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Oblique strike-slip motion off the Southeastern Continental Margin of India: Implication for the separation of Sri Lanka from India

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ABSTRACT

The ocean floor in the Bay of Bengal has evolved after the breakup of India from Antarctica since the Early Cretaceous. Recent geophysical investigations including updated satellite derived gravity map postulated two phases for the tectonic evolution of the Bay of Bengal, the first phase of spreading occurred in the NW-SE direction forming its Western Basin, while the second phase occurred in the N-S direction resulting in its Eastern Basin.

Lack of magnetic data along the spreading direction in the Western Basin prompted us to acquire new magnetic data along four tracks (totaling ~3000 km) to validate the previously identified magnetic anomaly picks. Comparison of the synthetic seafloor spreading model with the observed magnetic anomalies confirmed the presence of Mesozoic anomalies M12n to M0 in the Western Basin. Further, the model suggests that this spreading between India and Antarctica took place with half-spreading rates of 2.7–4.5 cm/yr.

The trend of the fracture zones in the Western Basin with respect to that of the Southeastern Continental Margin of India (SCMI) suggests that SCMI is an oblique transform margin with 37° obliquity. Further, the SCMI consists of two oblique transform segments separated by a small rift segment. The strike-slip motion along the SCMI is bounded by the rift segments of the Northeastern Continental Margin of India and the southern margin of Sri Lanka.

The margin configuration and fracture zones inferred in its conjugate Western Enderby Basin, East Antarctica helped in inferring three spreading corridors off the SCMI in the Western Basin of the Bay of Bengal. Detailed grid reconstruction models traced the oblique strike-slip motion off the SCMI since M12n time. The strike-slip motion along the short northern transform segment ended by M11n time. The longer transform segment, found east of Sri Lanka lost its obliquity and became a pure oceanic transform fault by M0 time. The eastward propagation of the Africa-Antarctica spreading center initiated the anticlockwise separation of Sri Lanka from India by M12n time. Seafloor spreading south of Sri Lanka due to the India-Antarctica spreading episode and the simultaneously occurring strike-slip motion east of Sri Lanka restricted this separation resulting in a failed rift. Thus Sri Lanka with strike-slip motion to its east, failed rift towards west, continental extension to its north and rifting to its south behaved as a short lived microplate during the Early Cretaceous period and remained attached to India thereafter.

1. Introduction

The breakup of Eastern Gondwanaland since the Late Jurassic resulted in the formation of Greater India, Antarctica and Australia; and subsequent seafloor spreading between India and Antarctica formed the Bay of Bengal and its conjugate, Enderby Basin, off East Antarctica (Mckenzie and Sclater, 1971; Powell et al., 1988; Royer and Coffin, 1992). Recently, the evolution of the Bay of Bengal and Enderby Basin has been attributed to two episodes of breakup and spreading (Gaina et al., 2003; Krishna et al., 2009; Desa et al., 2013; Talwani et al., 2016). The first episode of spreading is the southwestward continuation of the Greater India-Australia spreading center which resulted in the opening of the Bay of Bengal and Enderby Basin in NW-SE direction (Powell et al., 1988; Williams et al., 2013). The arrival of the Kerguelen plume beneath Northeastern India by ~124 Ma (Kent, 1991; Talwani et al., 2016) caused the NE-SW trending spreading center to jump to the plume resulting in the transfer of oceanic crust and some microcontinents from the Indian plate to the Antarctica plate (Gaina et al.,

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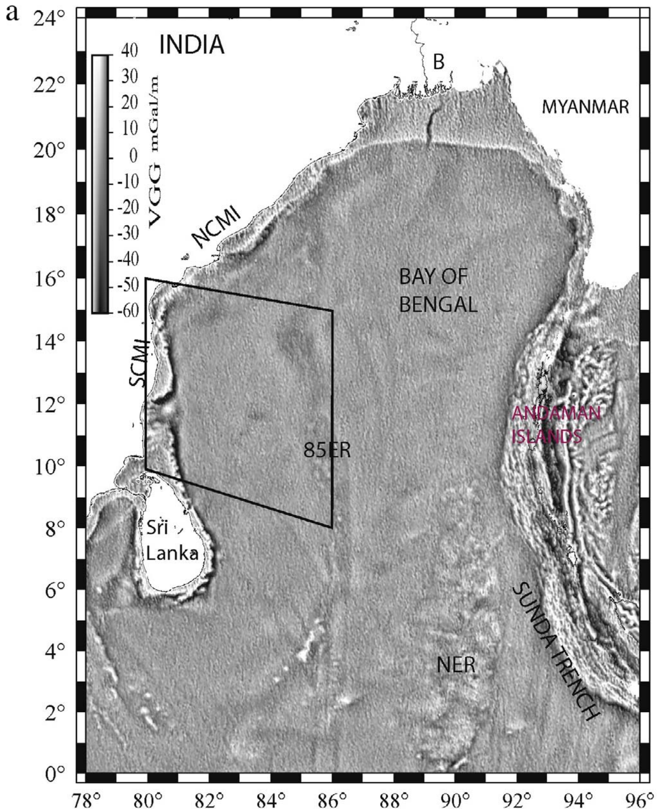

Fig. 1a. VGG model of the Bay of Bengal depicting the various structural and tectonic features (Sandwell et al., 2014). NW-SE trends are seen east of Sri Lanka. The study area is outlined in black. 85ER: 85°E Ridge; B: Bangladesh; NCMI: Northeastern Continental Margin of India; NER: Ninetyeast Ridge; SCMI: Southeastern Continental Margin of India.

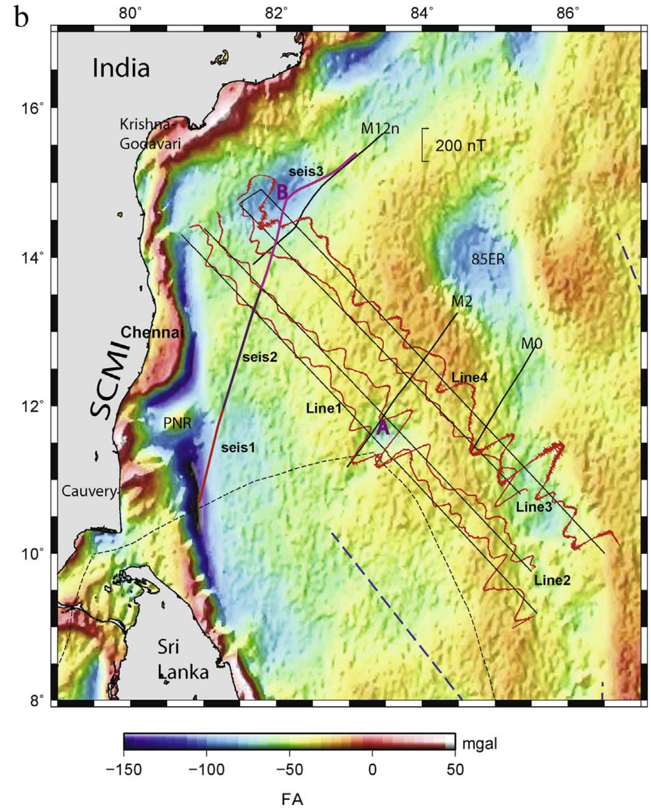

Fig. 1b. Full resolution satellite gravity of the Western Basin of the Bay of Bengal (Sandwell et al., 2014). The new magnetic data used in the present study is plotted along the tracks. The location of the seismic sections seis1 to seis3 is shown in different colors. The magnetic anomalies identified by Talwani et al. (2016) are shown in black. The fracture zone inferred by Wessel et al. (2015) is shown as blue dashed line. Strong shelf edge gravity low is seen along the SCMI. NNW-SSE to N-S trending negative gravity low belongs to the 85°E Ridge (85ER). Sri Lankan EEZ which restricted our data collection is shown as thin black dashed outline. Two circular gravity lows A and B are seen.

2003, 2007). The timing and mechanism of the ridge jump, and the extent of the crust transferred have been postulated (Talwani et al., 2016). A major plate reorganization took place during the Middle Cretaceous (Powell et al., 1988; Desa and Ramana, 2016) and the second spreading episode occurred in the N-S direction.

Various structural and tectonic elements have been inferred in the Bay of Bengal (Fig. 1a), such as the Bengal Fan, the Sunda Trench, the 85°E and Ninetyeast Ridges, and the Eastern Continental Margin of India (ECMI). The collision of India with Asia resulted in the uplift of the Himalayas and their subsequent erosion and deposition resulted in the ‘Bengal Fan’, the largest sedimentary fan in the world. The Bay of Bengal is floored by this fan whose sediment thickness is > 20 km at the apex and reduces to ~1 km at the equator (Curray, 1994). The Sunda Trench constitutes the subduction zone along which the Indian Plate is obliquely subducting beneath the Eurasian/Burmese plates (Kieckhefer et al., 1980). The Ninetyeast Ridge is considered the trace of the Kerguelen hotspot as the Indian plate moved north over it (Mahoney et al., 1983). The 85°E Ridge is attributed various evolution mechanisms until date due to its enigmatic geophysical signatures (Curray and Munasinghe, 1991; Kent et al., 1992; Ramana et al., 1997; Talwani et al., 2016; Ismaiel et al., 2017).

The ECMI is characterized with a narrow shelf (as narrow as 16 km) and a steep slope (~90 m/km) south of 14°N; and a wider shelf (up to 200 km) and a gentle slope (~30 m/km) towards north (Rao and Rao, 1986). The N-S trending narrow zone of strong gravity lows south of 14°N stands in contrast to the relatively wide zone towards north having fairly low amplitude gravity anomalies (Sandwell et al., 2014; Fig. 1b). Based on linear bathymetry along the Southeastern Continental Margin of India (SCMI) and its conjugate, the Kron Prins Olav Kyst region of East Antarctica, Powell et al. (1988) suggested 87 km of dextral motion at the initial breakup time. Further, an offset in the Continent Ocean Boundary (COB) was postulated at 12°N based on the offsets in the 200 m and 2000 m isobaths.

Strong contrasts in bathymetry, gravity and seismic stratigraphy divides the ECMI into the southern transform and northern rifted segments (Subrahmanyam et al., 1999). Admittance analysis indicated an elastic thickness of 10–25 km for the northern segment of the ECMI and ~3 km thickness for the southern segment (Chand et al., 2001; Chand and Subrahmanyam, 2001). Chand et al. (2001) suggested that the SCMI seems to have separated from its conjugate initially by shearing and later developing into a closely spaced transform-rift setting. Published seismic sections of the SCMI reveal abrupt downfaulting of the continental basement, rising continental Moho and a narrow transition zone connecting to the oceanic crust (Bastia et al., 2010). These seismic signatures are typical of a transform margin. NNE-SSW trending horst and graben structures in the SCMI oblique to the coastline extend from onshore to offshore (Sastri et al., 1981). The Cauvery rift zone is inferred as an intra-continental rift and probably linked to the separation of Sri Lanka from India (Twinkle et al., 2016).

The enormous sediment load reduced the visibility of the fracture zone signatures in the Bay of Bengal, which in turn constrained any inference on the seafloor spreading direction and magnetic anomaly identifications. The earliest magnetic data in the 1990’s was collected perpendicular to the coast assuming seafloor spreading was orthogonal as in normal conditions. This dataset prompted the identifications of Mesozoic magnetic anomalies in the Central Bay of Bengal (Curray and Munasinghe, 1991; Ramana et al., 1994). Several fracture zones having varying azimuths have been inferred in the Bay of Bengal (Ramana et al., 1994, 2001; Gopala Rao et al., 1997; Krishna et al., 2009;