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Anomalous bathymetry and palaeobathymetric models of the Mozambique Basin and Riiser Larsen Sea

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A B S T R A C T

In this study we introduce a palaeobathymetric model for the conjugate Mozambique Basin and Riiser-Larsen Sea built by employing backstripping techniques, compensating for dynamic topography and plate motions. The model is presented at $0.2° \times 0.2°$ grid resolution, making it suitable for future oceanographic and climate simulation model experiments aimed at a better understanding of the climatic and oceanographic relevance of oceanic gateways in the southern ocean. At the present day, the seafloor next to the Mozambican continental margin is around 300 m shallower, and that in the central Mozambique Channel is almost 1300 m shallower, than their conjugate areas or the predictions of oceanic thermal subsidence models. The cause of this anomalous depth is difficult to determine confidently because of sparse data, in particular concerning sediment thickness, and because of the wide range of amplitudes in modelled present-day dynamic topography. The distribution of shallow seafloor suggests that it might be attributed to the presence of thicker-than-usual oceanic crust, which in turn can be attributed to the Paleogene passage of the Quathlamba plume beneath the basin. We portray these effects in our palaeobathymetric models. In contrast, the Riiser-Larsen Sea has experienced fairly stable subsidence since its formation in Jurassic times, with only slight observable changes attributable to the onset of Antarctic glaciation and during the middle Miocene climate transition. Both basins display flexure over half-wavelengths of ∼60–80 km with amplitudes of 1500 m towards their continental margins. This plays an important role in models of palaeobathymetry for times older than 100 Ma. Near the margins, isolated areas of transitional or debatable crustal composition, including Beira High and Gunnerus Ridge, are depicted to subside in a similar fashion to oceanic crust. Further into the Indian Ocean, oceanic lithosphere younger than 100 Ma on both plates has subsided to depths that are typical of thermal subsidence models. Finally, the new palaeobathymetry had distinct consequences for the current systems in the young Southern Ocean during the time periods. The onset of coast-parallel bottom currents and associated contourite deposition in the Mozambique Channel at palaeo water depths of 3500–4000 m may be a consequence of either an opening of a deep-water passage into the South Atlantic between Southwest Indian Ridge and Agulhas plateau or into the Tethys Ocean in the Late Cretaceous.

1. Introduction

Palaeobathymetric models are essential for quantitative testing of palaeo-climate hypotheses, and as constraints on models of regional sediment transport and deposition and the linkages between tectonics and surface processes. This was recognized as early as the 1970s with subsidence studies in sedimentary basins (Steckler and Watts, 1978; Watts and Ryan, 1976). Since then, a variety of parameters that influence the evolution of basin depth have been identified, and techniques for modelling have been refined, to create improved models. Recent, detailed palaeo-bathymetric studies in the Northern Atlantic Ocean and Weddell Sea show the significance of such improved models for the polar regions to improve numerical circulation models and increase confidence in their interpretation (Ehlers and Jokat, 2013; Huang et al., 2014; Wold, 1995).

Here, we describe a palaeobathymetric modelling study for the African–Antarctic corridor, with a focus on its extremities, the Riiser Larsen Sea and Mozambique Basin (Fig. 1). The basins and the corridor are of interest palaeo-climatically, because of suggestions that early stage excess volcanism in them led to the formation of oceanic plateaux that restricted vertical mixing and water exchange, leading periodically to large-scale eutrophication. This

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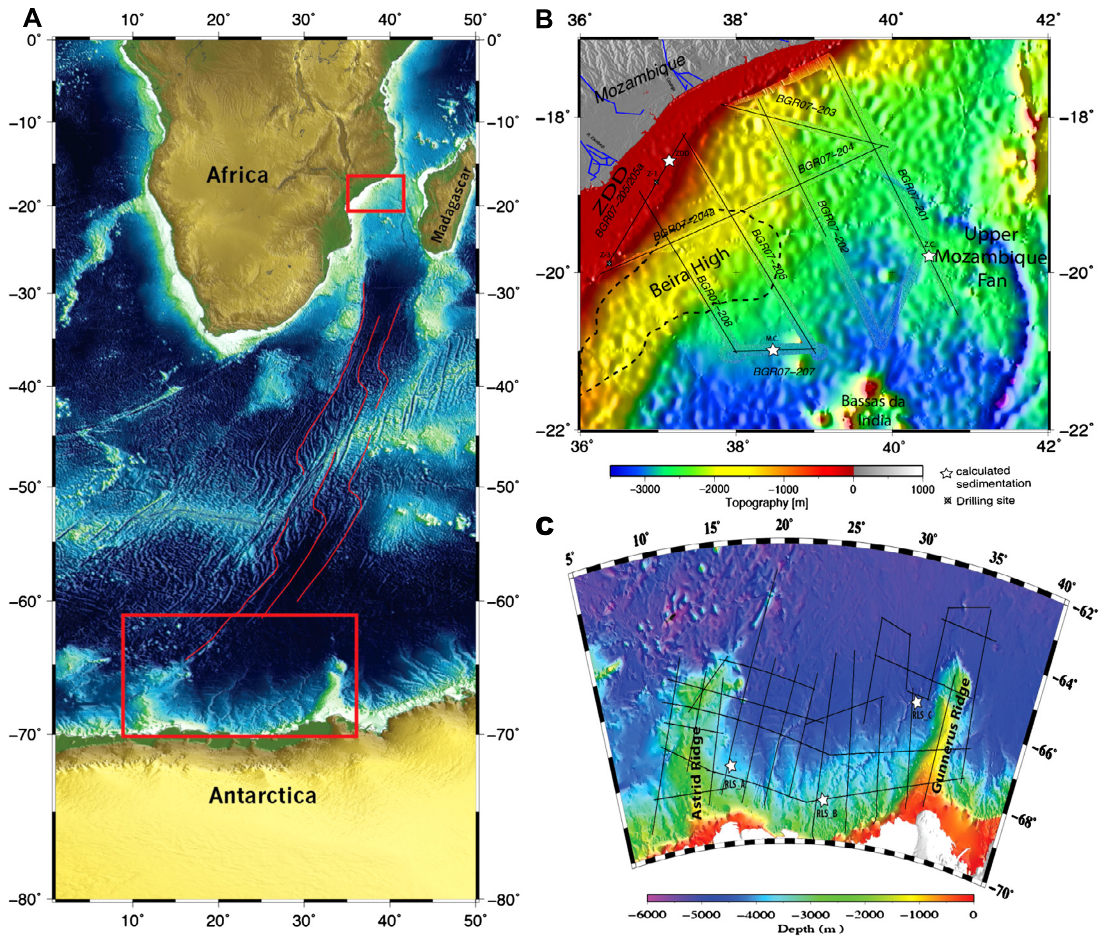

Fig. 1. (A) Bathymetric map of Africa–Antarctic corridor. The red flow lines indicate the Southwest Indian ridge motion between Africa and Antarctica. Red boxes indicate the study area of the reconstructed palaeobathymetry. Bathymetry map of the (B) Mozambique Basin and (C) Riiser-Larsen Sea. The outline of Beira High (dashed line) is interpreted from gravity anomaly. Gunnerus and Astrid ridges are identified by their shallow topography. The seismic lines used in this study are indicated with black lines. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

possibility has been linked as a possible cause to one or more of several anoxic events that occurred during the Jurassic and Cretaceous (Burgess et al., 2015; Turgeon and Creaser, 2008). Rigorous tests of this or related suggestions with climate and oceanographic circulation models will require high-resolution palaeobathymetric reconstructions of the region for this time period. Such models are now possible for the African–Antarctic corridor thanks to the collection of extensive seismic (Fig. 1) and magnetic datasets in recent years (Castelino et al., 2015; König and Jokat, 2006; Leinweber et al., 2013; Leitchenkov et al., 2008) that have yielded new and detailed information on stratigraphy, the age of the oceanic crust, and the location of the continent–ocean transition zone.

1.1. *Geological constraints on palaeobathymetry: plate kinematics and regional vertical motions*

The break-up of Gondwana started with the separation of East Gondwana (comprising Antarctica, Madagascar, India, and Australia) from West Gondwana (comprising Africa and South America) during the Early Jurassic. In the study area, this breakup led to formation of the present-day East African passive margins and their Antarctic conjugates, and the Riiser Larsen Sea and Mozambique basins. The initial phase of separation was characterized by rifting and the emplacement of Karoo-Ferrar flood basalts during massive volcanism in Africa and Antarctica, with peak activity occurring between 178 and 184 Ma (Burgess et al., 2015; Eagles and König, 2008; König and Jokat, 2006). The oldest identified magnetic anomaly is M42 in the Somali and Mozambique Basins, implying seafloor spreading was underway at approximately 167 Ma (Gaina et al., 2015; Leinweber and Jokat, 2012). Several plate kinematic models exist that aim to describe the separation of the plates along the entire East African Margin (e.g. Gaina et al., 2013; Leinweber and Jokat, 2012; Eagles and König, 2008). The initial movements within Gondwana during this period are poorly constrained, although Eagles and König (2008) suggest that the orientation of plate motion is likely to have remained constant through the breakup phase on the basis of the parallelism of fracture zone and onshore fault trends in Tanzania. After this, in two phases of breakup, Antarctica moved first to the SSE relative to Africa as part of East Gondwana, leading to opening of the oldest basins off Mozambique and Somalia, and later moved southwards accompanying the disintegration of East Gondwana.

Because of its thick ice cover, little information is available on the tectonic and erosional history of Dronning Maud Land, Antarctica to enable detailed interpretation of its vertical motions since the Jurassic. In contrast, for the African plate, multiple lines of evidence have been put forward to suggest pulsed Miocene, Pliocene and ongoing uplift, by in total as much as 2.4 km, of continental South Africa in response to the transmission of viscous stresses from upwelling mantle rocks to the lithosphere (Burke, 1996; Gurnis et al., 2000; Partridge and Maud, 1987; Roberts and White, 2010). Prior to this time period, a more modest uplift is suggested to have followed a quiet tectonic period between 65 and 30 Ma,