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Continental shelf record of the East Antarctic Ice Sheet evolution: seismo-stratigraphic evidence from the George V Basin

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Abstract

The late Quaternary ice sheet/ice shelf extent in the George V Basin (East Antarctica) has been reconstructed through analyses of Chirp sub-bottom profiles, integrated with multi-channel seismic data and sediment cores. Four glacial facies, related to the advance and retreat history of the glaciated margin, have been distinguished: Facies 1 represents outcrop of crystalline and sedimentary rocks along the steep inner shelf and comprises canyons once carved by glaciers; Facies 2 represents moraines and morainal banks and ridges with a depositional origin along the middle-inner shelf; Facies 3 represents glacial flutes along the middle-outer shelf; Facies 4 is related to ice-keel turbation at water depths <500 m along the outer shelf. A sediment drift deposit, located in the NW sector of the study area, partly overlies facies 2 and 3 and its ground-truthing provides clues to understanding their age. We have distinguished: (a) an undisturbed sediment drift deposit at water depth >775 m, with drape/sheet and mound characters and numerous undisturbed sub-bottom sub-parallel reflectors (Facies MD1); (b) a fluted sediment drift deposit at water depth <775 m, showing disrupted reflectors and a hummocky upper surface (Facies MD2). Radiocarbon ages of sediment cores indicate that the glacial advance producing facies MD2 corresponds to the Last Glacial Maximum (LGM) and that during the LGM the ice shelf was floating over the deep sector of the basin, leaving the sediment drift deposit undisturbed at major depths (Facies MD1). This observation further implies that: (a) glacial facies underneath the sediment drift were the result of a grounding event older than the LGM, (b) this sector of the East Antarctic fringe was sensitive to sea-level rise at the end of the LGM; thus potentially contributing to meltwater discharge during the last deglaciation.

1. Introduction

Understanding how past oceanographic and glacial changes have affected depositional processes on the continental shelf of East Antarctica is a key point for testing palaeoclimatic scenarios in the Southern Ocean. Several investigators have modeled the configuration of the Antarctic Ice Sheet (AIS) during the Last Glacial Maximum (LGM) and its contribution to post-LGM sea-level rise (Denton et al., 1986; Huybrechts, 1990, 2002; Denton et al., 1991; Nakada et al., 2000, Denton and Hughes, 2002). These authors suggested for instance that the East and the West AIS did not advance and retreat in concert with one another during the last glacial–interglacial cycle. Anderson et al. (2002), in their review of the AIS retreat history, observed also that there is emerging evidence for an ice sheet not expanded to the shelf edge during the LGM. Despite that, the limited knowledge regarding the extent of the AIS during the LGM and its behaviour at the ice–ocean margin calls for studies on advance and retreat histories of the glaciated margin (Barker et al., 1998). Seismic and stratigraphic data indicate that the deep basins on the inner continental shelf probably experienced dramatic environmental changes related to fluctuations in the ice

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volume (Barron et al., 1991; Anderson et al., 2002). The retreat of the ice sheet across such areas, once excavated by grounding ice (i.e. ice directly resting in contact with the underlying sediment or sedimentary/crystalline rock) and nowadays ice-free, left a relict sea-floor morphology that records direction of ice-flow and grounding ice vs. floating ice conditions (e.g. O'Brien et al., 1999; Anderson et al., 2001; Camerlenghi et al., 2002; Canals et al., 2002).

In an effort to constrain timing and modes of ice-sheet retreat, the continental shelf off the George V Coast (East Antarctica) was targeted in February/March 2000 by an Italian–Australian marine geoscience research voyage (WEGA Project—Wilkes Land Glacial History; Brancolini et al., 2000). This study uses seismic (multi-channel and Chirp sub-bottom profiles) and sediment core data to define the distribution of glacial erosional and depositional features. A number of Chirp transects were concentrated in the north-western sector of the study area, where a Quaternary sediment drift deposit, up to 35 m thick, had been discovered and surveyed ("Mertz Drift", MD, Harris et al., 2001). The MD drapes and masks locally the relict morphology, which in turn can be investigated through Chirp profiles. We examine seismic profiles showing morphological features and acoustic facies related to sub-glacial and glacial-marine processes, both underneath and within the MD, as well as in the rest of the shelf. We distinguish facies on the basis of reflector geometry and acoustic signature (i.e. amplitude of signal, spacing and continuity of reflectors). The analysis provides new evidence for the dynamics of grounding and floating ice masses onto the shelf during the LGM and previous glacial periods. These results are used to produce a map of the different glacial features generated by the ice sheet/ice shelf when it extended further. The key questions addressed are the ice extent and sedimentary history of the inner continental shelf during Late Quaternary glacial–inter-glacial periods. By comparing the study area with other areas around East Antarctica, we also aim at contributing to the ongoing discussion concerning the last deglaciation in relation to the global meltwater signal.

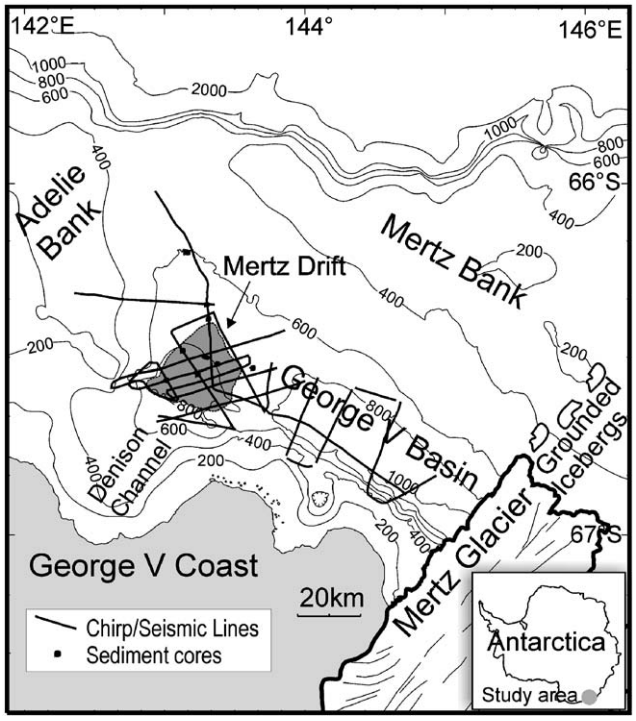

Fig. 1. Bathymetry of the shelf off the George V Coast targeted by the WEGA geoscience research voyage, showing seismic profiles and position of sediment cores recovered during the cruise. The Mertz Drift (MD) is located in the northwestern sector of the George V Basin. Inset map: location of the George V Coast, East Antarctica.

2. Study area: the George V Basin

2.1. Morphology and stratigraphy

The continental shelf offshore the Wilkes Land sector of East Antarctica shelf between 142°E and 146°E is known as George V Land (Fig. 1). Water depth over the shelf averages 500 m and generally increases onshore from the shelf break. The inner-middle shelf contains the >1000 m deep George V Basin, a landward dipping bathymetric depression of glacial origin on the west of the Mertz Glacier floating ice tongue. The basin is U-shaped in cross section and is steep-sided towards the coast, shoaling towards the NW. The Quaternary Mertz Drift deposit is located in the NW sector of the basin between 700 and 900 m water depth (Fig. 1). An inner shelf channel (Denison Channel) joins transversally the western sector of the basin. This channel is a hanging valley of glacial origin and, in the past, it comprised the seaward portion of a glacial drainage system for minor coastal glaciers (Vanney and Johnson, 1979). Other minor coastal canyons are transverse to the main axis of the George V Basin (oriented NW–SE) and are relict features originated by small outlet coastal glaciers. Relatively shallow Mertz and Adelie Banks (<200 m depth) trend oblique to the main orientation of the shelf edge and bound the basin on its northern and western margins (Fig. 1).

Exposed bedrock on the adjacent coast is limited to coastal cliffs and *nunataks*. A geologic boundary, east of the surveyed area (at about 147°E), separates a crystalline basement complex of metamorphic rocks and dolerites, west of the Mertz Glacier, from granites and Triassic sandstones (Craddock, 1972; Kleinschmidt and Talarico, 2000). Stratigraphic evidence indicates that the George V Basin was excavated at the structural boundary between crystalline and sedimentary rocks (Domack, 1987). Pleistocene maximal extension and thickening of inland ice produced the overdeepening of