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Research paper

Internal structure of the 85°E ridge, Bay of Bengal: Evidence for multiphase volcanism

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ABSTRACT

The 85°E Ridge, located in the Bay of Bengal of the northeastern Indian Ocean is an enigmatic geological feature as it possesses unusual geophysical signatures. The ridge's internal structure and mode of eruptions are unknown due to lack of deep seismic reflection and borehole data control. Here, we analyze 10 km of long-streamer seismic reflection data to unravel the ridge's internal structure, and thereby to enhance the understanding of how the ridge was originated and grew over a geologic time. Seismic facies analysis reveals the ridge structure consisting of volcanic vent and several stratigraphic units including packs of prograding clinoforms. The clinoform sequences are interpreted as volcanic successions, and led to the formation of lava-delta fronts. Interpreted features of lava-fed deltas and intervening erosional surfaces, and mass flows along ridge flanks suggest that the 85°E Ridge is a volcanic construct, and was built by both subaqueous and multiphase sub-marine volcanism during the Late Cretaceous (approximately from 85 to 80 Ma). At later time, from Oligocene-Miocene (~23 Ma) onwards the ridge was buried under the thick sediments of the Bengal Fan system.

1. Introduction

The 85°E Ridge, one of the enigmatic aseismic ridges of the world oceans extends from the Mahanadi Basin in the northern Bay of Bengal to location of the Afanasy Nikitin seamount (ANS) in the equatorial Indian Ocean (inset map, Fig. 1). The northern part of the ridge is buried under thick sediment sequences of the Bengal Fan system, whereas the southern part intermittently exposes to the seafloor. The ridge in the Bay of Bengal region is associated with prominent negative free-air gravity anomaly and alternative streaks of positive and negative magnetic anomalies (Fig. 1). On the whole, the 85°E Ridge is an unusual aseismic ridge and its geophysical signatures contrastingly differ from that of many of the well-studied aseismic ridges of world oceans. Earlier geophysical studies over the 85°E Ridge have brought out morphology of the ridge's exterior surface and discussed possible sources contributing to the anomalous geophysical fields of the ridge (Liu et al., 1982; Curray and Munasinghe, 1991; Gopala Rao et al., 1997; Ramana et al., 1997; Subrahmanyam et al., 1999, 2001; Krishna, 2003; Anand et al., 2009; Krishna et al., 2009a; Bastia et al., 2010; Michael and Krishna, 2011; Sreejith et al., 2011; Radhakrishna et al., 2012; Desa et al., 2013; Krishna et al., 2014a; Choudhuri et al., 2014; Srinivasa Rao et al., 2016; Talwani et al., 2016). Although a range of theories for the origin of the 85°E Ridge have been discussed, the mantle source (volcanic eruptions) hypothesis is the preferred one that reasonably explains the ridge structure and anomalous geophysical signatures associated with it. However, its internal structure, mode of volcanism and deposition pattern yet remained unclear as the ridge is buried at great depths below the thick pile of fan sediments; also all previous seismic data acquired over the ridge were not capable enough of retrieving details of the ridge's internal structure. So, it is believed that internal structure of the ridge may provide some important insights for detail understanding of mode of eruption/volcanism and lava flows within the ridge. In the present study, we carried out detailed analysis of exceptionally high-quality long streamer seismic reflection data across the 85°E Ridge to map its internal structure and to

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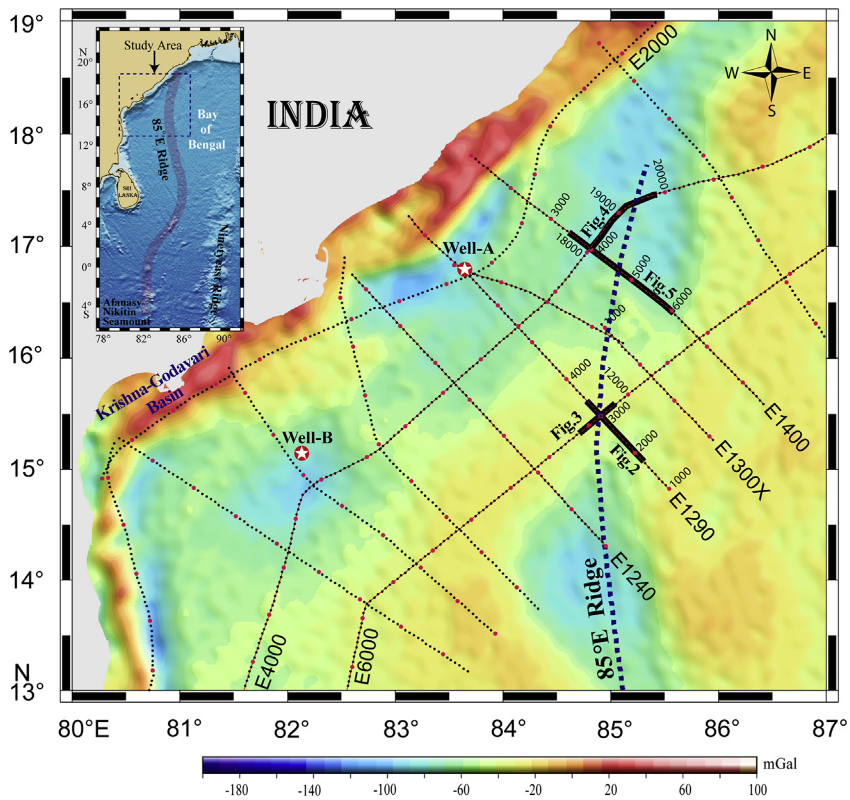

Fig. 1. Satellite free-air gravity anomaly color code map of the 85°E Ridge and adjacent area of the Bay of Bengal (Sandwell et al., 2014). Black dotted lines show the network of ION/GXT multi-channel seismic profiles investigated in the present work. The solid red circles with white star show the locations of industry (ONGC) drill wells "A" and "B" located on Eastern Continental Margin of India. Thick black lines show the locations of seismic sections illustrated in Fig. 2 and 3. The inset map shows the satellite derived bathymetry image of the Bay of Bengal and trace of the 85°E Ridge from the Mahanadi Basin in the north Bay of Bengal to the Afanasy Nikitin seamount in the equatorial Indian Ocean. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

understand how the ridge was initiated and evolved through time.

2. Geological setting of the Bay of Bengal

The ocean floor in most part of the Bay of Bengal was accreted by the Early Cretaceous seafloor spreading between two landmasses of the Eastern Gondwanaland, Greater India and Australian-Antarctic block (Curray et al., 1982; Royer and Coffin, 1992; Gaina et al., 2007; Krishna et al., 2009a; Veevers, 2009; Talwani et al., 2016). Its conjugate part is believed to exist beneath the western Enderby Basin off East Antarctica continental margin. At around 118 Ma, there was a major ridge jump towards the northeastern part of the Indian subcontinent to split the continental fragments of Elan Bank and part of the present Kerguelen Plateau (Talwani et al., 2016). As a result, age of the oceanic floor in the Western Basin of the Bay of Bengal is older than the other parts. In southeastern quarter of the Bay of Bengal, the ocean floor was evolved with a N-S spreading fabric by the India-Antarctica and Wharton ridge-systems during the Mid-Cretaceous period (Royer et al., 1991; Krishna et al., 1995, 1999, 2012; Krishna and Gopala Rao, 2000). Subsequently, the ocean floor in the Bay of Bengal was modulated into elongated basinal parts with the emplacement of two linear aseismic ridges, called the 85°E and Ninetyeast ridges along 85°E and 90°E meridians, respectively (Curray et al., 1982; Gopala Rao et al., 1997; Michael and Krishna, 2011). While the origin of the Ninetyeast Ridge was clearly deciphered due to the Kerguelen hotspot volcanism, but in the case of 85°E Ridge, despite huge efforts put forth by several researchers, the debate on contributing source is still undergoing. Eventually, the basement topography across the Bay of Bengal, i.e. from the Eastern Continental Margin of India (ECMI) to the Andaman Islands is manifested as alternate rises (85°E and Ninetyeast ridges) and wide depressions (Western, Central and Nicobar basins). Numerous river systems from the Indian subcontinent have almost continually discharged terrigenous sediments into the Bay of Bengal right from beginning of break-up of the Indian landmass from the Eastern Gondwanaland. The Indian peninsular rivers including the Mahanadi, Krishna–Godavari and Cauvery rivers have transported the eroded materials from land to the continental margin and beyond before and even after formation of both the linear aseismic ridges (Krishna et al., 2016). In a later phase (since the Oligocene-Miocene time), as a consequence of ongoing interactions between the Himalayan tectonics and Asian climate, the Ganges and Brahmaputra river systems have discharged a huge volume of sediments into the Bay of Bengal (Krishna et al., 2016) and they have been extended up to 7°40′S over a distance of ~3000 km (Krishna et al., 1998, 2001). During the Mid-to Late Miocene the oceanic lithosphere and overlying sediment strata in the distal Bengal Fan were systematically folded and faulted in E-W direction as a response to the continuous collision between the continents, India and Asia (Krishna et al., 2001, 2009b; Bull et al., 2010).

3. Geophysical dataset and analysis

In the present study, 2-D multi-channel seismic reflection data acquired by ION/GX Technology as part of deep-water exploration over the 85°E Ridge and adjacent regions were investigated (Fig. 1) to delineate the internal structure and evolutionary mechanism of