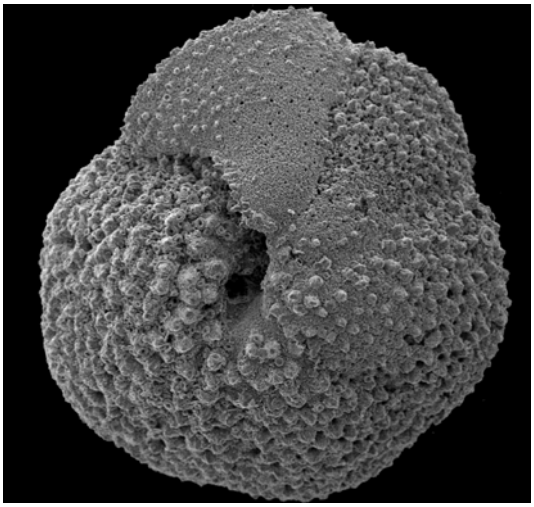
Early Palaeogene planktic foraminiferal assemblages in Australasian sequences: links to past changes in climate and carbon cycling.



SEM micrograph of the Late Paleocene

planktic foraminifera Igorina albeari

Thesis submitted by

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PREFACE

In August/October, 2001, I sailed as a scientist/sedimentologist on the *JOIDES Resolution* Ocean Drilling Program Leg 198 to the Shatsky Rise, central-west Pacific. The cruise objectives targeted rapid intervals of global warming in the generally warm periods of the Cretaceous and Palaeogene, with obvious applications to modern climate problems. This thesis contributes a new body of knowledge derived from a dataset acquired during Leg 198, which documents carbonate dissolution episodes in the Paleocene and Eocene and is a major contribution to the leg's objectives. Furthermore, it represents the first study of this kind focused on the Paleocene and Eocene.

Two consecutive field seasons were spent with the New Zealand geological survey logging stream sections and collecting samples from early Palaeogene strata in the Clarence Valley, Marlborough, south island of New Zealand. Specific skills exercised included field mapping and targeting techniques in mountainous terrain, section logging, magnetometer reading, hard rock sample collection for planktic foraminiferal biostratigraphy and isotope analysis and working within a tight-knit team of professionals. One month after each of two field seasons was spend at the Institute of Geological and Nuclear Sciences (IGNS), Lower Hutt (NZ) laboratories preparing hard rock samples for foraminifera and isotope analysis and working with other members of the palaeontological department on the Marlborough projects.

A three month summer project was undertaken at the Woods Hole Oceanographic Institute (WHOI), Massachusetts, (US) with Dr. Richard Norris investigating a coiling reversal in the Late Paleocene planktic foraminifera *Igorina albeari.* In the process I learnt to identify critical Late Paleocene planktic foraminifera under key workers in the field, including researchers affiliated with petroleum companies.

The publication "Early Palaeogene planktic foraminiferal and carbon isotope stratigraphy, Hole 762C, Exmouth Plateau, northwest Australian margin", is based on a

dataset collected for my BSc (Honours) thesis. However, minor additions were made to the data set as well preparing a manuscript for publication as part of my doctoral program. Consequently the published paper is included with this thesis as an appendix.

ACKNOWLEDGMENTS

Thanks go to my primary and secondary PhD supervisors, Gerald Dickens and Robert Henderson, for their continual encouragement, guidance, support, discussions and reviews related to chapters in this thesis. Thanks go to the IGNS Marlborough Project members: Chris Hollis, Percy Strong, and Brad Field, for their field support and for making facilities available at the Lower Hutt laboratories. Thanks go to the ODP for giving me a berth as a scientist on Leg 198 to the Shatsky Rise, and to all of the crew members, especially the co-chiefs Tim Bralower, Isabella Premoli-Silva and chief scientist Mitch Malone. Thanks go to WHOI for providing me with a three month internship and use of facilities and to Richard Norris for project guidance and discussions. Thanks go to Ellen Thomas for helpful discussions and benthic foraminiferal identifications. William Berggren, Brian Huber, Richard Olsson, Frederique Quillevere are also thanked for their invaluable help with planktic foraminiferal species identifications.

This PhD was funded by the James Cook University (JCU) Prestigious Postgraduate Research Scholarship, the JCU Doctoral Merit Research Scheme (WHOI project), and a JCU completion scholarship. The Dee Stream project was funded by student grants from the Mid-American Paleontological Society (MAPS), Paleontological Society, and the *Journal of Foraminiferal Research*, Palaeobiology Department, Smithsonian Institute.

ABSTRACT

The early Palaeogene (65-45 million years ago (Ma)) is of great interest to the earth science community, as significant perturbations in climate and carbon cycling marked this time interval clearly evidenced by major turnovers in biota, and profound variations in global carbon isotope ($\delta^{13}C$) records. The most prominent of these $\delta^{13}C$ changes include an interval of extreme ^{13}C-enrichement, the Paleocene Carbon Isotope Maximum (PCIM) (~59-57 Ma), a fairly rapid and extraordinary decline at the Basal Eocene Thermal Maximum (BETM) (~55.5 Ma), and an interval of very low $\delta^{13}C$ that initiated the Early Eocene Climatic Optimum (EECO).

Although the climate and carbon cycling perturbations in the early Palaeogene are global, most records come from the Northern Hemisphere and Atlantic Ocean and relatively few from the Indian and Pacific Oceans, especially in the Southern Hemisphere. Biotic and sedimentary response to the climate and carbon cycle perturbations in the early Palaeogene is just being appreciated. This thesis addresses these issues.

Chapter 2 examines seafloor carbonate dissolution in the central Pacific Ocean during the Paleocene and Eocene. Ocean Drilling Program (ODP) Holes 1209A (2387 m water depth) and 1211A (2907 m water depth) recovered 115 and 65 m-thick sections of nannofossil ooze of this age respectively, on Shatsky Rise. Carbonate content, coarse size fraction (>38 μm), benthic foraminifer abundance (BENTH), and planktic foraminifer fragmentation ratio (FRAG) were measured to create a record of dissolution. There are three intervals where dissolution parameters indicate prominent dissolution episodes for both holes between 65 and 33.7 Ma: during the middle Paleocene (~59 Ma), during the BETM (~55.5 Ma), and during the Middle to Late Eocene (~37-33.7 Ma). Enhanced preservation of planktic foraminiferal assemblages marks the start of both the Paleocene and Eocene epochs. Of the dissolution indices, BENTH and FRAG are the most reliable indicators. The dissolution record at Holes

1209A and 1211A provides the first detailed dissolution record for the Paleocene and Eocene in the Pacific Ocean.

In Chapter 3, the middle Paleocene (~59 Ma) dissolution episode is further investigated, especially to determine coeval oceanographic changes. Planktic foraminiferal assemblages were examined for their biozonation, isotope record and coiling direction in *Igorina albeari*. I show that the dissolution episode is widespread throughout the central Pacific and that it is associated with a coiling shift from dextral to sinistral in the Late Paleocene planktic foraminifera *Igorina albeari*. It coincides with a ~+0.5‰ $\delta^{13}C$ excursion near the base of the PCIM suggesting a link to enhanced carbon burial at this time. The coiling shift at the Pacific sites closely approximates the first appearance of *Globanomalina pseudomenardii*, the zonal marker for planktic foraminiferal Zone P4.

Chapter 4 examines carbonate contents in a section offshore eastern New Zealand. The abyssal ODP Hole 1121B, north-east of Campbell Plateau, contains a 30 m-thick interval of siliceous nannofossil ooze sediment deposited during the Late Paleocene. The presence of carbonate is unusual given present and past water depths, and suggests a drop in the carbonate compensation depth (CCD). Carbonate contents were analyzed to better document and understand this interval. When combined with age data, carbonate accumulation correlates temporally with the early part of the PCIM, and deposition of the Waipawa Formation, an organic rich unit, which is widely represented in New Zealand Palaeogene basins. It is likely that high surface water productivity led to an expanded oxygen minimum zone, and a deepening of the CCD.

Chapter 5 examines the stratigraphy of an expanded early Palaeogene section on South Island, New Zealand. Dee Stream, in Clarence Valley of Marlborough, cuts Muzzle Group, a sequence of well-bedded siliceous limestones and marls deposited from the late Cretaceous to the middle Eocene. An ~100 m thick portion of this sequence was mapped and logged, and samples were collected for planktic foraminiferal biostratigraphy and bulk carbon isotope analyses. The section spans planktic foraminiferal biozones Zone P4 to Subzone P6b in the global sub-tropical scheme or the *Subbotina triloculinoides* to *Pseudohastigerina wilcoxensis* zones of the New Zealand scheme. Bulk carbon isotopes through the section show $\delta^{13}C$ trends very similar to those

observed in global compilations. This includes a 1 m thick interval across the BETM, where a -1.5‰ decrease in $\delta^{13}C$ corresponds to an anomalous presence of *Morozovella aequa* and a major benthic foraminiferal extinction event (BFEE). The Teurian/Waipawan boundary corresponds to the BETM, which is a globally recognized event. Overall, the Dee Stream section together with other stream sections in the region, are important sites for understanding environmental change at high latitude continental margins in the Southern Hemisphere during the early Palaeogene.

In Chapter 6, another early Palaeogene interval of anomalous deep-sea carbonate accumulation is investigated. Deep Sea Drilling Project (DSDP) Site 259 on the Perth Abyssal Plain, southwestern Australian margin, contains a ~30 m-thick unit of carbonate-rich sediment sandwiched between zeolitic clay and indicating a deepening of the CCD at this time. Carbonate contents, planktic and benthic foraminiferal assemblages, carbon and oxygen isotopes, and non-carbonate mineralogy were analyzed to further investigate the timing and nature of early Palaeogene carbonate deposition at Site 259. Carbonate content ranges from 3 to 80%, and generally exceeds 50% between 35 and 57 metres below sea floor (mbsf). The section spans planktic foraminiferal Zones P4c through P6b (~57-52 Ma) and contains a BETM interval. The BETM occurs across a clay-rich interval and is characterized by a significant BFEE, and an influx of large *Acarinina* planktic foraminifera. The $\delta^{13}C$ records of bulk carbonate and *Nuttallides* spp. carbon isotopes exhibit trends similar to those observed in Upper Paleocene-Lower Eocene sediment (~57-52 Ma) from other locations. Two successive decreases in $\delta^{13}C$ of 0.5‰ and 1.0‰ start at the BFEE. The mineralogy of the non-carbonate fraction of sediment consistently comprises expanding clay, quartz, heulandite (zeolite), pyrolusite (MnO_2), feldspar and minor mica. The uniformity of this assemblage suggests that Site 259 experienced continuity in sediment provenance and that the sediment record reflects a drop in the CCD from ~57 to 52 Ma.

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