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Middle Cretaceous geomagnetic field anomalies in the Eastern Indian Ocean and their implication to the tectonic evolution of the Bay of Bengal

Maria Ana Desa [a], Mangipudi V. Ramana [b]

[a] National Institute of Oceanography (CSIR), Dona Paula, Goa, 403 004, India
[b] Sagarika Apartments, Nagali Hills, Dona Paula, Goa, 403 004, India

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ABSTRACT

The Middle Cretaceous period is largely known for its stable normal polarity in the Earth's magnetic field. A few reversals (ISEA, M-3r; M-2r and M-1r) have been postulated during this period but are yet to be accepted in total. Recently, two anomalies Q1 (92 Ma) and Q2 (108 Ma) have been identified globally and proposed as internal time markers useful to trace the evolution of the world oceans. While the evolutionary history of the Indian Ocean from Late Cretaceous to present is well-established, the older (Middle to Early Cretaceous) record is still ambiguous. The occurrence of a major plate reorganization during the Middle Cretaceous period has added to the dilemma in understanding the early evolution of the Eastern Indian Ocean. The detailed evolution of the Bay of Bengal and its conjugate Enderby Basin has remained speculative to date due to various constraints such as lack of good geophysical dataset and drill sites, and the presence of thick sedimentary load.

In the present study, an attempt is made to validate the occurrence of the Middle Cretaceous internal time markers in the Eastern Indian Ocean. These time markers are used to provide additional constraints for tracing the evolution of the Eastern Indian Ocean since Late Jurassic. Identification of these markers aided to confirm the timing of spreading ridge extinction in the Perth Basin as 102 Ma. In the Bay of Bengal, these markers facilitated to infer the evolution of the Middle Cretaceous crust, east of the buried 85°E Ridge. The age of the oceanic crust increases from south to 115 Ma at the northern tip of the Bay of Bengal. Seafloor spreading occurred in ~ NNE-SSW direction between 115 Ma and 102 Ma, and thereafter it changed its direction to ~N-S. Half spreading rates ranging from 4.0 to 4.2 cm/yr between 108 Ma and 84 Ma in the Bay of Bengal are higher than its conjugate Enderby Basin. This spreading system belongs to the second rifting episode between Antarctica and India, and was caused by the Kerguelen mantle plume activity. The 85°E Ridge south of 12°N is emplaced on a transform fault that constitutes the northern extension of the 86°E Fracture Zone and active since 102 Ma. The study suggests that excess crustal accretion occurred on the Indian plate since the Middle Cretaceous.

1. Introduction

The Middle Cretaceous period referred as the Cretaceous Magnetic Quiet Zone period is bounded by chrons M0 and A34. This period is also considered as the Cretaceous Normal Superchron with high geomagnetic field strength and low reversal frequency (Larson 1991; Tarduno et al. 2001; Tarduno and Cottrell 2005; Aubert et al. 2010). Though this period has been associated with smooth positive geomagnetic field, chaotic magnetic signatures have been reported. Despite the disorderly pattern in the magnetic anomalies, several polarity reversals have now been speculated. The first reversal was inferred at 115 Ma and named as ISEA (Tarduno 1990). Later, additional reversals such as the M-3r (ending at 102 Ma) and M-2r (ending at 108 Ma) have been inferred, while the M-1r at 118.5 Ma was suspected to be ISEA (Gradstein et al. 2012).

The geomagnetic field depicted high variability in the beginning of this superchron while the magnetic signal was subdued in the last nine million years (Granot et al. 2012). Further, Granot et al. (2012) identified two internal time markers Q1 and Q2 at 92 and 108 Ma respectively in different oceans and proposed their application to date the oceanic crust. The long-wavelength anomaly Q2 and the short-wavelength anomaly Q1 were used to trace the early evolution of the South Atlantic Ocean (Granot and Dyment 2015). The occurrence of global-scale plate reorganization characterized with major changes in seafloor spreading direction and rates, has been postulated between 105 and 100 Ma (Matthews et al. 2012).

The present work is based on the study by Granot et al. (2012), wherein profiles from different oceans were used to infer magnetic anomalies Q1 and Q2 during the Middle Cretaceous Magnetic Quiet

E-mail address: mdesa@nio.org (M.A. Desa).

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Zone period. Here, an attempt is made to identify the internal time markers (Q1, Q2, M-3r, M-2r, M-1r and ISEA) of the Middle Cretaceous period in the Eastern Indian Ocean. This exercise would validate the occurrences of these anomalies globally and help in dating some of the events which have taken place during the Middle Cretaceous period in the Eastern Indian Ocean. Further, these markers would serve as

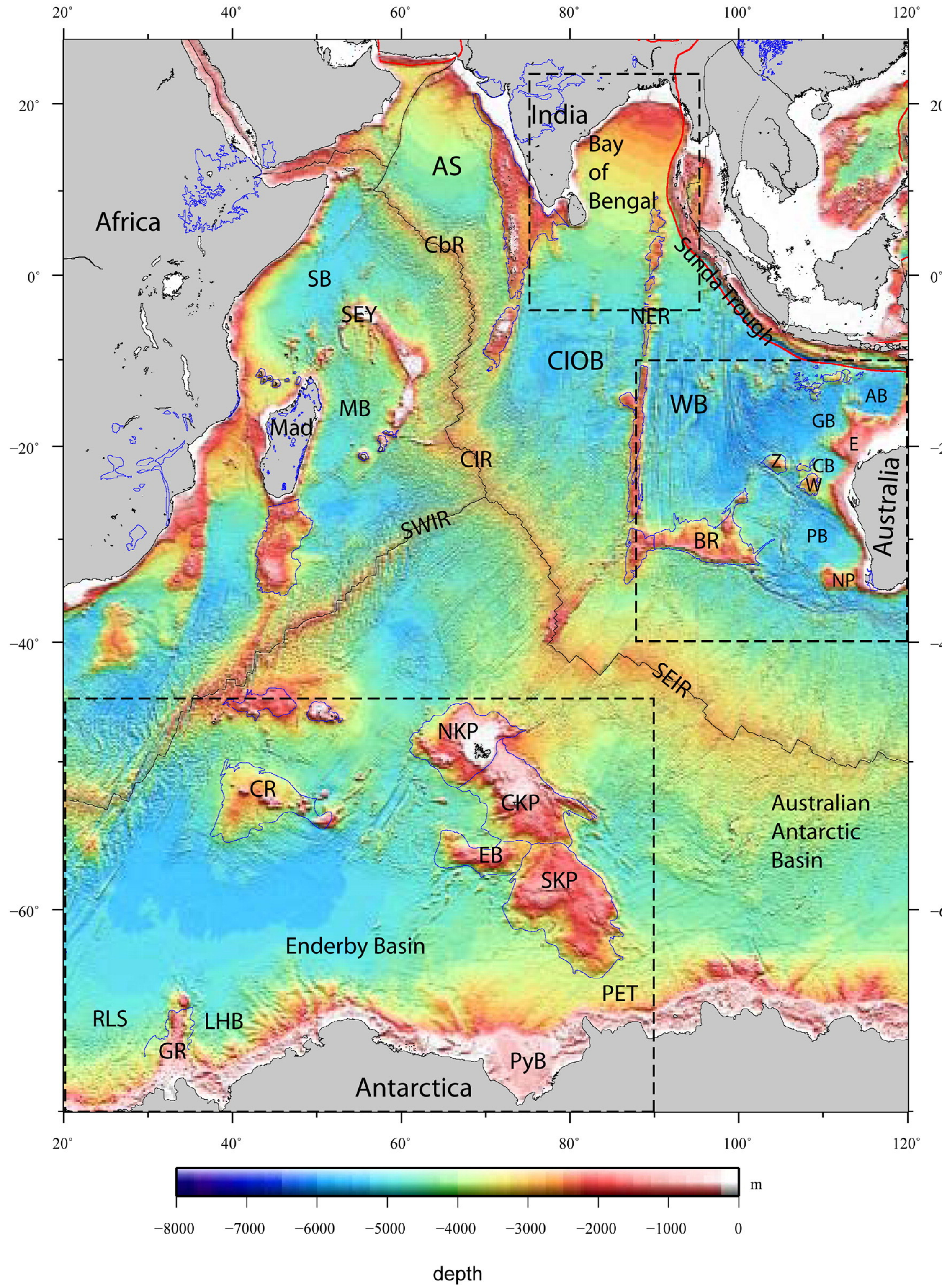

Fig. 1. Predicted bathymetry of the Indian Ocean and the adjoining Southern Ocean depicting various topographic features (Smith and Sandwell 1997). Large igneous provinces are marked in blue (Eldholm and Coffin 2000). The present-day Indian Ocean mid-oceanic ridge system is traced in black. The three study areas are enclosed in dashed rectangles. AB: Argo Basin; AS: Arabian Sea; BR: Broken Ridge; CB: Cuvier Basin; CbR: Carlsberg Ridge; CIOB: Central Indian Ocean Basin; CIR: Central Indian Ridge; CKP: Central Kerguelen Plateau; CR: Conrad Rise; E: Exmouth Plateau; EB: Elan Bank; GB: Gascoyne Basin; GR: Gunnerus Ridge; LHB: Lutzow-Holm Bay; MB: Mascarene Basin; Mad: Madagascar; NER: Ninetyeast Ridge; NKP: Northern Kerguelen Plateau; NP: Naturaliste Plateau; PB: Perth Basin; PET: Princess Elizabeth Trough; PyB: Prydz Basin; RLS: Riiser-Larsen Sea; SB: Somali Basin; SEIR: Southeast Indian Ridge; SEY: Seychelles; SKP: Southern Kerguelen Plateau; SWIR: Southwest Indian Ridge; W: Wallaby Plateau; WB: Wharton Basin; Z: Zenith Plateau. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)