

## Sedimentary Environments for CRP-3

### Introduction

The ten papers in this section present a variety of analyses relating mostly to depositional setting and sedimentation patterns (facies analysis, sequence stratigraphic analysis, textural analysis) but also describing carbonate and organic content (minimal) in this 823-m-thick record of early Oligocene (and possibly latest Eocene) basin margin sedimentation. Some reports take into account the overlying strata cored in CRP-2/2A. The origin of the extensive smectite cement in the lower part of the core is also investigated. Reports on diagenesis and high frequency analysis of physical properties of the Cenozoic strata, and of the petrology of the underlying Devonian Beacon strata will appear in a later issue of *Terra Antartica*.

The first paper, by Powell et al., summarises the characteristics of facies encountered in the younger strata of the two previous drillholes, and their occurrence in the CRP-3 sequence. The CRP-3 core includes ten facies that occur in 5 major associations. These record a changing depositional environment from the initial talus/alluvial fan setting of a glaciated rift margin, through deposits interpreted as deltaic and distal to tidewater glaciers fed from the palaeo-Mackay valley, to sediments deposited in ice-marginal, possibly grounding line fan settings. The relationship between glacier fluctuations and inferred sea level changes is discussed, and caution urged in attempting correlation between local and global events and  $\delta^{18}\text{O}$  curves.

Sequence patterns and facies architecture for CRP-3 are reviewed by Fielding, Naish & Woolfe, who have divided the Cenozoic core into three parts based on the presence and character of depositional cycles. The upper part comprises 14 cycles in CRP-3 (down to 330 mbsf), characterised by a facies pattern similar to that of CRP-2/2A and designated Motif A. It typically comprises shallow water glacially influenced lower and upper section, and a deeper water less glacially influenced middle section, inferred to represent variations in relative sea level driven by ice sheet fluctuations. The strata between 330 and 480 mbsf include a further 9 cycles, but with the facies organised in a simple fining-upward pattern and lacking a fine-grained core (Motif B). They still include glacial features such as out-sized clasts but contain no indication of direct glacial deposition. Below 480 mbsf the core comprises a thick succession of sandstones with occasional fining-upward sandstone-conglomerate units. The authors suggest that these lower units are more likely to represent event deposits related to local geomorphic thresholds than lowstands in relative sea level. A key conclusion from the analysis of the cyclic sequences is that the thickness of each cycle reflects accommodation space and is hence directly related to tectonic subsidence.

Naish et al. review the cyclicity of sediments in CRP-2/2A and CRP-3 but with a particular focus on well-developed sequence scale cycles and intra-sequence scale variations for intervals with relatively good age control. The depth (time) series of grain-size data were subjected to spectral analysis, which has revealed Milankovitch frequencies (41 k.y. and possibly 100 k.y.) for the sequences, which are interpreted as representing variations in sea level and extent of the Oligocene-early Miocene East Antarctic ice sheets. The study provides further support for a similar conclusion based on the exceptionally well-dated sequences 9, 10 and 11 in CRP-2/2A (Naish et al., *Nature*, 2001). The analysis also reveals indications of intrasequence cyclicity that might relate to ice-rafting episodes unrelated to major ice volume changes. Intrasequence cyclicity is examined further using a range of physical core properties by Florindo et al. (*Terra Antartica*, submitted).

Grain size data for 115 samples from the Cenozoic strata in CRP-3 by sieve and Sedigraph analysis are presented by Barrett as a check on the visual core descriptions. Most analyses confirm them but a few differ significantly. The paper also reviews the depositional setting of these strata, concluding that all but the lower few tens of metres were deposited on an open coast in a nearshore marine environment. He also finds that variations in size frequency distributions through the cycles in the upper part of CRP-3 are consistent with variations in water depth inferred from sequence stratigraphic analysis. Details of the textures also reveal periods of ice-rafting, and the occurrence of diagenetic clays in the lower part of CRP-3, studied in depth by Wise et al. (see below).

Grain size data for 719 samples from CRP-3 by a rapid laser technique are presented by Fielding, Dunbar and Bryce. This uses a much smaller sample size (~1 g) than the standard

sieve technique (20 g). Checks on the initial data set and some reanalysis indicated incomplete disaggregation of some samples, which has led to a useful review both of the measuring system and sample processing procedures. They show that the laser system is capable both of consistent analyses (for sand +2%) and of results that are closely comparable with the sieve-Sedigraph technique. Fielding et al. take advantage of the relatively close-spaced sampling interval to undertake entropy analysis. This allowed the recognition of four groups of samples, each with its own distinctive grain-size distribution. Going downhole, group 1 (multi-modal, corresponding to *e.g.* mudrocks and diamictites) disappears and groups 3 and 4 (sand dominated) become dominant. This reflects the change from mudrock- and diamictite-rich lithology to clean well-washed sandstones with minor conglomerates. They also noted significant shifts in grain-size parameters and entropy group membership across sequence boundaries.

Glacial influence as reflected in clast features in both CRP-2/2A and CRP-3 is investigated by Atkins. He determined clast orientation and shape parameters for 22 whole core samples. Those from CRP-2/2A are mostly diamictite with a few conglomerate samples, whereas those from CRP-3 comprise just one diamictite (at 92 mbsf) with those at greater depth being conglomeratic. He concludes from the proportion of faceted clasts and the mix of roundness classes that most clasts have experienced subglacial transport. Clast fabrics from 7 diamictites just above sequence boundaries are generally weak or random, and imply that grounding did not occur at these intervals. However sample numbers are small, and a microfabric study by Passchier and van der Meer (*Terra Antartica*, 2000) for diamictites in the upper part of CRP-2/2A does indicate periods of subglacial grounding. Atkins notes that striated clasts and out-sized clasts are found scattered throughout the entire length of both cores, indicating a persistent glacial influence (calving and ice-rafting) through most of the time represented by them and even in the earliest Oligocene or possibly latest Eocene.

Hall et al. also studied clasts from CRP-3, but specifically the weathering rinds in a pilot study of two intervals in CRP-3 (272-300 and 480-562 mbsf) as a means of deducing terrestrial palaeoenvironmental conditions. They observed rind thicknesses of 0.2 to 2.0 mm, indicating relatively wet and warm terrestrial conditions. XRD analysis of those from the upper interval revealed the presence of vermiculite and smectite, typical of chemical weathering under such conditions. Analyses of clasts from the lower interval indicated little chemical change.

The extensive development of smectites as clay coatings on sand grains in the lower part of the CRP-3 is described by Wise et al., and the evidence reviewed in the context of similar occurrences elsewhere. Their preferred explanation is that the smectite formed by burial diagenesis at relative shallow depths and temperatures with material sourced from volcanogenic and heavy mineral grains from within the sequence. However, they also consider two other possibilities - that some may be a consequence of hydrothermal waters associated with igneous intrusions or nearby faults, and by mobilisation of "thermobaric" fluids along a nearby fault. Further studies should clarify the origin of the smectites further.

Carbonate content of 98 samples from CRP-3 is reported by Dietrich. The carbonate content is typically 1-2% above 220 mbsf and below 630 mbsf, but is erratically higher (2-5%, with 4 of the samples over 15%) in the middle section of the core. Carbonate cement is common as patches and horizons, as well as in thin veins throughout the hole, and will be described in detail by Aghib et al., (*Terra Antartica*, submitted).

Whole-rock organic geochemistry of 71 samples from CRP-3 is reported by Kettler. Total organic carbon content throughout CRP-3 is minute (average 0.3%), though it is slightly higher above 330 mbsf where there is a higher proportion of mudstone. A significant fraction of the organic matter is detrital coal, which is also recorded in visual core descriptions, and is most likely from the Permian coal measures in the mountains to the west. Total sulphur content is also very low, but indicates that a suggestion that the modiolid mussel communities in subunits 1.1 and 13.1 reflect an H<sub>2</sub>S-rich environment is unlikely.

As a final comment we note that sedimentological studies of CRP-1 and CRP-2/2A established that sedimentation in the late Oligocene-early Miocene was primarily shallow marine, although under the strong influence of a fluctuating ice margin, with well-defined sequence boundaries relating to grounding events or ice marginal processes and changes in sea level. This pattern extends down into the early Oligocene of CRP-3, although in earliest Oligocene times sedimentation appears to have been less obviously glacially influenced by either ice margin or sea level fluctuations, perhaps as a consequence of rapid basin subsidence.

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