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Delineation of the 85°E ridge and its structure in the Mahanadi Offshore Basin, Eastern Continental Margin of India (ECMI), from seismic reflection imaging

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A B S T R A C T

The passive Eastern Continental Margin of India (ECMI) evolved during the break up of India and East Antarctica in the Early Cretaceous. The 85°E ridge is a prominent linear aseismic feature extending from the Afanasy Nikitin Seamounts northward to the Mahanadi basin along the ECMI. Earlier workers have interpreted the ridge to be a prominent hot spot trail. In the absence of conclusive data, the extension of the ridge towards its northern extremity below the thick Bengal Fan sediments was a matter of postulation. In the present study, interpretation of high resolution 2-D reflection data from the Mahanadi Offshore Basin, located in the northern part of the ridge, unequivocally indicates continuation of the ridge across the continent–ocean boundary into the slope and shelf tracts of the ECMI. Its morphology and internal architecture suggest a volcanic plume related origin that can be correlated with the activity of the Kerguelen hot spot in the nascent Indian Ocean. In the continental region, the plume related volcanic activity appears to have obliterated all seismic features typical of continental crust. The deeper oceanic crust, over which the hot spot plume erupted, shows the presence of linear NS aligned basement highs, corresponding with the ridge, underlain by a depressed Moho discontinuity. In the deep oceanic basin, the ridge influences the sediment dispersal pattern from the Early Cretaceous (?)/early part of Late Cretaceous times till the end of Oligocene, which is an important aspect for understanding the hydrocarbon potential of the basin.

1. Introduction

The northward migration of the Indian Plate over different mantle plumes resulted in the emplacement of volcanic provinces in the Indian shield with their trace in the oceanic crust (Curray and Munasinghe, 1991; Kent, 1991; Storey, 1995; Storey et al., 1995; Műller et al., 1997). The 85°E Ridge is interpreted to be one such trace in the Bay of Bengal, north-east Indian Ocean. However, the recognition of the ridge in the northernmost tracts, in offshore Mahanadi basin, was cryptic due to its burial under thick Bengal Fan sediments. South of 5°N, the ridge intermittently rises above the seafloor and finally joins with the Afanasy Nikitin Seamount (ANS), after a sharp bend off Sri Lanka (Fig. 1). The buried northern part of the ridge is associated with a prominent gravity low, while a prominent linear positive trend is seen to the south where the ridge rises above the seafloor. Liu et al. (1982) interpreted the negative gravity field to be caused by the emplacement of the ridge onto a young oceanic crust and subsequent burial under a massive sediment cover. Curray and Munasinghe (1991) postulated that Rajmahal traps in eastern India, the 85°E Ridge and the ANS represent the trace of the Crozet hot spot (Fig. 1). The subsurface structure of the ridge was earlier mapped from seismic reflection data up to 17°N in the Bay of Bengal (Curray and Moore, 1971, 1974; Curray et al., 1982). Based on the gravity signature and magnetic trends many workers (Ramana et al., 1997; Nayak and Rao, 2002; Subrahmanyam et al., 2008) interpreted the 85°E Ridge to be abutting against the Mahanadi coast. The characteristic gravity low attributed to the ridge is obscured by the shelf edge anomaly of the ECMI, and therefore it does not present a definitive interpretation of the ridge below the Mahanadi shelf. Anand et al. (2009) inferred termination of the ridge at 15°N and proposed that the structure seen along 17°N profile of Curray et al. (1982) could be a geomorphic expression of the basement. In order to address these issues, a detailed investigation of the 85°E Ridge across the continent–ocean boundary (COB) in the Mahanadi offshore is carried out based on several closely spaced high resolution 2-D seismic profiles (Fig. 2). The study is useful to understand the architecture and mode of emplacement of the 85°E ridge in the vicinity of the ECMI. In addition, the effect of the ridge on subsequent sediment dispersal pattern in the

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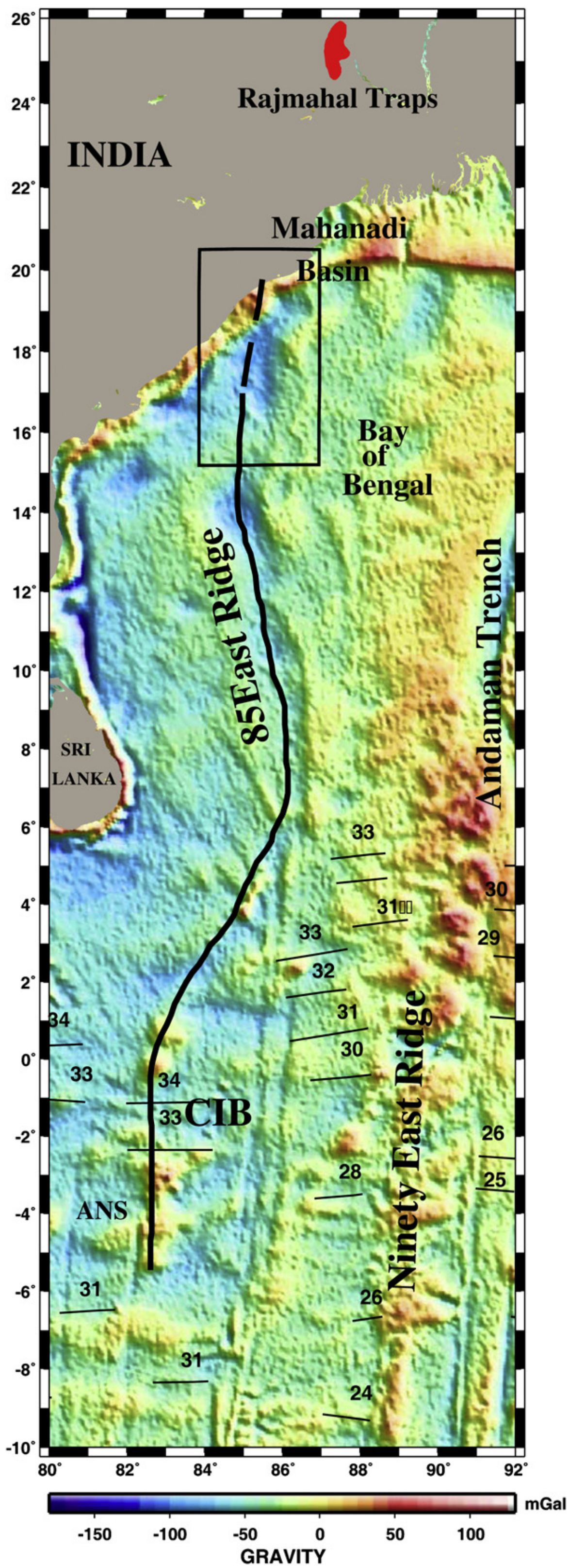

Fig. 1. Satellite derived gravity (Geosat) image of the 85°E Ridge and surrounding Bay of Bengal region. The thick line indicates the trace of the 85°E Ridge. The present study area is marked as a rectangular block. CIB – Central Indian Basin.

Mahanadi offshore basin is examined for its relevance to deep water petroleum prospectivity.

2. Data

Regional scale 2-D seismic lines, acquired as part of the exploration activity in the deep water Mahanadi offshore, have been studied to decipher the signature of the 85°E Ridge and to understand the causes for its emplacement. Seismic data are also used to prepare isochronopach maps between regionally significant sequence boundaries to aid the understanding of the interplay between the ridge morphology and the sediment depositional fairway. For the present purpose, selected 2-D lines are illustrated to bring out significant features and evidences regarding the morphology, structure and evolution of the ridge. The data are discussed in sections based on major structural sectors of the studied area.

3. Seismic character of the 85°E ridge off the Mahanadi margin

3.1. Shelf region

Seismic profiles a1, a2, b and c (Fig. 3a–c) traversing across the continental shelf show the presence of a prominent seismic event around 1.5 s two-way travel time (TWT), recognized as the Acoustic Basement Top (ABT), below which the seismic facies display a chaotic character without any discernible seismic reflections. Several wells drilled on the Mahanadi shelf have penetrated this event which corresponds to the top of a suite of effusive basic volcanic rocks. These rocks have been assigned an Early Cretaceous age based upon the age of the overlying paleontologically dated sediments, and have been correlated with the Rajmahal Traps that are exposed further to the north in the Indian continental shield (Fuloria et al., 1992; Fig. 1). In the neighbouring Bengal and Krishna–Godavari (K–G) basins, typical seismic signatures of rifted passive margins are recorded, and drilled wells have penetrated into non-volcanic crystalline continental crust (Bastia, 2006). This suggests that the massive outpouring of lavas may inhibit the recognition of such typical rift-related features in the Mahanadi shelf region.

3.2. Slope region

Thick wedges bounded by Seaward Dipping Reflectors (SDR's) are observed below the correlated top of volcanics (i.e., the ABT) in the slope region (Profiles a2, b and c in Fig. 3). These wedges become progressively younger and thicker in a basinward direction. The combined thickness of these wedges sharply varies between 2.5 and 4 s along the slope. The thicknesses as well as the dips are anomalous when compared to the normal thickness of SDR's associated with typical oceanic crust. Away from the main ridge axis, towards north-east and south-west, the SDR's are not seen in the slope region, while features showing typical linkage of normal continental curst to oceanic crust through rifted margin and proto-oceanic crust are observed (Fig. 3d and e). The presence of similar wedges bound by SDR's was reported from the Walvis ridge in SE Atlantic Ocean (Elliott et al., 2009). Near the base of the slope, several prominent upward doming events are observed, below which the SDR's are absent (Profiles a3 and b in Fig. 3). The region of prominent SDR's corresponds to the broad basinward plunging nose seen on the TWT map (Fig. 2) of the ABT. This region in the slope represents the northern limit of the morphological ridge in the Mahanadi offshore basin. However, as evidenced by a drilled well as well as by seismic data, it is suggested that the associated volcanism is present further northward in the shelf area.