Foraminiferal Biostratigraphy and Palaeoecology from two Intervals of the CRP2/2A Drilhole, Victoria Land Basin, Antarctica

S. GALEOTTI[1*], M.B. CITA[2] & R. COCCIONI[1]

[1]Istituto di Geologia & Centro di Palinologia dell'Universita, Campus Scientifico, Localita Crocicchia, 61029 Urbino - Italy
[2]Dipartimento di Scienze della Terra, via Mangiagalli, 34, 20133 Milano - Italy

*Corresponding author (s.galeotti@uniurb.it)

Abstract - An analysis of foraminifera from two stratigraphic intervals of the CRP-2/2A drillhole (Ross Sea, Antarctica) revealed the presence of poor assemblages dominated by benthic, calcareous-hyaline species. The virtual absence of planktonic foraminifera and of useful stratigraphic markers in benthic foraminiferal assemblages precludes long-distance correlation beyond Antarctica. Benthic foraminiferal assemblages indicate that the upper part of the upper Oligocene-lower Miocene CRP/2A core was deposited in a shallow water environment, possibly characterised by stressed sea floor conditions. A deeper depositional setting and a more stable environment is suggested for the lowermost part of the sequence (?Eocene- Oligocene) based on benthic foraminiferal assemblage data.
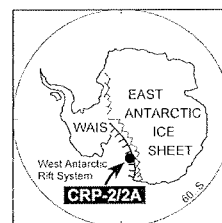
INTRODUCTION

One of the primary goals of the Cape Roberts Project (CRP) is to better understand the evolution of the Antarctic ice sheet and its influence on global climate changes and sea-level fluctuations. Such a goal is clearly dependent on establishing long-distance correlation with areas beyond Antarctica, where multiple palaeoclimatic and palaeoceanographic proxies have been tied to sequences with well established global stratotype sections and points (GSSP). The Oligocene/Miocene (O/M) and Eocene/Oligocene (E/O) GSSPs, which define boundaries between Epochs, and which may be associated with the evolution of the Antarctic ice sheet, have been officially approved by the International Commission on Stratigraphy in the past decade. The former (O/M) is defined in the Lemme section (northern Italy), in a continuous marine section positioned within chron C6Cn-2, at the base of foraminiferal Zone M1 and of calcareous nannofossil Zone NN1, and has a numerical age of about 23.8 Ma. The E/O boundary is defined in the Massignano section of central Italy, in a continuous marine section positioned in the lower part of chron C13n, at the base of foraminiferal Zone P18, within nannofossil Zone NP 21, and is dated at 33.7 Ma by radiometric age determination of ash layers.

The CRP/2/2A drill hole extended to 624 meters below the sea floor (mbsf) to strata dated at approximately 31-33 Ma, encompassing the Oligocene-Miocene boundary and possibly approaching the Eocene-Oligocene boundary (Cape Roberts Science Team, 1999; Wilson et al., this volume). In this study we explore the possibility of identifying these Cenozoic epoch boundaries within the CRP2/2A succession by direct foraminiferal correlation with northern hemisphere boundary stratotypes. Regional correlation with other sequences drilled in the Ross Sea area and a palaeoecological interpretation of the two foraminiferal assemblages are also attempted.

MATERIAL AND METHODS

A set of 20 samples was obtained from an interval (referred to here as Interval 1) between 122.70 mbsf to 140.63 mbsf, which according to age determination by CRP-2 Science Team would include the O/M boundary (Cape Roberts Science Team, 1999). A second set of 19 samples was obtained from an interval (referred to here as Interval 2), which spans the lowest 44 meters of the CRP2/2A core (from 582.49 mbsf to 624.07 mbsf). The sample location within this second interval was selected on the basis of criteria presented in the section on sequence stratigraphy (Fielding et al., this volume).

Sample preparation for foraminiferal study involved the gentle crushing of 10-cc sediment samples and disaggregation with diluted hydrogen peroxide solution, washing through a 63 µm sieve and drying. Samples from the lower of the two intervals investigated (Lithostratigraphic Units 15.3 to 15.6) were well-indurated and difficult to disaggregate. To obtain a reasonable quantity of residue, a triple cycle of the above described laboratory procedure was carried out on these samples. Residues were splitted into 3 fractions, 63-125 um, 125-450 um, and >450 um. Samples were then thoroughly analysed by picking all foraminiferal tests present in the two finer fractions.

RESULTS

The distribution of identified species from Intervals 1 and 2 is reported in figures 1 and 2, respectively, along with CRP2/2A core lithology, lithostratigraphic units, and comments on the state of foraminiferal preservation.

Interval 1 (122.70 mbsf to 140.63 mbsf; Fig. 1)

Test numbers in samples from Interval 1 are generally low and five samples were found to be barren of foraminifera. Preservation ranges from very poor to fairly good. Most of the samples studied provided fewer than ten specimens, with a maximum of 32 specimens recovered in a sample from 139.25-139.27 mbsf. A total of 14 species were identified. No significant changes in the taxonomic composition of foraminiferal assemblages were observed within the interval examined. Assemblages are dominated by calcareous-hyaline benthic forms. Faunal diversity in single samples is very low and never exceeds 8 species. Only one planktonic foraminiferal test (*Globigerina* sp.) was recorded. Arenaceous forms such as *Rhizammina* and

Haplophragmoides are extremely rare, with single specimens occurring at 122,70-122,72 mbsf and 130,09-130,11 mbsf, respectively. The benthic fauna consists mostly of infaunal taxa. Characteristic taxa include *Cribroelphidium magellanicum*, *Melonis barleeanum* and *Nonion graniferum*. No evidence for reworking of tests was detected.

Interval 2 (582.49 mbsf to 624.07 mbsf; Fig. 2)

Samples from this interval provided a much more impoverished fauna compared to that of Interval 1. Only 5 of the 19 studied samples contained foraminifera. This poor return might be partly due to sample preparation. Repeated mechanical disaggregation might have further contributed to the loss of foraminiferal specimens. Broken specimens have, in fact, been observed in sample 582.49-482.52 mbsf. A maximum of 25 specimens were recovered in the latter sample. A total of 11 species has been identified from Interval 2. Characteristic taxa include *Cassidulinoides parkerianus*, *Anomalinoides* cf. *capitatus*, *Cibicidoides* cf. *bradyi* and *C. temperatus*.
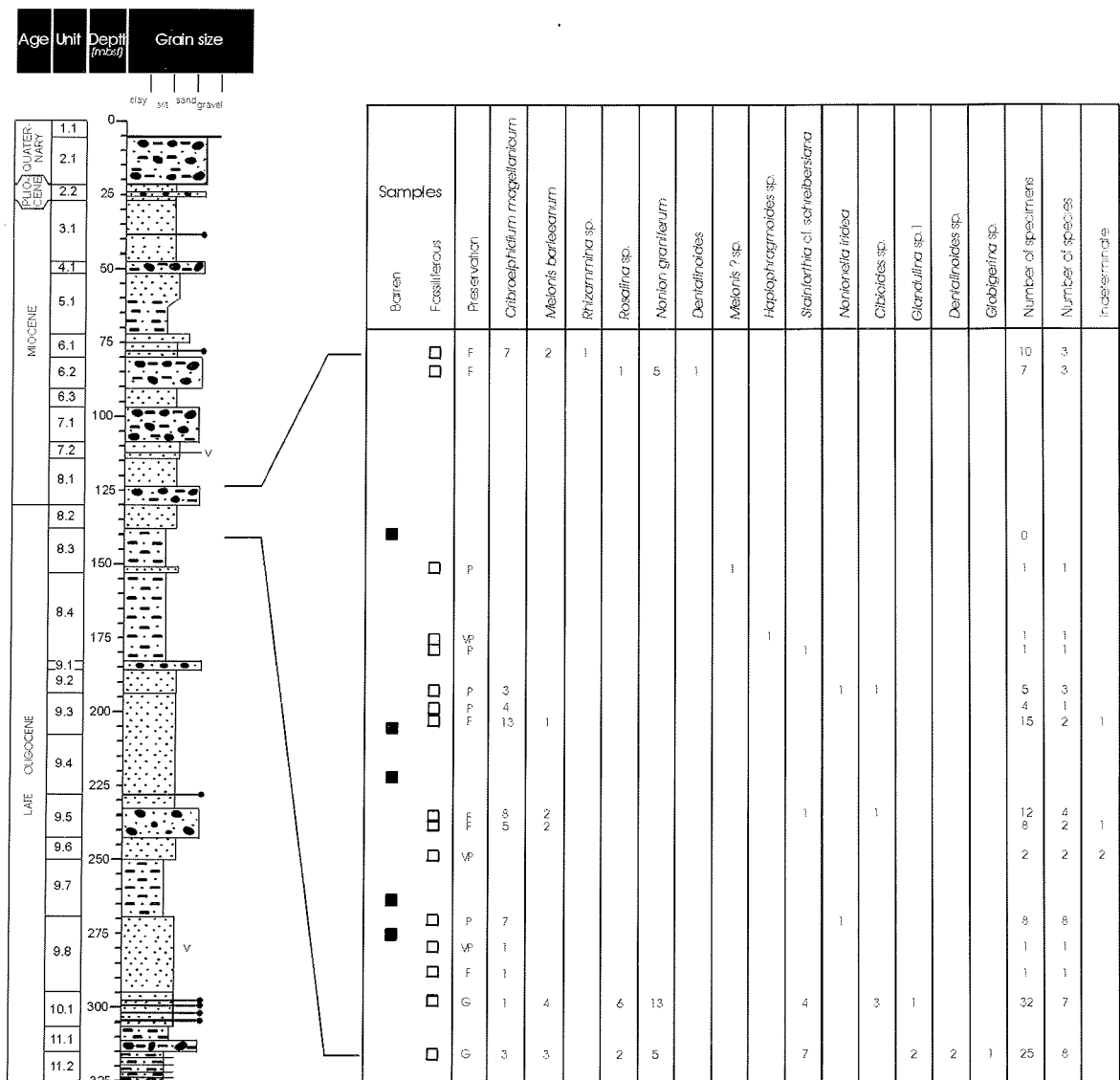

Fig. 1 - Distribution of foraminiferal species from Interval 1 of CRP2/2A. State of preservation as follows: VP= Very Poor; P= Poor; F= Fair, G= Good.

DISCUSSION

BIOSTRATIGRAPHY

The absence of planktonic foraminifera and lack of useful stratigraphic markers in benthic foraminiferal assemblages from both Interval 1 and Interval 2 precludes long-distance correlation, and calibration with biostratigraphic data provided by diatoms (see Cape Roberts Science Team, 1999; Scherer et al., this volume).

Interval 1 (Fig. 1) contains a benthic foraminiferal fauna comparable to assemblages previously described from other sites drilled in the Ross Sea region. In particular, assemblages dominated by *Cribroelphidium magellanicum*, *Nonion graniferum*, and *Melonis barleeanum* have been observed in the Miocene succession of the CRP-1 drillhole (Galeotti and Coccioni, 1998; Strong and Webb, 1998). Both successions are characterised by the virtual absence of planktonic foraminifera and benthic agglutinated taxa. As already reported by Galeotti and Coccioni (1998), this foraminiferal

association is reminiscent of faunas previously described from other sites drilled in the Ross Sea such as DSDP Site 270 (Leckie and Webb, 1986) CIROS-1 (Webb, 1989) and DVDP-10 and 11 in eastern Taylor Valley (Ishman and Webb, 1988), and seems to represent a common biofacies in the Miocene of the Ross Sea basins. Other CRP-2/2A taxa in common with the Miocene CRP-1 are *Stainforthia* cf. *schreibersiana*, *Globocassidulina subglobosa*, and *Nonionella iridea*.

A quite different foraminiferal assemblage was recovered from Interval 2. Although much more impoverished compared to Interval 1 assemblages, faunas from the lower part of CRP2/2A resemble ?late Eocene-early Oligocene foraminiferal assemblages from the CIROS-1 core (Webb, 1989; Coccioni and Galeotti, 1997). Taxa in common with the lower part of the CIROS-1 core include *Stainforthia* cf. *schreibersiana*, *Anomalinoides* cf. *capitatus*, *Cibicidoides* cf. *bradyi*, and *C. temperatus*. The consistent presence of *Cibicidoides* cf. *bradyi* and *Stainforthia* cf. *schreibersiana*, in particular, allows us to compare Interval 2 assemblages with Assemblage C of
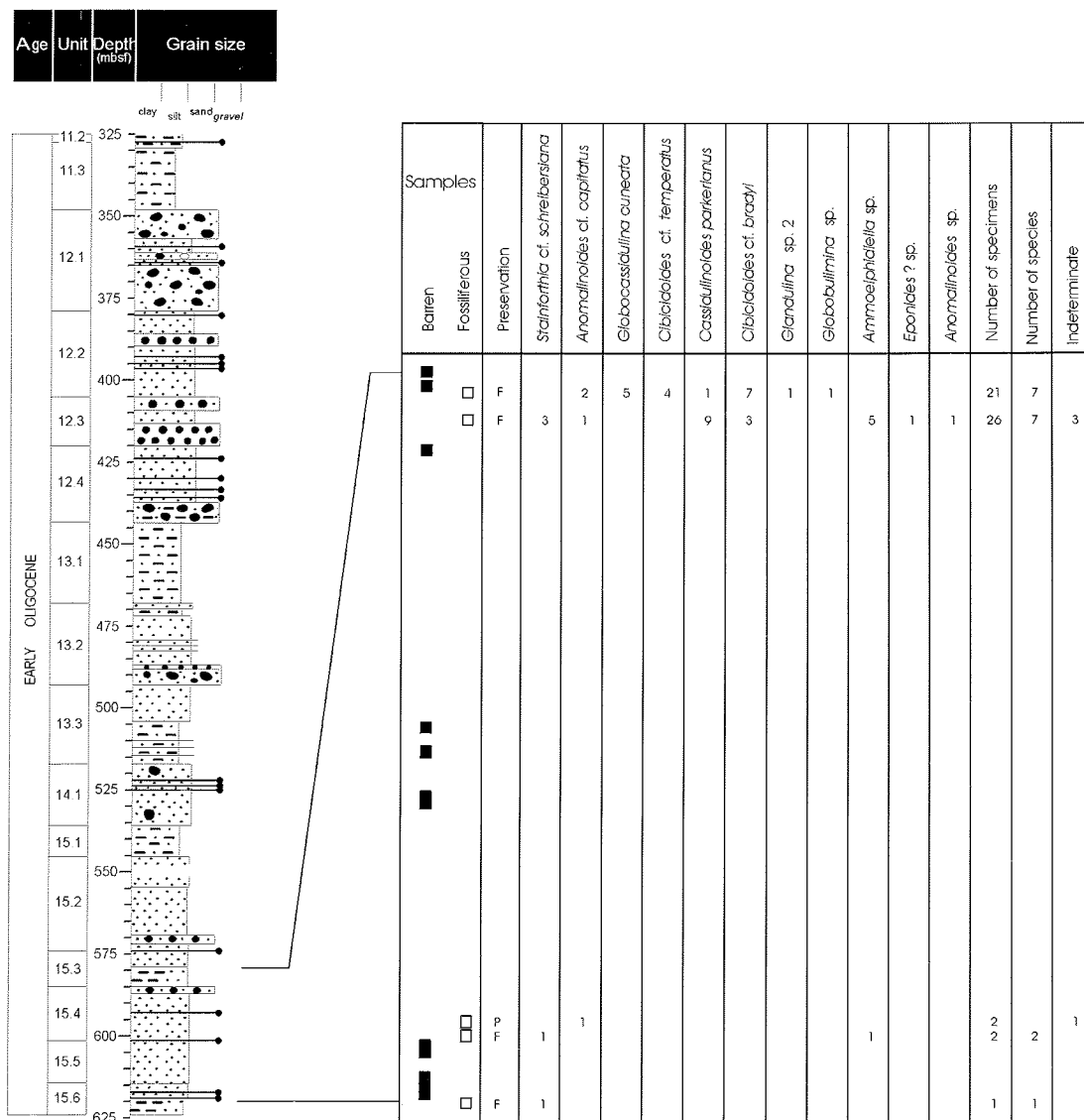

Fig. 2 - Distribution of foraminiferal species from Interval 2 of CRP2/2A. State of preservation as follows: VP= Very Poor; P= Poor; F= Fair, G= Good.

Coccioni & Galeotti (1997) in the CIROS-1 core. However, faunas recovered from the lower part of CRP2/2A core are also characterised by the consistent presence of *Cassidulinoides parkerianus* and of the genus *Cribroelphidium*, which are characteristic taxa of the Early Oligocene CIROS-1 Foraminiferal Assemblage D of Coccioni and Galeotti (1997).

Although Foraminiferal Assemblage C and D from CIROS-1 and Interval 2 assemblages from CRP-2/2A do not share many other features in terms of taxonomic composition and diversity, the assemblages from the lower part of CRP2/2A have elements in common with both and might be regarded as transitional between the late Eocene-Oligocene Assemblage C to the early Oligocene Assemblage D. Such a transitional assemblage was not observed in CIROS-1 core (Webb, 1989; Coccioni & Galeotti, 1997). The presence of a major hiatus at c. 366 mbsf in CIROS-1 core (Hambrey *et al*., 1989; Wilson *et al*., 1998), which separates foraminiferal Assemblage C from Assemblage D, might account for the lack of such a transition. The lower part of the CRP2/2A drillcore might, therefore, represent a time interval which is lost in the CIROS-1 core in the major hiatus recorded at 366 mbsf. Alternatively, elements from older strata (possibly from the interval represented by the major hiatus in CIROS-1 core) might have been reworked and mixed with early Oligocene foraminiferal assemblages represented by Foraminiferal Assemblage D in CIROS-1 core.

PALAEOENVIRONMENT

Foraminiferal assemblages from the CRP2/2A core are almost entirely composed of calcareous-hyaline forms (see also Strong and Webb, this volume), with arenaceous forms (*Rhizammina* and *Haplophragmoides*) being extremely rare and confined to single specimens in Lithostratigraphic Subunit 8.1 and 8.2.

The distinct separation of calcareous-hyaline and arenaceous assemblages seems to be a common characteristic of the present day Ross Sea Basin microfaunas where these forms rarely occur together, but rather predominate in different parts of the region (Ostermann and Kellogg, 1979). Different hypotheses have been postulated to explain this phenomenon which is also a common feature of benthic foraminiferal assemblages in the Weddell Sea (Anderson, 1975a, b). McKnight (1962) and Pflum (1966) have suggested that ocean currents removed calcareous foraminifera from certain areas in the Ross Sea floor. Kennett (1966) plotted depth distributions of benthic foraminifera and proposed that a shallow (550 m) Carbonate Compensation Depth (CCD) existed in the Ross Sea, effectively prohibiting calcareous faunas at greater depths. Later observations by the same author (Kennett, 1968) of calcareous-hyaline faunas at depths greater than 550 m were attributed to sediment slumping. A mechanism of reworking of calcareous-hyaline faunas from older sediments into water depths greater than 400 m was also invoked by Fillon (1975) based on comparison of benthic foraminiferal assemblage and grain-size distribution. However, Ostermann and Kellogg (1979)

showed that the dissimilar distribution of calcareous-hyaline and agglutinating forms which results in contrasting distribution of the two groups is not linearly related to water depths. They found that benthic faunas from the eastern Ross Sea consist of arenaceous species whereas calcareous species predominate in the western sector of the Ross Sea. Following Anderson (1975a, b), the latter authors suggested that such a pattern results from an uneven depth of a CCD that is related to the concentration of CO_2 in the water column, and in turn, related to different productivity levels. In particular, high concentration of CO_2 would result from heavy pack-ice concentrations and concomitant low rates of photosynthesis, causing the CCD to occur at shallower depths. However, although explaining the exclusion of calcareous-hyaline forms from areas characterised by a shallower CCD, this hypothesis does not elucidate why arenaceous forms are virtually absent from areas dominated by calcareous-hyaline species.

On the other hand, calcareous-hyaline species dominated assemblages are a common characteristic of Cenozoic drillhole successions in the Ross Sea area, *e.g.*, such as at CIROS-1 (Webb, 1989; Galeotti and Coccioni, 1997), CRP-1 (Galeotti and Coccioni, 1998; Strong and Webb, 1998), CRP-2 (see also Strong and Webb, this volume). Understanding the factors limiting arenaceous forms is, therefore, an important key to better understanding the distribution of deep water masses in this areas and relationships to the presence/absence of an ice cover.

However, some general considerations based on benthic foraminiferal assemblages from CRP2/2A are still possible. In Interval 1, in particular, the dominance of infaunal taxa (*e.g. Melonis, Cribroelphidium, Nonion*) is interpreted as reflecting a restricted environment with moderate oxygenation on a stressed sea floor. These forms, in particular, show an extended stratigraphic range beginning in the early Oligocene in the Ross Sea area and being often dominant in low-diversity assemblages of Oligocene-Miocene sequences. They may be regarded as opportunistic and adapted to glacially influenced environments. Evidence for stressed seafloor conditions have also been documented at CRP2/2A by the Cape Roberts Science Team (1999) where there is a low abundance of benthic diatoms. In contrast, at CRP-1 and CIROS-1, there are intervals with a significant abundance of benthic diatoms, typically indicative of shallow-water deposition (<50 m) (Harwood, 1989; Harwood et al., 1998). According to CRP Science Team (1999), benthic diatoms might be excluded from parts of the stratigraphic section due to high sediment input and turbid waters. In particular, a high suspended sediment load would allow limited light penetration and a highly mobile bottom may have limited colonisation by many benthic diatom taxa.

Such a palaeoecological situation might have favoured the repeated colonisation of a disturbed (possibly azoic) substrate by infaunal species which have a higher dispersal rate among benthic foraminifera (see Alve, 1999 for a review on this topic). A similar setting might, however, have been produced by periodic retreat and extension of marine glacier ice fronts. A more stable sea-floor environment is indicated by benthic foraminiferal

assemblages from Interval 2 where the consistent presence of epifaunal forms is documented.

PALAEOBATHYMETRY

A clear distinction can be made between the assemblages of Interval 1 and Interval 2 in terms of palaeobathymetric depositional setting. The consistent occurrence of *C. magellanicum* which dominates assemblages throughout Interval 1, is considered to be indicative of an inshore setting. This taxon has been reported to be common in Oligocene-Miocene sediments from the Ross Sea Basins (DSDP Site 273, D'Agostino, 1980; DSDP Site 270, Leckie & Webb, 1986; DVDP 10 and DVDP 11, Ishman & Webb, 1988; CRP-1, Galeotti and Coccioni, 1998; Strong and Webb, 1998). The palaeobathymetric interpretation based on foraminiferal assemblages agrees well with a depositional depth of ca. 50 m as suggested by the near absence of benthic diatom taxa (see Cape Robert Science Team, 1999) throughout the interval recovered in CRP2/2A.

A deeper depositional setting is indicated by foraminiferal assemblages from Interval 2. Following Van Morkhoven *et al.* (1986), the consistent presence of *Cibicidoides* cf. *bradyi* and *Anomalinoides* cf. *capitatus* together with the presence of *Epistominella exigua* reported to occur in adjacent stratigraphic interval by Strong and Webb (this volume) is indicative of a bathyal/abyssal affinity for benthic foraminiferal assemblages recovered from the lower part of CRP2/2A drillcore. However, although these taxa have a cosmopolitan distribution, their upper depth limit in polar waters might have been much shallower than reported by Van Morkhoven et al. (1987) from tropical-subtropical settings. In fact, as reported by Milam and Andersson (1981) from the modern polar environments, benthic foraminifera exhibit a shallower upper depth limit at high latitudes than is characteristic of low latitudes. Assemblages from the lower part of CRP2/2A (*i.e.*, Interval 2) are interpreted as reflecting a neritic to upper bathyal depositional setting at a palaeodepth of 100-200 metres.

CONCLUSIONS

Very low to medium diversity foraminiferal assemblages, nearly exclusively composed of calcareous-hyaline benthic taxa, characterise the two intervals studied from the CRP-2/2A drillhole.

The lack of planktonic foraminifera and critical stratigraphic markers among the benthic foraminiferal assemblages precluded correlations with standard Palaeogene-Neogene zonations and comparison with lower latitudes sequences and the GSSPs' of Lemme and Massignano.

An assemblage-based correlation with other sites previously drilled in the Ross Sea region is possible. The assemblages documented here suggest a shallow water depositional setting *(c.* 50 m) in the upper part of the CRP2/2A sequence; a deeper depositional setting (100-

200 m) is suggested for assemblages from the lowermost part of the drillhole.

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