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3D Lithosphere density structure of southern Indian shield from joint inversion of gravity, geoid and topography data

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ABSTRACT

We present the 3D crustal and lithospheric structure and crustal average density distribution of southern Indian shield (south of 18°N), Sri Lanka and adjoining oceans. The model is based on the assumption of local isostatic equilibrium and is derived from joint inversion of free air gravity and geoid anomalies and topography data. The derived crustal thickness of 10–25 km in the oceanic region increases to 34–35 km along the coast. A crustal thickness of 34–38 km is obtained beneath the Eastern Dharwar Craton and 36–45 km beneath the Western Dharwar Craton and the Southern Granulite Terrain. Sri Lanka has a thinner crust of 30–35 km. The lithosphere–asthenosphere boundary is located at depths of 70–120 km under oceanic regions and ~150–180 km below the Dharwar Craton and the Northern block of Southern Granulite Terrain. A notably thinned lithosphere of ~130 km near Bangalore in the Eastern Dharwar Craton, ~140 km beneath the Southern block of Southern Granulite Terrain and ~130 km in Sri Lanka is observed. The thickness of the lithosphere (~130 km) near Bangalore is inferred as the frozen in signature of a small fossil mantle plume and/or tectono-compositional effect of a rifted margin and a suture. Considerable stretching and/or convective removal of pristine lithosphere in the Southern block of Southern Granulite Terrain and adjoining Sri Lanka, before disappearing completely in the Archaean Northern block of Southern Granulite Terrain and Dharwar Craton, is suggested.

1. Introduction

The region encompassing the southern Indian shield (south of 18°N) and Sri Lanka (Fig. 1) is a mosaic of ancient continental domains assembled between the mid-Archaean and Neo-Proterozoic (Braun and Kriegsmann, 2003; Meert et al., 2010). All these amalgamated tectonic domains are separated by major shear zone systems, some of which represent collision sutures (Chetty and Santosh, 2013). Several competing geodynamic scenarios have been proposed to explain the tectonic and magmatic evolution of the southern Indian shield starting from a sequence of Pacific subduction to Himalayan type collision (e.g., Chadwick et al., 2000; Singh et al., 2004; Santosh et al., 2009), crustal decoupling, rapid exhumation and extensional collapse (e.g., Singh et al., 2006, 2011), repeated thermal perturbation (Ghosh et al., 2004), lithospheric remobilisation (e.g., Pandey and Agrawal, 1999; Jagadeesh and Rai, 2008), melting of continental roots (Negi et al., 1986; Kumar et al., 2007), and sub-crustal metasomatism (Griffin et al., 2009; Mall et al., 2012; Chalapathi Rao et al., 2013). Most of these scenarios rely on models of the present-day lithospheric structure beneath the region. The depth of Sri Lankan LAB, which is not yet available and the argument that the cratonic segment of this region is modified need to be ascertained.

While the deep crustal structures of the southern Indian shield are better resolved, the depth of the lithosphere–asthenosphere boundary (LAB) remains elusive although a variety of geophysical methods in isolation were applied (e.g., Negi et al., 1986; Gupta et al., 1991; Pandey and Agrawal, 1999; Mitra et al., 2006; P. Kumar et al., 2007, 2013; Kiselev et al., 2008; Ramesh et al., 2010; Naganjaneyulu and Santosh, 2012; Patro et al., 2014; Singh et al., 2014), partly because the results of these studies are not complementary owing to large differences in resolution. Besides their own set of assumptions and limitations, the proxies of individual geophysical (thermal, seismic and magnetotelluric) methods are also contentious and sometimes poorly understood (Eaton et al., 2009). A regional LAB structure using a combination of different proxies is needed to reconstruct the orogenic processes that mediated lithospheric evolution and built up topography through the force of buoyancy.

Present-day elevation of relict orogenic belts reflect the buoyancy of the lithosphere supporting the topographic load. The two

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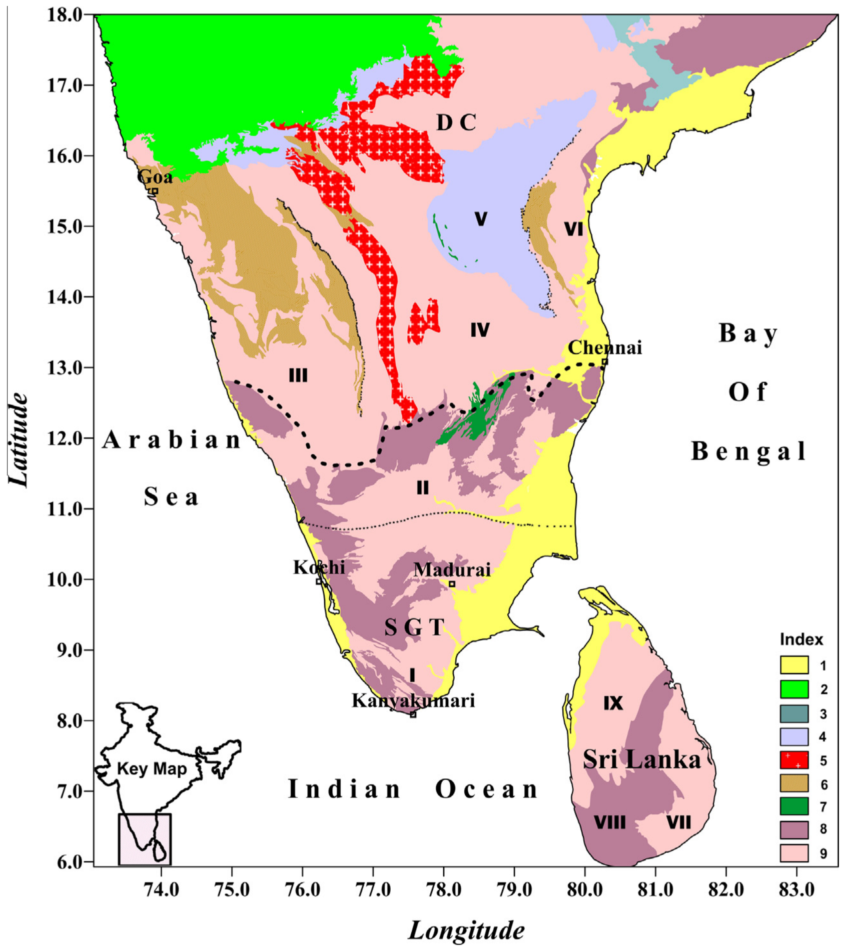

Fig. 1. Location map of the principal structural units of southern Indian shield, Sri Lanka and adjoining Indian Ocean. DC: Dharwar Craton, SGT: Southern Granulite Terrain, I: Southern block of the SGT, II: Northern block of the SGT, III: Western Dharwar Craton, IV: Eastern Dharwar Craton, V: Cuddapah basin, VI: Eastern Ghats Mobile belt, VII: Vijyan complex, VIII: Highland complex, IX: Wanni complex. [1] Phanerozoic sediments; [2] Deccan Traps; [3] Gondwana sediments; [4] Proterozoic sediments [5] Granites; [6] Schist belts; [7] Alkaline rocks; [8] Charnockites and khondalites; [9] Granite gneiss.

are intimately related through the phenomenon of isostasy and best manifested in the gravity data. Gravity anomalies together with the topography data may thus help to determine the state of the lithosphere under the assumption of isostatic equilibrium, which can be interpreted as a result of past processes due to which the lithosphere acquired its actual architecture (Lachenbruch and Morgan, 1990). Integrating free air gravity and geoid anomalies and topography data along with the seismic and geothermal information (Zeyen and Fernàndez, 1994; Zeyen et al., 2005), lithospheric modelling along three geo-transects of more than 1000 km in length each, crossing the southern Indian shield and adjoining oceans has recently been done (N. Kumar et al., 2013). To overcome the limitations of 2D modelling in the southern Indian shield with 3D structures on regional scale, we here used the integrated 3D inversion algorithm developed by Motavalli-Anbaran et al. (2013) using the free air gravity (in the following, for simplicity, only called gravity) and geoid anomalies and topography data as proxies. Stabilization of the inversion process is obtained though parameter damping and smoothing as well as use of a priori information like average crustal density and thicknesses from seismic studies.

2. Methodology and data

The method used is a direct, linearized, iterative inversion procedure in order to determine lateral variations of Moho and LAB depths and, average crustal density (Fig. 2). The area of interest is subdivided into rectangular columns of constant size in E-W (X) and N-S (Y) direction. In depth (z), each column is subdivided into four layers: sea water (with known thickness, i.e. bathymetry, and a density of 1030 kg/m^3), crust, lithospheric mantle and asthenosphere. The model parameters we are imaging are Moho and LAB depths with respect to sea level and average crustal density in every column (Fig. 3).

The density distribution in the crust is modelled using a linear vertical density increase with depth. We fixed the density at the crust-mantle boundary (Moho) at 3000 kg/m^3 and inverted for

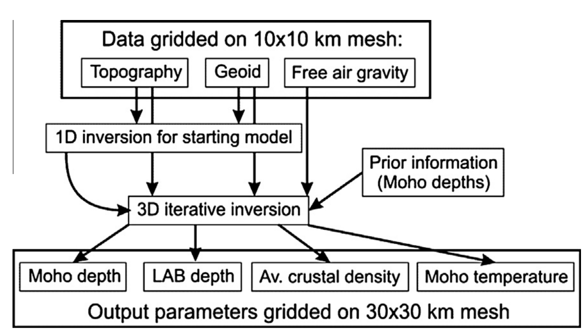

Fig. 2. Flow chart of the inversion procedure.