Journal of Asian Earth Sciences 42 (2011) 341–353

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Crustal density structure across the Central Indian Shear Zone from gravity data

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ARTICLE INFO

Article history:
Available online 13 June 2011

Keywords:
Central Indian Shear Zone
Central Indian Tectonic Zone
Bouguer gravity anomaly
Horizontal gravity gradient
Crustal reflectivity pattern
Wide angle reflection

ABSTRACT

The Central Indian Shear Zone is a distinct tectonic feature in the central part of India that separates the Central Indian Tectonic Zone from the Bastar Craton. The complete Bouguer anomaly map of the region encompassing Central Indian Shear Zone is characterised by a broad relative gravity high over Central Indian Tectonic Zone as compared to the Bastar Craton. The paired gravity anomaly across the two crustal domains signifies that the Central Indian Shear Zone is a locus of density discontinuity along which the two crustal domains accreted. Horizontal gravity gradient analysis further demonstrates the northward subduction of the Bastar Craton beneath the Bundelkhand Craton. 2½D gravity modelling along Mungwani–Rajnandgaon profile, constrained by Seoni–Kalimati seismic section, delineates a thick crust beneath the Bastar Craton as compared to the Central Indian Tectonic Zone. Northward dipping contact of the two crustal domains when projected on the surface coincides with the Central Indian Shear Zone. With a well defined Moho offset and crustal density discontinuity, Central Indian Shear Zone represents a suture zone that separates the Bastar Craton from the Central Indian Tectonic Zone. A low-velocity (6.4 km/s)/density (2.90 g/cm^3) layer at the base of the crust and relatively lower density (3.21 g/cm^3) subcrustal mantle may be the imprint of thermal remobilization beneath the Central Indian Tectonic Zone.

1. Introduction

Evolutionary history of continents and supercontinents require an understanding of crustal growth processes through time and space (e.g., Santosh, 2010). Proterozoic shields are often viewed as wide orogenic domains of amalgamated terranes but with smaller plates and longer ocean ridge lengths (de Wit, 1998). The long-lived shear systems between amalgamated terranes are commonly assumed to represent boundaries of Proterozoic continental collision (e.g., Santosh and Yoshida, 1996; Santosh et al., 2009). Imprints of subsequent tectonic signatures lead to very different geological signatures in terms of tectonometamorphic evolution. Unravelling those superimposed signatures and delineation of ancient cryptic sutures is of seminal importance to understand the crustal growth process that shaped the Proterozoic continents and supercontinents. The Indian shield in general and its central part in particular is one of the critical examples in the current debate (Desai et al., 2010; Meert et al., 2010, 2011; Naganjaneyulu and Santosh, 2010; Chatterjee and Ghose, 2011) (Fig. 1).

The crustal architecture of Central India comprises large Archaean cratons (Bastar, Singhbhum and Bundelkhand) well separated by crustal scale Proterozoic Satpura orogenic belt (also known as Central Indian Tectonic Zone: CITZ) (CRUMANSONATA, 1995 and references therein). The CITZ has been interpreted as a Proterozoic mobile belt, a tectonic suture (Naqvi et al., 1974), and an active Precambrian rift (Nayak, 1990). According to Radhakrishna and Naqvi (1986) the collage of Dharwar, Bastar and Singhbhum cratons collided with a northerly block consisting of the Bundelkhand Craton during the Palaeoproterozoic period. Central Indian Shear Zone (CISZ), southern border of the CITZ, is the one regarded to have acted principally as the suture between the Bundelkhand Craton and the Bastar Craton (Yedekar et al., 1990, 2003; Jain et al., 1991). Crustal structure and geodynamic processes across the CISZ have been studied earlier covering a wide spectrum of geomorphology, geology, and geophysics (e.g., CRUMANSONATA, 1995; Divakara Rao et al., 1998). Yedekar et al. (1990) provided the first plate tectonic model for evolution of the CISZ, by invoking southerly dipping subduction of the Bundelkhand Craton below the Bastar Craton. In contrast, later tectonic models invoked a north-directed subduction of the oceanic crust of the Bastar Craton below the Bundelkhand Craton (Bhowmik et al., 1999; Acharyya and Roy, 2000). With equivocal direction of subduction, CISZ is perhaps one of the less understood regions of crustal growth processes and its role in East Gondwana reconstruction during late Mesoproterozoic period (Acharyya, 2003; Bhandari et al., 2010; Mohanty, 2010).

Several geophysical studies employing active seismology (e.g., Sain et al., 2000; Tewari and Kumar, 2003; Murty et al., 2008), potential field data (e.g., Mishra, 1992; Verma and Banerjee, 1992; Singh and Meissner, 1995; Singh, 1998; Rajaram and Anand,

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1367-9120/$ - see front matter
doi:10.1016/j.jseaes.2011.04.023

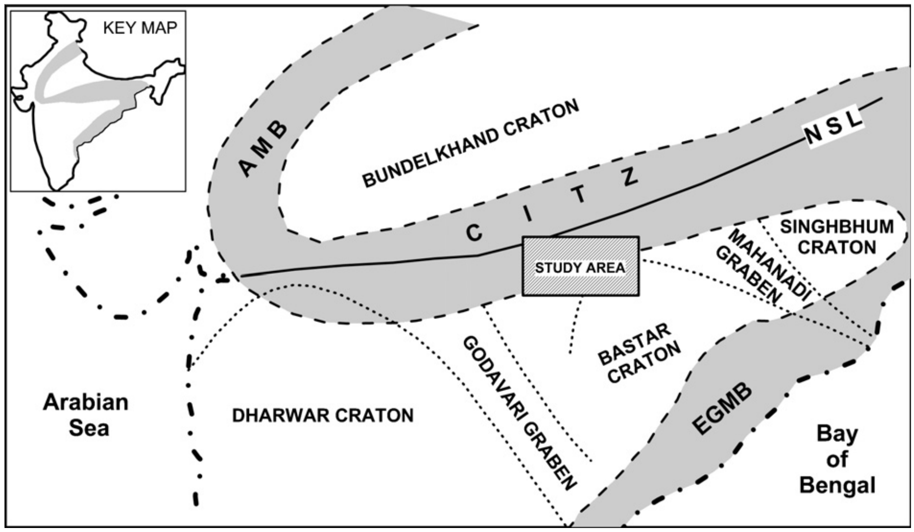

Fig. 1. Simplified geology and tectonics of the Central India including the old cratons and mobile belt (modified after Divakara Rao et al. (1998)). Abbreviations used are AMB: Aravalli Mobile Belt, CITZ: Central India Tectonic Zone; EGMB: Eastern Ghat Mobile Belt, NSL: Narmada–Son Lineament.

2003) and magnetotelluric (e.g., Gokarn et al., 2001; Patro et al., 2005; Naganjaneyulu, 2010; Naganjaneyulu and Santosh, 2010; Naganjaneyulu et al., 2010) provide deep insights into the crustal structure and tectonic evolution of the CITZ. In contrast the only coincident seismic reflection and refraction/wide-angle reflection study along Seoni–Kalimati profile provided some vital information about its crustal configuration (Reddy et al., 1996). A diffused reflectivity over a 20–30 km wide zone however, indicates that the structure around CISZ is indistinct (Mall et al., 2008). Through the integration of gravity data along the available seismic section (Reddy et al., 1996) a better constrained crustal structure across the CISZ (Mishra et al., 2000) was provided; an opposite direction of subduction along the CISZ is however proposed, recently (Mall et al., 2008). To ascertain the deep crustal structure and unequivocal direction of subduction across the CISZ, gravity signature is analyzed along with the recent seismic information. The horizontal gravity gradient technique (Cordell and Grauch, 1985) was employed to ascertain the lateral extension of the CISZ and possible direction of subduction. Mungwani–Rajnandgaon gravity profile (Fig. 2), integrating constraints from Seoni–Kalimati seismic profile (Mall et al., 2008), is modelled using 2½D forward modelling algorithm to reconstruct the deep crustal structure across the CISZ. The geometric constraints thus obtained from the derived crustal density model are utilised to infer the likely tectonic domains that shaped the CISZ.

2. Geological setting

A synthesis of the available geological information (Fig. 2) reveals that the southern part of the CITZ is mostly occupied by Mesoproterozoic Sausar metasediments and Tirodi gneisses. Ramakona–Katangi granulite (RKG) occurs discontinuously over a strike length of 240 km in the north of the Sausar supracrustal belt. Similarly, Balaghat–Bhandara granulite (BBG) belt is exposed over a strike length of 190 km near southern margin of the CITZ. A pile of basaltic lava flows of Deccan Traps forms another important litho-suite with occasional thin intertrappean beds. Laterite forming the cap over the basalt is preserved in the Seoni area and to the southeast. Gondwana sediments of Mahanadi Basin cover the eastern part of the CITZ. The volcanic and volcanoclastics of Sakoli, Nandgaon, Khairagarh and Chilpi Groups, Malanjkhand and Dongargarh granite plutons and Chattisgarh shelf sediments lie over the Bastar Craton (GSI, 1998).

The ENE–WSW trending divide line (CISZ), a 0.2–4 km wide and 500 km long ductile shear zone extending from southeast of Nagpur to south of Korba, is characterised by mylonites and phyllites with minor amounts of cataclasites. Other notable shear zones of the region are the Southeast Sakoli and Tan Shear. The tectonic trends in Bastar Craton vary from WNW–ESE to N–S, in contrast to ENE–WSW to E–W in the Bundelkhand Craton. The regional structural grain on the CITZ is thus concordant with the CISZ while that of Bastar Craton is discordant with it. CISZ has therefore been suggested as a suture that separates the two distinct Precambrian crustal domains (Yedekar et al., 1990; Jain et al., 1991; Roy and Prasad, 2003).

According to Yedekar et al. (1990), the southward subduction of Bundelkhand Craton below Bastar Craton led to the development of rift basins and arc related intrusions (e.g. Dongargarh and Malanjkhand granites) in the Bastar Craton. This subduction system culminated with the continent–continent collision, during which the passive margin Sausar sediments were metamorphosed. This model considers Bhandara–Balaghat granulite belt to be the obducted granulitic oceanic crust, which was exhumed during collisional orogeny. In contrast, the Mahakoshal rift basin is considered as a back-arc rift primarily related to north-directed subduction of the Bastar Craton below the Bundelkhand Craton (Bhowmik et al., 1999; Acharyya and Roy, 2000). The northerly dipping structural grain along the RKG belt further supports the south-directed thrusting during the collision (Acharyya, 2003; Roy and Prasad, 2003). This collision resulted in anomalous crustal thickening and attending migmatization and lower crustal melting. This stage was followed by rapid decompression, during which ~15 km thick crust was removed and granulites were brought to middle crustal levels (Bhowmik et al., 1999).

3. The data

3.1. Topography

The topographic image in Fig. 3 is based on the original version of the Shuttle Radar Topography Mission (SRTM) 90 M elevation data (ftp://edcsgs9.cr.usgs.gov/pub/data/srtm). The most prominent topographic feature of the region is the Satpura Mobile Belt/CITZ with a maximum elevation of about 1100 m. Around Amarkantak, the two rivers Narmada and Son flow towards the west and the east, respectively. Down south, a relatively low lying Bastar Craton is characterised by 100–500 m high moderate topography.