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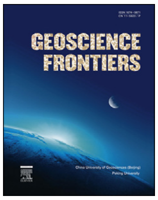

Research paper

Basement tectonics and flexural subsidence along western continental margin of India

D.K. Pandey*, Nisha Nair, Anju Pandey, G. Sriram

ESSO-National Centre for Antarctic and Ocean Research, Goa, India

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A B S T R A C T

The Paleocene-recent post-rift subsidence history recorded in the Mumbai Offshore Basin off western continental margin of India is examined. Results obtained through 2-D flexural backstripping modelling of new seismic data reveal considerable thermo-tectonic subsidence over last ca. 56 Myr. Reverse post-rift subsidence modelling with variable β stretching factor predicts residual topography of ca. 2000 m to the west of Shelf Margin Basin and fails to restore late Paleocene horizon and the underlying igneous basement to the sea level. This potentially implies that: (1) either the igneous basement formed during the late Cretaceous was emplaced under open marine environs; or (2) a laterally varying cumulative subsidence occurred within Mumbai Offshore Basin (MOB) during ca. 68 to ca. 56 Ma. Pre-depositional topographic variations at ca. 56 Ma across the basin could be attributed to the extensional processes such as varied lower crustal underplating along Western Continental Margin of India (WCMI). Investigations about basement tectonics after unroofing of sediments since late Paleocene from this region support a transitional and heavily stretched nature of crust with high to very high β factors. Computations of past sediment accumulation rates show that the basin sedimentation peaked during late Miocene concurrently with uplift of Himalayan–Tibetan Plateau and intensification of Indian monsoon system. Results from basin subsidence modelling presented here may have significant implications for further studies attempting to explore tectono–climatic interactions in Asia.

1. Introduction

Passive continental margins such as the Western Continental Margin of India (WCMI) are typically defined as seismically quiescent margins where adjoining oceanic and continental lithospheres are gelled together. Passive margins are often flanked by relatively young and expanding ocean basins adjacent to their shelves (White and McKenzie, 1989; Allen and Allen, 2006). The transition from rifted margin to passive continental margin takes place at the rift to drift transition depending upon whether or not the sea-floor spreading stage was reached. Role of mantle plumes in shaping up of passive rifted margins has been widely debated for long time (McKenzie and Sclater, 1971; White and McKenzie, 1989; Anderson, 2001 and references therein). Plume-rift interactions can significantly modify the crustal geometry including Continent–Ocean Transition (COT) (White and McKenzie, 1989; Kusznir et al., 1995; Watts, 2001). Therefore, identification of COT along passive margins is often crucial due to anomalous nature of underlying crust. Knowledge about COT permits determination of the nature and extent of rifting along a margin. Further, passive margins usually experience broad regional subsidence over a period of time. This is due to lithospheric cooling following partial/complete attenuation of the continental lithosphere (White and McKenzie, 1989; Kusznir et al., 1995; Buck, 2001) and sediment accumulations. Therefore, the total subsidence–a function of the tectonic, eustatic sea level and climatic changes over long periods (Watts, 2001; Allen and Allen, 2006) can be used to decipher extensional tectonics along a margin. Precise knowledge about periodic sedimentation on a margin would provide key constraints about its evolutionary journey through time (Hopper and Buck, 1996). Post-rift sediment thicknesses developed beneath the outer shelf and slope on such margins, may range from a few hundreds of meters to tens of kilometers (Clift et al., 2002). Marginal sedimentary basins are often imbibed with enormous resource potential. Deep penetrating seismic reflection, borehole information and other corroborative

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* Corresponding author.
E-mail address: pandey@ncaor.gov.in (D.K. Pandey).

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geophysical data are some of the best utilized tools to perform basin subsidence analyses to know more about periodic sedimentation and its effects on the extensional tectonics.

The central part of WCMI near Bombay High (Fig. 1) is geologically referred as Mumbai Offshore Basin (MOB). This region, having thick sediments and rich resource potential, is among least explored margins in terms of detailed 2-D flexural subsidence analyses. In the present study, we explore magnitude of total subsidence along WCMI through analyses of marine geophysical data (Fig. 1). Previous studies (e.g. Mohan, 1985; Agrawal and Rogers, 1992; Whiting et al., 1994; Chand and Subrahmanyam, 2003) used 1-D backstripping analyses to reconstruct geohistory from basin stratigraphy along WCMI. However, previous studies were primarily based upon scattered borehole data and used 1-D Airy type isostatic compensation (Watts, 2001). The Airy type (i.e. local isostasy) is known to have several limitations as it omits the flexural strength of the lithosphere. Resultantly it tends to work well with very low effective elastic thickness (i.e. $T_e \approx 0$) which is not valid in case of shorter wavelengths of loads on a margin (such as structures in the range of ca. 10–25 km). Consequently, use of Airy rather than flexural backstripping tends to overestimate factors and may deliver erroneous subsidence history (Kusznir et al., 1995; Roberts et al., 1998). The flexural approach on the other hand allows one to account for 'sideways' loads (Kusznir et al., 1995) and produces much more reliable estimates for calculating basin subsidence.

The primary objective of this study is to investigate subsidence history along WCMI using 2-D flexural backstripping approach (Kusznir et al., 1995; Roberts et al., 1998). In particular, we attempt to examine creation of accommodation space *vis-a-vis* flexural adjustments in the basin which is poorly understood at the moment. Role of eustatic changes as well as sediment loading from possible 'sources' such as Indus fan and denudational discharge from peninsular India since its inception is examined. Based on new deep penetrating multi-channel seismic (MCS) data and constraints from industry boreholes from WCMI, we reconstruct the vertical tectonics since initiation of late Cretaceous rift-drift process.

2. Regional setting and tectonic framework

The WCMI, surrounded by adjoining ocean basins in the Arabian Sea, is a passive continental margin extending more than 2000 km long from Gujarat coast in the north to Kerala coast in the south (Fig. 1). The breakup of East Gondwana initiated in early Jurassic c.a. 150 Ma (Courtillot et al., 1986; Storey et al., 1995) followed by separation of Greater India (India–Madagascar) from Africa ca. 130–120 Ma (Reeves and de Wit, 2000). Later, India–Madagascar break-up occurred at ca. 88 Ma which is considered as the first major rifting event that modified the WCMI (Agrawal et al., 1992; Storey et al., 1995; Chand and Subrahmanyam, 2003; Yatheesh et al., 2009). Subsequently, a ridge jump in Mascarene Basin during the late Cretaceous led to the break-up of Seychelles and India (Norton and Sclater, 1979; Naini and Talwani, 1982; Schlich, 1982; Biswas, 1999; Chaubey et al., 2002; Yatheesh et al., 2009). The emplacement of Deccan flood basalts at ca. 65 Ma is opined to be contemporaneous with the rifting between Seychelles and India (McKenzie and Sclater, 1971; Hooper, 1990; Venkatesan et al., 1993; Subrahmanya, 1998; Pande et al., 2001). The rifting episode is

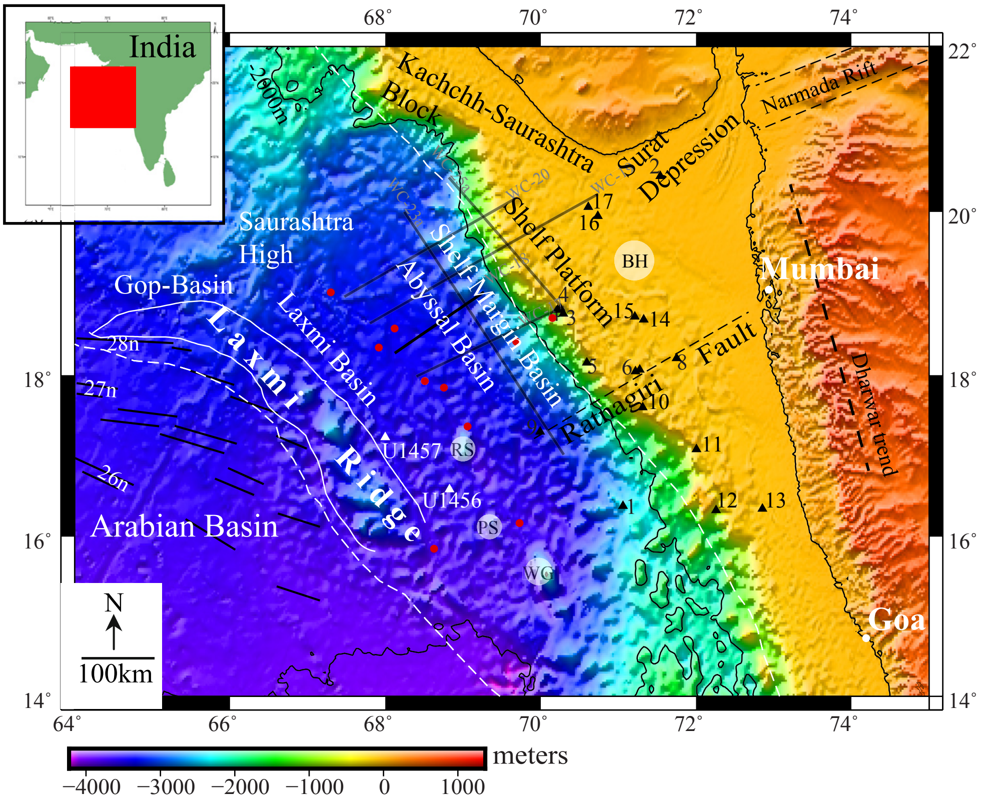

Figure 1. Regional bathymetry (m) map of the western continental margin of India (WCMI). Superposed are the major tectonic elements and locations of seismic profiles (solid black lines) used in this study. Solid black triangles with superscripted numbers denote locations of the commercial wells in the region (see Table 2 for more information). Solid white triangles denote locations of Sites (U1456 and U1457) from IODP expedition 355 (Pandey et al., 2016) in the Arabian Sea. Magnetic anomalies are plotted after Royer et al. (2002). Solid red circles denote locations of seismic refraction stations (after Naini and Talwani, 1982); RS-Raman Seamount; WG-Wadia Gyot; PS-Panikkar Seamount; BH-Bombay High. White dashed lines represent possible locations of Continent Ocean Boundary (COB) depending upon the nature of crust in between.

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