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Seismic evidence of crustal low velocity beneath Eastern Ghat Mobile Belt, India

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ABSTRACT

The Eastern Ghat Mobile Belt (EGMB), a tectonically active area extends along the eastern margin of Peninsular India, is divided into three provinces, namely, Eastern Ghat Province, the Jeypore Province, and the Krishna Province. The Ongole domain of Krishna Province is a seismically active region that has experienced four moderate earthquakes of magnitude $\geqslant$5.0, of which largest one is of magnitude 5.4 occurred on 27th March 1967. The crustal shear wave velocity structure in the Eastern Ghat Mobile Belt has been investigated using joint inversion of receiver functions and Rayleigh wave group velocity at 5 locations in the study region. The results show crustal thickness variation from 37 to 42 km and average shear velocity variation from 3.67 to 3.78 km/s in the study region. A low velocity layer of variable thickness and velocities 3.54–3.7 km/s) is also observed in the region. The low velocity layer in most of the stations is observed at a depth of ~20 km. This low velocity layer may be due to the presence of fluid in the crust, which also be one of the causes of the intraplate earthquakes in the study region.

1. Introduction

The Eastern Ghats Mobile Belt (EGMB) is a NE-SW trending arcuate Precambrian fold belt of high grade rocks along the east coast of India (Fig. 1). It is a highly eroded part of an extensive orogenic belt delineating the eastern boundary of the archean cratons of India. The belt consists of supracrustals of charnockites and enderbites, which are products of highly deformed and multiply metamorphosed protolith. The presence of sapphirine bearing granulites predicts the occurrence of ultra-high metamorphism (UHT) which probably has been caused due to crustal delamination. The striking similarity between the rocks exposed in the EGMB and Antarctica, particularly in the Enderby Land area (Napier and Rayner Complexes) clearly shows the association of the EGMB with the South West United States and East Antarctica (SWEAT) and the involvement of EGMB in the separation of two major supercontinents, Columbia (Rogers and Santosh, 2002; Zhao et al., 2002, 2004) and Rodinia (Li et al., 2008) and it has been unanimously agreed upon by the scientific community (e.g., Rao et al., 2011; Kumar and Leelanandam, 2008; Vijaya Kumar et al., 2011).

Most of the geophysical anomalies viz., seismic velocity, gravity, heat flows and seismicity are more pronounced in the mobile belts. The crustal velocity structure and Moho configuration are the important parameters to understand the tectonic process and the evolution of any region. They can be used to calculate the stress generation and to understand the seismicity of intraplate regions. Mandal (1999) has evaluated the amount of stress generated due to crustal density/velocity heterogeneities (subsurface load) in various parts of the Indian shield and demonstrated its significance in the seismicity of the region. Reddy (1995) also indicated the importance of crustal thickness and velocity distribution in stress generation with reference to the Indian shield.

The behavior of the continental crust under stress depends chiefly on the temperature and the duration of the stresses. The hotter the crust, the more it behaves like a ductile solid deforming by plastic flow (Condie, 2005). If it is cool, it behaves like an elastic solid deforming by brittle fracture and frictional gliding (Rutter and Brodie, 1992). The distribution of strength with depth in the crust varies with the tectonic setting, the strain rate, the thickness and composition of the crust, and the geotherm. The brittle-ductile transition corresponding to an average surface heat flow of 50 mWm^{-2} is around a 20-km depth, which corresponds to the depth limit of most shallow earthquakes. The brittle-ductile transition occurs around a 20-km depth in the rift, whereas in the cooler and stronger Proterozoic shield, it occurs around 30 km. In general,

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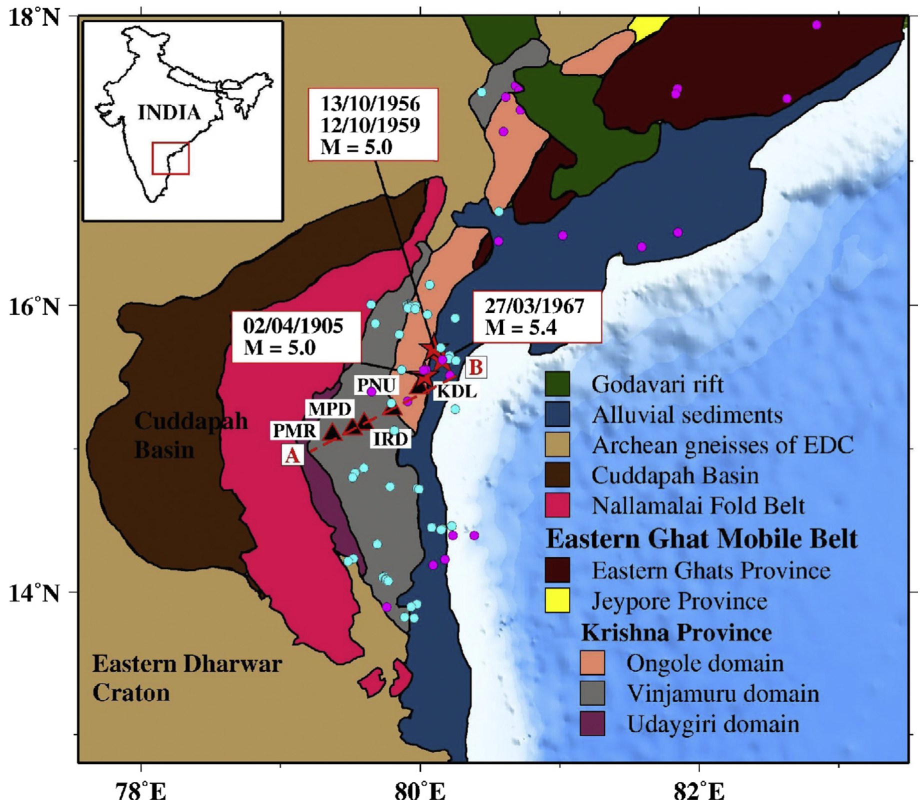

Fig. 1. Major tectonics features in the study region along with broadband seismic stations, shown by black triangles. Earthquakes in the region are marked cyan (International Seismological Centre (ISC) catalogue; www.isc.ac.uk) and magenta circle (Saikia and Rai, 2016), of which M ⩾ 5.0 earthquakes are shown by red stars. Red dashed line (AB) is a cross-section along which Common Conversion Point image is constructed in Fig. 7. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the brittle-ductile transition occurs at relatively shallow depths in warm and young crust (10–20 km), whereas in cool and old crust, it occurs at greater depths (20–30 km).

Fluid transport in the crust is an important process affecting both rheology and chemical evolution. Because crustal fluids are mostly inaccessible for direct observation, this process is poorly understood and difficult to study. Studies of fluid inclusions trapped in metamorphic and igneous minerals indicate that shallow crustal fluids are chiefly water, whereas deep crustal fluids are mixtures of water and CO_2 (Bohlen, 1991; Wickham, 1992). Fluids are reactive with silicate melts, and in the lower crust they can promote melting and can change the chemical and isotopic composition of rocks. In the lower crust, small amount of fluids can be generated by the breakdown of hydrous minerals and the major source of fluids comes from the mantle. Studies of xenoliths suggest that the mantle lithosphere provides a potentially large source for CO_2 in the lower crust, and the principal source for CO_2 may be important in the production of deep crustal granulites (Condie, 2005).

The Eastern Ghat Mobile Belt is a tectonically active region and the Ongole domain, a part of this, is known to have experienced intermittent seismic activity since the eighteenth century including four moderate earthquakes, viz. 13th October 1956, 12th October 1959, 2nd April 1905, of magnitude 5.0 and 27th March 1967 of magnitude 5.4 (red star in Fig. 1). Apart from the moderate events, small earthquakes are also reported in the region. Fig. 1 shows the epicenters of all the earthquakes listed in the International Seismological Centre (ISC; www.isc.ac.uk) bulletin (magenta circle) and the research work carried out by Saikia and Rai (2016) to study the seismicity in the South India based on analysis of local earthquakes recorded at 54 broadband seismic stations operated by CSIR-NGRI during February 2009 and April 2012 (cyan circle). Seismicity in and around the Ongole area is attributed to a combination of neotectonic activity coupled with the effects of Indo-Antarctica breakup and periodical reactivation of fault, since geological past (Reddy and Chandrakala, 2004).

Until now, no proper seismological investigation has been carried out in this particular important domain to address the plausible cause of intraplate seismicity. In this study we have investigated the crustal shear velocity structure beneath the EGMB by the joint inversion of receiver functions and the group velocity dispersion data, and have tried to investigate the possible cause of the seismicity in the study region, along with its plausible correlation (if exists) with the crustal parameters, such as thickness, shear wave velocity, Vp/Vs ratio etc.

1.1. Previous geophysical studies

Most of the geophysical studies over southern India are focused on the crustal structure of Dharwar craton in general and EGMB, in particular. Previous seismological studies by Ramesh et al. (2010) reveal the presence of two distinct westerly dipping interfaces at depths centered on 150 km and 200 km in the study region, which they interpreted as boundaries that represent remnant structures fashioned by the collisional processes that affected this region in the Proterozoic and early Paleozoic. Seismic imaging by the recent receiver function study by Das et al. (2015), Saikia et al. (2016) in South India found a crustal thickness variation of 35–42 km in the EGMB. Chandrakala et al. (2015) predicted that the entire stretch of EGMB-Cuddapah Basin collisional zone is underplated by a thick (~20 km) high velocity (7.0–7.4 km/s) magma layer above the Moho, indicating strong crust-mantle thermal perturbation and