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High resolution geomorphic map of a submerged marginal plateau, northern Lord Howe Rise, east Australian margin

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ABSTRACT

High resolution multibeam bathymetry is used to map and interpret seabed geomorphology for part of the northern Lord Howe Rise plateau in the Tasman Sea. A mapping system of geomorphic units and elements is used, extending the previous hierarchy of geomorphic provinces and features used for the Australian margin. The mapped area covers ~25,500 km^2 and incorporates broad ridges, valleys and plateaus. Superimposed on these features are clusters of volcanic peaks, smaller ridges, holes, scarps and aprons. An additional characteristic of the seabed in this area is an extensive network of polygonal furrows that covers the plateau and the lower slopes of larger ridges. These furrows are formed in stiff, unconsolidated carbonate ooze that forms a near-continuous sediment cover across the area. Peaks are the only geomorphic feature not fully draped in pelagic ooze. The distribution of geomorphic units suggests strong controls from underlying geological structures. In water depths of 1400 to 1600 m some peaks occur in clusters on ridges that sit above acoustic basement highs and volcanic intrusions. Elsewhere, broad plateaus and valleys slope to the southwest following the regional dip of the Lord Howe Rise plateau. In contrast, localised geomorphic elements such as moats and holes have likely explanation in terms of spatial variations in sedimentation rates in relation to bathymetric highs. Polygonal furrows are attributed to dewatering processes. The geomorphology of the seabed mapped in this study incorporates examples of forms that have not been previously mapped in such detail on the Australian margin. These are unlikely to be unique to the mapped area of the Lord Howe Rise and can be expected to occur elsewhere on the Rise and presumably on other parts of the Australian margin with a similar geological history.

1. Introduction

The geomorphology of the seabed is being revealed in increasing detail as new areas are mapped using high resolution multibeam sonar in study areas ranging from the continental shelf to the deep ocean (e.g., Wille, 2005; Hillier et al., 2008; Todd and Greene, 2008). Mapping at these improved scales has opened new opportunities for quantitative studies that seek to relate seabed geomorphology to sub-surface geological structure at the regional scale, and at the local scale to formative geomorphic processes. Developing an understanding of the potential associations between geomorphic features, underlying geology and physical processes operating on the seabed is necessary because it provides a basis for testing theories of landform evolution, gives physical context for benthic habitat studies, and can inform an evaluation of the geomorphic stability, or otherwise, of those environments.

For the Australian margin, the geomorphology of the seabed has recently been systematically mapped in full for the first time by Heap and Harris (2008), using a bathymetric model with a spatial resolution of 250 m. While comprehensive in its coverage, the continent-wide geomorphic map is just the first step towards an improved understanding of the form and origin of the features that comprise this passive margin. Clearly, the next phase is to use this geomorphic map as a template on which to map finer-scale geomorphology. The geomorphology can then be related to sub-surface geological structure across a range of scales and be used to derive models of landform evolution. Multibeam sonar mapping can provide the means for achieving this.

Our study addresses a data gap regarding the detailed geomorphology of offshore marginal plateaus. The Australian margin is an important region in this regard because it contains approximately 20% of the total area of marginal plateaus in the world (Heap and Harris, 2008). Results from this study will help improve our understanding of the geomorphology, and provide insights to the formative seabed processes, for these deep-sea features.

In this paper we use newly acquired high-resolution multibeam sonar data to characterise the fine-scale (50 m spatial resolution)

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geomorphology of a portion of the Lord Howe Rise marginal plateau, located to the east of mainland Australia in the Tasman Sea. Surface sediments for the area are also described. This submarine plateau is the largest within the Australian maritime jurisdiction, covering approximately 476,500 km^2 (Heap and Harris, 2008) and as such is a key structural element in the tectonic history of the continent. In this context we also use previously published 2D seismic reflection data from the area to identify associations between the distribution of geomorphic features and underlying geological structures.

2. Geologic and geomorphic setting

The Lord Howe Rise plateau is the largest bathymetric feature in the Tasman Sea, extending approximately 2800 km from the eastern Coral Sea in the north to the Challenger Plateau in the south (Standard, 1961; Van der Linden, 1970). Crestal water depths across the plateau range from 750–1220 m. Structurally, Lord Howe Rise is a fragment of continental crust, 250–600 km wide, that separated from East Gondwana during the Late Cretaceous Epoch as the Tasman Sea opened. It reached its present position approximately 52 Ma and then subsided to its present depth by the Neogene (~23 Ma) (Gaina et al., 1998; Van de Beuque et al., 2003; Exon et al., 2004a, b, 2006).

The geological structure of the Lord Howe Rise divides into three provinces that broadly influence the regional bathymetry (Stagg et al., 2002): (i) to the east, the Lord Howe Platform comprises crustal basement that forms structural highs in water depths of 1000 to 1300 m; (ii) the Central Rift province which incorporates down-faulted basement blocks and rift basins in 1300 to 1700 m water depth, and; (iii) the Western Rift province located along the western side of the Lord Howe Rise that forms a series of rift basins that deepen to the west across water depths of 1700 to ~2200 m.

Geomorphic mapping and interpretation is especially limited for the Lord Howe Rise, which to date has been described only in general terms (e.g., Van der Linden, 1970; Stagg et al., 2002; Van de Beuque et al., 2003). Small-scale geomorphic features on the Lord Howe Rise are particularly poorly documented as previous studies in the region have tended to focus on seamounts of the Tasmantid and Lord Howe seamount chains (e.g. McDougall et al., 1981; Quilty, 1993; Exon et al. 2004b). On the recently published geomorphic map of the Australian margin, the area covered by this study is represented by a single geomorphic feature, a plateau (Heap and Harris, 2008).

The newly mapped area used for this study is located on the western flank of the northern part of Lord Howe Rise between latitude 26.0 to 27.9°S and longitude 160.20 to 161.86°E, and covers approximately 25,500 km^2 (Fig. 1). Water depths across this part of the Lord Howe Rise range from 1200–2600 m, increasing to the southwest. The area spans parts of the Central Rift and Western Rift provinces. The survey area lies within Australia's maritime jurisdiction and is one of the new offshore frontier areas chosen for reconnaissance survey as part of the Offshore Energy Security Programme (2007–2011) undertaken by the Commonwealth Government of Australia.

Previous work in the vicinity of the mapped area relates mostly to deep-sea coring and drilling. Eade and Van der Linden (1970) describe a short core collected from the crest of Lord Howe Rise in 1450 m water depth. This 4.2-m core comprised bioturbated sandy foraminiferal mud, with an age profile that spans Holocene to Upper Pleistocene time (ca. 160,000 yrs). On this basis, Late Quaternary sedimentation rates on the rise are estimated to have ranged from ~1 cm/ka during interglacial periods to 3-4 cm/ka during the last glacial period (Eade and Van der Linden, 1970). Deep sediment cores recovered on Leg 90 of the Deep Sea Drilling Program (DSDP) provide further information on thickness and age of unconsolidated sediment across the Lord Howe Rise (Nelson, 1986). Site 588 is of particular relevance to this study, being located within the mapped area in 1533 m water depth (26°06.7′S, 161°13.6′E; Fig. 2). This core recovered 236 m of soft nannofossil ooze overlying nannofossil chalk that extends to the base of the core at ~480 m depth (Nelson, 1986). This sequence is uninterrupted and on the basis of nannoplankton biostratigraphy is inferred to span the Late Oligocene to Holocene, with the chalk to ooze contact formed in Middle Miocene sediments. Sedimentation rates of ooze at this site vary from 1.7 cm/ka during the mid to late Miocene, to 3 cm/ka in the Pliocene and 1.2 cm/ka throughout the Quaternary (Nelson, 1986). Quaternary deposits at site 588 are ~34 m thick (Kennett et al., 1986).

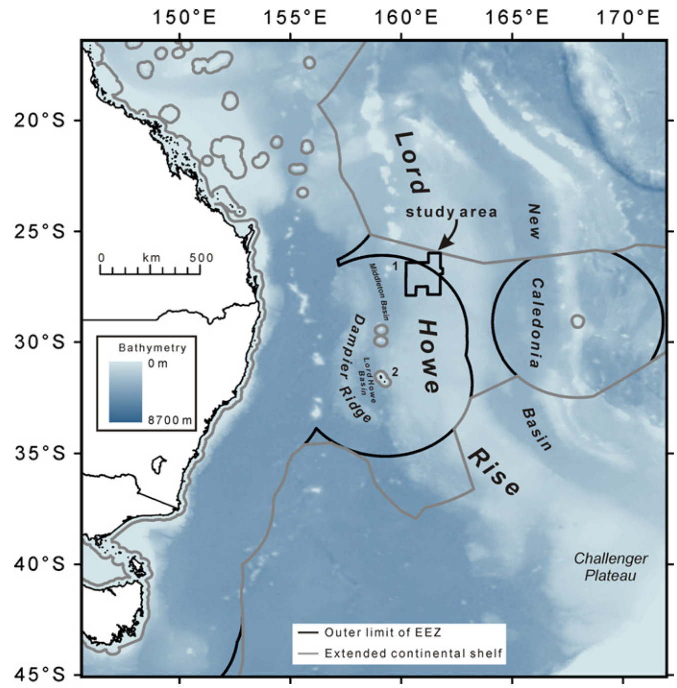

Fig. 1. Bathymetric map of the Tasman Sea showing the location of the study area on the Lord Howe Rise. Locations of major bathymetric features mentioned in the text are indicated, including: 1 – Gifford Guyot and 2 – Lord Howe Island. The outer limit of the exclusive economic zone (EEZ) and extended continental shelf of Australia are also shown.

3. Data and methods

Bathymetric data were collected during Geoscience Australia survey TAN0713 on the RV *Tangaroa* in 2007 using a Simrad EM300 30-34 kHz multibeam sonar system (Heap et al., 2009). Geomorphic mapping is based upon a 50 m spatial-resolution digital elevation model derived from multibeam data that was processed using Caris HIPS/SIPS v.5.4 software. The classification of seabed geomorphology uses a three-tier hierarchical scheme comprising geomorphic features, units and elements (Table 1). This scheme is designed to add detail to the geomorphic provinces and features already mapped for the Australian margin (Heap and Harris, 2008). For the study area, the Lord Howe Rise plateau is the geomorphic feature upon which geomorphic units are mapped. These include ridges, valleys, plateaus and basins. Geomorphic elements are in turn superimposed upon units and include peaks, holes and moats, scarps, aprons and polygonal furrows.

Mapping of geomorphic units and elements involved defining boundaries from bathymetric profiles drawn in Fledermaus IVS v.6