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The nature and thickness of lithosphere beneath the Archean Dharwar Craton, southern India: A magnetotelluric model

K. Naganjaneyulu[a,*], M. Santosh[b]

[a] Division of Engineering Geophysics, National Geophysical Research Institute (NGRI), Council of Scientific and Industrial Research, Hyderabad 500 007, India
[b] Division of Interdisciplinary Science, Faculty of Science, Kochi University, Kochi 780-8520, Japan

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ABSTRACT

The Dharwar Craton in the southern Indian shield region occupies a key position in reconstructions of the earliest supercontinent "Ur" as well as in the global Neoarchean configurations of continental assembly. Here we synthesize the available geophysical data that include heat flow, seismic tomography, temperature profile derived from xenoliths and magnetotellurics (MT) from the Dharwar Craton. A thickness of more than 200 km is identified for the lithosphere beneath this craton by magnetotelluric model. Our inference lends support to the models from recent seismological investigations that argue for the presence of a thick lithosphere, as well as the upper mantle structure derived from the analysis of mantle xenoliths. A synthesis of recent geophysical and geochemical data, together with our magnetotelluric model indicate the existence of a thick lithospheric root beneath the Dharwar Craton and suggest that not much of the lithosphere has been eroded since Precambrian in this region, leading to the conclusion that the Dharwar Craton preserves an Archean tectosphere. An increase in the lithospheric thickness from east to west in the Dharwar Craton and the Lithosphere–Asthenosphere Boundary (LAB) migration to shallower levels observed from geophysical data towards the east is interpreted as a probable reflection of the Mesoproterozoic subduction-erosion of the Archean cratonic keel.

1. Introduction

Estimation of lithospheric thickness and determination of both physical and chemical properties of the sub-continental lithospheric mantle (SCLM) are among the topics of major importance for the largely unexplored deep structures of the Indian shield region (Fig. 1). Whereas the crustal structure has been investigated in some of the domains from combined geological and geophysical data (see Naganjaneyulu and Santosh, 2010a,b, 2011a,b, in press-c for recent models), studies that focus on the Lithosphere–Asthenosphere Boundary (LAB) are limited to a small number and provide contradictory models on lithospheric thickness estimates (e.g., Kumar et al., 2007; Griffin et al., 2009; Ramesh et al., 2010). This is probably because unlike the definition for Moho, the definition for LAB is rather ambiguous. The Lithosphere–Asthenosphere Boundary represents the base of the Earth's lithosphere, the rigid and relatively cool outer shell characterized by a conductive thermal regime, and isolated from the convecting asthenosphere below. Recent studies identify the LAB as a movable boundary which becomes shallower due to thermal and chemical erosion of the lithosphere, assisted by upwelling plumes and extension (Eaton et al., 2009; O'Reilly and Griffin, 2010; Santosh, 2010). As a result, the terms thermal, seismic, chemical and electrical lithospheres are in use in diverse data sets (see Jones (1999) for a review).

The lithospheric depths estimated by various geophysical and geological methods may or may not overlap (Artemieva, 2009). However, a correlation of low resistivity zones with low velocity zones in the upper mantle was reported as early as 1960s (Adam, 1963). Similarly, Adam (1976, 1980) proposed empirical formulae to identify the location of low resistivity layers within the upper mantle using heat flow data. Thus, in some of the earlier studies, the LAB is delineated based on heat flow data and has provided valid estimates on the approximate depth to Lithosphere–Asthenosphere Boundary for several regions, although in some cases, the technique has not been found to be appropriate (see Jones, 1999). The overlap in determining thickness of lithosphere in some of these estimates can be attributed to the response of mantle rocks to various geophysical methods, and similarly the mismatches can also be related to limitations in data quality and quantity. Poor understanding of these results have created a confusion as well as initiated some interesting debates like how thick or thin is the Indian lithosphere (for example, Ramesh et al., 2010).

In this study, we present an analysis of magnetotelluric data obtained from the Dharwar Craton to examine the hypothesis relating to the thick vs. thin lithosphere, in this case, the electrical lithosphere. We also synthesize and re-interpret other geophysical

* Corresponding author. Tel.: +91 40 23434700x2406; fax: +91 40 27171564.
E-mail address: kasturi_kasturi@rediffmail.com (K. Naganjaneyulu).

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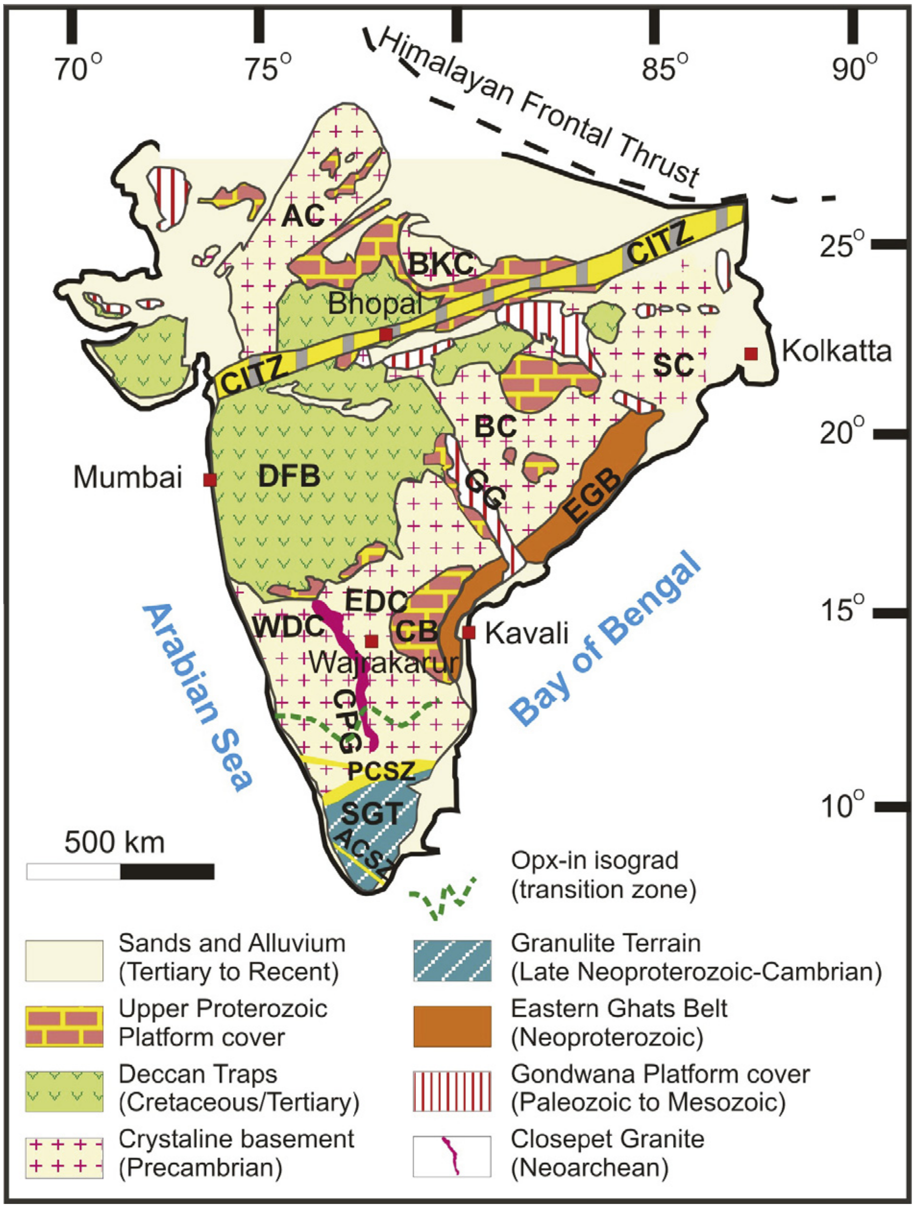

Fig. 1. (a) Geological framework of Indian shield region AC: Aravalli Craton, ACSZ: Achankovil Suture Zone; BC: Bastar (Bhandara) Craton, BKC: Bundhelkhand Craton, CB: Cuddapah Basin, CITZ: Central India Tectonic Zone, CPG: Closepet Granite, DFB: Deccan Flood Basalt, EDC: Eastern Dharwar Craton, GG- Godavari Graben; PCSZ: Palghat-Cauvery Suture Zone, SC: Singbhum Craton, SGT: Southern Granulite Terrain, WDC: Western Dharwar Craton.

evidence from this region including seismic lithosphere estimates and chemical tomography lithospheric estimates. Such an approach enables us to evaluate some of the outstanding issues including: (a) estimation of the lithospheric thickness beneath one of the oldest cratons in the world; (b) evaluation of any significant change in the lithospheric thickness associated with the tectonic processes attending the Proterozoic supercontinent cycles.

2. Tectonic framework

The Dharwar Craton in southern India (Fig. 1) preserves an Archean cratonic nucleus with a basement assemblage of linear schist belts in association with a widespread TTG (tonalite–trondhjemite–graniodiorite) gneiss complex, and intruded by younger granites (e.g., Bhaskar Rao and Naqvi, 1978; Swami Nath and Ramakrishnan, 1981; Anil Kumar et al., 1996; Hegde and Chavadi, 2009). The TTG blocks surrounded by greenstone belts signify continental growth by arc accretion during early Precambrian, similar to the scenario in major Precambrian cratons elsewhere on the globe (e.g., Zhai and Santosh, 2011). The metamorphic grade increases from greenschist facies in the north to granulite facies in the southern margin of the craton (e.g., Halls et al., 2007). The northern part is further sub-divided into the Eastern Dharwar Craton (EDC) and the Western Dharwar Craton (WDC). The WDC began to evolve at about 3.5 Ga and possibly earlier (e.g., Bhaskar Rao et al., 1992; Rogers, 1996), with the Indian Ocean marking its western margin from where Madagascar rifted away during Gondwana breakup in the Middle Jurassic. The northern margin is overlain by Neoproterozoic/Early Phanerozoic sedimentary basins and Cretaceous/Tertiary Deccan basalts (e.g., Ray et al., 2008). The EDC is characterized by a Neoarchaean dioritic–granitic basement, with linear schist belts (Chadwick et al., 1996, 2000; Nutman et al., 1996). The border between WDC and EDC is defined by the Closepet granite batholith complex, which consists of several plutons along a nearly straight belt that extends northward