

Structure and Tectonics of Western Continental Margin of India: Implication for Geologic Hazards

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The geomorphological and geological characteristics of Western Continental Margin of India (WCMI) are closely related to the tectonic history of the Indian subcontinent, its break up during continental rifting, magmatic and sedimentary history, northward movement of India and finally collision with the Eurasian plate. The margin is characterized by extensional tectonics resulted during early stage of passive margin formation. The WCMI evolved due to breakup of India from (i) Madagascar during mid-Cretaceous producing non-volcanic continental margin in the south, and (ii) Seychelles micro-continent during the early-Tertiary producing volcanic continental margin in the north (Courtillet et al., 1988; White and McKenzie, 1989; Storey et al., 1995; Bhattacharya and Chaubey, 2001 and references therein). The configuration of the WCMI was also dominated by two major geodynamic events: the onset of Reunion hotspot activity and Indo-Eurasian continental collisions.

The Reunion hotspot activity caused widespread volcanism over the Indian landmass and created the Deccan Continental Flood Basalt (DCFB) province on the western and central Indian (Duncan, 1990) as well as continental flood basalt on the Praslin Island in the Seychelles microcontinent (Devey and Stephens, 1991). The DCFB is the largest known continental flood basalts that mainly erupted in less than 1 million year during Chron 29R (~65.6 – 64.8 Ma) through the Cretaceous-Tertiary boundary. It covers an area of more than 5×10^5 km², almost one-sixth of the total surface area of the Indian Peninsula. It is believed that nearly equivalent area, adjoined to the DCFB province of western and central India, has been submerged in the western offshore region of India in the Arabian Sea. The extrusion of DCFB due to Reunion hotspot is inferred as late syn-rift-to-breakup volcanism contemporaneous with separation between Seychelles and India (Todal and Eldholm, 1998). It was opined that average extrusion

rate was in excess of $1 \text{ km}^3 \text{ a}^{-1}$ for a total duration of 1 m.y. (Courtilot et al., 1986), whereas globally $2-4 \text{ km}^3 \text{ a}^{-1}$ basaltic layer is formed due to seafloor spreading. Evidently, the event, which produced such a large amount of basaltic magma on the earth's surface, and often considered for the Cretaceous/Tertiary (K/T) biological mass extinction, must have had a profound influence on the crustal evolution (Ajay and Chaubey, 2008) including the present-day configuration of the continental margin concealing the pre-existing geology and crustal structure.

Shortly after Deccan volcanism, seafloor spreading between Seychelles and India started. This new spreading center (Paleo-Carlsberg Ridge) separated Seychelles from India by spreading-ridge propagation and started evolving the conjugate Arabian and the eastern Somali Basins (Bhattacharya and Chaubey, 2001 and references therein; Chaubey et al., 2002a; Royer et al. 2002). As the India plate continued to move northward, the adjacent offshore areas came under the influence of the Reunion hotspot that resulted in magmatic intrusions within stretched continental crust of the western continental margin of India.

The Indo-Eurasian continental collision is another major geological event, which has important consequences in various fields ranging from hydrocarbon exploration to seismological hazard to climatology. The Indo-Eurasian continental collision started at about chron 24n (52 Ma; Patriat and Achache, 1984) and has continued up to now.

The WCMI is a typical passive continental margin of the Atlantic type, and characterized by ~300 km wide continental shelf in Kutch-Saurashtra area which gradually narrows down southward to ~50 km in Kerala offshore area. Complementary to this, the continental slope is narrow in the north but widens towards south. The shelf area is comprised of mainly four shelf sub-basins, namely Kutch, Saurashtra, Bombay and Konkan-Kerala offshore basins. The margin hosts a number of deep-seated faults, rift systems, basement highs, numerous NW-SE trending structural features namely Laccadive Ridge, Laxmi Ridge, Prathap Ridge Complex, Panikkar Ridge, Seamount chain (Fig. 1), which are mostly buried under the Indus Fan sediments (Bhattacharya and Chaubey, 2001 and references therein;

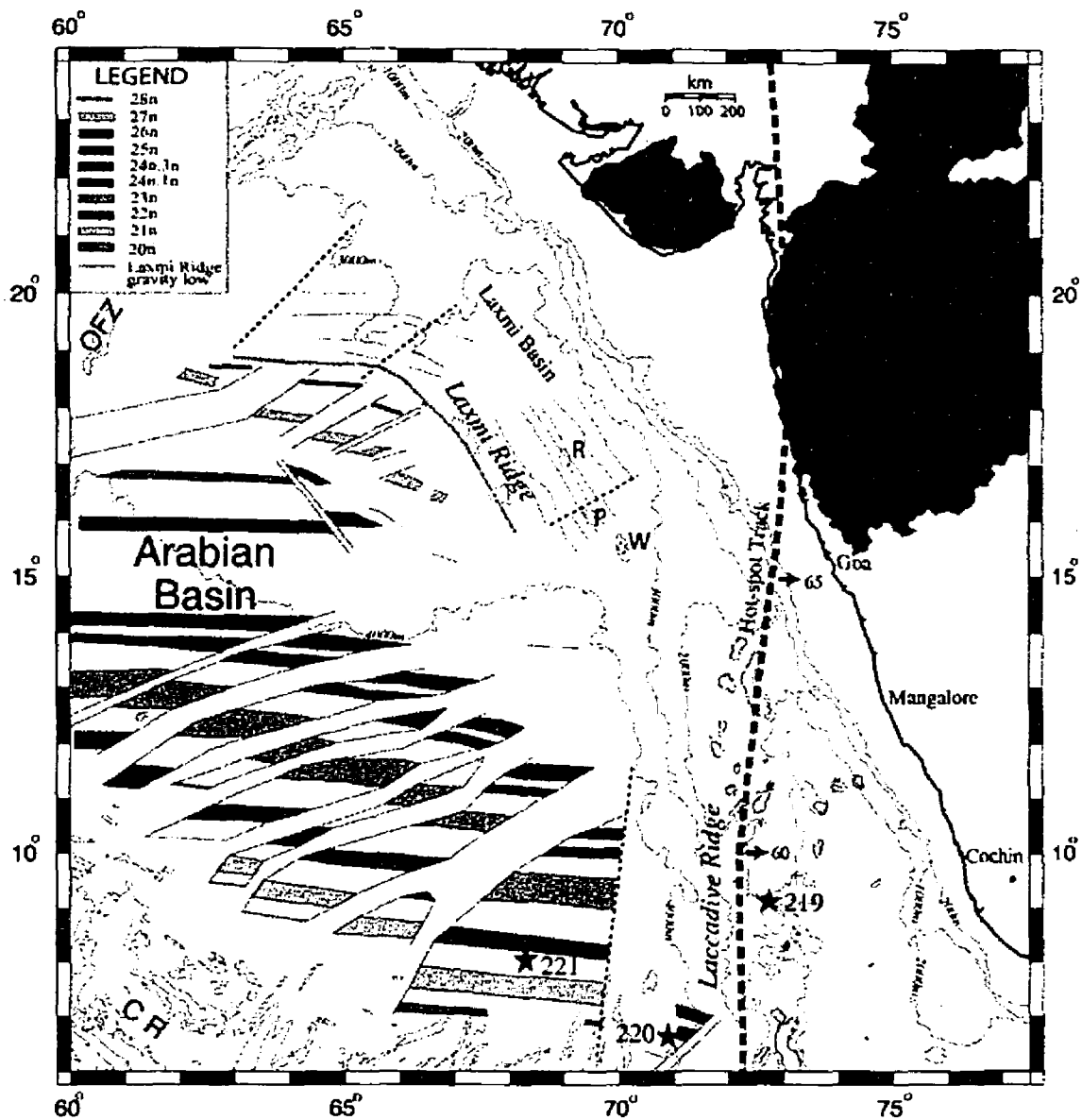


Fig. 1. Generalized tectonic map of the western continental margin of India and adjoining Arabian Basin showing magnetic lineations, pseudofaults (thin blue lines), fracture zones (dashed-lines) and main structural features (Chaubey et al. 2002a). DSDP drill sites are shown by solid stars; solid thick dashed line represents computer-modelled Reunion hotspot track; numbers along the hotspot track are predicted ages in Ma; thin red lines represent magnetic lineations in the Laxmi Basin (Bhattacharya et al. 1994a). CR: Carlsberg Ridge, OFZ: Owen Fracture Zone. R: Raman Seamount, P: Panikkar Seamount, W: Wadia Guyot (Bhattacharya et al., 1994b; Bhattacharya and Chaubey, 2001 and references therein).

Subrahmanyam et al., 1995; Chaubey et al., 2002b; Krishna et al., 2006; Subrahmanyam and Chand, 2006; Chaubey et al., 2008). Several onshore lineaments extend over a considerable distance into the offshore region. It includes faults and basement arches of the shelf and is mainly parallel to the Dharwar (NW-SE to NNW-SSE) and Eastern Ghat (NE-SW) trends. Biswas (1987) has pointed out that the horst-graben structures, basement arches and fault patterns of the shelf areas are formed due to rifting and movements along the ancient Precambrian structural trends. All these features indicate a weakened and stressed crust.

Long Indian coastline (~7500 km) and a large exclusive economic zone (~ 2.02 million km²) that includes two major groups of islands - Andaman and Lakshadweep, are susceptible to different geologic hazards - a natural geologic event that can endanger human lives and threaten human property (Krishna, 2005). Re-activation of existing fault systems (Subrahmanyam et al., 1993), slumping and mass movements due to slope failure (Fig. 2), igneous activity, uplift and subsidence, and erosion can pose natural geologic hazards on the WCMI. Along the WCMI and Lakshadweep islands, slope failures and mass movements are related to different factors in different areas. Slumping is not uniformly distributed along the margin, being more extensive in the north than in the south. Dissociation of gas hydrates, re-activation of existing fault system (Fig. 3), earthquake activity, and high sedimentation rates can indirectly play a vital role in generating slumping and mass movement along the WCMI (Vestal and Lowrie, 1982; Chauhan and Chaubey, 1992; Rao et al, 2002). It is therefore essential to build a record of slope failures and mass flows through time and space and determine the frequency of occurrence.

A key element in reducing geologic hazard impacts is to develop a more thorough scientific understanding of geologic factors of the Indian continental margins that make certain locations particularly vulnerable to hazard impacts. Monitoring micro-earthquake activities in deep-offshore region of the WCMI using network of ocean bottom seismometers will be helpful in understanding ongoing seismic activity of the area.

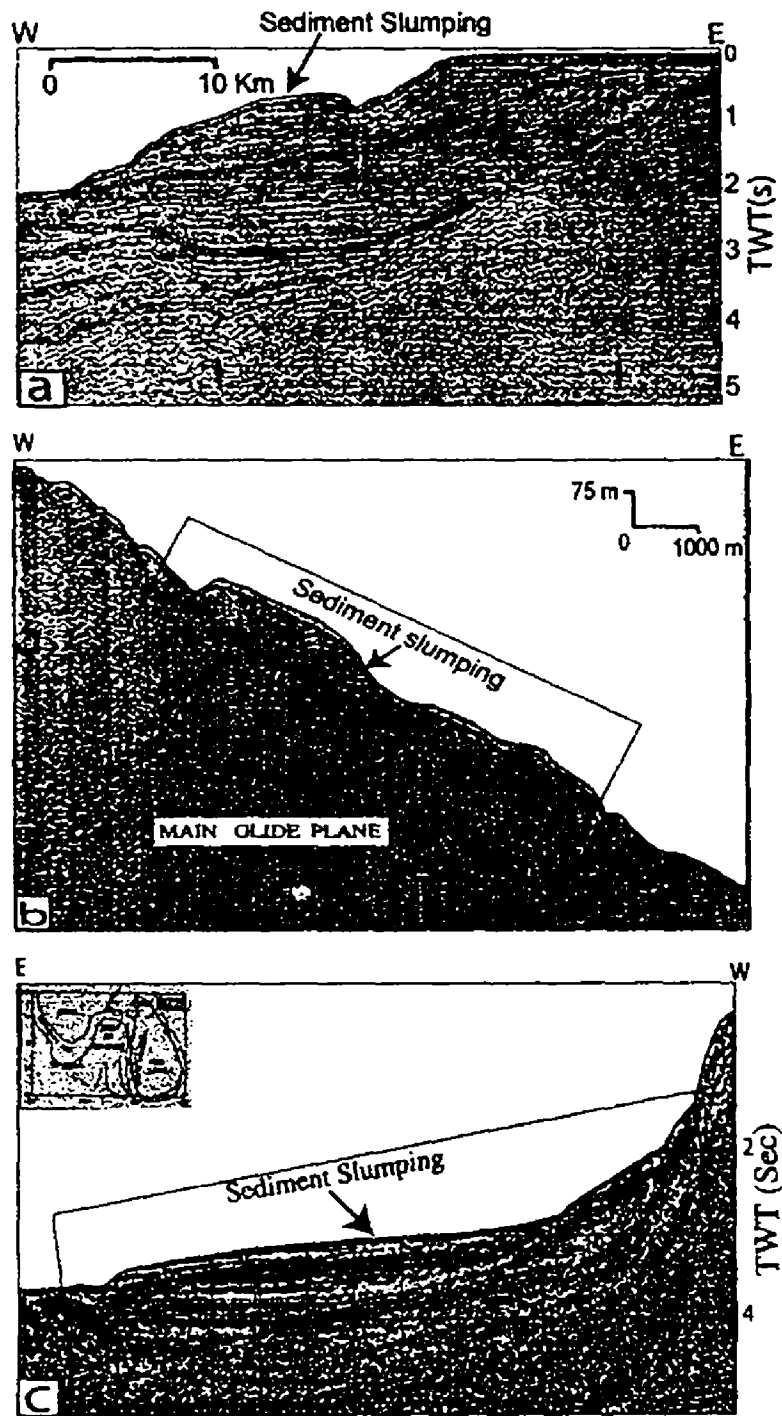


Fig. 2(a) Seismic section from Cochin offshore region, showing slumping on the continental slope region. (b) Seismic section off Amini Island, Lakshadweep, showing slump deposits at the foot of slope. Please note smoothness of main glide plain. (c) Seismic section off southern tip of India, showing slump deposit where main glide plain is difficult to identify.

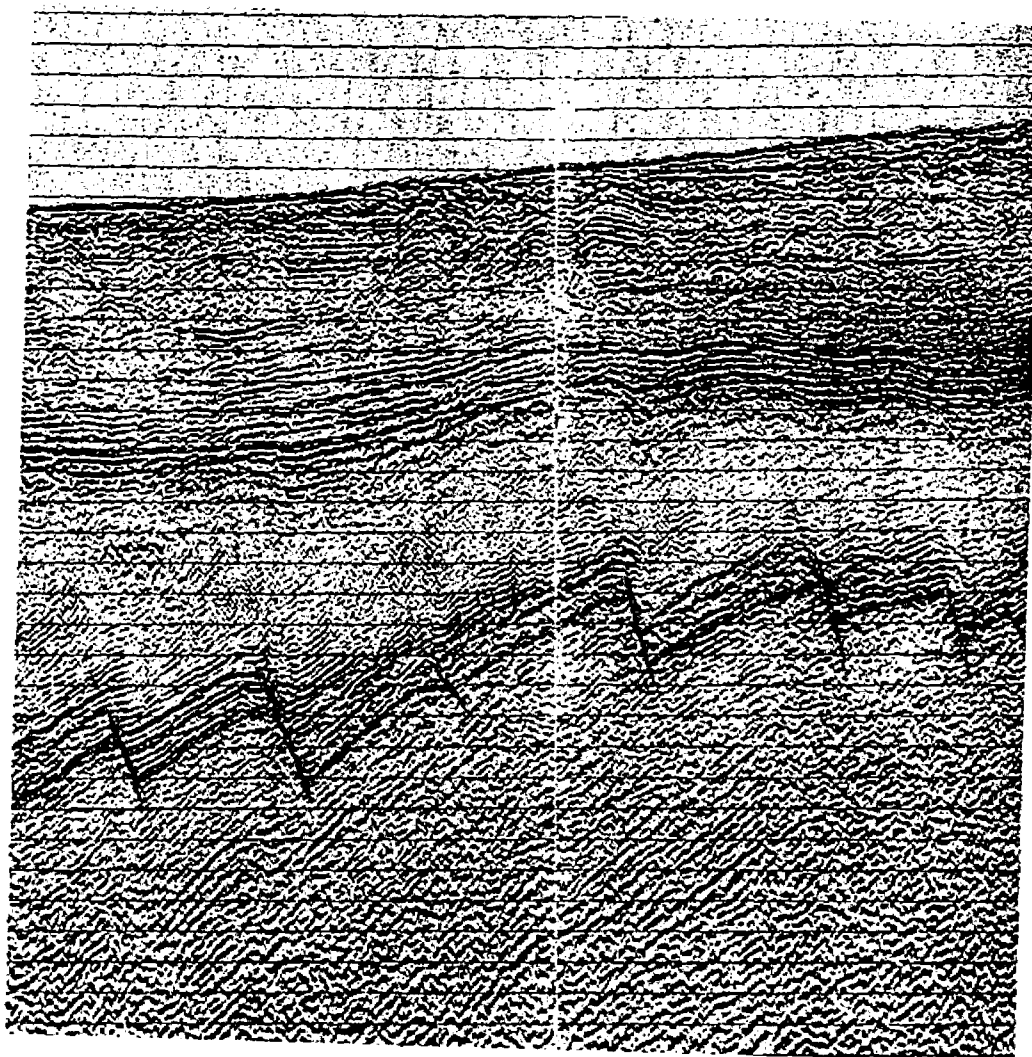


Fig. 3. Pattern of reverse faults observed in multi-channel seismic profile located off Goa across the western continental margin of India. Vertical scale is in TWT (s).

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