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Research paper

Deep sea benthic foraminifera as proxies for palaeoclimatic fluctuations in the New Caledonia Basin, over the last 140,000 years

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ABSTRACT

The New Caledonia Basin (NCB), SW Pacific, a deep bathyal to abyssal basin bordered by the Lord Howe Rise to the west and the Norfolk Ridge to the east, has received little scrutiny with regard to the taxonomic diversity of benthic organisms in its Quaternary to Recent deep sea sediments. In 2001, Gravity Core 4 (GC4) was extracted from the NCB and the uppermost 141 cm, representing approximately the last 140,000 years, was investigated for chemical isotopic, carbonate, non-carbonate and trace element signatures. In this study, subsamples of the same uppermost 141 cm of GC4 were picked and sorted for all foraminiferal taxa. At selected intervals in GC4, all benthic species were identified and counted for measures of relative abundance. A total of 161 species of benthic foraminifera were obtained from the core and 46 species occurred in sufficient numbers to investigate changing patterns and trends in biodiversity and relative abundance. Changes found within the foraminiferal distribution down the core can be related to some oceanic and palaeoclimatic fluctuations during the last ~140,000 years. Within GC4, two distinct foraminiferal assemblages were detected using Bray–Curtis cluster analysis and Multidimensional Scaling (MDS) analysis. Foraminiferal Assemblage 1 occurs in lower bathyal to abyssal depths and was largely influenced by high oxygen levels at the sediment–water interface throughout Marine Isotopic Stage (MIS) 6–3 (approximately 128–25 ka). Foraminiferal Assemblage 2 dominated the upper bathyal shelf during MIS 2 (approximately 25–10 ka), with surface waters characterised by high sea surface productivity (SSP) and eutrophic conditions. During the time covered by GC4, there are instances where the relative abundance of the dominant taxon *Epistominella exigua* (Brady) and other key taxa decreases and opportunistic species of *Uvigerina*, adapted to lower oxygen levels, increase in relative abundance, indicating a shift of conditions at the sediment–water interface. Factors that influence the foraminiferal assemblages include environmental setting, SSP, oxygen levels at the sediment–water interface and transportation by oceanic current systems operating within the region.

1. Introduction

Benthic foraminifera have high preservation potential and because most species exhibit a significant level of sensitivity to fluctuating environmental conditions, they make excellent tools for palaeoceanographic investigations (Corliss, 1979; Kurihara and Kennett, 1992; Gooday, 1993; Nees, 1997; Gooday, 2003; Murgese and DeDeckker, 2005; Sun et al., 2006). Foraminiferal assemblage variations usually reflect migrations, extinctions and the effects of biotic competition and evolution (Kurihara and Kennett, 1992). Previous work suggests that assemblage composition reflects connections that exist between sea-surface conditions and the underlying benthos, oceanographic currents that operate within the area and adaptation to changing environmental conditions (Corliss et al., 1986; Tomczak and Godfrey, 1994; Nees, 1997; Gooday, 2003; Murray, 2006; Jorissen et al., 2007; Gooday and Jorissen, 2012).

Sediments of the New Caledonia Basin (NCB), located in the Tasman Sea (Fig. 1), have recently been subject to foraminiferal investigation particularly by Debenay (2012) and colleagues on Quaternary to Recent reef (Debenay and Payri, 2010; Debenay et al., 2011) and other benthic shallow-water foraminifera (Debenay, 1988a, 1988b; Debenay and Cabioch, 2007; Debenay et al., 2009a, 2009b). However, deeper sediments have received little attention with regard to documentation of the sedimentology and taxonomic diversity of benthic organisms.

In September 2001, several deep sea sediment cores were obtained during *RV Franklin* cruise FR7/01, from Brisbane to Noumea. The cruise completed a number of deep sea and sea surface analyses (DeDeckker, 2001). The scientific aims of the cruise included documenting oceanic change spanning the past 150,000 years at the sea surface, sea floor and varying depths (DeDeckker, 2001). In order to provide supporting

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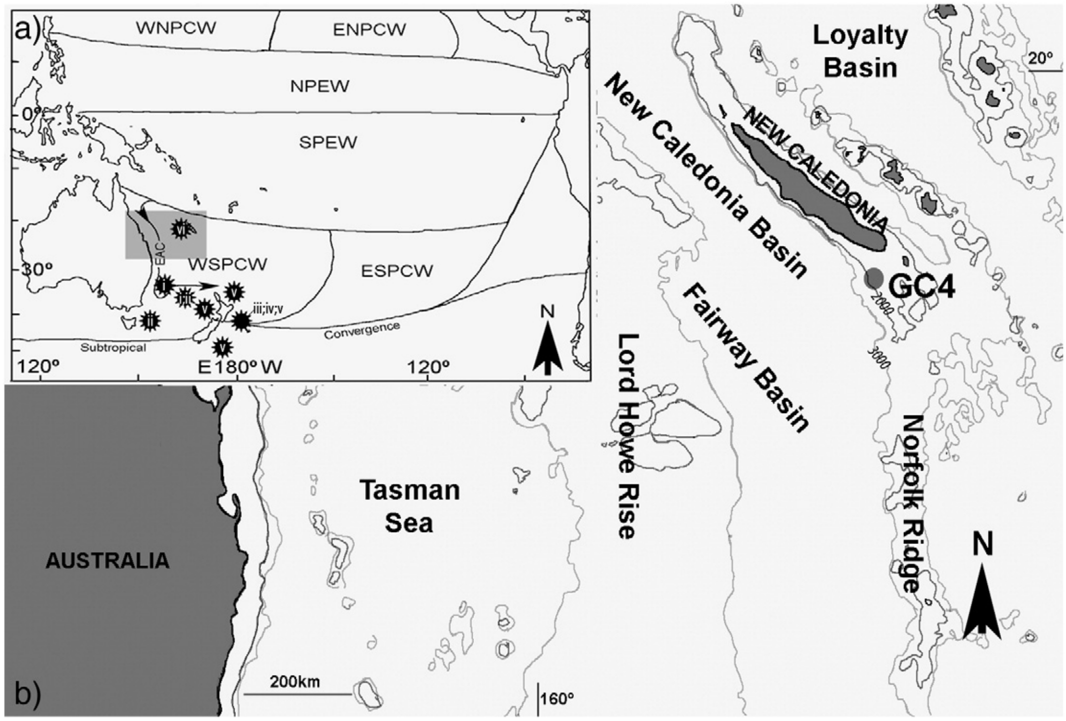

Fig. 1. Location map illustrating the location of CG4 taken by the *RV Franklin* in 2001 and its surrounding significant bathymetric features (b). Inset (a) illustrates global location, sites of previous foraminiferal investigations used in this study for comparison (stars with numerals stand for the following: i — Eade and van der Linden (1970); ii — Nees (1997); iii — Lupi et al. (2008); iv — Cobianchi et al. (2012); v — Hayward et al. (2002, 2004, 2010); vi — Wirrmann et al. (2011)) and major oceanic water masses and current systems circulating in and around the Tasman Sea (Abbreviated oceanic water masses and currents stand for the following: EAC — East Australian Current; WSPCW — Western South Pacific Central Waters; ESPCW — Eastern South Pacific Central Waters; SPEW — South Pacific Equatorial Waters; NPEW — North Pacific Equatorial Waters; WNPCW — Western North Pacific Central Waters; ENPCW — Eastern North Pacific Central Waters).

data on foraminiferal assemblages, this study examined Gravity Core 4 (GC4), a 410 cm long deep sea sediment core obtained from the New Caledonia Basin (Fig. 1b) during the *RV Franklin* cruise FR7/01.

The aims of this investigation are to taxonomically identify and document the relative abundances of benthic foraminifera throughout the upper 141 cm of GC4 and evaluate the depositional settings associated with these assemblages, advancing the understanding of the sedimentology and nutrient fluxes operating within the NCB during approximately the last 140,000 years (i.e., since late Marine Isotopic Stage (MIS) 6–MIS 1). The results provide novel comparisons with neighbouring basins in the Pacific involving palaeoenvironmental reconstructions, past deep ocean currents, sea level change and nutrient levels at the sediment–water interface.

2. Regional setting

2.1. Geology

The NCB (Fig. 1a) covers an area of approximately 665,600 km^2 (Taubert and Laurie, 2002), with an average depth of ≥3000 m below present sea level; maximum depth (~3600 m) lies near to New Caledonia with a general shallowing southwards to New Zealand (Russon et al., 2009). The main depocentres of the basin are located between the Lord Howe Rise and the Fairway Basin to the west and New Caledonia (the northernmost part of the Norfolk Ridge) to the east. The Challenger Plateau lies directly to the south (Taubert and Laurie, 2002). The entire region is a network of complex volcanic arc ridge and basin systems (Cluzel et al., 2001; Gretton, 2002) and the sea floor is most likely a combination of both oceanic and thinned continental crust (Uruski and Wood, 1991; Auzende et al., 2000a) with overlying soft carbonate and siliciclastic sediments and outcrops of sedimentary rocks (Taubert and Laurie, 2002; Anderson et al., 2011). Upper Cretaceous to Recent marine and non-marine (and minor volcanogenic) sediments reach a maximum water depth of 4 km (Auzende et al., 2000b).

The series of basins and ridges that form the area of the NCB are the result of subduction of the Australian Plate beneath the Pacific Plate to form the New Hebrides Volcanic Island Arc (Auzende et al., 2000a). During the last 125,000 years, the NCB has endured continuous warping through the effects of flexure-faults that facilitated uplift of the Central Chain and subsidence of both the western and eastern margins (Lafoy et al., 2000). Exon et al. (2004) report the initial formation of the NCB to have been brought on by the rifting and separation of the Norfolk Ridge. The NCB was likely formed in a two-stage process wherein there was an initial period of crustal thinning where Cretaceous rift basins formed tectonic depressions. This was subsequently followed by a second phase of subsidence during the Eocene–Oligocene which is associated with lithospheric delamination and trough in-filling (Sutherland et al., 2010; Hackney et al., 2012).

2.2. Oceanography

The Pacific Ocean is subjected to influences from a large number of different circulating water bodies (Fig. 1a). The south western portion of the Pacific Ocean is dominated by two large water masses: the Western South Pacific Central Waters (WSPCW) and the South Pacific Equatorial Waters (SPEW) (Tomczak and Godfrey, 1994). The primary productivity for the region varies depending on biogeochemical domains established by Longhurst et al. (1995). The Eastern Australian Coastal domain covers the Coral Sea coasts of Australia, the Great Barrier Reef, and New Caledonia, with a mean daily net primary production rate of 0.64 g C m^{-2} day^{-1}. The Western Pacific Warm Pool and Western Pacific Archipelagic Deep Basin domains cover the area of the WSPCW