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Foraminiferal biostratigraphy and palaeoecology in Upper Oligocene–Lower Miocene glacial marine sequences 9, 10, and 11, CRP-2/2A drill hole, Victoria Land Basin, Antarctica

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Abstract

Three Cape Roberts Project drillholes (CRP-1, -2/2A and -3) penetrated, in aggregate, a 1500 m succession of glacial marine Oligocene–Lower Miocene strata on the margins of Victoria Land Basin, the upper 1000+ m of which consists of a stack of more than 50 unconformity-bounded stratigraphic sequences. The benthic foraminiferal biostratigraphy, ecology, and lithofacies relationships of three contiguous sequences (Sequences 9, 10, and 11; 130.27–306.65 mbsf) from CRP-2/2A, were first determined and then tested against *Motif A*, a sedimentation model developed for the drillhole succession. These sequences apparently represent relatively complete glacial–deglacial cycles which span an interval of ~450 kyr straddling the Oligocene–Miocene boundary (~24 Ma). Sedimentological and paleontological data suggest shoreface–inner shelf to outer shelf basin margin settings with deposition under the influence of near-shore traction currents, subglacial ice contact, ice-rafting, meltwater, and turbidity associated with ice margin advance and retreat, along with sea level variations in the order of 50 m.

Stratigraphic distribution data for benthic foraminifera are at an average sampling interval of ~1 m (=~1000 to 3000 years), which offers stratigraphic resolution at less than orbital cycle frequencies in all major lithofacies within the three sequences. Taxa recovered represent a restricted immigrant group that repeatedly penetrated the shallow coastal waters during deglacial phases of each cycle and originated in the much more diverse assemblages of West Antarctic Rift System basins. Both eurytopic and stenotopic taxa are recognized. The former occur in all lithofacies and appear tolerant to a wide range of environmental parameters at and near the seafloor. Representative genera include, *Trochammina*, *Cassidulinoides*, *Fursenkoina*, *Eponides*, *Epistominella*, *Cibicides*, *Nonionella*, *Melonis*, *Pullenia*, *Elphidium*, *Ammoelphidiella*, and *Cribroelphidium*. Stenotopic taxa are less common, occur mainly in fine-grained lithofacies, represent maximum oceanicity, and coincide with maximum retreat of coastal glaciers and sea level highstands. Representative genera include, *Quinqueloculina*, *Pyrgo*, *Triloculina*, *Lenticulina*, *Marginulina*, *Vaginulinopsis*, *Nodosaria*, *Pseudonodosaria*, *Pyrulinoides*, *Oolina*, *Fissurina*, *Parafissurina*, *Rosalina*, *Anomalinoides*, and *Hanzawaia*. Planktic foraminifera are absent.

Our foraminiferal data provide strong support for the *Motif A* model, and allow interpretation of intra-model facies and events. *Motif A* is an idealized glacial stratigraphic sequence construct derived from analysis of the entire Upper Oligocene–Lower Miocene sequence stack. In this model, Lowstand System Tract (LST) diamictites form the base of the sequence. Diamictites with microfaunas are considered glaciomarine, those without are more likely ice-proximal or subglacial. Fine-grained sandstone, muddy sandstone, and mudstone of mid-sequence aggradational Transgressive System Tract (TST) and Highstand System Tract (HST) strata reflect high stands of sea level, inshore penetration of open marine waters, and peak recession of ice margins, and normally

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contain the most diverse and abundant microfaunas (up to 17 spp/sample). Sediments of the overlying Regressive System Tract (RST) display low and upwardly-declining foraminiferal diversity in response to glacier ice advance, sediment progradation across the basin margin, and falling sea level. The time-variable Glacial Surface of Erosion (GSE) or sequence boundary terminates the Regressive System Tract (RST) and demarcates the base of the succeeding stratigraphic sequence.
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Keywords: Antarctica; Victoria Land Basin; Oligocene; Miocene; Benthic foraminifera; Sequence stratigraphy; Glacial history

1. Introduction

In 1997, 1998 and 1999, the Cape Roberts Project (CRP) completed three drillholes (CRP-1, CRP-2/2A and CRP-3; CRST-Cape Roberts Science Team., 1998, 1999, 2000) from annual sea ice off the coast of the southwestern Ross Sea (Fig. 1). All three drill sites are located on Roberts Ridge, close to the western margin of the Victoria Land Basin. In total, the wells cored some fifteen hundred meters of Lower Oligocene–Lower Miocene (~34 to ~17 Ma) strata. Much of this succession comprises a multi-cyclic stack of at least 50 glacial marine clastic sequences, formed as a response to a dynamic terrestrial ice sheet margin and sea level fluctuations in this region of Antarctica over a period of some 17 million years from 34 Ma onward.

Naish et al. (2001a,b) selected three (9, 10 and 11) contiguous marine stratigraphic sequences, or glacial–deglacial cycles, from the 22 recognized in CRP-2/2A, and used sedimentary and chronostratigraphic evidence from them to propose orbital control of the ice sheet margin at the time of the Oligocene–Miocene transition (~24 Ma). This interpretation is likely to apply to deposition of the entire Lower Oligocene–Lower Miocene multi-cyclic sequence stack recovered in the CRP drillholes. Our data set for the benthic foraminiferal record (no planktics were recovered) in the same three contiguous stratigraphic sequences is used to assess the implications of these data for an idealized sedimentation model, or *Motif*. Because each stratigraphic sequence has an apparent duration of about 10^4 to 10^5 years and sediment accumulation rates were rapid, our metre-scale sample suite provides opportunities to track foraminiferal responses to changes in a variety of environmental parameters within single sequences, and to compare paleontological and biostratigraphical patterns between contiguous sequences.

The 22 Lower Oligocene to Lower Miocene sequences identified in CRP-2/2A vary considerably in thickness due to sedimentation patterns, accommodation space, and post-depositional erosion (Fielding et al., 2001, Fig. 4). We selected Sequences 9 (55.69 m, 130.27–185.96 mbsf), 10 (56.74 m, 185.96–242.70 mbsf) and 11 (63.95 m, 242.70–306.65 mbsf) for our study primarily because they are contiguous, reasonably fossiliferous, and constrained by robust chronostratigraphic control, with relatively complete glacial–deglacial cycles, high sediment accumulation rates (for high resolution sampling), well developed facies architecture including bounding unconformities (GSE or Glacial Surfaces of Erosion), and extensive supporting datasets. Further, these sequences featured in a keystone paper on results from the Cape Roberts Project (Naish et al., 2001a).

Foraminiferal data generated in this ice-proximal setting is relevant to issues such as the nature of glacier–ice stream–ice shelf advances and retreats close to a coastline, the impact of glacier–ice shelf grounding and detachment episodes, phases of iceberg launching, ice-rafted debris melt-out patterns, sedimentary processes, glacial lithofacies development, sea level and bathymetric oscillations, and the effects of changes in marine water mass structure and properties. The Victoria Land Basin maintained connections with the global ocean during the Early Oligocene–Early Miocene and so there is also the potential for major trends and episodes identified in the near-shore Antarctic glacial record to be recognized in low and middle latitude shallow continental shelf and deep ocean environments.

2. CRP-2/2a drillhole stratigraphy

2.1. Background

CRP-2/2A, sited 14 km east of Cape Roberts (77.006° S; 163.719° E) in 178 m of water, was drilled to a total depth of 625 mbsf during October–November 1998. Overall core recovery was 95% (CRST, 1999, p. 68, Fig. 3.3, and p. 166, Fig. 7.4). Quaternary and Pliocene strata occur to a depth of 26.79 mbsf. Sediments between 26.79 and 564.63 mbsf are Early Miocene (~17 Ma) to Early Oligocene (~31 Ma), and probably are Early Oligocene from 564.63 to 624.15 mbsf (total depth) (Wilson et al., 2000). Stratigraphic Sequences 3–24 are identified in the Oligocene–Miocene succession of glacial marine near-shore to offshore clastic sediments (CRST, 1999). These sediments are thought to be part of a regionally extensive marine

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