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# Pseudofaults and associated seamounts in the conjugate Arabian and Eastern Somali basins, NW Indian Ocean – New constraints from high-resolution satellite-derived gravity data

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ABSTRACT

Marine gravity data derived from satellite altimeters are effective tools in mapping fine-scale tectonic features of the ocean basins such as pseudofaults, fracture zones and seamounts, particularly when the ocean basins are carpeted with thick sediments. We use high-resolution satellite-generated gravity and seismic reflection data to map boundaries of pseudofaults and transferred crust related to the Paleocene spreading ridge propagation in the Arabian and its conjugate Eastern Somali basins. The study has provided refinement in the position of previously reported pseudofaults and their spatial extensions in the conjugate basins. It is observed that the transferred crustal block bounded by inner pseudofault and failed spreading ridge is characterized by a gravity low and rugged basement. The refined satellite gravity image of the Arabian Basin also revealed three seamounts in close proximity to the pseudofaults, which were not reported earlier. In the Eastern Somali Basin, seamounts are aligned along NE-SW direction forming ~300 km long seamount chain. Admittance analysis and Flexural model studies indicated that the seamount chain is isostatically compensated locally with Effective Elastic Thickness ($T_e$) of 3–4 km. Based on the present results and published plate tectonic models, we interpret that the seamounts in the Arabian Basin are formed by spreading ridge propagation and are associated with pseudofaults, whereas the seamount chain in the Eastern Somali Basin might have probably originated due to melting and upwelling of upper mantle heterogeneities in advance of migrating/propagating paleo Carlsberg Ridge.



## 1. Introduction

The Arabian and Eastern Somali basins (Fig. 1), located in the north-western part of the Indian Ocean, were evolved due to rifting between Seychelles and Laxmi Ridge-India and subsequent seafloor spreading along paleo-Carlsberg Ridge since the Paleocene (magnetic Chron 28n, ~63 Ma). The evolution of these two large conjugate ocean basins (Fig. 2) was dominated by two major geodynamic events - the Deccan volcanic eruptions and the Indo-Eurasian continental collisions. The Deccan volcanic eruptions due to the Reunion hotspot during 68.5–62 Ma, found as continental flood basalts on the western Indian shield as well as on the Praslin Island in the Seychelles microcontinent (Devey and Stephens, 1991), probably triggered the rapid northward motion of India (Cande and Stegman, 2011). The Indian plate slowed down remarkably after the commencement of Indo-Eurasian collision at ~52 Ma (Patriat and Achache, 1984). Chagos-Laccadive and Mascarene ridges mark the track left by the Reunion plume in the western Indian Ocean (Morgan, 1981; Duncan and Hargraves, 1990) when the Indian plate moved over it. These tectonic events had a profound impact on both the evolving conjugate ocean basins; as a result, structural and tectonic elements of the basins are complex.

Earlier studies suggest that oceanic crustal accretion of the basins occurred through complex processes of propagating spreading ridge segments under the influence of the then nearby Reunion hotspot (Miles and Roest, 1993; Chaubey et al., 1998, 2002a,b; Dyment, 1998; Royer et al., 2002). The propagating spreading ridge-hotspot system, responsible for the creation of oceanic crusts of both the basins, generated three basic zones of lithosphere with distinct bathymetry and magnetic anomaly patterns. They are (i) normal lithosphere, (ii) propagating ridge lithosphere, and (iii) transferred lithosphere. These zones are separated by the propagating ridge tectonic elements such as propagating ridge, receding

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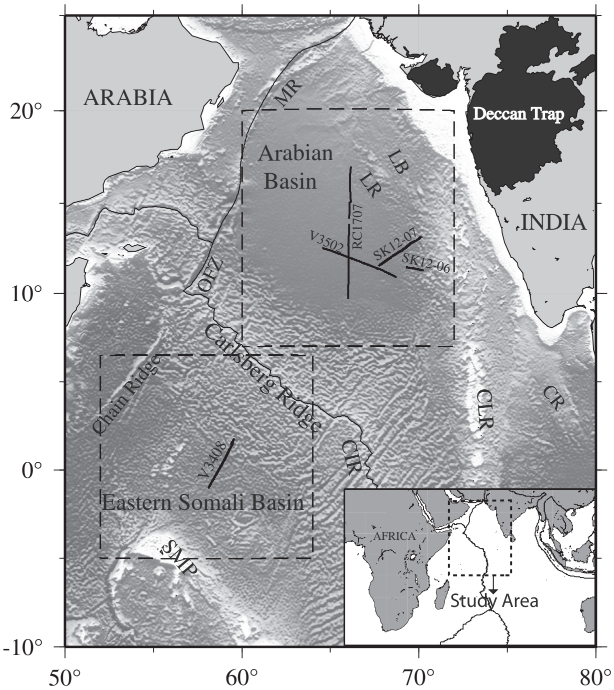


**Fig. 1.** Topographic Map of the northwest Indian Ocean (ETOPO-1) showing location of the Arabian and Eastern Somali basins. Locations of seismic and gravity profiles are indicated by thick black lines. Plate boundaries (thick black line) and study area (dashed line) is also shown. CIR = Central Indian Ridge, CLR = Chagos-Laccadive Ridge, CR = Carlsberg Ridge, LB = Laxmi Basin, LR = Laxmi Ridge, MR = Murray Ridge, OFZ = Owen Fracture Zone, SMP = Seychelles-Mascarene Plateau, CR = Comorin Ridge.

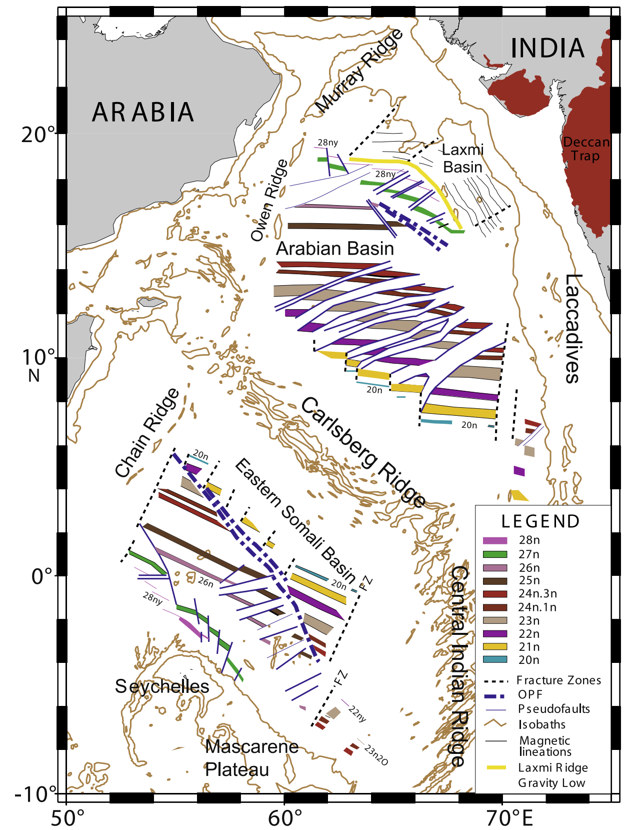


**Fig. 2.** Tectonic chart of the Arabian and Eastern Somali basins. Thick dark blue lines in the Arabian and Eastern Somali basins are major Pseudofaults. Inferred magnetic lineation in the Laxmi Basin (after Bhattacharya et al., 1994) and north of the Laxmi Ridge (after Malod et al., 1997) are marked as thin black lines. The 200 and 3000 m GEBCO isobaths are shown for reference. OPF = Outer Pseudofault. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

ridge, failed ridge, inner and outer pseudofaults. The propagating ridge systems delineated in these ocean basins are primarily based on marine magnetic data (Miles and Roest, 1993; Chaubey et al., 1998, 2002a; Dyment, 1998; Royer et al., 2002) which now warrant further study in order to bring out the finer details of the geometry of the pseudofaults, and other tectonic elements. Additional closely spaced magnetic tracks are required to be acquired for such a detailed study. In the absence of such dataset, we attempted to demarcate and characterise tectonic elements of the propagating rift system generated during a complex pattern of spreading ridge propagation using high-resolution satellite gravity, shipborne seismic datasets and results of the earlier studies. The main objectives of this study are to (i) present refined position of the pseudofaults, its extension and basement characteristics using refined gravity and available seismic data, and to (ii) understand the relationship between pseudofaults and seamounts/seamount chain and their isostatic compensation mechanism.

## 2. Study area and geophysical data

The present study focuses on the Arabian and Eastern Somali basins of the north-western part of the Indian Ocean (Fig. 1). Geographically, the Arabian Basin is bounded to the west by the Owen Fracture Zone, which demarcates the transform boundary between the Indian and Arabian plates; to the south by the active Carlsberg Ridge, which separates the Indian and African plates; and to the north and east by the Laxmi Ridge and the northern portion of the Chagos - Laccadive Ridge, respectively. The Eastern Somali Basin is bounded by the Carlsberg and Central Indian ridges in the north and east, the Seychelles block and the northern Mascarene plateau to the south, and the Chain Ridge to the west. In the Arabian Basin, water depth and sediment thickness varies from 3.4 km to 4.3 km and from 1.3 km to 4.2 km respectively. Whereas, in the Eastern Somali Basin, water depth varies from 3.5 km to 5.0 km.

We have utilized satellite altimeter-derived gravity data of Sandwell et al. (2014) for this study. This gravity data is derived by merging the CryoSat-2 and Jason-1 satellite altimeter data to the existing data from ERS-1 and GEOSAT, resulting two-four times improvement in accuracy than the previous global gravity models (Eg. Sandwell and Smith, 2009). The data is particularly effective in mapping fine-scale manifestations of plate tectonics such as pseudofaults and buried seamounts apart from major tectonic features of the ocean floor (Sandwell et al., 2014). In addition, shipborne gravity and bathymetry data collected by Indian and International agencies were utilized for the present study. Further, Single Channel Seismic (SCS) reflection data from NGDC and Multi-Channel Seismic (MCS) reflection data along tracks SK12-06 and SK12-07 across the central-western continental margin of India collected onboard ORV Sagar Kanya were used for the study (Fig. 1). Positions along the track were obtained by an integrated navigation system using a dual-channel satellite receiver as primary navigational aid. The MCS data were acquired using a 24-channel seismic streamer with 32 hydrophones per group spaced at 25 m intervals. The MCS data were processed at CSIR-National Institute of Oceanography, Goa using ProMAX seismic data processing software.