VESPA Dating Study Supplemental File 8. Biostratigraphy

Crundwell, M.P.; Morgans, H.E.G.; Hollis, C.J. 2016. Micropaleontological report on dredge samples collected during the 2015 VESPA (Volcanic Evolution of South Pacific Arcs) expedition, *GNS Science Internal Report* 2016/22. 83 p.

Micropaleontological report on dredge samples collected during the 2015 VESPA (Volcanic Evolution of South Pacific Arcs) expedition

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GNS Science Internal Report 2016/22
July 2016

BIBLIOGRAPHIC REFERENCE

Crundwell, M.P.; Morgans, H.E.G.; Hollis, C.J. 2016. Micropaleontological report on dredge samples collected during the 2015 VESPA (Volcanic Evolution of South Pacific Arcs) expedition, *GNS Science Internal Report* 2016/22. 83 p.

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ABSTRACT

Sixty-seven sedimentary rock (dredge) samples, collected from 28 dredge sites during the 2015 VESPA (Volcanic Evolution of South Pacific Arcs) expedition of the research ship l'Atalante to the Norfolk, Loyalty and Three Kings ridges, southeast of New Caledonia, were analysed for age and paleoenvironment using foraminifera. Thirty-three samples contained no foraminifera, or foraminifera of no age significance. The remaining samples contained faunas that ranged in age from Eocene to Holocene, including mixed faunas, comprised of foraminifera from the host-rock and from younger sediment in burrows or sediment adhering to the surface of samples. Paleowater depths ranged from inner shelf (<50 m) to deep lower bathyal (>1500 m), and some downslope reworking of shallow-water taxa was also noted.

Eight samples were also processed for radiolarians; six contained no radiolarians, one contained poorly preserved spumellarians of no age significance (DR23D), and one sample contained a sparse moderately preserved assemblage of Late Cretaceous age (DR40F).

KEYWORDS

Dredge samples, Norfolk Ridge, Loyalty Ridge, Three Kings Ridge, New Caledonia, Cretaceous, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, Holocene, foraminifera, radiolarians

1.0 INTRODUCTION

The 2015 VESPA (Volcanic Evolution of South Pacific Arcs) expedition to the Norfolk, Loyalty and Three Kings Ridges, between New Zealand and New Caledonia (Figure 1.1), was led by chief scientists Dr Nick Mortimer of GNS Science, and Dr Martin Patriat of IFREMER. The expedition was primarily a rock dredging expedition, with some shallow seismic and magnetic profile data acquisition. The objective was to obtain submarine arc and backarc basin lavas for age, geochemistry and isotopic composition analysis in order to piece together the tectonic history of the backarc basins between New Zealand and New Caledonia. Of major interest was the Cook Fracture Zone transform fault, which offsets the Loyalty and Three Kings ridges by 300 km.

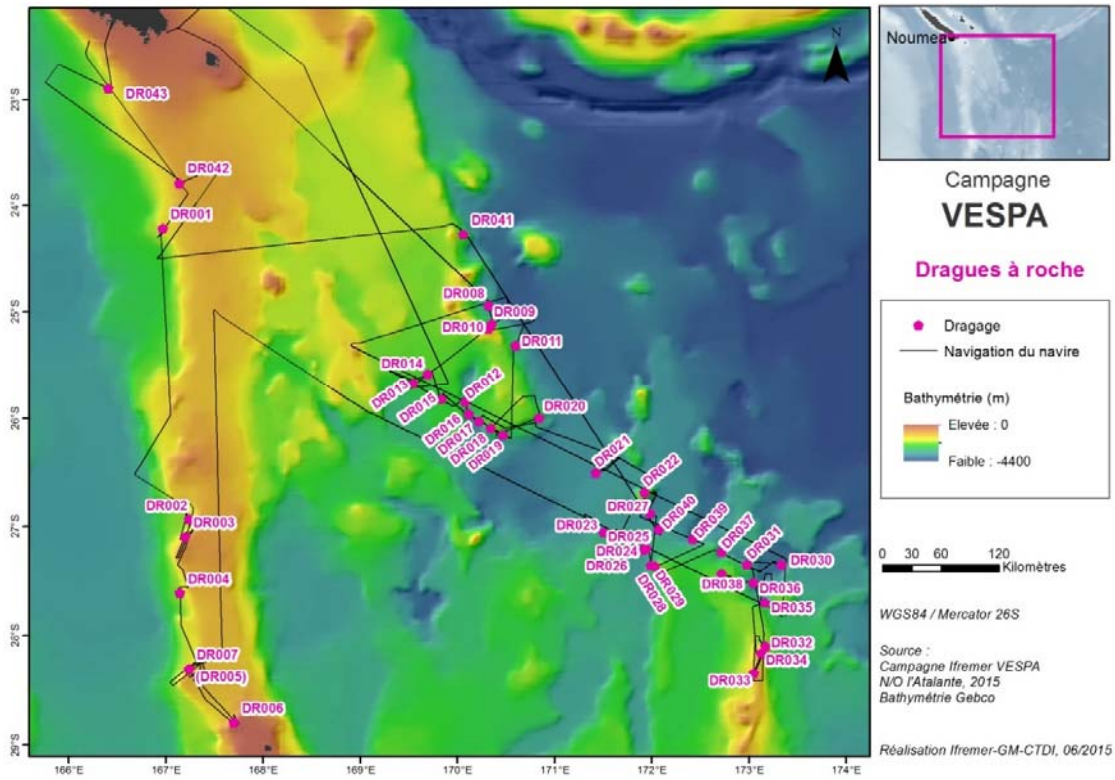


Figure 1.1 Locality map, showing seafloor bathymetry, expedition track-lines, and the sites of dredged samples collected from the Norfolk, Loyalty, and Three Kings ridges, between New Zealand and New Caledonia.

1.1 SAMPLES AND PROCESSING

Sixty seven samples of sedimentary rocks collected by the 2015 VESPA expedition, especially those intimately related with lavas and with different lithologies and/or generations of sediment, were selected by Hamish Campbell and Martin Crundwell for micropaleontological analysis.

Each sample was photographed and sub-samples were taken before the processing commenced. Sixty-seven samples and sub-samples were processed for foraminifera, and eight of these samples were also processed for radiolarians.

The composite numbers that are used in this report for samples include the dredge site number and a letter of the alphabet, for different rock samples in the same dredge haul (e.g. DR29C), and where appropriate, a number in brackets for sub-samples of different lithologies or generations of sediment from the same rock (e.g. DR29C (2)).

1.1.1 Foraminiferal samples

All samples were prepared for foraminifera by Randall MacDonnell (GNS Science Technician) and/or Martin Crundwell using the following methods:

- Firm (compacted) mudstone/siltstone/sandstone samples were dried, soaked in water, disaggregated by hand, and then washed over a 75 μm mesh screen to remove all mud and silt-sized material.
- Hard cemented samples were dried and partially crushed, then soaked in water and washed over a 75 μm mesh screen to remove mud and silt-sized material.
- Limestone samples were dried, crushed beneath a steel plate, and then washed to remove mud and silt-sized material. The 1–5 mm size fraction of each sample was then treated in 80% acetic acid for 9 to 10 days, before being washed thoroughly in water.
- Limestone samples that yielded poor faunas were reprocessed. The >1 mm size fractions of samples DR03Aii (2), DR08B (2), DR10B, DR10D (2), DR15Cii, DR22B, DR23A (1), DR23F (2), DR23G (2), DR24Ai, DR26Gi, DR29C, and DR33Cii that remained after the initial acetic acid treatment were crushed beneath a steel plate and washed to remove mud and silt-sized material.

The coarser >150 μm sediment size fraction of each sample was examined under a binocular microscope for key age and environmentally significant foraminifera. All samples were examined by Martin Crundwell, and all Early Miocene to Eocene samples were also examined by Hugh Morgans.

The taxonomy of Neogene and Quaternary foraminifera follows Kennett & Srinivasan (1983), Hornibrook et al. (1989), Scott et al. (1990), and Crundwell (2015). The adopted ranges of foraminifera are reported in terms of planktic foraminiferal N-zones of Banner and Blow (1965) and Blow (1969). The adopted ages of biohorizons (planktic foraminiferal datums) that are shown in Table 1.1, are based on the 2012 Geologic Time Scale (Gradstein et al. 2012, and Crundwell 2014). The taxonomy of Paleogene planktic foraminifera follows Hornibrook et al. (1989) and the adopted ages are reported in terms of New Zealand Stages (Raine et al. 2015). Series and stages of the New Zealand Miocene are shown in Figure 1.2, and the New Zealand Paleogene are shown in Figure 1.3.

All fossil material and results relating to foraminiferal samples are curated confidentially within the GNS Science laboratory F-number catalogue and the NZ Fossil Record database. A summary of biostratigraphic results is given in Table 1.2.

1.1.2 Radiolarian samples

Radiolarian samples DR14H, DR15Cii, DR15D, DR15I, DR23A, DR23D, DR24Ai, and DR40F were prepared by Sonja Bermudez (GNS Science Technician) using the following methods:

- Calcareous samples were crushed, washed in water, and material in the 2–5 mm size fraction of each sample was treated in 10% HCl for 1–2 days, and then washed twice in water. Washed >63 µm.
- Siliceous (chert-like) sample DR23A (1) was crushed between two steel plates and washed to remove mud and silt-sized material. A sub-sample of material in the 2–5 mm size fraction was also treated with 5% hydrofluoric acid for 2-hours to preferentially extract siliceous microfossils, and then neutralized and washed thoroughly in water. Washed >63 µm.

All fossil material and results relating to radiolarian samples are curated confidentially within the GNS Science laboratory RD-number catalogue and the NZ Fossil Record database. Biostratigraphic results for radiolarian samples are summarized in Table 1.3.

Table 1.1 Adopted biostratigraphic zonation for Neogene and Quaternary planktic foraminifera, after Kennett and Srinivasan (1983), Hornibrook et al. (1989), Scott et al. (1990), and Crundwell (2014). Biohorizon (planktic foraminiferal datum) ages are based on Gradstein (2012) and Crundwell (2015), and the Geologic Time Scale (Gradstein et al. 2012). LO = lowest occurrence; HO = highest occurrence. Horizontal lines represent N- and P-zone boundaries and/or epoch boundaries with ages (Ma).

Biohorizon (datum)	Epoch	Zone	Age (Ma)	Calibrated	Published error	
LO *Hirsutella hirsuta*	Middle Pleistocene	N22	0.45	South Atlantic		
HO *Zeaglobigerina apertura*	Early Pleistocene	N22	1.64	South Atlantic	± 0.03 Ma	
HO *Zeaglobigerina woodi* s.s.	Early Pleistocene	N22	2.30	New Zealand	± 0.02 Ma	
LO *Truncorotalia truncatulinoides*	Early Pleistocene	N22	2.58	South Pacific		2.58 Ma
HO *Dentoglobigerina alitispira*	Late Pliocene	N21	3.13	South Atlantic	± 0.02 Ma	
HO *Sphaeroidinellopsis seminulina*	Late Pliocene	N21	3.16	South Atlantic	± 0.02 Ma	
LO *Truncorotalia tosaensis*	Late Pliocene	N21	3.35	Equatorial Pacific		3.35 Ma
HO *Pulleniatina primalis*	Early Pliocene	N19-20	3.66	Equatorial Pacific		
HO *Pulleniatina spectablis*	Early Pliocene	N19-20	4.21	Equatorial Pacific		
LO *Globoconella inflata*	Early Pliocene	N19-20	~4.3	New Zealand		
HO *Zeaglobigerina nepenthes*	Early Pliocene	N19-20	4.37	South Atlantic	± 0.01 Ma	
HO *Sphaeroidinellopsis kochi*	Early Pliocene	N19-20	4.53	South Atlantic	± 0.17 Ma	
HO *Globigerinoides seigleri*	Early Pliocene	N19-20	4.72	Equatorial Pacific		
LO *Sphaeroidinellopsis dehiscens* s.l.	Late Miocene	N19-20	5.53	South Atlantic	± 0.04 Ma	5.53 Ma
LO *Globorotalia tumida*	Late Miocene	N18	5.57	Equatorial Pacific		
LO *Globoconella pliozea*	Late Miocene	N18	5.67	South Pacific		5.57 Ma
HO *Globoquadrina dehiscens*	Late Miocene	N17b	5.92	Equatorial Pacific		
LO *Pulleniatina primalis*	Late Miocene	N17b	6.60	South Pacific		
HO *Globoconella miotumida* s.s.	Late Miocene	N17a	6.96	New Zealand		
LO *Neogloboquadrina humerosa*	Late Miocene	N17a	8.56	Equatorial Pacific		8.58 Ma
LO *Neogloboquadrina pachyderma/incompta*	Late Miocene	N14	10.56	New Zealand		
HO *Paragloborotalia mayeri* s.l.	Late Miocene	N14	10.56	New Zealand		
LO *Menardella limbata*	Late Miocene	N14	10.64	Gradstein et al. 2012	± 0.24 Ma	
LO *Truncorotalia juanai*	Late Miocene	N14	10.90	New Zealand		
LO *Zeaglobigerina nepenthes*	Late Miocene	N14	11.63	South Atlantic	± 0.02 Ma	11.63 Ma
HO *Fohsella peripheroronda*	Middle Miocene	N10	13.80	South Atlantic		
HO *Menardella archeomenardii*	Middle Miocene	N10	13.87	South Atlantic		14.24 Ma
HO *Menardella praemenardii*	Middle Miocene	N9	14.38	South Atlantic		
LO *Orbulina suturalis*	Middle Miocene	N9	15.10	South Atlantic		15.10 Ma
LO *Preorbulina cirularis*	Middle Miocene	N8	~15.4	New Zealand		
LO *Praeorbulina glomerosa*	Middle Miocene	N8	~15.7	New Zealand		
LO *Preorbulina curva*	Middle Miocene	N8	15.97	New Zealand		
Globoconella miozea coiling shift (20% dex)	Early Miocene	N8	16.02	New Zealand		16.28 Ma
HO *Globoconella incognita*	Early Miocene	N7	16.38	Indian Ocean		
LO *Globoconella miozea*	Early Miocene	N7	16.70	Indian Ocean		
LO *Globoconella zealandica*	Early Miocene	N7	17.26	Indian Ocean		
HO *Paragloborotalia semivera*	Early Miocene	N7	17.26	South Atlantic		
HO *Catapsydrax dissimilis*	Early Miocene	N7	17.54	South Atlantic		17.54 Ma
LO *Globoconella praescitula*	Early Miocene	N5-N6	18.26	South Atlantic		
LO *Globoconella incognita*	Early Miocene	N5-N6	20.93	Indian Ocean		
HO *Turborotalita angulisuturalis*	Early Miocene	N5-N6	20.94	South Atlantic		
HO *Fohsella kugleri*	Early Miocene	N5-N6	21.12	South Atlantic		21.12 Ma
HO *Globigerina ciperoensis*	Early Miocene	N4a	22.90	South Atlantic		
LO *Globigerinoides trilobus* s.l.	Early Miocene	N4a	22.96	South Atlantic		
LO *Fohsella kugleri*	Early Miocene	N4a	22.96	South Atlantic		22.96 Ma
HO *Zeaglobigerina euapertura*	Late Oligocene	P22 (N3)	23.03	Indian Ocean		
Base common *Globigerinoides primordius*	Late Oligocene	P22 (N3)	23.50	South Atlantic		
LO *Globoquadrina dehiscens*	Late Oligocene	P22 (N3)	25.2	New Zealand		
HO *Paragloborotalia opima* s.s.	Late Oligocene	P22 (N3)	26.93	Gradstein et al. 2012		26.93 Ma
LO *Turborotalita angustisuturalis*	Early Oligocene	P21 (N2)	29.18	South Atlantic		29.18 Ma
HO *Subbotina angiporoides*	Early Oligocene	P20 (N1)	29.84	South Atlantic		
HO *Turborotalia ampliapertura*	Early Oligocene	P20 (N1)	30.28	South Atlantic		29.84 Ma
HO *Globigerinatheka index*	Late Eocene	P16	34.61	Indian Ocean		

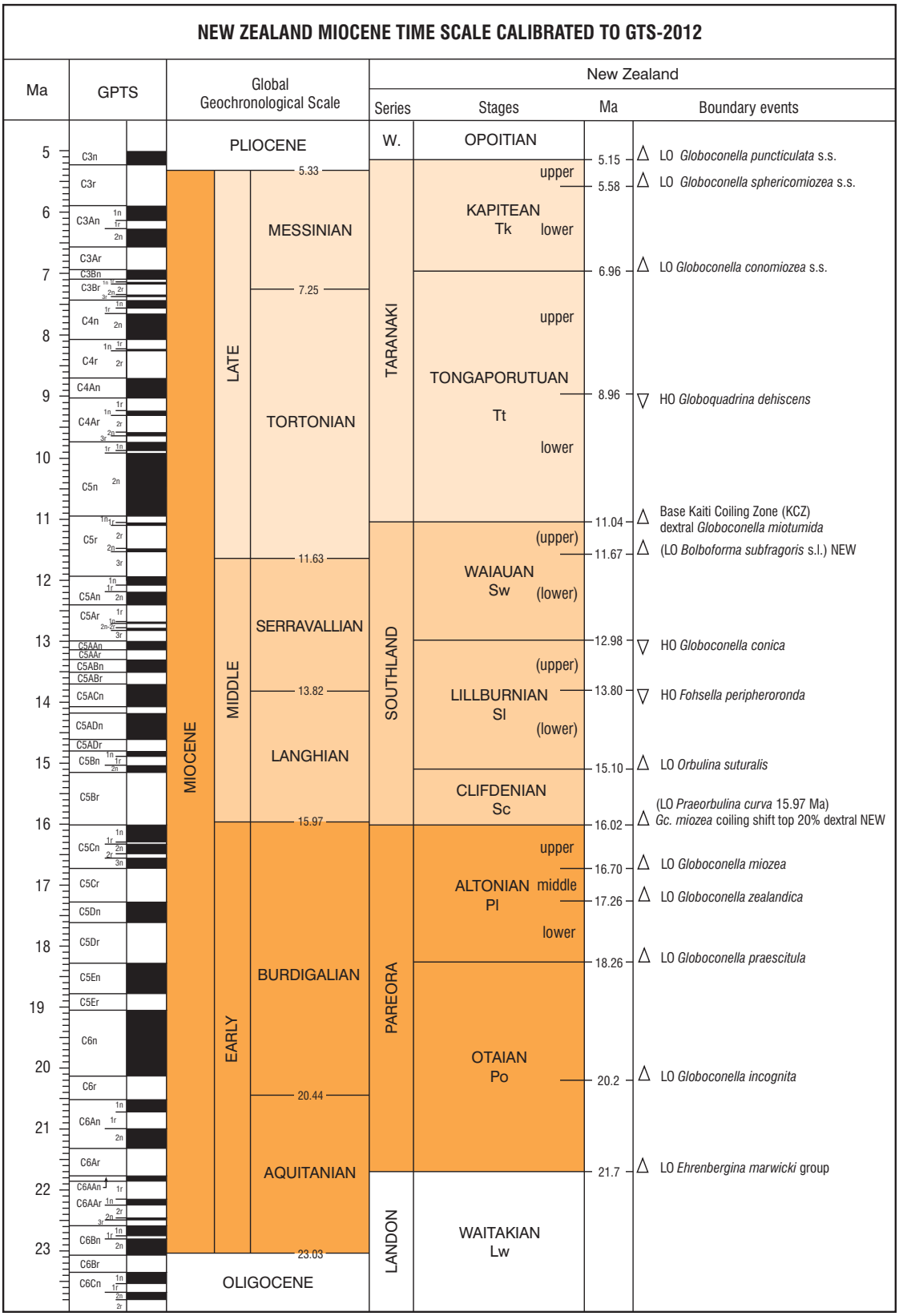


Figure 1.2 Series and stages of the New Zealand Miocene correlated with the series and stages of the Global Geochronological Scale and with the Geomagnetic Polarity Time Scale (after Raine et al. 2015). The boundary-defining event for each New Zealand stage is shown.

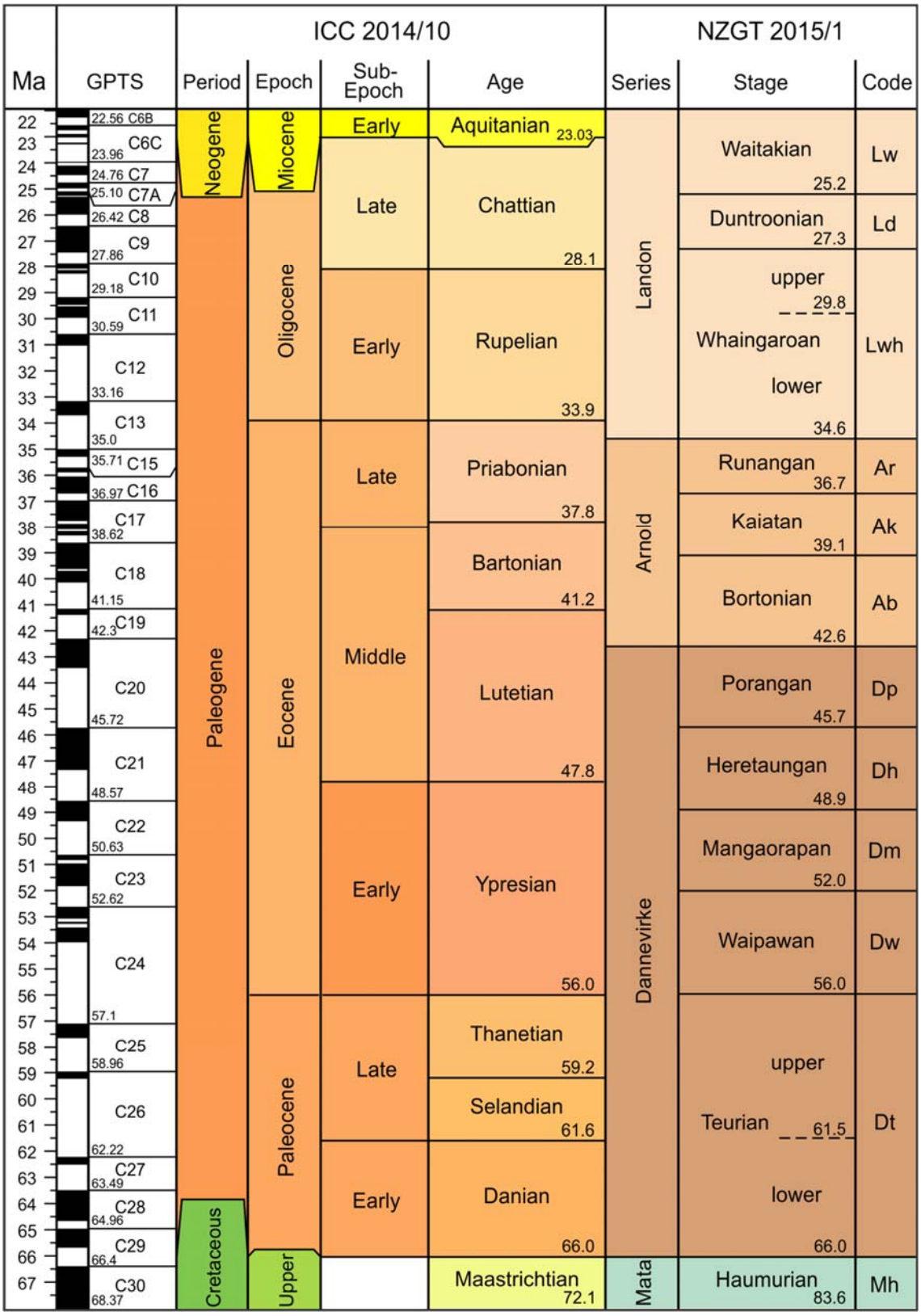


Figure 1.3 Series and stages of the New Zealand Paleogene correlated with the series and stages of the Global Geochronological Scale and with the Geomagnetic Polarity Time Scale (Raine et al. 2015).

1.2 FORAMINIFERAL RESULTS

VESPA Sample DR02A Soft, very pale orange, weakly indurated foram ooze/limestone. Moderately bored (10x1cm branching burrows), infilled with sediment.

NZ Fossil Record # SE26167/f001

GNS Science Laboratory # F49676

Preparation Disaggregated in water; washed >75 µm.

Fauna Well preserved subtropical microfauna comprised mostly of planktic foraminifera.

Adopted age Late Miocene Zone N16 to N17b (9.83-5.92 Ma).

Comment on age MC. Constrained by *Globigerinoides seigliei*, *Globoconella miotumida* and *Globoquadrina dehiscens*; possibly younger based on *Menardella exilis*.

Paleodepth Mid bathyal or deeper >600 m; *Karreriella bradyi*.

Planktics

Globoconella miotumida	NZ, Middle Miocene to Late Miocene (16.02-6.96 Ma)
Menardella exilis	Late Miocene (N18) to Pleistocene (N22)
Hirsutella scitula	
Globoquadrina dehiscens	Late Oligocene (P22) to Late Miocene (N17b) 25.2-5.92 Ma
Globoquadrina venezuelana	Middle Eocene to Early Pliocene
Globigerinoides quadrilobatus	
Globigerinoides sacculifer	
Globigerinoides trilobus	
Globigerinoides obliquus	
Globigerinoides seigliei	Late Miocene (N16 to N18)
Zeaglobigerina nepenthes	base Middle Miocene (N14) to Early Pliocene (N19)
Neogloboquadrina pachyderma	

Benthics

Karreriella bradyi	mid bathyal marker >600 m
Siphotextularia sp.	
Lenticulina sp.	
Siphouvigerina sp.	
Sphaeroidina bulloides	
Pullenia bulloides	uppermost bathyal marker >600 m
Globocassidulina subglobosa	
Chilostomella ovoidea	
Pleurostomella alternans	bathyal
Osangularia bengalensis	bathyal

Other material

Echinoid spines	rare

VESPA Sample DR03Aii (1) Light-coloured surficial carbonate sediment

NZ Fossil Record # SE27167/f001

GNS Science Laboratory # F49677

Preparation Sub-sampled, crushed and treated in acetic acid; washed >63 µm.

Fauna Well-preserved, tropical/subtropical microfauna, predominantly planktic foraminifera.

Adopted age Pleistocene to Holocene, Zone N22 (<2.58 Ma); possibly Early Pleistocene (2.58–1.81 Ma).

Comment on age MC. Constrained by *Truncorotalia truncatulinoides*; possibly Early Pleistocene based on the overlap with *Neogloboquadrina humerosa*.

Paleodepth Shelf <200 m; no bathyal markers.

Planktics	Pliocene (N19-N20) to Recent
Globoconella inflata	(0S:4D); Pliocene (N19 to N21)
Pulleniatina praecursor?	(2S:9D); possible variants of *Tr. crassaformis*
Truncorotalia cf. crassacarina	(2S:32D); Early Pleistocene (N22) to Recent
Globorotalia tumida	(20S:0D); Late Miocene (N18) to Recent
Hirsutella scitula?	(0S:3D)
Neogloboquadrina humerosa	Late Miocene (N18) to Early Pleistocene (N22)
Neogloboquadrina incompta	
Globigerina falconensis	
Globigerina bulloides	
Globigerina sp.	
Orbulina universa	
Globigerinella aequilateralis	
Sphaeroidinella dehiscens	
Globigerinoides conglobatus	
Globigerinoides quadrilobatus	
Globigerinoides sacculifer	non-saccate form
Globigerinoides ruber	
Globigerinoides pyramidalis	

Benthics

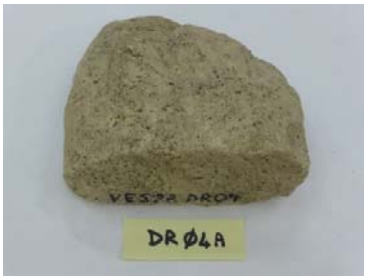
Textularia sp.
Quinqueloculina sp.
Pyrgo sp.
Pullenia sp.
Globocassidulina subglobosa
Oridorsalis cf. *tenera*
Cibicides sp.
Discorbinella sp.?
Lenticulina sp.

Other material	
Echinoid spines	few
Micro-gastropods	few
Holothurian spines	rare
Bryozoan fragments	rare
Fish teeth	rare
Ostracods	rare

VESPA Sample DR03Aii (2)	Light-brown volcaniclastic breccia.
NZ Fossil Record #	SE27167/f001
GNS Science Laboratory #	F49677

Preparation	Sub-sampled, crushed and treated in acetic acid; washed >63 µm. Reprocessed, crushed and partially disaggregated in water; washed >75µm.
Fauna	Extremely rare, poorly preserved foraminifera. Unlikely to be from the volcaniclastic breccia.
Adopted age	Non-determinate (ND).
Benthics	
Sigmoilopsis sp.?	fragment
Other material	
Echinoid spines	few

VESPA Sample DR04A	Soft, ashy, yellowish-grey sandy mudstone. Sand grains are orange sideromelane glass; and variably altered lava.
NZ Fossil Record #	SE27167/f002
GNS Science Laboratory #	F49678



Preparation	Crushed and disaggregated in water; washed >63 µm.
Fauna	Well-preserved microfauna, mostly planktic foraminifera.
Adopted age	Late Eocene to Oligocene, Zone P17 to P20 (34.61-29.84 Ma).
Comment on age	MC+HM. Based on *Subbotina angiporoides* s.s. and no *Globigerinatheka* index.
Paleodepth	Bathyal >200 m, possibly lower bathyal >1000 m; *Cibicides* cf. *robertsonianus*.

Planktics

Chiloguembelina cubensis	Early/Middle Eocene to Oligocene (P21), >28.09 Ma
Chiloguembelina ototara	NZ, Bortonian to mid Whaingaroan
Globorotaloides turgidus?	
Globigerina ampliapertura	NZ, Whaingaroan to early Waitakian
Subbotina angiporoides minima	NZ, ?Porangan to Runangan
Subbotina angiporoides s.s	Late Eocene to Oligocene (P20)
Subbotina gortonii	
Globoquadrina sp.?	

Benthics

Stilostomella sp.	
Lagena sp.	
Lenticulina sp.	
Pleurostomella sp.	bathyal
Bolivina sp.	
Gyroidinoides sp.	
Melonis maorica?	
Pullenia sp.	
Cibicides sp.	
Cibicides cf. *robertsonianus*	lower bathyal >1000 m?
Cibicides cf. *perforatus*	
Cassidulina sp.	

Other material

Ostracods	rare

VESPA Sample DR04F	Light-coloured carbonate sediment (limestone) and volcaniclastic breccia.
NZ Fossil Record #	SE27167/f003
GNS Science Laboratory #	F49679

Preparation	Sub-sampled, crushed and treated in acetic acid; washed >63 µm.
Fauna	Moderately well-preserved microfauna, mostly planktic foraminifera. Wall surfaces of specimens corroded.
Adopted age	Middle to Late Eocene, Zone P14 to P16 (39.12-29.84 Ma).
Comment on age	HM. *Globigerinatheka index* in combination with the absence of *Acarina*, especially *Acarina primitiva* and also *Bulimina bortonica*, suggest mid to Late Eocene (mid Kaiatan to Runangan).
Paleodepth	Bathyal >200 m; *Pleurostomella* and *Dentalina*?

Planktics

Globigerinatheka index	NZ, Bortonian to Runangan
Subbotina angiporoides?	NZ, Bortonian to early Whaingaroan
Subbotina linaperta?	Early to Middle Eocene (P15)
Globigerina sp.	

Benthics

Dentalina sp.?	
Lenticulina sp.	
Bulimina sp.	
Gyroidinoides sp.	
Cibicides cf. *perforatus*	
Pleurostomella sp.	bathyal

Other material

Radiolarians	few

VESPA Sample DR06A Cemented yellowish-white biogenic packstone (limestone).

NZ Fossil Record # SE28167/f006

GNS Science Laboratory # F49676

Preparation Crushed and partially disaggregated in water; washed >75 µm.

Fauna Moderately sparse, poorly preserved microfauna; specimens infilled with calcite and recrystallized.

Adopted age Pleistocene to Holocene, Zone N22 (<2.58 Ma); possibly Early Pleistocene (2.58-1.81 Ma).

Comment on age MC. Constrained by *Truncorotalia truncatulinoides*; possibly Early Pleistocene based on the overlap with *Globoconella triangula*.

Paleodepth Shelf <200 m; possibly inner shelf <50m based on the dominance of inner shelf taxa (*Elphidium* biofacies). *Hoeglundina elegans* suggests deeper, but there are no typical bathyal markers.

Planktics

Globoconella triangula	NZ, Early Pliocene to Early Pleistocene
Globoconella inflata	Pliocene (N19-N20) to Recent
Pulleniatina obliquiloculata?	Early Pliocene (N19) to Recent
Truncorotalia truncatulinoides	Early Pleistocene (N22) to Recent
Orbulina universa	
Globigerinoides trilobus	

Benthics

Amphistegina sp.?	shallow shelf
Quinqueloculina spp.	
Spiroloculina sp.	
Nodosaria raphanus?	
Fissurina sp.?	
Lenticulina sp.	
Elphidium crispum?	common; shallow shelf
Elphidium novozealandicum?	
Cibicides corticatus?	common
Cibicides spp.	
Rosalina bradyi	shallow shelf
Melonis sp.?	
Hoeglundina elegans	few

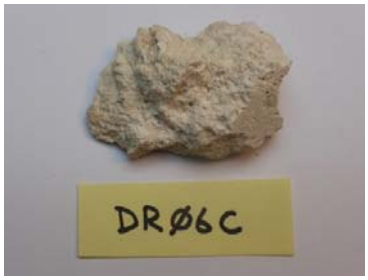
Other material

Echinoid spines	common
Micro-bivalves	few
Micro-gastropods	common
Bryozoan fragments	few

VESPA Sample DR06C White bioclastic limestone (packstone), contains molluscan and coral debris, and algal balls.

NZ Fossil Record # SE28167/f007

GNS Science Laboratory # F50188



Preparation Crushed and partially disaggregated in water; washed >75 µm.

Fauna Moderately sparse, poorly preserved microfauna. Specimens recrystallized and infilled with calcite.

Adopted age Pleistocene to Holocene (<2.34 Ma); possibly Early Pleistocene (2.34-1.81 Ma).

Comment on age MC. Constrained by *Truncorotalia crassacarina*; possibly Early Pleistocene based on the overlap with *Globoconella triangula*. *Truncorotalia truncatulinoides* supports a Pleistocene-to-Holocene age.

Paleodepth Shelf <200 m; possibly inner shelf <50m. Based on the dominance of inner shelf taxa (*Elphidium* biofacies). *Hoeglundina elegans* deeper, but there are no typical bathyal markers.

Planktics

Truncorotalia truncatulinoides	Early Pleistocene (N22) to Recent
Truncorotalia crassacarina	NZ, Early Pleistocene to Recent (<2.34 Ma)
Globoconella triangula	NZ, Early Pliocene to Early Pleistocene
Globoconella inflata?	Pliocene (N19-N20) to Recent
Globorotalia tumida	Late Miocene (N18) to Recent
Orbulina universa	

Benthics

Nodosaria raphanus	
Quinqueloculina spp.	
Pyrgo sp.	
Spiroloculina sp.	
Rosalina bradyi	shallow shelf
Pileolina sp.	shallow shelf
Elphidium crispum?	common
Melonis sp.?	
Cibicides spp.	common
Hoeglundina elegans	

Other material

Echinoid spines	common
Micro-bivalves	few
Micro-gastropods	common
Bryozoan fragments	few

VESPA Sample DR08B (1) Soft-white surficial carbonate sediment

NZ Fossil Record # SE24170/f001

GNS Science Laboratory # F49681

Preparation Sub-sampled and treated in acetic acid; washed >63 µm.

Fauna Well-preserved tropical/subtropical microfauna, mostly planktic foraminifera.

Adopted age Late Miocene to Early Pliocene Zone N19-N20 (5.44-4.37 Ma).

Comment on age MC. *Globoconella pliozea* in combination with *Zeaglobigerina nepenthes* and *Truncorotalia* cf. *juanai* suggests Late Miocene to Early Pliocene.

Paleodepth Mid bathyal or deeper >600 m; *Oridorsalis umbonatus*, *Osangularia culter* and *Euuvigerina peregrina?*

Planktics

Pulleniatina primalis	Late Miocene (N17b) to Early Pliocene (N20)
Globoconella pliozea	NZ, Late Miocene to Early Pliocene (5.44-4.49 Ma)
Menardella menardii	Middle Miocene (N12) to Recent
Truncorotalia crassaformis	rare; NZ, Late Miocene to Early Pleistocene (5.45-2.45 Ma)
Truncorotalia cf. *juanai*	rare
Globoconella cf. *puncticuloides*	rare
Hirsutella aff. *praehirsuta*	
Dentoglobigerina altispira	Early Miocene (N4b) to Early Pleistocene (N21)
Neogloboquadrina pachyderma	rare
Neogloboquadrina incompta	
Globigerinoides obliquus	
Globigerinoides quadrilobatus	
Globigerinoides sacculifer	
Globigerinoides conglobatus	
Beella digitata?	
Sphaeroidinellopsis kochi	
Sphaeroidinellopsis seminulina	
Orbulina universa	
Orbulina bilobata	
Globigerinoides trilobus	
Globigerina spp.	
Globigerina falconensis	
Zeaglobigerina woodi	
Zeaglobigerina nepenthes	Middle Miocene (N14) to Pliocene (N19-N20) 4.37 Ma
Globigerinita glutinata	
Globigerinella aequilateralis	

Benthics

Stilostomella sp.	
Bulimina truncanella	deep bathyal
Siphouvigerina sp.	
Euuvigerina peregrina?	bathyal
Pullenia bulloides	uppermost bathyal marker >200 m
Gyroidina sp.	
Oridorsalis umbonatus	bathyal
Osangularia culter	
Globocassidulina subglobosa	
Globocassidulina sp.	
Cassidulina laevigata	

Other material

Echinoid spines	rare

VESPA Sample DR08B (2) Breccia-conglomerate of basaltic clasts.

NZ Fossil Record # SE24170/f001

GNS Science Laboratory # F49681

Preparation Sub-sampled and treated in acetic acid; washed >63 µm. Reprocessed, crushed and partially disaggregated in water; washed >75µm.

Fauna Sparse, very poorly preserved microfauna. May not be from the breccia-conglomerate.

Adopted age Non-determinate (ND).

Planktics
Globigerina sp.

Benthics
Gyroidina sp.?
Anomalinoides sp.?

VESPA Sample DR10B Pale to pinkish-grey (partly silicified?) limestone with pumice fragments.

NZ Fossil Record # SE25170/f001

GNS Science Laboratory # F49682

Preparation Crushed and treated in acetic acid; washed >63 µm. Resampled, crushed and partially disaggregated in water; washed >75 µm.

Fauna Moderately to poorly preserved microfauna. Two faunal slides.

Adopted age Early Miocene Zone N4a to N4b (23.03-21.7 Ma)?

Comment on age HM. *Zeaglobigerina woodi-connecta* combined with a single specimen of *Zeaglobigerina brazieri* and a few good *Globoquadrina dehiscens* suggest Early Miocene (mid Waitakian)?

Paleodepth Bathyal >200 m; elongate nodosarids.

Planktics

Globoquadrina tripartita?	NZ, mid Oligocene to Early Miocene (27.3-17.26 Ma)
Globigerina spp.	
Globigerinoides sacculifer?	
Zeaglobigerina brazier	one specimen
Zeaglobigerina woodi-connecta group	
Globigerinita glutinata?	
Paragloborotalia pseudocontinuosa	
Globoquadrina dehiscens	Late Oligocene (P22) to Late Miocene (N17b)

Benthics

Quinqueloculina sp.	
Pyrgo sp.	
Dentalina spp.	
Lenticulina spp.	
Frondicularia sp.	large
Lagena spp.	
Fissurina spp.	
Amphicoryna sp.	
Bulimina sp.	
Pullenia sp.	
Sphaeroidina bulloides	
Euuvigerina sp.	
Melonis sp.	
Cibicides spp.	

Other material

Echinoid spines	few
Micro-gastropods	rare

VESPA Sample DR10D (1) Fine-grained yellowish-white carbonate sediment, burrow infill.

NZ Fossil Record # SE25170/f002

GNS Science Laboratory # F49683

Preparation Sub-sampled and treated in acetic acid; washed >63 µm.

Fauna Well-preserved tropical/subtropical microfauna.

Adopted age Pleistocene to Holocene (<2.40 Ma); possibly Early Pleistocene (2.40-2.30 Ma).

Comment on age MC. Constrained by *Truncorotalia crassula* and *Truncorotalia truncatulinoides*; possibly Early Pleistocene based on the overlap with *Zeaglobigerina woodi*. On the other hand, tentatively identified specimens of *Zeaglobigerina nepenthes* and *Zeaglobigerina druryi* suggest that the *Zg. woodi* could be from a population and that the sample has a mixed age fauna. The enigmatic absence of globoconellids, especially *Globoconella inflata*, warrants a cautionary caveat on the adopted age.

Paleodepth Bathyal >200 m; elongate nodosarids.

Planktics

Truncorotalia crassula?	rare; NZ, Early Pleistocene to Recent (<2.40 Ma)
Truncorotalia truncatulinoides?	weakly keeled; Early Pleistocene (N22) to Recent
Hirsutella cf. *scitula*	rare
Hirsutella sp.?	small
Neogloboquadrina incompta	
Paragloborotalia sp.?	one specimen
Zeaglobigerina woodi	Late Oligocene (P22) to mid Pleistocene (N22)
Zeaglobigerina druryi?	
Zeaglobigerina nepenthes?	
Globigerinoides trilobus	
Globigerinoides quadrilobatus	
Globigerinoides sacculifer?	
Globigerinoides ruber	
Globigerina spp.	
Globigerinita glutinata	
Orbulina sp.	juvenile, rare

Benthics

Dentalina spp.
Stilostomella sp.
Fissurina sp.
Lagena sp.
Virgulina bradyi
Gyroidinoides sp.?
Pleurostomella sp.
Anomalinoides parvumbilius?
Notorotalia sp.
Cassidulina laevigata

VESPA Sample DR10D (2)	Silicified limestone hard-ground; intensely modified by worm tubes, other encrusting shelly fauna such as corals. Mantled by a thick manganese-rind.
NZ Fossil Record #	SE25170/f002
GNS Science Laboratory #	F49683

Preparation	Sub-sampled, crushed and treated in acetic acid; washed >63 µm. Reprocessed, crushed and partially disaggregated in water; washed >75µm.
Fauna	Moderately well-preserved microfauna, mostly planktics.
Adopted age	Early Miocene Zone N4a to Zone N5-N6 (23.03-18.7 Ma)?
Comment on age	MC+HM. *Globoquadrina dehiscens*, *Zeaglobigerina woodi*, and no *Zeaglobigerina euapertura* or globoconellids, suggest Early Miocene (late Waitakian to Otaian).
Paleodepth	Mid bathyal or deeper >600 m; *Osangularia culter*.

Planktics

Globoquadrina dehiscens	Late Oligocene (P22) to Late Miocene (N17b)
Globigerinoides quadrilobatus?	
Zeaglobigerina connecta	NZ (~23.7-17.36 Ma)
Zeaglobigerina woodi	NZ (~24.0-2.30 Ma)
Globigerina sp.	
Globigerinita uvula	

Benthics

Lenticulina sp.	
Dentalina spp.	
Lagena striata?	
Bulimina spp.	
Cibicides spp.	
Cassidulina laevigata	
Cassidulina neocarinata	
Globocassidulina subglobosa	
Osangularia culter	bathyal
Anomalinoides cf. *macraglabra*	
Astrononion cf. *vadorum*	

Other material

Echinoid spines	few
Ostracods	rare

VESPA Sample DR11A (1) Soft, very light grey, intensely bioturbated siltstone.

NZ Fossil Record # SE25170/f003

GNS Science Laboratory # F49684

Preparation Sub-sampled, crushed and disaggregated using water; washed >63 µm.

Fauna Well-preserved, tropical/subtropical microfauna, mostly planktic foraminifera.

Adopted age Late Miocene Zone N14 (11.63-10.56 Ma); possibly early Tongaporutuan (10.64-10.56 Ma)?

Comment on age MC. Constrained by *Paragloborotalia mayeri* s.l. and *Zeaglobigerina nepenthes*; possibly early Tongaporutuan based on the overlap with *Menardella limbata*.

Paleodepth Lower bathyal or deeper >1000 m; *Planulina wullerstorfi*.

Planktics

Menardella limbata
Globoconella miotumida
Globoconella cf. *miozea*
Hirsutella sp.
Paragloborotalia mayeri s.l.
Globoquadrina dehiscens
Globoquadrina baroemoenensis?
Zeaglobigerina woodi?
Zeaglobigerina nepenthes
Globigerinoides ruber
Globigerinoides quadrilobatus
Globigerinoides trilobus
Sphaeroidinellopsis kochi
Orbulina universa
Globigerina spp.

Benthics

Dentalina spp.
Stilostomella sp.
Virgulina bradyi?
Bulimina truncanella deep bathyal
Pullenia bulloides
Gyroidinoides sp.
Oridorsalis umbonatus
Cibicides spp.
Planulina wullerstorfi
Globocassidulina subglobosa

Other material

Sponge spicules	few
Echinoid spines	rare
Ostracods	few

VESPA Sample DR11A (2) Soft, medium grey, intensely bioturbated siltstone.

NZ Fossil Record # SE25170/f003

GNS Science Laboratory # F49684

Preparation Sub-sampled, crushed and treated in acetic acid; washed >63 µm.

Fauna Relatively sparse, well-preserved tropical/subtropical microfauna, mostly planktic foraminifera. Fauna, indistinguishable from DR11A (1).

Adopted age Late Miocene Zone N14 (11.63-10.56 Ma), possibly early Tongaporutuan (10.64-10.56 Ma).

Comment on age MC. Constrained by *Paragloborotalia mayeri s.*l. and *Zeaglobigerina nepenthes*; possibly early Tongaporutuan based on the overlap with *Menardella limbata*.

Paleodepth Mid bathyal or deeper >600 m; *Pleurostomella alternans.*

Planktics

Paragloborotalia mayeri s.l.	late forms; NZ, Middle to Late Miocene (~13.8-10.56 Ma)
Menardella limbata	rare; Middle Miocene (N14) to Late Pliocene (N21)
Globoconella miotumida	common; NZ, Middle to Late Miocene (15.97-6.96 Ma)
Hirsutella sp.?	
Globoquadrina sp.	
Globoquadrina dehiscens	few; Late Oligocene (P22) to Late Miocene (N17b)
Zeaglobigerina woodi	
Zeaglobigerina nepenthes	Late Miocene (N14) to Early Pliocene (N19) 11.63-4.37 Ma
Globigerinoides trilobus	few
Sphaeroidinellopsis seminulina	few; Early Miocene (N7) to Late Pliocene (N21)
Orbulina universa	few; Middle Miocene (N9) to Recent
Globigerina spp.	
Globigerinita glutinata	rare

Benthics

Dentalina sp.	
Fissurina sp.	
Pullenia bulloides	
Pleurostomella sp.	bathyal
Sphaeroidina bulloides	
Cibicides sp.	
Globocassidulina subglobosa	
Alabamina sp.	

VESPA Sample DR11B Weakly indurated globigerina-ooze, bored with tube fossils.

NZ Fossil Record # SE25170/f004

GNS Science Laboratory # F49685

Preparation Disaggregated using water; washed >75 µm.

Fauna Well-preserved tropical microfauna comprised mostly of planktic foraminifera.

Adopted age Mixed age Early Miocene fauna from Zone N4a (22.96-21.12 Ma) and Zone N8 (16.28-15.97 Ma)?

Comment on age MC+HM. *Globigerinoides sicana, Paragloborotalia bella, Menardella archeomenardii,* and no *Praeorbulina* suggest Early Miocene (late Altonian), but *Fohsella kugleri* and the absence of *Globoconella*, especially *Globoconella miozea* and *Globoconella praescitula* indicate Early Miocene (late Waitakian to early Otaian?).

Paleodepth Mid-bathyal or deeper >600 m; *Karreriella bradyi*.

Planktics

Menardella archeomenardii	Early Miocene (N8) to Middle Miocene (N10)
Hirsutella cf. *scitula*	Middle Miocene (N9) to Recent
Paragloborotalia bella	NZ, Early Miocene (~7.5-15.7 Ma)
Fohsella kugleri	rare; Early Miocene Zone (N4a to N5)
Globorotaloides suteri	Middle Eocene to Early Miocene
Globoquadrina dehiscens	Late Oligocene (P22) to Late Miocene (N17b)
Globoquadrina baroemoenensis	Early Miocene (N5) to top late Miocene Zone (N18)
Dentoglobigerina altispira globsa?	Late Oligocene (P22) to Early Pliocene (N19)
Globigerinoides subquadratus?	Early Miocene (N4b) to Middle Miocene (N15)
Globigerinoides trilobus?	
Globigerinoides sicanus	Middle Miocene (N8 to N9)
Tenuitella cf. *clemenciae*	

Benthics

Karreriella bradyi	
Siphotextularia sp.	
Nodosaria sp.	
Stilostomella sp.	
Trifarina sp.?	
Bolivina sp.	
Globocassidulina globosa	
Globocassidulina cf. *globosa*	spined form
Ehrenbergina sp.	
Cassidulina carinata	
Discorbinella sp.?	
Astrononion sp.	
Oridorsalis umbonatus?	
Gyroidinoides zealandicus?	

Other material

Ostracods	
Echinoid spines	
Sponge spicules	
Radiolarians	diverse

VESPA Sample DR12A (1)	Soft, but indurated, light olive-grey mudstone.
NZ Fossil Record #	SE25170/f005
GNS Science Laboratory #	F49686

Preparation	Sub-sampled, crushed and treated in acetic acid; washed >63 µm.
Fauna	Barren.
Adopted age	No microfauna (NF).

VESPA Sample DR12A (2) Light-coloured, granule conglomerate layer.

NZ Fossil Record # SE25170/f005

GNS Science Laboratory # F49686

Preparation Sub-sampled, crushed and treated in acetic acid. Washed >63 µm.

Fauna No foraminifera; no faunal slide.

Adopted age Non-determinate (ND).

Other material
Echinoid spines

VESPA Sample DR12E	Soft mudstone.
NZ Fossil Record #	SE25170/f006
GNS Science Laboratory #	F49687

Preparation	Crushed and disaggregated in water; washed >63 µm.
Fauna	Rare, well-preserved microfauna, mostly benthics. The abundance and preservation of the microfauna suggests it is possibly associated with burrow infill rather than the host rock.
Adopted age	Non-determinate (ND); host rock possibly non-fossiliferous (NF).

Planktics

Turborotalita quinqueloba
Globigerinita glutinata
Globigerina sp.

Benthics

Nodosaria spp.	
Nodosaria longiscata	
Siphouvigerina canariensis?	
Oridorsalis umbonatus	bathyal
Nonionella sp.	
Gyroidinoides sp.	
Cibicides sp.	

Other material

Echinoid spines	rare

VESPA Sample DR13I	Laminated very fine grained muddy sandstone with disseminated and locally concentrated manganese. Not carbonaceous, as originally reported.
NZ Fossil Record #	SE25169/f005
GNS Science Laboratory #	F50189

Preparation	Crushed and disaggregated in water; washed >75 µm.
Fauna	Very sparse microfauna, possibly from surficial carbonate sediment rather than the muddy sandstone.
Adopted age	Non-determinate (ND).
Planktics *Globigerina* sp.	
Benthics *Dentalina* spp. *Oridorsalis tenera*	
Other material	
Radiolarians	few

VESPA Sample DR14H	Pale greenish-yellow calcareous mudstone; mantled by a manganese-rind. Ashy, no obvious forams.
NZ Fossil Record #	SE25169/f001
GNS Science Laboratory #	F49688

Preparation	Crushed and treated in acetic acid; washed >63 µm. Resampled and processed for radiolarians.
Fauna	A single fragment of a well-preserved nodosarid, which is unlikely to be from the mudstone.
Adopted age	Non-determinate (ND).
Benthics	
Nodosaria sp.	rare; from Recent/Sub-Recent surficial sediment?
Other material	
Radiolarians	few; (see radiolarian results)

VESPA Sample DR15Cii	Varicoloured, but overall yellowish-grey, poorly sorted polymict pebbly sandstone.
NZ Fossil Record #	SE25169/f002
GNS Science Laboratory #	F49689

Preparation	Crushed and disaggregated using water; washed >63 µm. Reprocessed, crushed and partially disaggregated in water; washed >75µm. Resampled and processed for radiolarians.
Fauna	Microfauna dominated by benthic foraminifera, but planktics are relatively common.
Adopted age	Early Miocene, Zone N5-N6 (20.93-18.7 Ma).
Comment on age	MC+HM. Mixed age fauna. *Subbotina angiporoides* and no *Globigerinatheka index* suggest Early Oligocene Zone P17 to Zone P20 (early Lwh 34.61-29.18 Ma); *Globoquadrina dehiscens*, *Globoconella incognita*, *Catapsydrax dissimilis*, *Zeaglobigerina woodi*, and possible *Zeaglobigerina connecta* indicate Early Miocene (late Po). The single specimen of *Subbotina angiporoides* and the absence of similar age taxa suggest the *Subbotina* has possibly been reworked from older sediment and is not diagnostic of the depositional age.
Paleodepth	Poorly constrained due to the mixed fauna. Bathyal >200 m, possibly lower bathyal or deeper >1000 m; *Cibicides* cf. *kullenbergi* and primitive deep-water agglutinates.

Planktics

Globoquadrina dehiscens	few; Late Oligocene (P22) to Late Miocene (N17b)
Globoconella incognita	Early Miocene (N5 to N7) 20.93-16.39 Ma
Subbotina angiporoides?	rare; late Middle Eocene to Early Oligocene (P20) >29.84 Ma
Catapsydrax dissimilis?	Oligocene (P20) to Early Miocene (N6), >17.54 Ma
Zeaglobigerina woodi	
Globigerina spp.	
Sphaeroidinellopsis sp.?	

Benthics

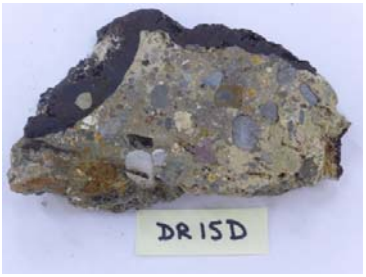
Saccamina sp.	
Ammodiscus sp.	
Bolivinopsis sp.	bathyal
Haplophragoides sp.?	
Martinottiella sp.?	
Sigmomorphina sp.	
Dentalina spp.	
Stilostomella sp.	
Chrysalogonium verticale?	
Lagena spp.	
Amphicoryna sp.	
Bulimina forticostata?	
Euuvigerina sp.	
Discorbinella sp.?	
Gyroidinoides sp.	
Gyroidinoides zealandicus	
Gyroidina sp.	
Anomalinoides sp.	
Bueningia creeki?	
Melonis sp.	
Pullenia bulloides	uppermost bathyal marker >200 m
Siphonia australis	

Cibicides molestus	
Cibicides cf. *kullenbergi*	lower bathyal marker >1000 m?
Cibicides spp.	
Planulina renzi	bathyal
Oridorsalis umbonatus	bathyal
Oridorsalis sp.	
Globocassidulina subglobosa	
Globocassidulina sp.	

Other material

Radiolarians	common; (see radiolarian results)
Fish teeth	few
Echinoid spines	rare

VESPA Sample DR15D	Pale olive-grey conglomerate; mantled by a thick manganese-rind.
NZ Fossil Record #	SE25169/f003
GNS Science Laboratory #	F49690



Preparation	Sub-sampled, crushed and treated in acetic acid; washed >63 µm. Resampled and processed for radiolarians.
Fauna	Very sparse, poorly preserved foraminifera.
Adopted age	Non-determinate (ND).
Planktics	
Globigerina sp.	
Benthics	
Gyroidina sp.?	internal cast
Other material	
Radiolarians	relatively common; (see radiolarian results)

VESPA Sample DR15I	Hard, indurated, pale olive-grey silty sandstone. Bedded and laminated on a mm-cm scale.
NZ Fossil Record #	SE25169/f004
GNS Science Laboratory #	F49691

Preparation	Crushed and disaggregated in water; washed >63 µm. Resampled and processed for radiolarians.
Fauna	Very sparse, variably preserved microfauna.
Adopted age	Non-determinate (ND).
Comment on age	MC. I suspect that the well-preserved foraminifera are from surficial sediment and that the silty sandstone is barren.
Planktics	
Neogloboquadrina incompta?	rare
Globigerinita glutinata	
Globigerina sp.	
Benthics	
Nodosaria longiscata	relatively common
Other material	
Radiolarians	few; (see radiolarian results)

VESPA Sample DR16G Soft yellowish-grey ashy siltstone (pumiceous?).

NZ Fossil Record # SE25170/f004

GNS Science Laboratory # F49692

Preparation Crushed and disaggregated in water; washed >63 µm.

Fauna Very sparse moderately well-preserved microfauna, mostly planktic foraminifera.

Adopted age Non-determinate (ND).

Paleodepth Bathyal >200 m; elongate nodosarids.

Planktics
Globoquadrina sp.?
Catapsydrax sp.?
Globigerina spp.
Turborotalita angustiumbilicata?
Globigerinita glutinata

Benthics
Gyroidinoides sp.
Dentalina sp.
Pullenia sp.
Osangularia bengalensis
Cibicides spp.

Other material
Echinoid spines relatively common

VESPA Sample DR18C	Moderately indurated white chalky limestone; from a cavity (crack) in basalt breccia.
NZ Fossil Record #	SE26170/f001
GNS Science Laboratory #	F49693

Preparation	Crushed and partially disaggregated in water; washed >75 µm. Resampled.
Fauna	Well-preserved tropical/subtropical microfauna, mostly planktic foraminifera. Two faunal slides.
Adopted age	Early Miocene, Zone N4a to N7 (23.03-18.7 Ma).
Comment on age	HM. *Globoquadrina dehiscens, Zeaglobigerina woodi, Zeaglobigerina connecta, Paragloborotalia semivera* and no *Zeaglobigerina euapertura* or globoconellids suggest Early Miocene (late Waitakian to mid Otaian).
Paleodepth	Mid bathyal or deeper >600 m; *Osangularia culter, Gyroidinoides neosoldanii* and *Euuvigerina peregrina.*

Planktics

Globoquadrina venezuelana	Middle Eocene to Early Pliocene
Globoquadrina dehiscens	Late Oligocene (P22) to Late Miocene (N17b)
Catapsydrax dissimilis	Late Eocene (P13) to Early Miocene (N6), >17.54 Ma
Globigerinoides primordius	
Globorotaloides suteri	
Zeaglobigerina woodi	Late Oligocene (P22) to Early Pleistocene (N22)
Zeaglobigerina connecta	
Paragloborotalia semivera	
Neogloboquadrina nana	Oligocene to Early Miocene (N7), >17.26 Ma

Benthics

Stilostomella sp.	
Amphicoryna sp.	
Rectuvigerina pohana?	
Trifarina bradyi	
Euuvigerina peregrina?	bathyal
Discorbinella sp.?	
Gyroidinoides sp.	
Gyroidinoides neosoldanii	deep bathyal
Gyroidinoides zealandicus	
Melonis doreeni	bathyal
Pullenia bulloides	uppermost bathyal marker >200 m
Globocassidulina arata	NZ, Early to Late Miocene (Otaian to Tongaporutuan)
Globocassidulina subglobosa	
Cassidulina neocarinata	
Frondicularia sp.?	
Cibicides spp.	
Planulina renzi?	bathyal
Planulina sp.	
Alabamina sp.?	
Oridorsalis tenera?	
Osangularia bengalensis	bathyal
Osangularia culter	bathyal

Other material

Ostracods	few

VESPA Sample DR19Jii (1)	Yellowish-brown coloured sediment; on surface of pale yellowish-green mudstone.
NZ Fossil Record #	SE26170/f002
GNS Science Laboratory #	F49694

Preparation	Sub-sampled and disaggregated in water; washed >63 µm.
Fauna	Very sparse, poorly preserved microfauna; all planktic foraminifera.
Adopted age	Oligocene to Early Miocene, Zone P18 to N6 (33.99-17.54 Ma)?
Comment on age	MC. Poorly constrained. Based on tentative identifications of *Catapsydrax dissimilis* and *Paragloborotalia semivera.*
Paleodepth	
Planktics	
Globigerina spp.	
Catapsydrax dissimilis?	Late Eocene (P13) to Early Miocene (N6), >17.54 Ma
Paragloborotalia semivera?	Oligocene to Early Miocene (N7), >17.26 Ma

VESPA Sample DR19Jii (2)	Pale yellowish-green mudstone.
NZ Fossil Record #	SE26170/f002
GNS Science Laboratory #	F49694

Preparation	Sub-sampled, crushed and disaggregated in water; washed >63 µm. Resampled.
Fauna	Very poorly preserved, almost entirely planktic fauna (heavily recrystallized tests).
Adopted age	Early Miocene, Zone N4a to Zone N7 (23.03-18.7 Ma)?
Comment on age	HM. *Catapsydrax dissimilis, Globorotaloides testarugosa, Zeaglobigerina woodi, Zeaglobigerina connecta* and possible *Globoquadrina dehiscens* suggest Early Miocene (late Waitakian to Otaian)?
Paleodepth	Lower bathyal or deeper >1000 m; *Cibicides kullenbergi* and *Euuvigerina peregrina*?

Planktics

Catapsydrax dissimilis	rare; Late Eocene (P13) to Early Miocene (N6)
Globorotaloides testarugosa	
Zeaglobigerina woodi	
Zeaglobigerina connecta	
Globoquadrina dehiscens?	

Benthics

Bathysiphon sp.?	
Sigmoilopsis schlumbergeri?	mid bathyal marker >600 m?
Euuvigerina peregrina?	bathyal
Gyroidina sp.	
Cibicides kullenbergi?	lower bathyal marker >1000 m?
Cibicides sp.	

Other material

Echinoid spines	few
Fish teeth	rare

VESPA Sample DR19Jiii	Pale grey calcareous mudstone.
NZ Fossil Record #	SE26170/f003
GNS Science Laboratory #	F49695

Preparation	Crushed and treated in acetic acid; washed >63 µm. Resampled, crushed and disaggregated in water; washed >75 µm.
Fauna	Sparse, poorly preserved foraminifera.
Adopted age	Late Oligocene, Zone P22 (28.09-23.03 Ma)?
Comment on age	HM. *Catapsydrax dissimilis, Neogloboquadrina nana, Globorotaloides testarugosus,* and no typical *Globoquadrina dehiscens, Zeaglobigerina euapertura*, *Subbotina* or *Globigerinatheka* index suggests Late Oligocene (late Whaingaroan to Duntroonian), but if the *Globoquadrina* cf. *dehiscens* are OK then maybe restricted to Waitakian.
Paleodepth	Bathyal >200 m; elongate nodosarids.

Planktics

Catapsydrax dissimilis	Late Eocene (P13) to Early Miocene (N6), >17.54 Ma
Globorotaloides testarugosus	NZ, Oligocene (Whaingaroan to early Waitakian)
Globoquadrina cf. *dehiscens*	
Zeaglobigerina sp.	
Globigerina sp	
Paragloborotalia semivera?	Oligocene to Early Miocene (N7), >17.26 Ma
Neogloboquadrina nana	

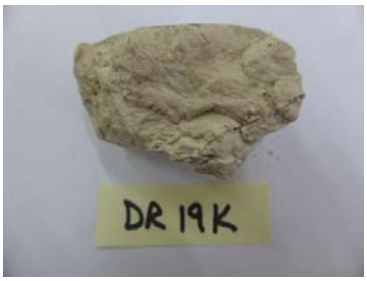
Benthics

Dentalina sp.?	
Gyroidinoides sp.	
Bueningia creeki	well-preserved; contaminant?

Other material

Echinoid spines	common
Fish teeth	few

VESPA Sample DR19K	Soft, pinkish-grey chalky limestone; probable cavity fill in DR19H breccia boulder.
NZ Fossil Record #	SE26170/f004
GNS Science Laboratory #	F49696



Preparation	Crushed and disaggregated in water; washed >75 µm. Resampled.
Fauna	Moderately well-preserved microfauna comprised mostly of planktic foraminifera.
Adopted age	Mid to Late Oligocene, Zone P20 to P22 (29.84-23.03 Ma).
Comment on age	MC+HM; *Zeaglobigerina euapertura,* no *Subbotina, Zeaglobigerina woodi,* or *Zeaglobigerina connecta;* and no *Globoquadrina dehiscens.*
Paleodepth	Mid bathyal or deeper >600 m; *Eggerella bradyi* and *Pleurostomella alternans.*

Planktics

Zeaglobigerina euapertura	Oligocene (P20 to P22) 29.84-23.03 Ma
Catapsydrax dissimilis	Late Eocene (P13) to Early Miocene (N6)
Globorotaloides testarugosa?	NZ, Whaingaroan to early Waitakian
Globorotaloides suteri	
Neogloboquadrina cf. *nana*	
Globoquadrina sp.	(early form)
Globoquadrina tripartita	NZ, mid Oligocene to Early Miocene (27.3-17.26 Ma)
Globigerina bulloides	

Benthics

Eggerella bradyi?	mid bathyal marker >600 m?
Dorothia minima?	
Dentalina sp.	
Pyrgo sp.	
Lagena sp.	
Fissurina sp.	
Bulimina miolaevis?	bathyal
Euuvigerina miozea?	
Cibicides spp.	
Gyroidinoides sp.	
Melonis sp.	
Cassidulina cf. *laevigata*	
Cassidulina pseudocrassa?	
Globocassidulina sp.	
Bueningia creeki	
Pullenia sp.	
Pleurostomella alternans	bathyal
Oridorsalis sp.	
Laticarinina pauperata	

Other material

Fish teeth	few
Ostracods	rare
Radiolarians	few

VESPA Sample DR21G Moderately sorted hyaloclastite breccia; mantled and penetrated by manganese-rind.

NZ Fossil Record # SE26171/f002

GNS Science Laboratory # F50190

Preparation Sub-sampled, crushed and treated in acetic acid; washed >63 µm.

Fauna Sparse moderately well-preserved microfauna – possibly associated with the manganese crust rather than the host rock.

Adopted age Late Oligocene, Zone P22 (25.2-23.03 Ma).

Comment on age HM. *Globoquadrina dehiscens, Zeaglobigerina euapertura, Zeaglobigerina woodi,* and *Catapsydrax dissimilis* suggest Late Oligocene (early Waitakian).

Paleodepth Bathyal >200 m, possibly lower bathyal >1000 m; *Cibicides kullenbergi?*

Planktics

Catapsydrax dissimilis	Oligocene (P20) to Early Miocene (N6), 30.28-17.59 Ma
Globoquadrina dehiscens	Late Oligocene (P22) to Late Miocene (N17b), 25.2-5.92 Ma
Globoquadrina tripartita?	NZ, mid Oligocene to Early Miocene (27.3-17.26 Ma)
Globorotaloides testarugosus?	
Globorotaloides suteri?	
Zeaglobigerina euapertura	Oligocene (P20 to P22), 29.84-23.03 Ma
Zeaglobigerina woodi	NZ, Early Miocene to Early Pleistocene (Lw to Wn)
Paragloborotalia semivera?	rare; Oligocene to Early Miocene (N7), >17.26 Ma
Fohsella cf. *kugleri*	rare
Globigerina spp.	
Zeaglobigerina sp.	
Globigerinita glutinata	

Benthics

Ammodiscus sp.	
Nodosaria cf. *raphanus*	
Dentalina sp.	
Fissurina sp.	
Lagena sp.	
Bulimina cf. *miolaevis*	bathyal
Gyroidinoides sp.	
Astrononion sp.	
Ammonia sp.?	
Cibicides cf. *subhaidingeri*	bathyal
Cibicides kullenbergi?	lower bathyal marker >1000 m?
Oridorsalis tenera?	
Globocassidulina subglobosa	

Other material

Fish teeth	common

VESPA Sample DR22B (1) Pillow basalt; with soft yellowish-white carbonate infill and a manganese crust.

NZ Fossil Record # SE26171/f001

GNS Science Laboratory # F49697

Preparation Sub-sampled, crushed and treated in acetic acid; washed >63 µm.
Reprocessed, crushed and partially disaggregated in water; washed >75µm.

Fauna Very sparse, poorly preserved microfauna, mostly planktic foraminifera. Most likely to be from the surficial carbonate sediment.

Adopted age Non-determinate; see DR22B (2).

Comment on age Poorly constrained; based on possible *Globoconella miotumida?*

Planktics
Globoconella cf. *miotumida?*
Dentoglobigerina sp.?
Hirsutella sp.?
Zeaglobigerina sp.
Globigerina sp.
Globigerinoides quadrilobatus?
Globigerinoides obliquus?

Benthics
Dentalina sp.
Lagena sp.
Gyroidinoides sp.

VESPA Sample DR22B (2) Relatively soft, yellowish-white, surficial carbonate sediment.

NZ Fossil Record # SE26171/f001

GNS Science Laboratory # F49697

Preparation Sub-sampled and disaggregated in water; washed >63 µm.

Fauna Well-preserved tropical/subtropical microfauna comprised mostly of planktic foraminifera.

Adopted age Late Pliocene, Zone N21 (3.35-2.58 Ma).

Comment on age Based on *Truncorotalia tosaensis, Menardella limbata,* and *Dentoglobigerina altispira,* and no *Truncorotalia truncatulinoides; Zeaglobigerina nepenthes* suggests older (>4.37 Ma). Possibly a mixed age fauna.

Paleodepth Lower bathyal or deeper >1000 m; *Hopkinsina mioindex* and *Planulina wuellerstorfi.*

Planktics

Globoconella inflata	Pliocene (N19-N20) to Recent
Globoconella triangula	NZ, Early Pliocene to Early Pleistocene
Truncorotalia tosaensis	dextral population; Late Pliocene (N21) to Pleistocene (N22)
Globorotalia tumida	Late Miocene (N18) to Recent
Menardella limbata	Middle Miocene (N14) to Late Pliocene (N21)
Globoconella cf. *miotumida*	
Truncorotalia crassaformis	rare (sin); NZ, Late Miocene to Pleistocene (5.45-2.45 Ma)
Truncorotalia ronda	rare (dextral)
Hirsutella praehirsuta	rare
Hirsutella scitula	rare
Dentoglobigerina altispira	Early Miocene (N4B) to Late Pliocene (N21)
Globoquadrina cf. *dehiscens*	
Neogloboquadrina humerosa	Late Miocene (N18) to Early Pleistocene (N22)
Neogloboquadrina incompta	
Globigerinoides ruber	
Globigerinoides obliquus	
Globigerinoides conglobatus?	
Globigerinoides sacculifer	
Globigerinoides quadrilobatus	
Globigerinoides trilobus	
Sphaeroidinellopsis kochi?	
Sphaeroidinellopsis seminulina	
Sphaeroidinella dehiscens?	
Orbulina universa	
Globigerinopsis obesa	
Globigerina bulloides	
Globigerina falconensis?	
Globigerina sp.	
Globigerinoides bollii	
Zeaglobigerina woodi	Late Oligocene (P22) to Early Pleistocene (N22)
Zeaglobigerina nepenthes	Middle Miocene (N14) to Early Pliocene (N19)

Benthics

Eggerella bradyi	mid bathyal marker >600 m
Lenticulina sp.	
Dentalina spp.	
Stilostomella sp.	
Nodosaria sp.	
Euuvigerina peregrina	bathyal
Hopkinsina mioindex	lower bathyal marker >1000 m

Gyroidina orbicularis?	
Anomalinoides sp.	
Anomalina cf. *aotea*	bathyal
Pullenia sp.	
Sphaeroidina bulloides	
Pleurostomella alternans	bathyal
Planulina wuellerstorfi	deep bathyal
Cibicides spp.	
Favocassidulina australis	
Globocassidulina subglobosa	
Gavelinopsis sp.?	

Other material

Ostracods	rare
Fish teeth	rare

VESPA Sample DR23A (1)	Hard, light olive-grey, mottled and weakly bedded sandy siltstone. Non-calcareous.
NZ Fossil Record #	SE27171/f001
GNS Science Laboratory #	F49698

Preparation	Crushed and treated in acetic acid; washed >63 µm. Reprocessed, crushed and partially disaggregated in water; washed >75 µm. A sub-sample was also reprocessed and treated in HF-acid for siliceous microfossils; washed >63 µm.
Fauna	No foraminifera.
Adopted age	Non-determinate (ND).
Other material	
Radiolarians	rare; (see radiolarian results)
Fish teeth	rare

VESPA Sample DR23A (2)	Light coloured burrow-infill; in light olive-grey siltstone.
NZ Fossil Record #	SE27171/f001
GNS Science Laboratory #	F49698

Preparation	Crushed and disaggregated in water; washed >63 µm.
Fauna	No foraminifera, except for a poorly preserved broken specimen of *Globigerina*.
Adopted age	Non-determinate (ND).
Planktics *Globigerina* sp.	
Other material Radiolarians	few

VESPA Sample DR23D	Hard, yellowish-grey, slightly calcareous siltstone.
NZ Fossil Record #	SE27171/f008
GNS Science Laboratory #	F49731

Preparation	Crushed and treated in acetic acid; washed >63 µm. Resampled and processed for radiolarians.
Fauna	No foraminifera. No faunal slide.
Adopted age	Non-determinate (ND).
Other material	
Radiolarians	rare; (see radiolarian results)

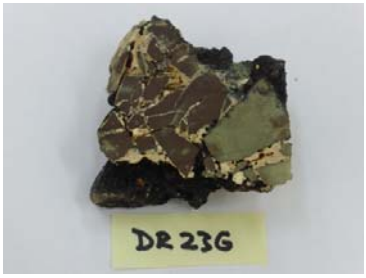
VESPA Sample DR23F (1)	Hard, cemented, pale green, monomict cataclastic siltstone breccia. Non-calcareous.
NZ Fossil Record #	SE27171/f009
GNS Science Laboratory #	F49732

Preparation	Sub-sampled, crushed and treated in acetic acid; washed >63 µm. Reprocessed, crushed and partially disaggregated in water; washed >75 µm.
Fauna	Barren. No faunal slide.
Adopted age	Non-fossiliferous (NF).

VESPA Sample DR23F (2)	Bulk sample including hard, cemented, pale green, monomict cataclastic siltstone breccia and pale yellowish-orange cement. Non-calcareous. Bulk sample including host rock + lighter coloured fracture-infill
NZ Fossil Record #	SE27171/f009
GNS Science Laboratory #	F49732

Preparation	Sub-sampled and treated in acetic acid; washed >63 µm.
Fauna	Extremely rare agglutinated foraminifera.
Adopted age	Non-determinate (ND).
Benthics *Bathysiphon* spp.	
Other material Radiolarians?	rare

VESPA Sample DR23G (1)	Micritic, non-calcareous cement, like DR23F; associated with polymict red and green siltstone breccia, see DR23G (2). Light coloured sediment infill
NZ Fossil Record #	SE27171/f002
GNS Science Laboratory #	F49699



Preparation	Sub-sampled and treated in acetic acid; washed >63 µm.
Fauna	Well-preserved microfauna, comprised mostly of planktic foraminifera.
Adopted age	Pleistocene to Holocene, Zone N22 (<2.58 Ma); possibly Early Pleistocene (2.58-1.81 Ma).
Comment on age	Constrained by *Truncorotalia truncatulinoides;* possibly Early Pleistocene based on the co-occurrence with *Neogloboquadrina humerosa.*
Paleodepth	Mid bathyal >600 m or deeper; *Euuvigerina peregrina* and *Oridorsalis umbonatus.*

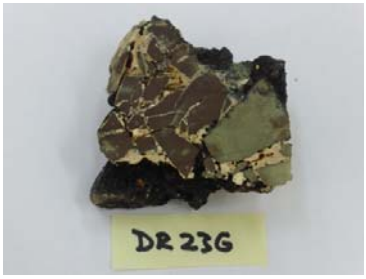
Planktics

Globoconella inflata	Pliocene (N19-N20) to Recent
Pulleniatina obliquiloculata	Early Pliocene (N19) to Recent
Pulleniatina cf. *praecursor*	
Truncorotalia truncatulinoides	dextral population; Early Pleistocene (N22) to Recent
Truncorotalia crassacarina	NZ, Early Pleistocene to Recent (<2.34 Ma)
Globorotalia tumida	Late Miocene (N18) to Recent
Truncorotalia aff. *crassula*	few
Truncorotalia crassula	rare; NZ, Early Pleistocene to Recent (<2.4 Ma)
Hirsutella scitula	
Dentoglobigerina sp.?	
Neogloboquadrina humerosa	Late Miocene (N18) to Early Pleistocene (N22)
Neogloboquadrina incompta	
Globigerinoides conglobatus	
Globigerinoides trilobus	
Globigerinoides quadrilobatus	
Globigerinoides sacculifer	
Globigerinoides ruber	
Globigerinoides pyramidalis	
Sphaeroidinella dehiscens	Early Pliocene (N19) to Recent
Orbulina universa	
Globigerinella aequilateralis	
Globigerina falconensis	
Globigerina sp.	
Turborotalita sp.	

Benthics

Euuvigerina peregrina	bathyal
Cibicides sp.	
Favocassidulina australis	
Laticarinina pauperata	
Oridorsalis umbonatus	bathyal

VESPA Sample DR23G (2)	Polymict red and green siltstone breccia; with micritic, non-calcareous cement, see DR23G (1).
NZ Fossil Record #	SE27171/f002
GNS Science Laboratory #	F49699



Preparation	Sub-sampled and treated in acetic acid; washed >63 µm. Reprocessed, crushed and partially disaggregated in water; washed >75 µm.
Fauna	Indistinguishable from the microfauna in DR23G (1).
Adopted age	Possibly non-fossiliferous (NF) – see comment on age.
Comment on age	MC. Based on the preservation of foraminifera, the microfauna as a whole is possibly associated with the lighter coloured infill rather than the host rock.

Planktics

Globoconella inflata	Pliocene (N19-N20) to Recent
Pulleniatina obliquiloculata	Early Pliocene (N19) to Recent
Truncorotalia truncatulinoides	dextral population; Early Pleistocene (N22) to Recent
Truncorotalia crassacarina	NZ, Early Pleistocene to Recent (<2.34 Ma)
Globorotalia tumida?	Late Miocene (N18) to Recent
Neogloboquadrina sp.	
Globigerinoides conglobatus	
Globigerinoides trilobus	
Globigerinoides quadrilobatus	
Globigerinoides sacculifer	
Globigerinoides ruber	
Globigerinoides pyramidalis	
Sphaeroidinella dehiscens	Early Pliocene (N19) to Recent
Orbulina universa	
Globigerinella aequilateralis	
Globigerina falconensis	
Globigerina sp.	
Globigerinita glutinata	

Benthics

Pyrgo sp.	
Fissurina sp.	
Sphaeroidina bulloides	
Pleurostomella cf. *alternans*	bathyal
Melonis doreeni	bathyal
Gyroidina sp.	
Cassidulina neocarinata	
Favocassidulina australis	
Globocassidulina subglobosa	
Oridorsalis umbonatus	bathyal

Other material

Fish teeth	rare

VESPA Sample DR24Ai Light-coloured sediment infill

NZ Fossil Record # SE27171/f003

GNS Science Laboratory # F49700

Preparation Sub-sampled and treated in acetic acid; washed >63 µm. Reprocessed, crushed and partially disaggregated in water; washed >75 µm. Resampled and processed for radiolarians.

Fauna Very sparse poorly preserved microfauna comprised of planktic foraminifera.

Adopted age Non-determinate (ND).

Planktics
Globigerina sp.
Globigerinita glutinata?

Other material
Radiolarians few; (see radiolarian results)

VESPA Sample DR26Gi (1) Hard, pale yellowish-orange micritic cement; associated with clast-supported, poorly sorted epiclastic polymict volcanic breccia.

NZ Fossil Record # SE27171/f004

GNS Science Laboratory # F49701

Preparation Sub-sampled, crushed and treated in acetic acid; washed >63 µm.
Reprocessed, crushed and partially disaggregated in water; washed >75 µm.

Fauna Very poorly preserved microfauna comprised mostly of planktic foraminifera.

Adopted age Early Miocene, possibly Zone N5 to N7 (21.12-20.93 Ma).

Comment on age MC. Poorly constrained. Based on tentatively identified specimens of *Globigerinoides altiapertura* and *Fohsella kugleri,* and no globoconellids. Poorly preserved specimens of *Praeorbulina/Orbulina* suggest younger. Possibly a mixed age fauna.

Paleodepth Poorly constrained. Possibly shelf <200 m?

Planktics

Globoquadrina dehiscens	Late Oligocene (P22) to Late Miocene (N17b)
Fohsella kugleri?	poorly preserved specimen
Globorotaloides suteri	Middle Eocene to Early Miocene
Globigerinoides altiapertura?	Early Miocene (N5 to N7)
Globigerinoides trilobus	
Praeorbulina/Orbulina	poorly preserved population, possibly *Or. universa?*
Globigerina bulloides	
Globigerina sp.	
Zeaglobigerina sp.	
Globigerinita glutinata?	

Benthics

Amphicoryna sp.?
Pileolina sp.?

VESPA Sample DR26Gi (2)	Relatively soft surficial carbonate sediment; on the surface of a hard clast-supported, poorly sorted epiclastic polymict volcanic breccia, with a pale yellowish-orange micritic cement.
NZ Fossil Record #	SE27171/f004
GNS Science Laboratory #	F49701

Preparation	Sub-sampled and treated in acetic acid; washed >63 µm.
Fauna	Well-preserved tropical/subtropical microfauna, comprised mostly of planktic foraminifera.
Adopted age	Pleistocene to Holocene, Zone N22 (<2.58 Ma); possibly Early Pleistocene (2.58-1.81 Ma).
Comment on age	MC. Constrained by *Truncorotalia truncatulinoides;* possibly Early Pleistocene based on the occurrence with *Neogloboquadrina humerosa.*
Paleodepth	Poorly constrained. Possibly lower bathyal >1000 m; *Planulina wuellerstorfi*.

Planktics

Globoconella inflata	Pliocene (N19-N20) to Recent
Globoconella cf. *triangula*	
Pulleniatina obliquiloculata	Early Pliocene (N19) to Recent
Truncorotalia truncatulinoides	dextral population; Early Pleistocene (N22) to Recent
Menardella limbata?	rare; Middle Miocene (N14) to Late Pliocene (N21)
Truncorotalia crassacarina	NZ, Early Pleistocene to Recent (<2.34 Ma)
Truncorotalia cf. *crassula*	
Truncorotalia crassula	NZ, early Pleistocene to Recent (<2.40 Ma)
Neoacarinina blowi	
Neogloboquadrina humerosa	Late Miocene (N18) to Early Pleistocene (N22)
Neogloboquadrina incompta	
Globigerinoides conglobatus	
Globigerinoides bulloideus?	
Globigerinoides ruber	
Globigerinoides pyramidalis	
Globigerinoides quadrilobatus	
Globigerinoides sacculifer	
Globigerinoides trilobus?	
Sphaeroidinellopsis seminulina	
Orbulina universa	
Globigerinella aequilateralis	
Globigerina falconensis	
Globigerina bulloides	
Globigerina sp.	
Globigerinita glutinata	

Benthics

Pullenia sp.	
Gyroidina sp.	
Planulina wuellerstorfi	deep bathyal
Globocassidulina subglobosa	
Favocassidulina australis	

Other material

Fish teeth	rare

VESPA Sample DR26Gii Hard, pale yellowish-orange micritic cement; associated with clast-supported, poorly sorted epiclastic polymict volcanic breccia.

NZ Fossil Record # SE27171/f005

GNS Science Laboratory # F49702

Preparation Crushed and treated in acetic acid; washed >63 µm. Resampled, crushed and disaggregated in water; washed >75 µm.

Fauna Mixed age microfauna comprised of poor to moderately well-preserved foraminifera and less common, well-preserved foraminifera that are possibly associated with surficial sediment. Two faunal slides.

Adopted age Late Oligocene Zone P22 (26.93-23.03 Ma).

Comment on age MC+HM. Mixed age fauna. *Globoquadrina dehiscens*, *Catapsydrax dissimilis, Globoquadrina tripartita,* and *Zeaglobigerina euapertura* suggest Late Oligocene (early Waitakian); and *Truncorotalia truncatulinoides* and *Truncorotalia crassula* suggest Pleistocene to Holocene.

Paleodepth Bathyal >200 m; elongate nodosarids.

Planktics

Globoquadrina dehiscens	Late Oligocene (P22) to Late Miocene (N17b)
Globoquadrina tripartita	NZ, mid Oligocene to Early Miocene (27.3-17.26 Ma)
Catapsydrax dissimilis	Oligocene to Early Miocene Zone (N6)
Neogloboquadrina nana	
Zeaglobigerina euapertura	
Globigerina praebulloides	
Globigerinita glutinata	

Benthics

Dentalina sp.	
Amphicoryna sp.	
Cibicides molestus	
Cibicides sp.	
Gyroidinoides sp.	
Globocassidulina subglobosa	
Globocassidulina arata	NZ, Miocene
Pleurostomella sp.?	

Pleistocene fauna

Globoconella triangula	NZ, Pliocene to Early Pleistocene
Truncorotalia crassula	NZ, Early Pleistocene to Recent (<2.40 Ma)
Truncorotalia truncatulinoides	Early Pleistocene (N22) to Recent
Neogloboquadrina incompta	
Globigerinoides ruber	
Globigerina falconensis	
Orbulina sp.	juvenile
Pullenia bulloides	
Globocassidulina subglobosa	

VESPA Sample DR29C (1)	Fossiliferous limestone matrix; associated with a volcanic conglomerate.
NZ Fossil Record #	SE27172/f001
GNS Science Laboratory #	F49703

Preparation	Sub-sampled, crushed and treated in acetic acid; washed >63 µm. Reprocessed, crushed and partially disaggregated in water; washed >75 µm.
Fauna	Sparse, very poorly preserved microfauna comprised mostly of benthic foraminifera.
Adopted age	Poorly constrained. Possibly Late Oligocene to Miocene.
Comment on age	MC+HM. Constrained by possible specimens of the benthic foraminifera *Cribrorotalia ornatissima.*
Paleodepth	Bathyal >200 m; elongate nodosarids and shelfal material that has possibly been transported downslope?

Planktics

Globigerina spp.
Globigerina praebulloides

Benthics

Cyclogyra sp.?	
Pyrgo sp.	
Quinqueloculina sp.	
Dentalina spp.	
Stilostomella sp.	
Lenticulina sp.	
Pyrgo sp.	
Fissurina sp.	
Asterigerina sp.	shallow shelf
Cribrorotalia ornatissima?	NZ, Late Oligocene to Late Miocene
Melonis barleenum?	uppermost bathyal marker >200 m?
Astrononion sp.	
Sphaeroidina bulloides	
Globocassidulina subglobosa	
Cibicides spp.	

Other material

Echinoid spines	common
Bryozoan fragments	few
Micro-gastropods	few
Fish teeth	rare

VESPA Sample DR29C (2)	Relatively soft surficial sediment; on the surface of a volcanic conglomerate with a fossiliferous limestone matrix.
NZ Fossil Record #	SE27172/f001
GNS Science Laboratory #	F49703

Preparation	Sub-sampled and treated in acetic acid; washed >63 µm.
Fauna	Sparse, poorly preserved foraminifera.
Adopted age	Poorly constrained. Pleistocene to Holocene (<2.58 Ma); possibly Early Pleistocene (2.58-1.81 Ma).
Comment on age	MC. Constrained by *Truncorotalia truncatulinoides;* possibly Early Pleistocene based on the co-occurrence with *Neogloboquadrina humerosa.*
Paleodepth	Very poorly constrained. Bathyal >200 m; elongate nodosarids and shelfal material that has possibly been transported downslope.

Planktics

Globigerina spp.	Late Miocene (N18) to Early Pleistocene (N22)
Neogloboquadrina humerosa?	
Neogloboquadrina pachyderma?	
Globigerinoides quadrilobatus	
Truncorotalia truncatulinoides	Early Pleistocene (N22) to Recent

Benthics

Bathysiphon sp.	
Pyrgo sp.	
Lenticulina sp.	
Sigmoidella sp.	
Vaginulina sp.	
Lagena sp.	
Patellinella inconspicua	shallow shelf
Cibicides sp.	
Cassidulina neocarinata	

Other material

Echinoid spines	common
Bryozoan fragments	rare
Micro-gastropods	few

VESPA Sample DR31Bi Soft, yellowish-grey calcareous mudstone. Bored.

NZ Fossil Record # SE27172/f002

GNS Science Laboratory # F49704

Preparation Crushed and disaggregated in water; washed >63 µm. Resampled.

Fauna Well-preserved microfauna, comprised mostly of planktic foraminifera.

Adopted age Early Miocene, Zone N4a to N4b (22.96-21.12 Ma).

Comment on age MC+HM. Constrained by *Fohsella kugleri;* Early Miocene age supported by *Zeaglobigerina connecta,* but possible *Zeaglobigerina euapertura* suggests Late Oligocene. Possibly a mixed early Waitakian and late Waitakian to Otaian fauna.

Paleodepth Lower bathyal or deeper >1000 m; *Cibicides kullenbergi.*

Planktics

Catapsydrax dissimilis	Late Eocene (P13) to Early Miocene (N6), >17.54 Ma
Fohsella kugleri	Early Miocene (N4a to N4b), 22.96-21.12 Ma
Paragloborotalia semivera	Oligocene to Early Miocene (N7), >17.26 Ma
Globoquadrina tripartita?	NZ, mid Oligocene to Early Miocene (27.3-17.26 Ma)
Globoquadrina dehiscens	Late Oligocene (P22) to Late Miocene (N17b), 25.2-5.92 Ma
Globorotaloides testarugosa	
Zeaglobigerina euapertura?	Oligocene (P20 to P22) 29.84-23.03 Ma
Zeaglobigerina connecta	Early Miocene
Zeaglobigerina woodi	
Globigerina praebulloides	
Globigerina spp.	
Globigerinoides sp.	
Globigerinita glutinata	

Benthics

Vulvulina pennatula?	deep mid bathyal marker >800 m?
Eggerella bradyi?	mid bathyal marker >600 m?
Siphotextularia spp.	
Dentalina spp.	
Chrysalogonium verticale	
Lenticulina sp.	
Lagena sp.	
Amphicoryna sp.	
Gyroidina sp.	
Gyroidinoides sp.	
Anomalinoides sp.	
Melonis sp.	
Sphaeroidina bulloides	
Pullenia sp.	
Astrononion sp.	
Pleurostomella alternans?	bathyal
Pleurostomella sp.	bathyal
Cibicides kullenbergi	lower bathyal marker >1000 m
Cibicides spp.	
Laticarinina pauperata	
Oridorsalis umbonifera	bathyal
Globocassidulina subglobosa	
Cassidulina sp.	
Bueningia creeki	
Alabamina sp.	

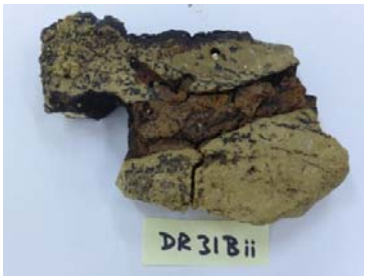
Other material

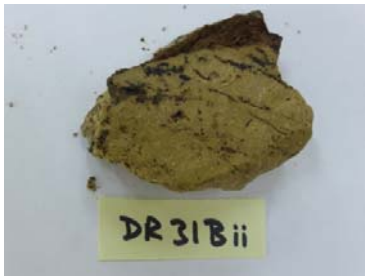
Fish teeth	few
Ostracods	rare

VESPA Sample DR31Bii Soft, dusky yellow calcareous mudstone. Bored and penetrated by manganese oxides

NZ Fossil Record # SE27172/f003

GNS Science Laboratory # F49705





Preparation Crushed and treated in acetic acid; washed >63 µm.

Fauna Extremely sparse foraminifera, and some well-preserved fossil material that is possibly Pleistocene to Holocene.

Adopted age Non-determinate (ND).

Planktics
Globigerina sp.

Benthics
Ammodiscus sp.

Other material

Fish teeth	few
Echinoid spines	few
Radiolarians	rare

VESPA Sample DR31C Soft, pinkish-grey, homogeneous calcareous mudstone.

NZ Fossil Record # SE27172/f004

GNS Science Laboratory # F49706

Preparation Crushed and disaggregated in water; washed >75 µm.

Fauna Well-preserved tropical/subtropical microfauna with good planktic and benthic assemblages.

Adopted age Early Miocene, Zone N4a to N4b (22.96-21.12 Ma).

Comment on age MC+HM. Constrained by *Fohsella kugleri;* Early Miocene age supported by *Zeaglobigerina woodi* and *Zeaglobigerina connecta*, but *Zeaglobigerina euapertura* suggests Late Oligocene. Possibly a mixed early Waitakian and late Waitakian to Otaian fauna.

Paleodepth Lower bathyal or deeper >1000 m; *Cibicides kullenbergi*.

Planktics

Globoquadrina venezuelana	Middle Eocene to Early Pliocene
Globoquadrina tripartita	NZ, mid Oligocene to Early Miocene (27.3-17.26 Ma)
Globoquadrina dehiscens	Late Oligocene (P22) to Late Miocene (N17b)
Catapsydrax dissimilis	Late Eocene (P13) to Early Miocene (N6)
Paragloborotalia semivera	Oligocene to Early Miocene (N7), >17.26 Ma
Paragloborotalia opima?	
Fohsella kugleri	Early Miocene (N4a to N4b), 22.96-21.12 Ma
Globorotaloides suteri?	
Globorotaloides testarugosa	
Neogloboquadrina nana	
Zeaglobigerina woodi	
Zeaglobigerina connecta	
Zeaglobigerina euapertura	
Globigerinita glutinata	
Globigerina sp.	

Benthics

Vulvulina sp.	bathyal
Karreriella bradyi	mid bathyal marker >600 m
Siphotextularia sp.	
Fissurina spp.	
Chrysalogonium verticale	
Nodosaria spp.	
Stilostomella sp.	
Pleurostomella sp.?	
Plectofrondicularia sp.	
Amphicoryna hirsuta	
Oolina hexagona	
Euuvigerina peregrina	bathyal
Cibicides spp.	
Cibicides kullenbergi	lower bathyal marker >1000 m
Pullenia sp.	
Pullenia bulloides	uppermost bathyal marker >200 m
Bulimina sp.	
Pleurostomella spp.	bathyal
Oridorsalis umbonatus	bathyal
Globocassidulina subglobosa	
Melonis barleenum?	bathyal >200 m
Anomalina aotea?	bathyal >600 m
Gyroidinoides sp.	

Other material

Echinoid spines	few
Ostracods	few
Fish teeth	rare

VESPA Sample DR33Cii	Hard limestone; attached to outside of DR33Ci, but catalogued separately.
NZ Fossil Record #	SE28173/f001
GNS Science Laboratory #	F49707

Preparation	Sub-sampled, crushed and treated in acetic acid; washed >63 µm. Reprocessed, crushed and partially disaggregated in water; washed >75 µm.
Fauna	Sparse, poorly preserved fauna.
Adopted age	Poorly constrained. Pliocene to Holocene (<5.33 Ma); possibly Pliocene to Early Pleistocene (5.33-2.3 Ma)?
Comment on age	MC. Constrained by *Globoconella inflata;* possibly Pliocene to Early Pleistocene based on the co-occurrence with *Zeaglobigerina woodi.*
Paleodepth	Poorly constrained. Possibly a mixed fauna with shallow shelf and bathyal taxa.

Planktics

Globoconella inflata	Pliocene (N19-N20) to Recent
Globigerinoides trilobus	
Globigerina sp.	
Globigerinita glutinata	
Zeaglobigerina woodi	
Zeaglobigerina sp.	
Neogloboquadrina sp.	
Paragloborotalia sp.?	
Haynesina sp.?	

Benthics

Quinqueloculina spp.	
Globocassidulina subglobosa	
Discorbinella sp.?	
Melonis doreeni	bathyal

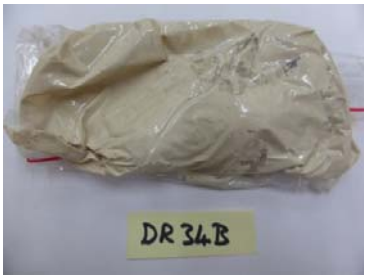
Other material

Echinoid spines	rare
Micro-gastropods	rare

VESPA Sample DR34B Very pale orange, unconsolidated sticky plastic clay.

NZ Fossil Record # SE28173/f003

GNS Science Laboratory # F49708



Preparation Crushed and disaggregated in water; washed >75 µm.

Fauna Well-preserved tropical/subtropical microfauna with good planktic and benthic assemblages.

Adopted age Pleistocene to Holocene, Zone N22 (<2.58 Ma); possibly Early Pleistocene (2.58-2.30 Ma).

Comment on age MC. Constrained by *Truncorotalia truncatulinoides;* possibly Early Pleistocene based on the overlap with *Neogloboquadrina humerosa* and *Zeaglobigerina woodi.*

Paleodepth Lower bathyal or deeper >1000 m; *Siphouvigerina notohispida*.

Planktics

Globoconella triangula	abundant; NZ, Late Pliocene to Early Pleistocene
Pulleniatina obliquiloculata?	Early Pliocene (N19) to Recent
Truncorotalia cf. *crassula*	ventroconical, NZ, latest Pliocene to Recent
Truncorotalia crassacarina	NZ, Early Pleistocene (N22) to Recent
Truncorotalia truncatulinoides	common; Early Pleistocene (N22) to Recent
Truncorotalia tosaensis	rare
Menardella multicamerata?	Middle Miocene Zone N14 to late Pliocene Zone N21
Globorotalia tumida?	Late Miocene (N18) to Recent
Hirsutella scitula	
Globoconella inflata	few; Pliocene (N19-N20) to Recent
Globoconella puncticulata?	few
Globigerinoides trilobus	
Globigerinoides sacculifer	
Globigerinoides sp.	
Globigerinoides ruber pyramidalis	
Globigerinoides ruber	
Globigerinoides conglobatus	
Sphaeroidinella dehiscens?	
Biorbulina sp.	
Orbulina universa	
Globigerina bulloides	
Globigerina falconenesis	
Neogloboquadrina humerosa	Late Miocene (N18) to Early Pleistocene (N22)
Neogloboquadrina incompta	
Zeaglobigerina woodi	NZ, Late Oligocene (P22) to Early Pleistocene (N22)
Globigerinita glutinata	
Globigerinopsis obesa	
Globigerinella aequilateralis	
Dentoglobigerina altispira?	rare; Early Miocene (N4b) to Early Pleistocene (N21)

Benthics

Eggerella bradyi	middle bathyal marker >600 m
Textularia sp.	
Pyrgo spp.	
Dentalina sp.	
Stilostomella sp.	
Orthomorphina sp.?	
Euuvigerina peregrina	bathyal
Siphouvigerina notohispida	lower bathyal marker >1000 m
Siphouvigerina sp.	

Cibicides cenop	bathyal
Cibicides spp.	
Planulina wuellerstorfi?	bathyal
Oridorsalis umbonatus	bathyal
Pullenia bulloides	uppermost bathyal marker >200 m
Globocassidulina subglobosa	
Cassidulina spp.	
Gyroidinoides spp.	
Laticarinina pauperata	
Planulinoides hamasuturalis	
Pleurostomella sp.	bathyal
Melonis barleenum	uppermost bathyal marker >200 m
Osangularia bengalensis	bathyal
Lenticulina sp.	

Other material

Echinoid spines	rare
Ostracods	few
Bivalve shell fragments	rare
Fish teeth	rare

VESPA Sample DR36B	Fine-grained basalt
NZ Fossil Record #	SE27173/f001
GNS Science Laboratory #	F49709

Preparation	Crushed and treated in acetic acid; washed >63 µm.
Fauna	Extremely sparse, very poorly preserved planktic foraminifera; most likely to be from surficial sediment.
Adopted age	Non-determinate (ND).

Planktics
Globigerina sp.

VESPA Sample DR36E	Soft, pale yellowish-grey calcareous mudstone.
NZ Fossil Record #	SE27173/f002
GNS Science Laboratory #	F49710

Preparation	Crushed and disaggregated in water; washed >63 µm.
Fauna	Well-preserved microfauna comprised mostly of planktic foraminifera.
Adopted age	Early Miocene, Zone N4a to N4b (22.96-21.12 Ma).
Comment on age	MC+HM. Constrained by *Fohsella kugleri; Globoquadrina dehiscens, Zeaglobigerina connecta, Zeaglobigerina woodi, Catapsydrax dissimilis,* and *Globorotaloides testarugosa* support an Early Miocene (late Waitakian to early Otaian) age.
Paleodepth	Lower bathyal or deeper >1000 m; *Cibicides kullenbergi.*

Planktics

Catapsydrax dissimilis	Oligocene (P20) to Early Miocene (N6)
Globoconella sp.	Possibly Pliocene to Holocene
Fohsella kugleri	Early Miocene (N4a to N4b) 22.96-21.12 Ma
Fohsella pseudokugleri?	
Catapsydrax unicavus?	
Catapsydrax stainforthia	one good specimen
Catapsydrax cf. *stainforthia*	no bulla (*Paragloborotalia nana pseudocontinuosa*)
Neogloboquadrina nana	
Globoquadrina tripartita	NZ, mid Oligocene to Early Miocene (27.3-17.26 Ma)
Globoquadrina dehiscens	Late Oligocene (P22) to Late Miocene (N17b)
Globorotaloides testarugosa	
Zeaglobigerina cf. *euapertura*	
Zeaglobigerina connecta	
Zeaglobigerina woodi?	
Globorotaloides sp.	
Globorotaloides suteri	
Globigerinita glutinata	
Turborotalita angustiumbilicata	
Globigerina praebulloides	
Globigerina spp.	

Benthics

Lenticulina sp.	
Vaginulina sp.	
Stilostomella sp.	
Dentalina sp.	
Gyroidina sp.	
Pullenia bulloides	uppermost bathyal marker >200 m
Pullenia sp.	
Sphaeroidina bulloides	
Laticarinina pauperata	
Cibicides spp.	
Cibicides kullenbergi	lower bathyal marker >1000 m
Oridorsalis umbonatus	bathyal
Globocassidulina subglobosa	
Cassidulina sp.	

Other material

Ostracods	rare

VESPA Sample DR38A	Relatively soft, white surficial carbonate sediment; on the surface of a hard, brown, extremely altered hyaloclastite breccia, which is encrusted and penetrated by a manganese rind.
NZ Fossil Record #	SE27172/f005
GNS Science Laboratory #	F49711

Preparation	Sub-sampled and treated in acetic acid; washed >63 µm.
Fauna	Moderately well-preserved microfauna comprised mostly of planktic foraminifera.
Adopted age	Early Pliocene, Zone N19 (5.33-4.37 Ma).
Comment on age	MC. Constrained by the overlap of *Truncorotalia crassaformis* and *Zeaglobigerina nepenthes;* possibly younger based on *Globoconella inflata.* Possibly a mixed age fauna.
Paleodepth	Lower bathyal or deeper >1000 m; *Planulina wuellerstorfi* and *Bulimina truncanella.*

Planktics

Globoconella inflata	Pliocene (N19-N20) to Recent
Truncorotalia crassaformis	NZ, Late Miocene to Early Pleistocene (5.45-2.45 Ma)
Menardella limbata	Late Miocene (N14) to Late Pliocene (N21)
Globoconella pliozea?	NZ, Late Miocene to Early Pliocene (5.44-4.49 Ma)
Hirsutella cf. *scitula*	
Dentoglobigerina altispira	Early Miocene (N4b) to Early Pleistocene (N21)
Globigerinoides quadrilobatus	
Globigerinoides trilobus	
Globigerinoides obliquus	
Sphaeroidinellopsis seminulina	
Orbulina universa	
Globigerinella aequilateralis	
Neogloboquadrina pachyderma	
Zeaglobigerina woodi	
Zeaglobigerina nepenthes	Middle Miocene (N14) to Early Pliocene (N19), >4.37 Ma
Globigerina falconensis	
Globigerina sp.	

Benthics

Bulimina truncanella	deep bathyal
Siphouvigerina sp.	
Planulina wuellerstorfi	deep bathyal

VESPA Sample Dr40Biii (1)	Porphyritic ankaramite clast, in breccia; encrusted by pale yellowish-orange micritic cement, followed by a manganese rind.
NZ Fossil Record #	SE27172/f006
GNS Science Laboratory #	F49712

Preparation	Sub-sampled, crushed and treated in acetic acid; washed >63 µm.
Fauna	Barren. No faunal slide.
Adopted age	Non-fossiliferous (NF).

VESPA Sample DR40Biii (2)	Pale yellowish-orange micritic cement?; on the surface of a porphyritic ankaramite clast; and encrusted by a manganese rind.
NZ Fossil Record #	SE27172/f006
GNS Science Laboratory #	F49712

Preparation	Sub-sampled and treated in acetic acid; washed >63 µm.
Fauna	Barren. No faunal slide.
Adopted age	Non-fossiliferous (NF).

VESPA Sample DR40F	Pale olive-grey, massive sandy siltstone and mudstone.
NZ Fossil Record #	SE27172/f0007
GNS Science Laboratory #	F49733

Preparation	Crushed and treated in acetic acid; washed >63 µm. Resampled and processed for radiolarians.
Fauna	No foraminifera and no faunal slide.
Adopted age	Non-determinate (ND).
Other material	
Radiolarians	Late Cretaceous? (see radiolarian results)

VESPA Sample DR41Di	Volcaniclastic breccia with a micritic matrix. Varicoloured, polymict, angular to sub-angular clasts of green, brown and grey basalt lithologies.
NZ Fossil Record #	SE24170/f004
GNS Science Laboratory #	F50191

Preparation	Crushed and disaggregated in water; washed >75 µm.
Fauna	Very sparse microfauna, preservation of foraminifera variable.
Adopted age	Poorly constrained. Possibly Late Oligocene to Early Miocene.
Comment on age	*Globoquadrina tripartita* and *Paragloborotalia semivera* suggest Late Oligocene to Early Miocene.
Paleodepth	Bathyal >200 m, possibly lower bathyal or deeper >1000 m; elongate nodosarids and *Planulina?*

Planktics

Globoquadrina tripartita	NZ, mid Oligocene to Early Miocene (27.3-17.26 Ma)
Globoquadrina sp.	
Paragloborotalia semivera?	Oligocene to Early Miocene (N7), >17.26 Ma
Neogloboquadrina nana?	
Globorotaloides suteri?	
Zeaglobigerina sp.	
Globigerina bulloides	
Globigerina sp.	
Globigerinita glutinata	

Benthics

Dentalina sp.
Nodosaria sp.
Amphicoryna sp.
Lagena striata
Bulimina sp.
Cibicides spp.
Planulina sp.?
Gavelinopsis sp.?
Gyroidinoides sp.

Other material

Holothurian spines	few
Fish teeth	rare
Bryozoan fragments	rare
Echinoid spines	rare
Radiolarians	rare

VESPA Sample DR41Dii (1)	Light olive-brown, volcaniclastic sandstone-conglomerate; with a pale yellowish-orange micritic cement infilling fractures.
NZ Fossil Record #	SE24170/f002
GNS Science Laboratory #	F49713

Preparation	Sub-sampled, crushed and partially disaggregated in water; washed >63 µm.
Fauna	Sparse, very poorly preserved microfauna including internal casts.
Adopted age	Very poorly constrained. Possibly Late Eocene to Early Miocene, Zone P13 to N6.
Comment on age	MC+HM. Based on the tentative identification of a very poorly preserved specimen of *Catapsydrax dissimilis.*
Paleodepth	Deep lower bathyal >1500 m; *Tritaxalina zealandica*. *Amphistegina* suggests there was common downslope reworking from the shelf.
Planktics	
Catapsydrax dissimilis?	Late Eocene (P13) to Early Miocene (N6)
Globigerina bulloides	
Globigerina sp.	
Benthics	
Tritaxalina zealandica	deep lower bathyal marker >1500 m
Amphistegina sp.	relatively common; shallow shelf (downslope)
Other material	
Sponge spicules	few
Echinoid spines	rare

VESPA Sample DR41Dii (2)

Pale yellowish-orange micritic cement, infilling fractures; associated with a light olive-brown, volcaniclastic sandstone-conglomerate.

Cream-coloured carbonate sediment.

NZ Fossil Record # SE24170/f002

GNS Science Laboratory # F49713

Preparation Sub-sampled, crushed and treated in acetic acid; washed >63 µm.

Fauna Poorly preserved, predominantly planktic foraminifera.

Adopted age Very poorly constrained. Mid Oligocene to Early Miocene Zone P22 to N7 (27.3-17.26 Ma); possibly mid Oligocene Zone P22 (27.3-23.03 Ma).

Comment on age MC+HM. *Catapsydrax dissimilis, Globoquadrina tripartita, Globorotaloides testarugosa,* and intermediate forms of *Zeaglobigerina euapertura-woodi* suggest mid Oligocene to early Miocene; possibly mid to Late Oligocene based on the absence of *Globoquadrina dehiscens.*

Paleodepth Deep mid bathyal or deeper >800 m; *Vulvulina pennatula*. Also shallow-water taxa typical of the shelf that have possibly been transported downslope.

Planktics

Catapsydrax dissimilis?	
Globorotaloides testarugosa?	
Globoquadrina tripartita	NZ, mid Oligocene to Early Miocene (27.3-17.26 Ma)
Zeaglobigerina euapertura-woodi	intermediate forms
Neogloboquadrina nana	

Benthics

Vulvulina pennatula	deep mid bathyal marker >800 m
Triplasia marwicki?	deep bathyal
Quinqueloculina sp.	
Dentalina spp.	
Stilostomella sp.	
Lagena sp.	
Anomalinoides sp.	
Siphonia australis?	
Bulimina sp.	
Pullenia bulloides	uppermost bathyal marker >200 m
Sphaeroidina bulloides	
Elphidium crispum waiwiriense?	shallow shelf (downslope)
Elphidium advenum macelliforme?	shallow shelf (downslope)
Laticarinina pauperata	
Gyroidinoides zealandicus	
Cibicides spp.	
Cibicides cf. *subhaidingeri*	bathyal
Planulina renzi?	bathyal
Globocassidulina subglobosa	
Globocassidulina crispula	
Ehrenbergina sp.	

Other material

Echinoid spines	few
Sponge spicules	rare
Ostracods	rare

VESPA Sample DR41Ei (1)	Cemented, yellowish-white foram limestone. Bored.
NZ Fossil Record #	SE24170/f003
GNS Science Laboratory #	F49714

Preparation	Sub-sampled, crushed and treated in acetic acid; washed >63 µm.
Fauna	Well-preserved, tropical/subtropical, predominantly planktic foraminifera.
Adopted age	Late Miocene, Zone N17B to N18 (8.56-5.53 Ma).
Comment on age	Based on *Globigerinoides conglobatus* and *Globoconella miotumida*; no *Globoquadrina dehiscens* suggests the age is possibly at the younger end of the adopted age range.
Paleodepth	Poorly constrained. Possibly bathyal >200 m?

Planktics

Menardella limbata	Middle Miocene (N14) to Pleistocene (N21)
Globoconella miotumida	NZ, Middle to Late Miocene (16.02-6.96 Ma)
Hirsutella scitula	
Neogloboquadrina dutertrei	
Neogloboquadrina incompta	
Globigerinoides obliquus	
Globigerinoides sacculifer	
Globigerinoides quadrilobatus	
Globigerinoides trilobus	
Globigerinoides conglobatus	Late Miocene (N17B) to Recent
Orbulina universa	Middle Miocene (N9) to Recent
Orbulina bilobata	Middle Miocene (N9) to Recent
Globigerinita minuta?	
Globigerinopsis obesa?	
Globigerina bulloides	
Globigerina falconensis	
Globigerina sp.	
Zeaglobigerina nepenthes	Middle Miocene (N14) to Early Pliocene (N19)
Zeaglobigerina woodi	Late Oligocene to Pleistocene

Benthics

Lenticulina sp.	
Fissurina sp.	
Sphaeroidina bulloides	
Cibicides sp.	
Oridorsalis umbonatus	bathyal
Globocassidulina subglobosa	

Other material

Fish teeth	rare

VESPA Sample DR41Ei (2) Soft, pale-brown burrow infill; associated with a bored, cemented, yellowish-white foram limestone.

NZ Fossil Record # SE24170/f003

GNS Science Laboratory # F49714

Preparation Sub-sampled and disaggregated in water; washed >75 µm.

Fauna Well-preserved, tropical/subtropical, predominantly planktic foraminifera.

Adopted age Pleistocene to Holocene, Zone N22 (<2.58 Ma); possibly Early Pleistocene (2.58-1.81 Ma).

Comment on age MC. Constrained by *Truncorotalia truncatulinoides;* possibly Early Pleistocene based on the co-occurrence with *Globoconella triangula.*

Paleodepth Poorly constrained. Mid bathyal or deeper >600 m; *Planulina renzi?*

Planktics

Globoconella triangula	NZ, Pliocene to Early Pleistocene (3.7-2.4 Ma)
Pulleniatina obliquiloculata	dextral pop, Early Pliocene (N19) to Recent
Truncorotalia truncatulinoides	Early Pleistocene (N22) to Recent
Truncorotalia cf. *crassula*	viola form
Menardella limbata	Middle Miocene (N14) to Late Pliocene (N21)
Menardella menardii?	
Globoconella cf. *miotumida*	
Hirsutella scitula	
Neogloboquadrina incompta?	
Neogloboquadrina dutertrei	
Globigerinoides ruber	Middle Miocene (N15) to Recent
Globigerinoides pyramidalis	
Globigerinoides sacculifer	Early Miocene (N6) to Recent
Globigerinoides quadrilobatus	Early Miocene (N5) to Recent
Globigerinoides trilobus	Early Miocene (N4B) to Pleistocene (N22)
Globigerinoides conglobatus	Late Miocene (N17B) to Recent
Globigerinoides fistulosus	rare, Late Pliocene (N21) to Pleistocene (N22)
Orbulina universa	Middle Miocene (N9) to Recent
Orbulina bilobata	Middle Miocene (N9) to Recent
Globigerinella aequilateralis	Middle Miocene (N12) to Recent
Globigerinita sp.?	
Globigerinita glutinata	
Globigerinella calida	Early Pliocene (N19) to Recent
Globigerina falconensis	
Globigerina bulloides	
Globigerina sp.	
Beella praedigitata?	Late Miocene (N16) to Late Pliocene (N21)
Candeina nitida	Late Miocene (N17) to Recent

Benthics

Laticarinina pauperata	
Planulina renzi?	bathyal

Other material

Ostracods	few
Echinoid spines	rare

VESPA Sample DR42A	Indurated, dusky yellow, graded siltstone; contains a 2 cm bed of very fine sandstone. Some trace fossils (filled burrows).
NZ Fossil Record #	SE23167/f001
GNS Science Laboratory #	F49715

Preparation	Crushed and treated in acetic acid; washed >63 µm.
Fauna	Extremely sparse microfauna, no foraminifera.
Adopted age	Non-determinate (ND).

Other material

Radiolarians	few
Diatoms?	few
Fish teeth	few
Sponge spicules	few

VESPA Sample DR42B (1) Cemented and heavily bioturbated, moderate brown, laminated, silicified limestone (hard-ground); with irregular 'pockets' of hard, pale pink limestone. Encrusted and penetrated by a thick manganese crust.

NZ Fossil Record # SE23167/f002

GNS Science Laboratory # F49716

Preparation Sub-sampled, crushed and treated in acetic acid; washed >63 µm.

Fauna Sparse, very poorly preserved, predominantly planktic foraminifera (mostly incomplete internal casts).

Adopted age Non-determinate (ND).

Comment on age No age diagnostic taxa.

Planktics
Globigerina sp.

Other material
Echinoid spines rare

VESPA Sample DR42B (2)	Pockets of hard, pale pink limestone; in a cemented and heavily bioturbated, moderate brown, laminated, silicified limestone (hard-ground).
NZ Fossil Record #	SE23167/f002
GNS Science Laboratory #	F49716

Preparation	Sub-sampled and treated in acetic acid; washed >63 µm.
Fauna	Extremely sparse, poorly preserved partial casts of planktic foraminifera? No faunal slide.
Adopted age	Non-determinate (ND).

VESPA Sample DR42C	Bioclastic calcarenite limestone (bryozoan packstone).
NZ Fossil Record #	SE23167/f003
GNS Science Laboratory #	F49717A

Preparation	Crushed and disaggregated in water; washed >75 µm.
Fauna	Moderately well-preserved microfauna comprised mostly of bryozoan fragments and benthic foraminifera.
Adopted age	Very poorly constrained. Late Oligocene to Late Miocene?
Comment on age	Based on the NZ range of *Cribrorotalia ornatissima?*
Paleodepth	Inner to mid shelf <100 m; based on the abundance of shallow-water epifaunal taxa and no bathyal markers or planktic foraminifera. Restricted oceanic circulation.

Benthics

Textularia sp.	
Sigmomorphina sp.	
Amphicoryna sp.?	
Pileolina spp.	shallow shelf
Gavelinopsis sp.	shelf
Discorbinella sp.?	
Discopulvulinulina sp.	shelf
Discopulvulinulina turgida?	shelf
Eponoides sp.	
Cribrorotalia ornatissima?	NZ, Late Oligocene to Late Miocene
Gyroidinoides sp.	
Melonis sp.	
Anomalinoides sp.	
Cibicides cf. *notocenicus*	

Other material

Bryozoan fragments	very abundant
Echinoid spines	common
Ostracods	few

VESPA Sample DR42Ci	Bioclastic calcarenite limestone (bryozoan packstone).
NZ Fossil Record #	SE23167/f003
GNS Science Laboratory #	F49717

Preparation	Crushed and treated in acetic acid; washed >63 µm.
Fauna	Moderately well-preserved, predominantly shallow-water benthic foraminifera.
Adopted age	Very poorly constrained. Late Oligocene to Late Miocene?
Comment on age	Based on the NZ range of *Cribrorotalia ornatissima?*
Paleodepth	Inner to mid shelf <100 m; based on the abundance of shallow-water epifaunal taxa and no bathyal markers or planktic foraminifera. Restricted oceanic circulation.

Benthics

Gyroidinoides sp.	
Gyroidina sp.	
Melonis sp.	
Pileolina sp.	shelf
Gavelinopsis sp.	
Discopulvulinulina sp.	shelf
Eponoides sp.	
Cribrorotalia ornatissima?	NZ, Late Oligocene to Late Miocene
Cribrorotalia sp.	shelf
Sigmomorphina sp.?	
Dyocibicides primitiva?	shelf
Cibicides cf. *notocenicus*	

Other material

Bryozoan fragments	abundant
Echinoid spines	common
Bivalve shell fragments	few
Ostracods	few

VESPA Sample DR42D	Soft, light olive-grey, homogeneous calcareous mudstone.
NZ Fossil Record #	SE23167/f004
GNS Science Laboratory #	F49718

Preparation	Crushed and disaggregated in water; washed >63 µm. Resampled.
Fauna	Well-preserved tropical/subtropical microfauna, comprised mostly of planktic foraminifera.
Adopted age	Early Miocene, Zone N4a to N4b (22.96-21.12 Ma).
Comment on age	MC+HM. Constrained by *Fohsella kugleri.*
Paleodepth	Deep lower bathyal >1500 m; *Tritaxalina zealandica* and *Cibicides robertsonianus?*

Planktics

Globoquadrina dehiscens	Late Oligocene (P22) to Late Miocene (N17b)
Globoquadrina tripartita	NZ, mid Oligocene to Early Miocene (27.3-17.26 Ma)
Globigerinoides primordius	Late Oligocene (N4a) to Early Miocene (N5)
Globigerinoides altiaperturus	Early Miocene (N5 to N7)
Globigerinoides trilobus	Early Miocene (N4a) to Pleistocene (N22)
Fohsella kugleri	Early Miocene (N4a to N4b), 22.96-21.12 Ma
Globorotaloides cf. *suteri*	
Paragloborotalia cf. *semivera*	
Zeaglobigerina woodi?	
Zeaglobigerina connecta?	
Zeaglobigerina cf. *euapertura*	
Globigerinella aequilateralis	
Globigerinita glutinata	

Benthics

Tritaxalina zealandica?	deep lower bathyal marker >1500 m?
Migros medwayensis?	bathyal
Vulvulina pennatula	deep mid bathyal marker >800 m
Martinottiella sp.	
Siphotextularia sp.	
Spiroloculina canaliculata	
Lenticulina spp.	
Saracenaria sp.	
Astacolus sp.	
Dentalina spp.	
Nodosaria spp.	
Vaginulina vagina	
Stilostomella sp.	
Chrysalogonium verticale	
Lagena sp.	
Fissurina sp.	
Bulimina truncanella	deep bathyal
Bulimina striata	
Bulimina sp.	
Bolivina spp.	
Bolivina lapsus	
Rectuvigerina rerensis?	
Siphouvigerina sp.	
Elphidium sp.	
Amphistegina sp.	shallow shelf (downslope)
Gyroidinoides sp.	
Anomalinoides sp.	

Anomalina sp.?	
Melonis sp.	
Sphaeroidina bulloides	
Pullenia sp.	
Cibicides robertsonianus?	lower bathyal marker >1000 m?
Cibicides spp.	
Pleurostomella alternans	bathyal
Laticarinina pauperata	
Oridorsalis cf. *tenera*	
Osangularia culter	bathyal

Table 1.2 Summary of adopted ages and paleo-water depths

VESPA dredge sample #	NZ Fossil record #	GNS Lab #	Adopted age	Paleo-water depth	Identifier
DR02A	SE26167/f001	F49676	Late Miocene Zone N16 to Zone N17b (9.83-5.92 Ma)	Mid bathyal or deeper >600 m	MC
DR03Aii (1)	SE27167/f001	F47677	Pleistocene or younger, Zone N22 (<2.58 Ma); possibly early Pleistocene (2.58-1.81 Ma)?	Shelf <200 m	MC
DR03Aii (2)	SE27167/f001	F47677	Non-determinate (ND)		MC
DR04A	SE27167/f002	F49678	Late Eocene to Oligocene, Zone P17 to P20 (34.61-29.84 Ma)	Bathyal >200 m, possibly lower bathyal or deeper >1000 m	MC+HM
DR04F	SE27167/f003	F49679	Middle to late Eocene, Zone P14 to P16 (39.12-29.84 Ma)	Bathyal >200 m	MC+HM
DR06A	SE28167/f006	F49680	Pleistocene or younger, Zone N22 (<2.58 Ma); possibly early Pleistocene 2.58-1.81 Ma?	Shelf <200 m	MC
DR06C	SE28167/f007	F50188	Pleistocene or younger (<2.34 Ma); possibly early Pleistocene 2.34-1.81 Ma?	Shelf <200 m	MC
DR08B (1)	SE24170/f001	F49681	Late Miocene to early Pliocene Zone N19-N20 (5.44-4.37 Ma)	Mid bathyal or deeper >600 m	MC
DR08B (2)	SE24170/f001	F49681	Non-determinate (ND)		MC
DR10B	SE25170/f001	F49682	Early Miocene Zone N4a to Zone N4b (23.03-21.7 Ma)?		MC+HM
DR10D (1)	SE25170/f002	F49683	Pleistocene or younger (<2.40 Ma); possibly early Pleistocene (2.40-2.30 Ma)?	Bathyal >200 m	MC
DR10D (2)	SE25170/f002	F49683	Early Miocene Zone N4a to Zone N5-N6 (23.03-18.7 Ma)?	Mid bathyal or deeper >600 m	MC+HM
DR11A (1)	SE25170/f003	F49684	Late Miocene Zone N14 (11.63-10.56 Ma); possibly lower Tongaporutuan (10.64-10.56 Ma)?	Lower bathyal or deeper >1000 m	MC
DR11A (2)	SE25170/f003	F49684	Late Miocene Zone N14 (11.63-10.56 Ma), possibly lower Tongaporutuan (10.64-10.56 Ma)?	Mid bathyal or deeper >600 m	MC
DR11B	SE25170/f004	F49685	Mixed age early Miocene fauna, Zone N4a (22.96-21.12 Ma) and Zone N8 (16.28-15.97 Ma)?	Mid bathyal or deeper >600 m	MC+HM
DR12A (1)	SE25170/f005	F49686	No microfauna (NF)		MC
DR12A (2)	SE25170/f005	F49686	Non-determinate (ND), no forams		MC
DR12E	SE25170/f006	F49687	Non-determinate (ND); Host rock possibly non-fossiliferous (NF)		MC
DR13I	SE25169/f005	F50189	Non-determinate (ND)		MC
DR14H	SE25169/f001	F49688	Non-determinate (ND)		MC
DR14H	SE25169/f001	RD4953	Non-determinate (ND)		CH
DR15Cii	SE25169/f002	F49689	Early Miocene, Zone N5-N6 (20.93-18.7 Ma)	Bathyal >200 m, possibly lower bathyal or deeper >1000 m	MC+HM
DR15Cii	SE25169/f002	RD4954	Non-determinate (ND), sandy		CH
DR15D	SE25169/f003	F49690	Non-determinate (ND)		MC
DR15D	SE25169/f003	RD4955	Non-determinate (ND), sandy		CH
DR15I	SE25169/f004	F49691	Non-determinate (ND)		MC
DR15I	SE25169/f004	RD4956	Non-determinate (ND), sandy		CH
DR16G	SE25170/f007	F49692	Non-determinate (ND)	Bathyal >200 m	MC
DR18C	SE26170/f001	F49693	Early Miocene, Zone N4a to N7 (23.03-18.7 Ma)	Mid bathyal or deeper >600 m	MC+HM
DR19Jii (1)	SE26170/f002	F49694	Oligocene to early Miocene, Zone P18 to N6 (33.99-17.54 Ma)?		MC+HM
DR19Jii (2)	SE26170/f002	F49694	Early Miocene, Zone N4a to Zone N7 (23.03-18.7 Ma)?	Lower bathyal or deeper >1000 m	MC+HM
DR19Jiii	SE26170/f003	F49695	Late Oligocene, Zone P22 (28.09-23.03 Ma)?	Bathyal >200 m	MC+HM
DR19K	SE26170/f004	F49696	Mid to late Oligocene, Zone P20 to P22 (29.84-23.03 Ma)	Mid bathyal or deeper >600 m	MC+HM
DR21G	SE26171/f002	F50190	Late Oligocene, Zone P22 (25.2-23.03 Ma)	Bathyal >200 m, possibly lower bathyal or deeper >1000 m	MC+HM
DR22B (1)	SE26171/f001	F49697	Non-determinate (ND)		MC
DR22B (2)	SE26171/f001	F49697	Late Pliocene, Zone N21 (3.35-2.58 Ma)	Lower bathyal or deeper >1000 m	MC
DR23A (1)	SE27171/f001	F49698	Non-determinate (ND), no forams		MC
DR23A (2)	SE27171/f001	F49698	Non-determinate (ND)		MC
DR23A	SE27171/f001	RD4960	Non-determinate (ND)		CH
DR23D	SE27171/f008	F49731	Non-determinate (ND), no forams		MC
DR23D	SE27171/f008	RD4957	Non-determinate (ND), spumellarians		CH
DR23F (1)	SE27171/f009	F49732	Non-fossiliferous (NF)		MC
DR23F (2)	SE27171/f009	F49732	Non-determinate (ND)		MC
DR23G (1)	SE27171/f002	F49699	Pleistocene or younger, Zone N22 (<2.58 Ma); possibly early Pleistocene (2.58-1.81 Ma)?	Mid bathyal or deeper >600 m	MC
DR23G (2)	SE27171/f002	F49699	Possibly non-fossiliferous (NF)		MC
DR24Ai	SE27171/f003	F49700	Non-determinate (ND)		MC
DR24Ai	SE27171/f003	RD4958	Non-determinate (ND), foram casts		CH
DR26Gi (1)	SE27171/f004	F49701	Early Miocene, possibly Zone N5 to N7 (21.12-20.93 Ma)?	Possibly shelf <200 m?	MC+HM
DR26Gi (2)	SE27171/f004	F49701	Pleistocene or younger, Zone N22 (<2.58 Ma); possibly early Pleistocene (2.58-1.81 Ma)?	Possibly lower bathyal >1000 m?	MC
DR26Gii	SE27171/f005	F49702	Late Oligocene Zone P22 (26.93-23.03 Ma)	Bathyal >200 m	MC+HM
DR29C (1)	SE27172/f001	F49703	Possibly late Oligocene to Miocene?	Bathyal >200 m	MC+HM
DR29C (2)	SE27172/f001	F49703	Pleistocene or younger (<2.58 Ma); possibly early Pleistocene (2.58-1.81 Ma)?	Bathyal >200 m	MC
DR31Bi	SE27172/f002	F49704	Early Miocene, Zone N4a to N4b (22.96-21.12 Ma)	Lower bathyal or deeper >1000 m	MC+HM
DR31Bii	SE27172/f003	F49705	Non-determinate (ND)		MC
DR31C	SE27172/f004	F49706	Early Miocene, Zone N4a to N4b (22.96-21.12 Ma)	Lower bathyal or deeper >1000 m	MC+HM
DR33Cii	SE27173/f001	F49707	Pliocene or younger (<5.33 Ma); possibly Pliocene to early Pleistocene (5.33-2.3 Ma)?	Possibly a mixed fauna with shallow shelf and bathyal taxa?	MC
DR34B	SE27173/f003	F49708	Pleistocene or younger, Zone N22 (<2.58 Ma); possibly early Pleistocene (2.58-2.30 Ma)?	Lower bathyal or deeper >1000 m	MC
DR36B	SE27173/f001	F49709	Non-determinate (ND)		MC
DR36E	SE27173/f002	F49710	Early Miocene, Zone N4a to N4b (22.96-21.12 Ma)	Lower bathyal or deeper >1000 m	MC+HM
DR38A	SE27172/f005	F49711	Early Pliocene, Zone N19 (5.33-4.37 Ma)	Lower bathyal or deeper >1000 m	MC
DR40Biii (1)	SE27172/f006	F49712	Non-fossiliferous (NF)		MC
DR40Biii (2)	SE27172/f006	F49712	Non-fossiliferous (NF)		MC
DR40F	SE27172/f007	F49733	Non-determinate (ND)		MC
DR40F	SE27172/f007	RD4959	Rare, well-preserved, Cretaceous?		CH
DR41Di	SE24170/f004	F50191	Possibly late Oligocene to early Miocene?	Bathyal >200 m, possibly lower bathyal or deeper >1000 m	MC+HM
DR41Dii (1)	SE24170/f002	F49713	Possibly late Oligocene to early Miocene?	Bathyal >200 m, possibly lower bathyal or deeper >1000 m	MC+HM
DR41Dii (2)	SE24170/f002	F49713	Mid Oligocene to early Miocene Zone P22 to N7 (27.3-17.26 Ma); possibly mid Oligocene Zone P22 (27.3-23.03 Ma)?	Deep mid bathyal or deeper >800 m	MC+HM
DR41Ei (1)	SE24170/f003	F49714	Late Miocene, Zone N17B to Zone N18 (8.56-5.53 Ma)	Possibly bathyal >200 m?	MC
DR41Ei (2)	SE24170/f003	F49714	Pleistocene or younger, Zone N22 (<2.58 Ma); possibly early Pleistocene (2.58-1.81 Ma)?	Mid bathyal or deeper >600 m	MC
DR42A	SE23167/f001	F49715	Non-determinate (ND)		
DR42B (1)	SE23167/f002	F49716	Non-determinate (ND)		
DR42B (2)	SE23167/f002	F49716	Non-determinate (ND)		
DR42C	SE23167/f003A	F49717A	Late Oligocene to late Miocene?	Inner to mid shelf <100 m	MC+HM
DR42Ci	SE23167/f003	F49717	Late Oligocene to late Miocene?	Inner to mid shelf <100 m	MC+HM
DR42D	SE23167/f004	F49718	Early Miocene, Zone N4a to N4b (22.96-21.12 Ma)	Deep lower bathyal >1500 m	MC+HM

1.3 RADIOLARIAN RESULTS

Eight VESPA samples were processed for radiolarians (Table 2). Six of these contained no radiolarians, one contained poorly preserved spumellarians of no age significance (DR23D), and one sample contained a sparse moderately preserved assemblage of Late Cretaceous age (DR40F).

The assemblage in sample DR40F is correlated with late Campanian-Maastrichtian (Haumurian) radiolarian zone RK9 of Hollis (1997) based on the presence of Dictyomitra andersoni, Lithocampe wharanui, Theocapsomma erdnussa and the absence of species restricted to the Paleocene (Teurian). Other Late Cretaceous-Paleocene species present in the sample include Amphipyndax stocki, Dictyomitra multicostata, Mita regina, Mita cf. regina (sensu Hollis 1997) and Stichomitra compsa. Long-ranging taxa, Lithelius minor gr, Spongodiscus spp. and Tholodiscus spp., are also present.

Close similarities are noted with the Late Cretaceous assemblages of the Mead Hill and Whangai Formations or eastern New Zealand. The absence of Amphipyndax tylotus suggests a mid- to high-latitude biogeographic affinity for the assemblage.

Table 1.3 Processing of radiolarian samples and results.

Sample #	GNS Lab #	Processing	Content
DR14H	RD4953	HCl/H_2O_2 x 2	Non-determinate (ND)
DR15Cii	RD4954	HCl/H_2O_2 x 2	Non-determinate (ND), sandy
DR15D	RD4955	HCl/H_2O_2 x 2	Non-determinate (ND), sandy
DR15I	RD4956	HCl/H_2O_2 x 2	Non-determinate (ND), sandy
DR23A	RD4960	HF, 5% 2hours x 2	Non-determinate (ND)
DR23D	RD4957	HCl/H_2O_2 x 2	Non-determinate (ND), spumellarians
DR24Ai	RD4958	HCl/H_2O_2 x 2	Non-determinate (ND), foram casts
DR40F	RD4959	HCl/H_2O_2 x 2	Rare, well-preserved: Cretaceous?

2.0 ACKNOWLEDGEMENTS

This report was reviewed by Hamish Campbell and formatted by Robert Digby (GNS Science).

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