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Magnetotelluric studies in the Central India Tectonic Zone: Implications for intraplate stress regimes and generation of shallow earthquakes

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ABSTRACT

The Central India Tectonic Zone (CITZ) dissects the Indian Peninsula into the northern and southern crustal blocks. The CITZ has been a seismically active region since the Precambrian. Whereas the relatively deep crustal earthquakes near the Narmada faults in the eastern part of the CITZ have been well-investigated, the mechanisms for the shallow earthquakes in the western part remain unknown. Here we present results from a new magnetotelluric study to derive the crustal structure and to understand its implications. Our data show a thick and highly resistive (>500 ohm m) crust in the south of Tapti River, as against a less resistive one in the north. These results in conjunction with heat flow values indicate that the crust below the southern part has stable continental cratonic signatures. On the northern side of the Tapti River, we infer the ascent of basaltic magmas from the mantle into the shallow crust and crystallization into layered intrusions. These mafic–ultramafic bodies could be a potential cause for the shallow earthquakes in the western part of the CITZ. The mafic–ultramafic bodies below the crust of CITZ would locally modify the intraplate stresses, which in turn would facilitate the occurrence of earthquakes due to reactivation of pre-existing faults. Thus, the large accumulation of strain energy in the deep crust beneath the region can be attributed to the presence of high stress bodies emplaced at depth during the Deccan Volcanic activity.

1. Introduction

The Central India Tectonic Zone (CITZ) is a prominent tectonic divide striking ENE–WSW with dimensions of approximately 800 × 400 km, and dissecting the Indian Peninsula into the northern and southern crustal blocks (Radhakrishna and Naqvi, 1986; Acharyya, 2003). The block to the north of CITZ incorporates the Archaean Bundelkhand craton, whereas the composite block to the south is composed of the Dharwar, Bhandara and Singbhum cratons (Fig. 1a). Major part of this region is covered by continental flood basalts which are recognized to be part of one of the world's prominent Large Igneous Provinces (Olsen, 1999). The geological framework of the CITZ includes metamorphosed supracrustal belts, metamorphosed mafic and ultramafic bodies, metacarbonates, iron and manganese formations, TTG (tonalite–trondhjemite–granodiorite) gneisses, charnockites and related magmatic suites, exhumed high pressure and ultrahigh temperature metamorphic belts, and post-collisional K-rich granites (e.g., Acharyya, 2003; Bhowmik and Roy, 2003; Bhowmik et al., 2005; Bhandari et al., 2010). Various geophysical studies were carried out in this region to derive the crustal structure and its possible implications (Fig. 1b). These studies include deep seismic, gravity, heat flow, seismology and magnetotellurics. The CITZ is seismically active since the Precambrian (West, 1962; Choubey, 1971) and has been the region of a number of moderate to strong earthquakes. Prominent among these are the 1938 Satpura and the 1998 Jabalpur earthquakes (Fig. 2a). The general tendency observed is that in the eastern part the hypocenters were generally located in the lower crustal depths whereas in the western part of the CITZ, the earthquake hypocenters are at shallow depths of less than 20 km (Fig. 2b).

In general, within continental rift regions like the Reelfoot rift (US), the Kenya rift (Kenya and Tanzania) and the Amazonas rift (Brazil) hypocenters of earthquakes have been located in the lower crust. Association of deep crustal intraplate seismicity is attributed to the accumulation of strain associated with the mafic intrusives or rift pillows in the lower crust for the Reelfoot rift (Pollitz et al., 2002), the Amazonas rift (Zoback and Richardson, 1996). Lower crustal earthquakes in the Kenya Rift are attributed to melt movements (Young et al., 1991). In the case of the Bhuj region

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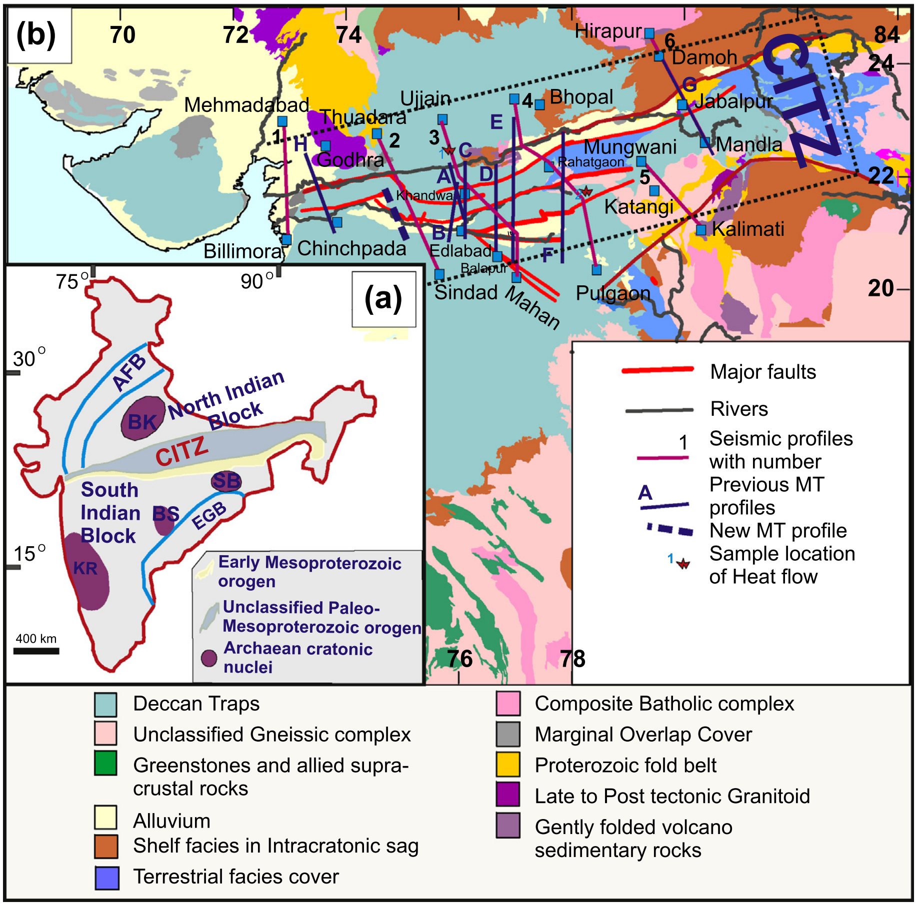

Fig. 1. (a) Disposition of the major cratonic blocks and tectonic elements within Peninsular India. CITZ: Central Indian Tectonic Zone (b) geological map of the Central India region showing the transects of deep seismic sounding profiles, magnetotelluric (MT) profiles and heat flow measurements along with major faults in the region (modified after Narula et al., 2000).

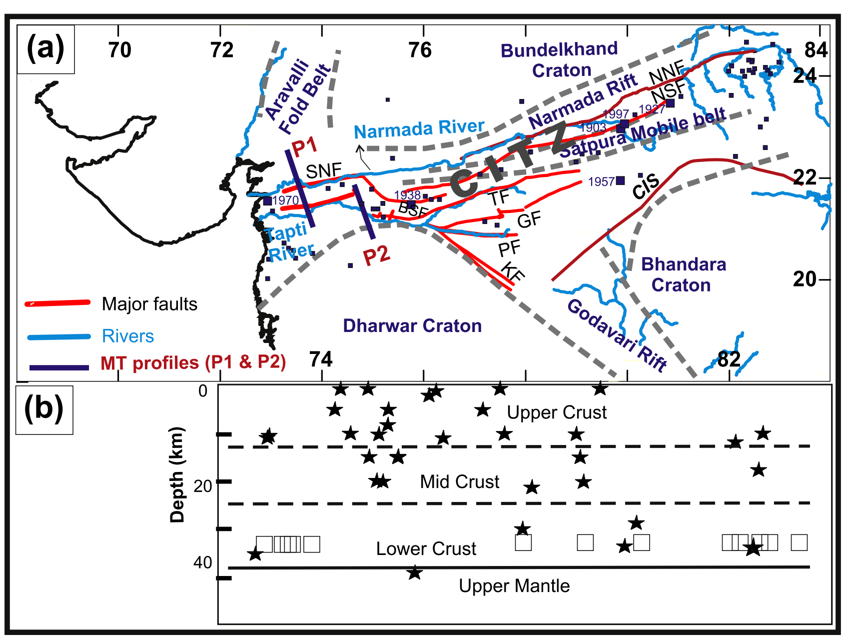

Fig. 2. (a) Tectonic framework of Central India showing the major cratonic blocks of Dharwar, Bhandara and Bundelkhand with inferred boundaries. The Central India Tectonic Zone (CITZ) is a major suture zone that welds the South and North Indian blocks and expressed as several shear systems and faults, some of which are currently active (GSI report, 1995). Squares indicate the ISC reported earthquakes (1967–1999). Bigger squares with numbers indicate earthquakes of magnitude more than five in the last century (Gahalaut et al., 2004). The region lying south of the CITZ is referred to as the cratonic region. (b) Stars indicate ISC reported depth distribution of earthquakes in the CITZ. Unfilled squares represent the restricted focal depths at 33 km (Gahalaut et al., 2004). The crustal division is indicative only. BSF: Barwani Sukta Fault; CIS: Central Indian Suture; GF: Gavligarh Fault; KF: Kaddam Fault; NNF: Narmada North Fault, NSF: Narmada South Fault; PF: Purna Fault; SNF: Son Narmada Fault; TF: Tapti Fault.