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Crustal velocity structure of the Neoarchean convergence zone between the eastern and western blocks of Dharwar Craton, India from seismic wide-angle studies

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ABSTRACT

The Dharwar Craton in the southern part of the Indian shield comprises two distinct blocks viz. the Meso-Neoarchean western and the predominantly Neoarchean eastern blocks, which are popularly referred to as Western Dharwar Craton (WDC) and Eastern Dharwar Craton (EDC). The boundary between the WDC and EDC is marked by a prominent shear zone, the Chitradurga eastern margin shear zone (CSZ). Several studies suggested Neoarchean convergence between the EDC and WDC, although there is diversity of opinion on the tectonic process. We present here the results of a new seismic refraction/wide-angle reflection experiment along a 200 km long profile across the WDC and EDC encompassing the CSZ to elucidate the crustal velocity structure of the convergence zone. Travel time inversion and amplitude modeling of the seismic data delineate a five-layered crustal velocity model for the Dharwar Craton with a 42 km (minimum) thick crust in the WDC grading to a distinctly thinner crust up to 38 km, in the EDC. The transect is also characterized by a high-velocity (7.0–7.1 km s^{-1}) mafic lower-crustal layer, but with distinctly variable thickness, 10 km in WDC and 8 km in EDC. The transition from thick to thinner crust coincides with the CSZ. The thick crust with a high-velocity basal layer is atypical of Archean cratons, but more akin to Proterozoic terrains. The crustal velocity structure across the EDC–WDC boundary zone is consistent with the Neoarchean plate convergence model that invoke tectonic scenarios, such as accretion of a hot orogen, the EDC and/or westward subduction of the latter beneath the WDC. Spatial variation in the high-velocity lower-crustal layer across the craton is ascribed to post-accretional mafic magmatism and underplating mainly during the Paleoproterozoic and Phanerozoic.

1. Introduction

The Neoarchean period, especially the age interval between 2.8 and 2.5 Ga is paramount to global continental geodynamics as it encompasses a major peak in the growth of continental crust owing to the high production rate of juvenile crust (Condie and Aster, 2010; Condie and Kroner, 2013). Several large cratons (e.g., Superior, Yilgarn and Dharwar) were assembled and stabilized during the Neoarchean and the constituent granite-greenstone terrains of these cratons provide a rare window into geodynamics of ancient Earth (de wit and Ashwal, 1997; Condie, 2000; Griffin et al., 2004; Jayananda et al., 2013a). The Dharwar Craton, southern India (Fig. 1) is a classic granite-greenstone terrain with a geologic record that dates back to the Mesoarchean (ca. 3.5 Ga) (Nutman et al., 1992). The Craton is divisible into Meso-Neoarchean western and a dominantly Neoarchean eastern blocks, popularly known as the Western Dharwar Craton (WDC) and Eastern Dharwar Craton (EDC). This subdivision is based on difference in ages of Archean greenstone-gneiss and granitoid units, crustal thickness, conditions of Neoarchean metamorphism and degree of melting in response to terminal Archean thermal and tectonic events, which are responsible for dominant structural grain across the craton. The boundary between EDC and WDC comprises a steep sheared mylonitic zone (Ramakrishnan and Vaidyanathan, 2010) along the eastern boundary of the Chitradurga greenstone belt, here after referred as the Chitradurga eastern margin Shear Zone – CSZ (Kaila et al., 1979;

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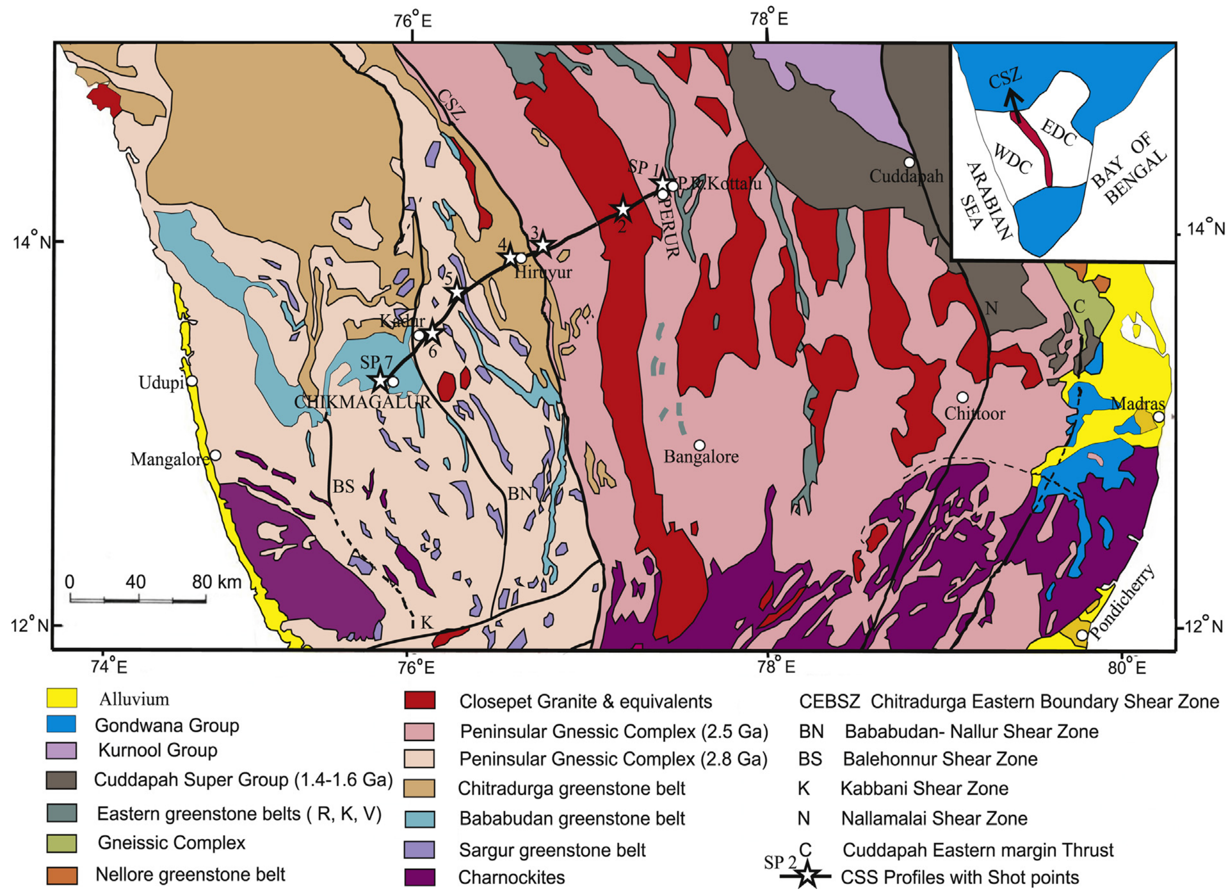

Fig. 1. The location of seismic refraction and wide-angle reflection profile in the Dharwar Craton, southern India. The inset shows an outline of India and the part of the Dharwar Craton. The Perur–Chikmagalur seismic profile—this study is shown with shot points SP1 to SP7. Major litho-units and abbreviations are explained in the legend and text. Modified after GSI and ISRO (1994).

Reddy et al., 2000; Jayananda et al., 2006; Chardon et al., 2011 and references therein). There are different opinions regarding the tectonic evolution of the Dharwar Craton, although most authors invoke Neoarchean convergence and amalgamation of the EDC and WDC (Chadwick et al., 2000; Manikyamba and Kerrich, 2012; Ram Mohan et al., 2013; Dey, 2013; Chardon et al., 2011).

In recent years, the long standing perspective that once cratonized, the Archean cratons remain stable forever, has been subject to considerable revision (Foley, 2008; Zhang et al., 2013a). The complexities in the structure, dynamics and evolution of various Archean cratons necessitate detailed studies on different cratons. Importantly, deep seismic refraction and reflection profiles worldwide have revealed crustal and mantle structures of the cratons and their margins within the Precambrian shields. Of particular interest, has been the structure and architecture of convergent tectonic zones within cratons revealed by seismic refraction experiments (Calvert et al., 1995; Gorman et al., 2002; Musacchio et al., 2004; Rumpfhuber and Randy Keller, 2009).

In the Dharwar Craton, previous seismic studies have yielded variable results with regard to crustal thickness and velocity structure. The first seismic refraction experiment was carried out along the Kavali–Udipi profile way back in 1974–1977 using low-dynamic range narrowband analog equipment. Kaila et al. (1979) produced a depth section with a crustal thickness of 34–36 km for EDC and 38–41 km for WDC based on the concept of effective velocity and 1-D migration (Kaila and Krishna, 1979). They suggested that the Dharwar crust was divided into a number of blocks each bounded by steep crustal scale faults on either side. Later, Reddy et al. (2000) suggested a relatively thick crust with lower average crustal velocity for WDC as against thinner crust with a high average crustal velocity for EDC. Sarkar et al.'s (2001) kinematic modeling of the same data resulted in a two-layered velocity model with a crustal thickness of 37–40 km for the WDC. Mall et al. (2012) later digitized this analog data, and derived a 6-layered velocity model with a 45 km thick crust along with a high-velocity lower-crustal layer. There has been hardly any consistency in crustal thickness or velocity structure amongst these crustal models.

Seismological studies using tomography, surface waves and receiver function (Sarkar et al., 2003; Rai et al., 2003; Borah et al., 2014) revealed a crustal thickness of 35–38 km with prominent felsic composition for the EDC and 43–55 km with a relatively mafic composition for the WDC. However, the source-receiver density of such data was limited, precluding a detailed crustal velocity configuration. Regional gravity studies over the Dharwar Craton indicate −70 mGal to −130 mGal Bouguer anomalies spread over the entire region (NGRI, 1978).

Wide variation in the above results necessitated a fresh seismic refraction/wide-angle reflection experiment to be undertaken. A new profile between Perur and Chikmagalur (Fig. 1) that is reasonably close to the earlier transect is selected for this study, enabling a comparison and improvement in the resulting models. We focus here on the crustal seismic velocity structure of the convergent zone between the EDC and WDC, variations in Moho topography and evaluate the possibility of modification of the Dharwar crust during the post-Archean thermal and tectonic perturbations.