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Seismic imaging across the Eastern Ghats Belt-Cuddapah Basin collisional zone, southern Indian Shield and possible geodynamic implications

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ABSTRACT

The evolutionary nature of the area encompassing Cuddapah basin, Nellore Schist Belt and the Ongole domain of Eastern Ghats Belt (south India), which contains Paleo-Neoproterozoic imprints of thick sedimentation, intense magmatism, subduction/accretion and possible collision between eastern Dharwar craton and east Antarctica, is still being debated. An attempt has been made here to decipher the deep crustal structure and tectonics of this region, by reprocessing Deep Seismic Sounding data acquired earlier through the modeling of first arrival refraction and wide angle reflection travel times. The derived crustal seismic velocity structure reveals that the intracratonic Proterozoic Cuddapah basin containing only 4 km thick sediment is bounded by two major faults. The Moho reaching fault detected on its eastern boundary, demarcates Cuddapah basin from the Nellore Schist Belt. Although a deep normal fault is mapped within the Nallamalai Fold Belt, but no thrusting signatures are apparent. Almost all the crustal layers beneath Nellore Schist Belt and the Ongole domain of Eastern Ghats Belt, show distinct eastward dipping trend conforming to an upthrusted feature, suggesting possible presence of a collisional suture. Besides, the areas lying east of Cuddapah Basin appear to be an accreted orogenic terrain, beneath which lower crust has upwarped substantially. The entire stretch of the studied region is underplated by unprecedentedly thick (~20 km) high velocity (7.0-7.4 km/s) magma layer above the Moho, indicating strong crust-mantle thermal perturbation and massive subcrustal erosion. Further, an expression of a deep seated mantle thermal anomaly has also been found below the Parnapalle region of the SW Cuddapah basin beneath which deeper crustal layers have exhumed.

1. Introduction

Deep Seismic Sounding (DSS) studies were started in India in early 1970s mainly to delineate deep seated crustal/structural variations and their manifestations on near surface geological structures, using wide angle reflections/refractions data. Such a beginning was felt necessary as average regional velocity-depth details obtained from earthquake data, could not provide sufficient inputs to solve specific structural problems. It was thus desired to find more detailed crustal structure of the Indian shield for better understanding of relationship prevailing between various geotectonic segments. The first profile, initiated with Indo-Soviet collaboration, was shot from Kavali (K) on the east coast to Udupi (U) on the west coast (Fig. 1). This profile traversed through all the major geological units of southern Indian shield such as southern part of Eastern Ghats Belt (EGB), Nellore Schist Belt (NSB), Cuddapah basin (CB), Closepet granite and Chitradurga Schist Belt, thereby covering the entire stretch of both eastern and western Dharwar cratons. Initial seismic studies along this profile (Kaila et al., 1979), identified discontinuous reflectors, variations in the Moho depths and delineated deep seated faults which penetrated till Moho depth. One of the interesting features identified by this study was the detection of double Moho below the eastern part of CB. Later on, an attempt was made by Mall et al. (2008), to study CB and its adjacent regions on its west, which indicated that all the crustal layers have considerably upwarped in the southwestern part of CB near Paranpalle. Further studies in this region, emphasized the differences in the crustal seismic velocities between CB and adjacent Closepet granitic region toward western side (Chandrakala et al., 2010). Another interesting study is the delineation of a much lesser sediment thickness (only ~4 km) in CB (Chandrakala et al., 2013), as against 10 km or so reported in earlier studies (Ramam and Murty, 1997; Nagaraja Rao et al., 1987; Kaila et al., 1979; Kaila and Tewari, 1985). This study clearly

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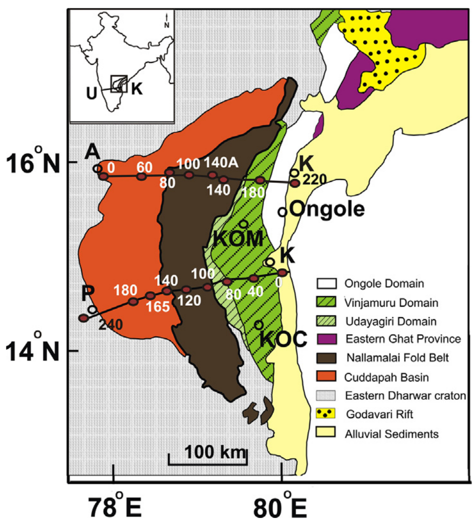

Fig. 1. Detailed geological map of the studied region showing the locations of Cuddapah Basin, Vinjamuru and Udayagiri domain of Nellore Schist Belt and Ongole domain of Eastern Ghats Belt (Henderson et al., 2014). Solid lines with shot point locations indicate DSS profiles. P–K refers to Parnapalle–Kavali segment of Kavali-Udipi DSS profile (K-U), and A-K to Alampur–Koniki profile. KOC and KOM indicate the locations of Kandra Ophiolite Complex and Kanigiri Ophiolite Melange, respectively.

demarcated the basinal structure and brought out the velocity differences between upper and lower Cuddapah sediments as well.

However, the stretch comprising the NSB and the adjacent domain of EGB (Fig. 1), has largely been neglected so far. Interestingly, very strong dipping reflectors have earlier been reported below NSB and its adjoining regions (Kaila et al., 1979) as mentioned earlier. Such reflectors have not been recorded anywhere along the entire 600 km stretch of the Kavali-Udipi profile. In order to study the geodynamic implications of these reflectors, as well as its link with the formation of EGB, we made a fresh attempt to delineate the crustal structure of this region, especially between Parnapalle and Kavali (Fig. 1). This particular domain bears the imprint of multi-stage crustal development, apart from important geodynamic link between the southern Indian shield and eastern Antarctica during erstwhile Gondwana assembly. Till now, almost all the proposed evolutionary models for this region have been based on geological and geochronological investigations, carried out mainly in the last decade (Dasgupta et al., 2013; Henderson et al., 2014; Saha et al., 2015 and references therein).

2. Regional geology

Dharwar craton of the south Indian shield consists of three major Archean–early Proterozoic geotectonic blocks, western Dharwar craton (WDC), eastern Dharwar craton (EDC) and southern granulite terrain (SGT) (Naqvi and Rogers, 1987; Radhakrishna and Naqvi, 1986; Ramakrishnan and Vaidyanadhan, 2008). It is partly covered by Proterozoic sedimentary basins, that includes Cuddapah basin (CB), which is the largest among them. This intracratonic rifted basin is situated close to the eastern margin of the EDC (Fig. 1). It is dominantly filled with succession of igneous and >1.9 Ga and younger sedimentary rocks of the Cuddapah and Kurnool super groups (Saha and Tripathy, 2012), which rest over the granitic-gneissic basement. Western part of the basin has been relatively lesser affected by tectonic activity, compared to eastern part, which is characterized by a prominent NW-SE to NE–SW trending Nallamalai Fold Belt (NFB), interpreted as an allochthonous feature and bordered by two major thrust zones (Saha et al., 2015). The thrust zone that separates this fold belt from the adjacent NSB, is considered a major intracontinental thrust zone, usually termed as Vellikonda thrust front (Venkatakrishnan and Dotiwala, 1987; Saha, 2002; Saha et al., 2010). In CB, extrusive and intrusive mafic volcanic rocks are exposed at the surface, as well as in the lower stratigraphic horizons. They are mostly in the form of lava flows and sills, that occur in an arcuate pattern, parallel to the margins of the basin. The initial phase of extension, sedimentation and magmatism in the basin seems to have taken place as early as 1.9 Ga or even earlier (Mallikarjuna Rao et al., 1995; Anand et al., 2003; Saha et al., 2015).

Another prominent geotectonic feature which adjoins the NFB on its east is a curvilinear 300 km long NSB (Fig. 1), which occurs south of the Godavari graben and contains deformed Paleoproterozoic to Mesoproterozoic volcao-sedimentary succession. It is demarcated into four major units (Saha et al., 2015), Vinjamuru Group, 1.9 Ga Kandra Ophiolite Complex (KOC), 1.3 Ga Kanigiri Ophiolite Melange (KOM), and Udayagiri group. Outcrops of the Vinjamuru group are restricted to the eastern part of NSB and consists of amphibolites, metabasalts, migmatitic gneisses, while KOC consists of metagabbro, metabasalts and the metadolerite dykes, representing deformed remnants of accreted oceanic crust. Similarly, KOM too has been attributed to have oceanic crustal affinity, consisting heterogeneous assemblages of deformed metabasalts, metatuffs, basalt flows and metasedimentary rocks. Both KOC and KOM have been attributed to supra-subduction settings (Dharma Rao and Reddy, 2009; Dharma Rao et al., 2011; Vijaya Kumar et al., 2010; Saha, 2011; Saha et al., 2015). Udayagiri group containing low grade metasedimentary succession, is the youngest unit of NSB. This belt as a whole, undergone multiple deformation and metamorphism and emplacement of granitic and alkaline plutons (Saha, 2002, 2004, 2011; Dobmeier and Raith, 2003; Vijaya Kumar et al., 2010; Dharma Rao et al., 2011). Latest remobilization in NSB seemingly took place at around 500 Ma (Dobmeier et al., 2006). NSB rocks appear thrusted over the NFB (Saha, 2002; Saha et al., 2010).

In comparison, EGB which occurs further to the east of NSB, is considered a deformed granulite facies orogenic belt, running for about 1000 km along the eastern coast of India. The segment which lies south of the Godavari graben is usually known as the Ongole domain, which consists of polycyclic 1.7–1.6 Ga old granulite terrain (Dobmeier and Raith, 2003; Henderson et al., 2014). It seems to have accreted to Indian land mass during Neoproterozoic to early Cambrian era (Dobmeier and Raith, 2003; Saha et al., 2015) and thus considered a key element in India–Antarctica correlation (Yoshida et al., 2003). Available geological signatures thus conform to long term episodic growth of the eastern margin of EDC since Neoarchean/Paleoproterozoic era that includes multiple episodes of deformation, metamorphism, magmatism, apart from supra-subduction related ocean closure and accretion, which may have continued till the end of Pan-African era, as discussed later.

3. Seismic studies

3.1. Seismic data acquisition

DSS studies were carried out from Kavali on the east coast to Udipi on the west coast (Fig. 1), in three successive seasons across different geological units. Seismic refraction and wide-angle reflection data were acquired with continuous profiling with a frequency range of 4.5–30 Hz. Shot holes were drilled using rotary drilling rigs of type URB 2A, up to a depth of 20–30 m, with an interval of 10–15 m with each other. To acquire the seismic data, shots were fired with open cast gelignite or special gelatin explosives, with a minimum charge size of 50 kg to a maximum of 1500 kg for varying distances of the recording. In places of high background noise level, the charge size was increased to 1–2 tons for recording up to a distance of 200–300 km. Shot point interval of 10 km and 40 km were used for shallow and deeper crustal studies, respectively.