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Provenance and Climate from Petrological Studies for CRP-3

Introduction

The twelve papers presented in this section describe the results of petrological investigations of bulk sediment samples and of the different detrital components (clasts, sand grains, mud, clay minerals, heavy minerals and ferrimagnetic minerals) in CRP-3 samples. They document the extensive and manifold laboratory-based core characterization of the Oligocene CRP-3 sequence, and they focus on environmental magnetic properties, petrology and geochemistry to obtain new and clearer information on the sediment source area, the early uplift and erosional history of the putative Transantarctic Mountains, and the Oligocene palaeoenvironmental record in the southern Ross Sea region.

Granule- to boulder size fragments were investigated systematically throughout the core in order to determine both the petrographical and chemical character of the clasts, and to document their distribution patterns (Sandroni & Talarico). As in previous CRP drillcores, biotite±hornblende monzogranites are the most abundant basement-derived pebbles. They are ubiquitously distributed and indicate a local provenance. The clasts closely mirror the dominance of respective lithologies in the on-shore basement, where the Cambro-Ordovician Granite Harbour Intrusive Complex forms the most extensively exposed rock unit. Nevertheless, the occurrence of scattered clasts of foliated low-grade metasediments suggests that the low-grade Skelton Group, about 200 km south of the CRP-3 drill site, may also have contributed minor detritus to the CRP-3 sequence.

Detrital components of volcanic and subvolcanic origin have been investigated by Pompilio et al. in order to define their provenance and to reconstruct the volcanic history of the area. The granule- to boulder size clasts are geochemically and mineralogically comparable to the rocks of the Ferrar Supergroup. A few strongly altered glass shards had been detected in the sand and silt fractions of the sediments. They have a subalkalic magmatic affinity. The abundant and less altered clinopyroxene grains indicate an origin from subalkaline magmas. This excludes the influence of an alkaline activity comparable with that of the McMurdo Volcanic Group.

Detrital modes determined petrographically on sand grains provide multiple evidence for a local provenance rooted overwhelmingly in the Dry Valleys Block (Smellie). The modes also demonstrate that earliest erosion removed much of the capping Jurassic Kirkpatrick basalt sequence in the source area prior to the formation of the Victoria Land Basin. The oldest sediments present in CRP-3 were derived exclusively(?) from the Beacon Supergroup, initially the Victoria Group then Taylor Group, during an early Oligocene phase of rapid uplift. Above 788 mbsf, pre-Beacon basement became widely exposed in the Dry Valleys Block and contributed a relatively constant proportion of detritus (5-20%) to the sediments during a tectonically relatively stable period that extended to the top of CRP-3.

Factor logs derived from downhole-logging data (Bücker et al.) reflect basic geological controls, especially grain size, lithology (glacial influence) and sediment provenance, and cluster analysis of the logs successfully delineates many individual geological units. Two types of sandstones, distinguished mainly on their magnetic and radiogenic properties, were characterised in the lower part of CRP-3 (below 630 mbsf). A major change in sediment source at 630 mbsf, from Victoria Group below to Taylor Group above, mirrors changes also identified in the detrital modes.

Analysis of the environmental magnetic properties (Sagnotti et al.) identified at least four main rock magnetic intervals that do not correspond to lithostratigraphic or sequence stratigraphical boundaries. The authors correlate transitions between the intervals with significant environmental events, such as the major shift in the deep-sea oxygen isotopic records associated with the prominent cooling that occurs across the Eocene-Oligocene boundary, though palaeontological evidence of this is lacking (Hannah et al., this volume).

The heavy mineral composition of very fine sand fraction of the CRP-3 sediments was determined by microscopic investigation (Neumann). Above about 200 mbsf, the heavy mineral assemblage contains abundant pyroxenes, whereas below that depth a variety of stable minerals (*s* zircon, tourmaline), amphibole, and altered and opaque grains are more common. There are no alkaline ferromagnesian heavy minerals, indicating that McMurdo Volcanic Group activity was absent, a conclusion also supported by results of the detrital modes and bulk sand sediment geochemistry. The presence of pyroxene and garnet grains can be used to distinguish the Cenozoic sediments from Beacon Supergroup sandstones recovered below 823 mbsf, which the Cenozoic sediments otherwise strongly resemble. Garnet is locally very common, despite its paucity on plausible source rocks, and is tentatively attributed to selective partitioning during transport and deposition.

XRD analysis of bulk mineralogy (Neumann & Ehrmann) indicate that quartz, plagioclase, K-feldspar, pyroxene and minor amphibole are the most important non-clay minerals. Their distribution patterns reflect an evolving provenance: from the Victoria Group and Ferrar Supergroup below *c*. 620 mbsf, from Taylor Group between *c*. 620 and *c*. 420 mbsf, and from a mixed source including Ferrar Supergroup and basement rock units above *c*. 420 mbsf. The XRD analysis therewith supplement the data gained from clast analysis and detrital modes. They also provide evidence of some diagenetic alteration reflected by trace amounts of opal-CT in several intervals and of minerals of the heulandite group between 360 and 80 mbsf.

XRD and TEM techniques were used to investigate the clay fraction of the sediments, especially the abundance and crystallinity of smectites (Ehrmann) and their crystal-chemistry (Setti et al.). These studies clearly point out that the CRP-3 clay mineral assemblages are very different from those of the CRP-1 and CRP2/2A drill cores. Well-crystalline smectites of probably authigenic origin (intermediate members of the beidellite-saponite series) characterize the sequence between 800 and 625 mbsf, the clay fraction of which consists of almost 100% smectite. Also the interval 625-330 mbsf contains almost exclusively smectites, but they are moderately crystalline, chemically variable and at least in part of detrital origin. This assemblage indicates weathering under a relatively warm and wet climate. In the interval 330-145 mbsf smectites fluctuate between 50% and 100% and document alternating phases of warm and wet climate with chemical weathering and cool and dry climate with physical weathering. In contrast, an illite- and chlorite-dominated assemblage with only minor amounts of poorly crystalline detrital smectite (Fe-rich beidellites) is typical for the uppermost 145 mbsf. Such an assemblage reflects physical weathering under a polar climate and dominated also the sediments of cores CRP-1 and CRP-2/2A.

Bulk sample XRF geochemistry of fine to coarse sandstone samples (Sprovieri et al.) indicates an increased contribution from the Beacon Supergroup sandstones in the interval between 600 mbsf and 200 mbsf, and a dominant provenance from the Ferrar Supergroup above 200 mbsf and below 600 mbsf. The preliminary results obtained by spectral analyses of three selected signals suggest a possible direct link between astronomical forcing and the sedimentary system in the 340-790 mbsf interval.

XRF geochemical analyses on mudstones and siltstones (Krissek & Kyle) were used to investigate the provenance and the palaeoweathering intensities in the source. Also these data confirm that little or no McMurdo Volcanic Group detritus was incorporated into the CRP-3 sediments and that the main source was in the Transantarctic

Mountains. Furthermore, they verify that the importance of basement-derived material is greatest above *c*. 200 mbsf, whereas Beacon Supergroup and Ferrar Supergroup components dominate below that level. The general decreasing trend of the chemical index of alteration above 400 mbsf may indicate a decrease of chemical weathering, but this trend is superimposed by four cycles probably caused by changes in provenance.

Finally, analysis of bulk sandstone samples and sand grains in CRP-2/2A samples by laser-ablation ICP-MS and electron microprobe by Armienti et al. has documented an abundant contribution from alkaline McMurdo Volcanic Group multiple sources. Compositions range from alkali basalt to trachyte and peralkaline phonolite (Armienti et al.). The CRP-2/2A sequence also includes tephra-fall interbeds, the coarsest and thickest of which may have been erupted at an important local volcanic centre situated less than 30 km from the drill site at 21.44 Ma. However, no contemporaneous volcanic debris was found below 307 mbsf in CRP-2/2A or in older strata of CRP-3. Thus, the data also confirm that inception of McMurdo Volcanic Group activity in southern Victoria Land occurred much later (by about 24 Ma) than that in northern Victoria Land.

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