miotumida</i>			■	■																		
<i>Globorotalia cf. panda</i>		■																				
<i>Globorotalia conomiozea</i>		●	●	▲	■	●																
<i>Globorotalia sphericomiozea</i> (keeled)		●	●	●	■																	
<i>Globorotalia margaritae</i>		●	●																			
<i>Globigerina bulloides</i>					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Globorotalia puncticulata</i> s.s. (no keel)					▲	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Globorotalia crassaformis</i> (rounded form)					○																	
<i>Globorotalia scitula</i>					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Globorotalia p. puncticuloides</i>					●	●	▲	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Globorotalia crozetensis</i>					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Globigerina spp.</i>							■															
<i>Globorotalia inflata</i>							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
<i>Neogloboquadrina pachyderma</i>								○	△													
<i>Globigerinella aequilateralis</i>								○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
<i>Globorotalia cf. crassula</i> (small, hirsute)																						
<i>Globorotalia crassacarina</i>																						
<i>Globorotalia crassula</i>																						
<i>Globigerina dutertrei</i>																						
<i>Globigerina quinqueloba</i>																						
<i>Globigerinita uvula</i>																						
<i>Globigerina umbilicata</i>																						
<i>Globorotalia truncatulinoides</i>																						
<i>Globorotalia tosaensis</i>																						
<i>Neoacarinina blowi</i>																						
<i>Orbulina universona</i>																						
<i>Globigerinoides sacculifera</i>																						
<b>PLANKTONIC FORAMINIFERAL ZONES</b>		<b>This paper</b>		<i>G. miotumida</i>		<i>G. sphericomiozea</i>		<i>G. puncticulata</i>		<i>G. inflata</i>						<i>G. truncatulinoides</i>						
<b>Jenkins + Srinivasan (1985)</b>				<i>G. miotumida</i>		<i>G. sphericomiozea</i>						<i>G. inflata</i>										
<b>NEW ZEALAND STAGES</b>		TONGAPORUT - UAN (UPPER)		KAPITEAN		OPOITIAN																
<b>EPOCHS</b>		LATE MIOCENE		PLIOCENE						PLEISTOCENE												

**Table 1.** Distribution of planktonic foraminifera, uppermost Miocene to Pleistocene, Hole 594. ■ = occurrence, ◇ = open umbilicus, ▲ = abundant, △ = random, ○ = sinistral, ▼ = dextral, ● = cf., □ = aff, ? = uncertain identification.

to 21(3) 90–92 cm is correlated with the uppermost part of the Tongaporutuan Stage corresponding to the upper part of Chron 6.

The *G. sphericomiozea* Zone of Jenkins & Srinivasan (1985) included a lower *G. conomiozea* subzone in Cores 21(2) 90–92 cm to 20(3) 90–91 cm equivalent to lower Kapitean, Chron 5, (6 Ma to 5.4 Ma), and an upper *G. sphericomiozea* subzone in Cores 20(4) 90–92 cm to 20(2)

90–92 cm is upper Kapitean, basal Gilbert Chron 4 (5.4 Ma–c. 5.0 Ma) (Edwards, 1987; Wright & Vella, 1988). The interval of overlapping ranges of *G. sphericomiozea*, *G. juanai* and *G. margaritae* in Core 20 does not support Ciesielski's conclusion, (1985, fig. 3), that the basal Gilbert is missing in a hiatus. The base of the Opoitian Stage (basal Gilbert, Chron 4, c. 5 Ma) is at the base of the *G. puncticulata* Zone in Core 19 cc.

**Explanation of Plate 2**

**Figs 1–3.** *Globorotalia crassula* Cushman & Stewart: fig. 1, umbilical view, ×60; fig. 2, spiral side, ×65; fig. 3, lateral view showing distinctive weak peripheral keel, ×80, 594-5 cc. **Figs 4–6.** *Globorotalia crozetensis* Thompson: fig. 4, lateral view, ×80; fig. 5, umbilical view, ×90; fig. 6, spiral side, ×90, 594, 18 cc. **Figs 7, 8, 12.** *Globorotalia crassacarina* Scott, Bishop & Burt: fig. 7, umbilical view, ×65; fig. 8, lateral view, ×60; fig. 12, spiral side, ×80, 594, 18 cc. **Fig. 9.** *Globigerina umbilicata* Orr & Zeitzett, ×85, 594–5 cc. **Figs 10, 11.** *Neoacarinina blowi* Thompson: fig. 10, umbilical view, ×110; fig. 11, surface, enlarged to show typically densely porous and pustulose character, ×330, 594-4 cc. **Fig. 13.** *Globorotalia inflata* (d'Orbigny), umbilical view, ×95, 594, 20-2-90-92. **Figs 14–16.** *Globorotalia truncatulinoides* (d'Orbigny): fig. 14, umbilical view showing wide umbilicus, ×50; fig. 15, spiral side, ×67; fig. 16, lateral view showing strong peripheral keel, ×67, 594, 2 cc.

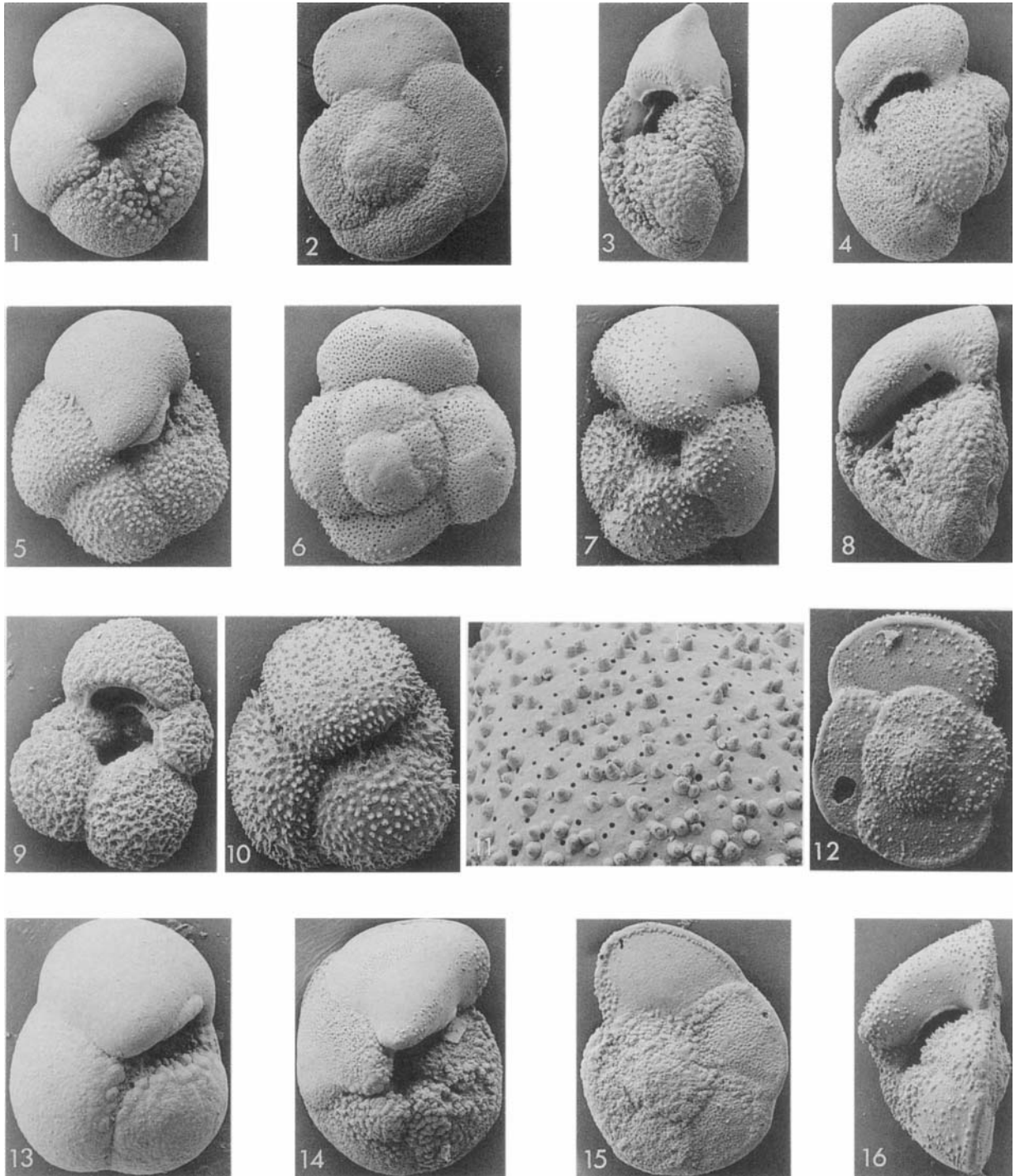


Plate 2

Ma	CHRON	INTERNATIONAL				NEW ZEALAND		Ma		
1 2 3 4 5 6 7	1 2 3 4 5 6 7	CENOZOIC	NEOGENE	PLEISTOCENE	M	PIACENZIAN	WANGANUI	HAWERAN	Wq	0.4
					E			CASTLECLIFFIAN	Wc	1.2
				PLIOCENE	LATE	ZANCLEAN	WANGANUI	NUKUMARUAN	Wn	1.8
					EARLY			MANGAPANIAN	Wm	2.4
				MIOCENE	LATE	MESSINIAN	TARANAKI	WAIPSIAN	Wp	3.1
								TORTONIAN upper	OPOITIAN	Wo
TONGAPORU-TUAN upper	Tt (u)	6.0								

Fig. 2. Geomagnetic time-scale and New Zealand Late Miocene to Pleistocene Series and Stages (After Edwards 1987.)

Compared to the established magnetostratigraphic positions of these planktonic foraminiferal datums in New Zealand on-land sequences, the following magnetostratigraphic correlatives adopted by Barton & Bloemendal (1985, fig. 26) in Hole 594 are too young. The established ages are given in brackets: FOD *Globorotalia conomiozea*, base Thvera 4.77 Ma (6–5.6 Ma); FOD *G. sphericomiozea* populations, close to Sidufjall, c. 4.4 Ma (5.4 Ma); FOD *G. puncticulata* populations, close to Nunivak, c. 4.1 Ma (5.0 Ma).

Either all of these datums occur much later in Hole 594 or the magnetostratigraphic interpretation is incorrect as has been claimed previously by Wright & Vella (1988).

The low-diversity cool-water assemblages and the relatively large sampling intervals combine to make correlations with the Upper Pliocene and Pleistocene in the latitude of New Zealand, north of the Subtropical Convergence, rather uncertain above Core 19, particularly as *G. crassaformis*, which has useful coiling reversal zones in the north, is extremely rare. Two sinistral specimens in Core 19(4) 90–92 cm are consistent with an Opoitian (Gilbert) age but the two dextral individuals in Core 15 cc, if an adequate sample of the population, are more consistent with a Mangapanian (Late Pliocene, upper Gauss) age.

Individual morphotypes of *Globorotalia puncticulata puncticuloides* appear in populations of *G. puncticulata puncticulata* in Core 18 cc and more abundant typical individuals, with strongly compressed margins and flared chambers, dominate mixed populations from Core 16 cc upwards. A similar sequence is also present in Hole 284 where rare morphotypes of *Globorotalia puncticulata puncticuloides* appear prior to large populations of this subspecies, abundant in the lower part of Core 7 (Hornibrook, 1982) near the Gilbert/Gauss boundary which was recorded in nearby Hole 593 (Fig.1).

An obvious anomaly is the sudden appearance of typical

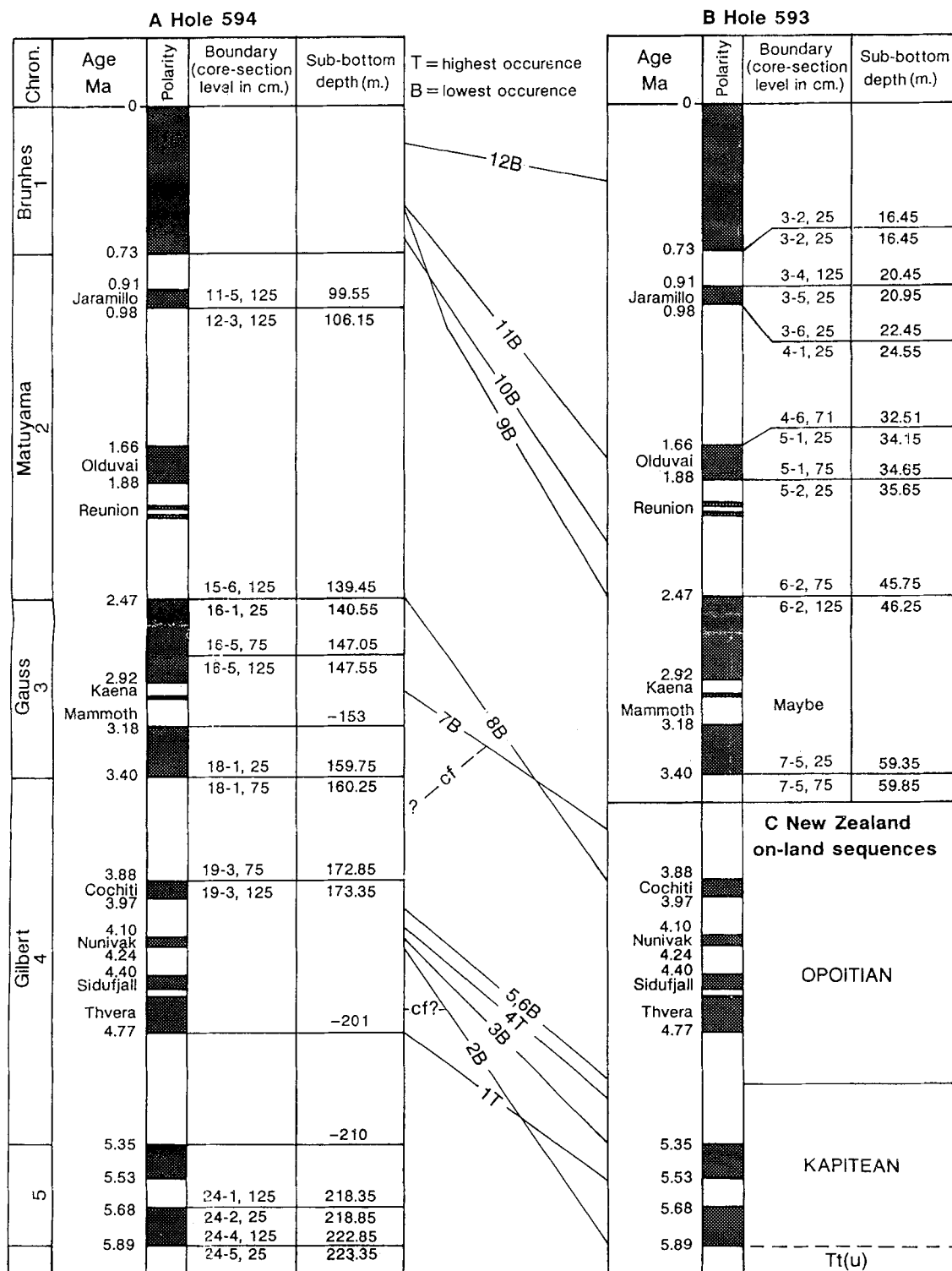
populations of *Globorotalia inflata* in Core 15 cc at the Gauss/Matuyama boundary in Hole 594 without any earlier record of the precursor transitional *G. puncticulata*–*G. inflata* populations which are usually present in the southwest Pacific. A sedimentary hiatus eliminating most of the Gauss in the interval of non-recovery in Core 17, proposed by Ciesielski (1985, fig. 3), could possibly account for the apparently late appearance of *G. inflata* although this species has not yet been recorded in the equivalent interval in Hole 594A, Core 10.

Evidence that *G. inflata* appeared in Subantarctic waters around southern New Zealand about 1 Ma later than it did north of the Subtropical Convergence does not seem to support Wei's suggestion (Wei, 1991) that the enhancement of the Antarctic Intermediate water-mass might have created new niches and triggered off the evolution of this species at about 3.5 Ma.

*Globorotalia crassacarina* recorded by Scott *et al.* (1990) from the Nukumaruan to Castlecliffian, Upper Pliocene to Pleistocene in New Zealand, is recorded earliest in Hole 594 Core 10 cc, rare and coiling dextrally. This is in contrast to its dominantly sinistral coiling habit in Hole 284 in which it appears at the bottom of Core 5 (Lower Matuyama in Hole 593) about 1 Ma earlier than in Hole 594.

*Globorotalia crassula* appears first, rare and atypical in Core 9 cc, becoming more abundant and having an atypical morphology from 7 cc upwards as high as Core 3(2) 90–92 cm. Compared with its entry in Holes 284 and 593, at the Gauss/Matuyama boundary, its earliest appearance in the uppermost Matuyama in Hole 594 is about 1 Ma later.

*Globorotalia truncatulinoides* appears first, rare and atypical, with a small umbilicus, in Core 7 cc, becoming more common in Core 3 cc which contains a fairly typical, strongly keeled population with a well developed, open umbilicus resembling individuals in the Pleistocene Castlecliffian and in the uppermost 3 cores of Hole 284



**Fig. 3.** Sequence of foraminiferal datums in Hole 594 compared with Hole 593 and New Zealand on-land palaeomagnetically-zoned sequences (mainly after Edwards, 1987). Columns A, B, Holes 594 and 593, adapted from Barton & Bloemendal (1985, figs 25, 26). Column C, position of datums in New Zealand on-land sequences. (1) *Globorotalia miotumida*, T; (2) *G. conomiozea*, B; (3) *G. sphericomiozea*, B; (4) *G. juanai*, T; (5) *G. puncticulata*, B; (6) *G. crassaformis*, B; (7) *G. puncticulata puncticuloides*, B; (8) *G. inflata*, B; (9) *G. crassula*, B; (10) *G. crassacarina*, B; (11) *G. truncatulinoidea*, early form (= *G. truncatulinoidea tosaensis* of Scott *et al.*, 1990) B; (12) *G. truncatulinoidea truncatulinoidea*, open umbilicus, keeled population, B. T = topmost occurrence; B = bottommost occurrence.

(Scott *et al.*, 1990), equal to Brunhes in adjoining Hole 593.

The last appearance of *Globorotalia puncticulata puncticulata* is recorded in Core 9(3) 90–92 cm in the vicinity of the Gauss/Matuyama boundary, co-occurring with *G. puncticulata puncticuloides*. Its last appearance in Hole 593 is in Core 8 below the Gauss Chron (Hoskins, 1990) whereas Wei (1991) gives its last occurrence datum, possibly including *G. puncticulata puncticuloides*, as *c.* 2.35 Ma, in the basal Matuyama.

Hornibrook *et al.* (1989) and Scott *et al.* (1990) show the last appearance of *G. puncticulata puncticulata* in the Waipipian (Gauss Chron) and that of *G. puncticulata puncticuloides* high in the Nukumaruan (Upper Matuyama) and possibly in the Castlecliffian (Brunhes). Hornibrook (1982) recorded *G. puncticulata puncticuloides* from as high as Core 3 and possibly Core 2 (Brunhes) in Hole 284, but Hoskins (1990) recorded it from only as high as Core 6 (Lower Matuyama) in Hole 593.

#### NEW RECORDS OF SPECIES IN THE NEW ZEALAND AREA

*Globorotalia crozetensis* and *Neoacarinina blowi* were originally described by Thompson (1973), from a piston core RC8-39, Lat. 42°53'S, Long. 40°21'E, from the western Crozet Basin in the southwest Indian Ocean, in Upper Pleistocene sediments. Neither species has been recorded previously from the southwest Pacific.

*G. crozetensis* (Plate 2, figs. 4–6) ranges from Core 18 cc (Lower Pliocene) to Core 2(2) 90–92 cm (Pleistocene) in Hole 594. An imbricate arrangement of chambers on the spiral side is particularly characteristic of this species which seems to have been restricted to cool seas.

*Neoacarinina blowi* (Plate 2, figs 10, 11) characterized by its globular, strongly spiny form, is present from Core 7 cc, (uppermost Pliocene or basal Pleistocene), to Core 2(2) 90–92 cm, and, like *G. crozetensis*, appears to be a southern cool-water species that became extinct in the Upper Pleistocene.

The species of *Globigerina*, with a wide open umbilicus and tending to produce end kummerform chamberlets (Plate 2, fig. 9) is provisionally referred to *G. umbilicata* of Orr & Zeitzeff (1971), and was first recorded from the Pliocene of California.

#### IMPLICATIONS FOR CORRELATIONS BETWEEN THE SUBANTARCTIC AND THE COOL SUBTROPICAL ZONES

Hole 594 has been valuable for providing a record of late Neogene microfaunal and microfloral plankton south of the Subtropical Convergence during the Miocene, Pliocene and Pleistocene. It provides examples of low species diversity compared with the biota of the northern part of New Zealand and clearly demonstrates the intolerance to cold water of some species such as *Globorotalia crassaformis* which was common in warmer waters in the Pliocene from Lat. 42°S northwards. Unfortunately, doubts regarding the interpretation of the magnetostratigraphy and the presence of possible sedimentary hiatuses introduce uncertainty in

evaluating the reliability of the foraminiferal biostratigraphy as a basis for north–south correlation. The recognition of a hiatus between 1.45 to 0.73 Ma by Dersch & Stein (1991), based on their interpretation of the sedimentology, is an example of this problem.

Although planktonic foraminiferal faunal diversity south of the Subtropical Convergence was very low in the uppermost Miocene and Lower Pliocene in Cores 23–16 in Hole 594, it is possible to recognise the following New Zealand stages (Figs 2, 3): Upper Tongaporutuan, (*Globorotalia miotumida* Zone, in part); Kapitean, (*G. sphericomiozea* Zone); and Opoitian, (*G. puncticulata* Zone, in part).

However, the correlation with the standard geomagnetic polarity sequence adopted by Barton & Bloemendal (1985), if correct, implies that all the standard regional foraminiferal datums, well integrated with magnetostratigraphy in on-land sections (Edwards, 1987), occur *c.* 1 Ma later at Site 594 than they do north of the Subtropical Convergence. While it could be argued that such an upward offset of regional datums was due to the effect of the Convergence, acting as a barrier to the southwards spread of warm-water species, their close spacing and their same order of appearance and disappearance as at DSDP Leg 29 Site 284 and Leg 90 Site 593 and in New Zealand on-land sequences, makes that reasoning seem unlikely. Furthermore, the late extinction level of the warm-water Miocene species, *Globorotalia miotumida* near the base of the Thvera in Hole 594, but observed to occur within the lower part of Chron 5 or earlier in the above-mentioned Sites (Fig. 3), implies the unlikely conclusion that this species was able to exist *c.* 1 Ma longer in cold southern waters, becoming extinct in the Early Pliocene when temperatures were rising again.

What is clear is that the following important foraminiferal datums occur in the same upwards order both south and north of the Subtropical Convergence: LOD *Globorotalia miotumida*, FOD *G. conomiozea*, FOD *G. sphericomiozea*, FOD *G. margaritae*, LOD *G. juanai*, FOD *G. puncticulata*, FOD *G. crassaformis*, FOD *G. puncticulata puncticuloides* (earlier in the south). The following species all appear later south of the Subtropical Convergence: FOD *G. inflata*, FOD *G. crassacarina*, FOD *G. crassula*, FOD *G. truncatulinoides* s.l. (Fig. 3).

*Globorotalia puncticulata puncticuloides* populations are especially abundant and typical in Hole 594. Watkins *et al.* (1973) identified these forms as falling within the normal variation of Early–Middle Pleistocene Subantarctic *G. puncticulata* populations. Typical populations are especially common in the Upper Pliocene Lower Nukumaruan assemblages containing the cold water mollusc *Chlamys delicatula* (Hornibrook, 1981) in the North Island East Coast Basin of New Zealand, where they may have more potential value as indicators of incursions of cold Subantarctic water rather than as reliable index fossils for regional correlation.

#### SUMMARY

1. The uppermost Miocene and Lower Pliocene in DSDP Leg 90 Hole 594 in the Bounty Trough can be correlated, using planktonic foraminifera, with the same interval of



that age in DSDP Leg 29 Hole 284 and DSDP Leg 90 Hole 593 in the Tasman Sea and in New Zealand with on-land sequences, but not with the interpretation of the magnetic polarity reversals by Barton & Bloemendal (1985: 1312, fig. 26).

2. Assuming that the interpretation of the magnetic polarity reversals through most of the Gauss and the overlying sequence by Barton & Bloemendal (1985) is dependable, and has not been affected by the presence of unrecognized hiatuses in sedimentation, their adopted magnetochronology would appear to be a more reliable basis for correlation with that of Hole 593 (p. 1306, fig. 22) than the foraminiferal biostratigraphy based on our rather widely spaced sampling intervals.
3. Planktonic foraminifera have not been shown to be reliable for correlation across the Subtropical Convergence in the Late Pliocene at Leg 90 DSDP Site 594.

#### ACKNOWLEDGEMENTS

We are grateful to G. H. Scott and A. R. Edwards for critically reading the manuscript. Lin Norton and Gaye Evans drafted the figures and tables, and Valerie Deisler typed the manuscript in the National Museum of Wales, Cardiff.

Manuscript received: March 1993

Manuscript accepted: November 1993

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