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Preserved and modified mid-Archean crustal blocks in Dharwar craton: Seismological evidence

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ABSTRACT

We report significant lateral variability in shear wave velocity and Moho depth in the Archean crust, beneath the Dharwar craton, using earthquake waveform data recorded over 50 broadband seismographs. The craton is a continuously exposed Archean continental fragment divided into the west Dharwar craton (WDC) of age 2.7–3.36 Ga, and the east Dharwar craton (EDC) of age, dominantly, 2.5 Ga. The craton progressively transitions into the Southern Granulite Terrain (SGT) with age of metamorphism around 2.6 Ga.

The inversion and modeling of receiver function data reveal significant variation of Moho depth, viz., 38–54 km in the WDC, and 40–46 km in the SGT and 32–38 km in the EDC. The average shear wave velocity (Vs) of crust beneath the WDC is ~3.85 km/s as compared to ~3.6 km/s in the EDC. We infer highly variable thickness (16–30 km) of mafic cumulate (Vs ≥ 4.0 km/s and Vp ≥ 7.0 km/s) beneath the WDC, in contrast with a thin one (<5 km) beneath the late Archean EDC. The 3.36 Ga greenstone belt in the WDC has maximum basal layer thickness of ~30 km. These results suggest the intermediate-mafic composition and exceptional thickness of crust beneath the WDC (>50 km) as compared to felsic to intermediate composition for the EDC crust with almost flat Moho (down to ~38 km). These results suggest preserved mafic crustal root beneath the middle Archean terrain in the WDC that has remained inert since then. On the other hand, felsic to intermediate composition of crust with a nearly flat Moho beneath the late Archean EDC could be a consequence of regional delamination of lower crust. The preserved distinct Moho topography across the Archean terrains suggests it as compositional boundary. Considering the surface exposure of 15–20 km crust, based on P–T condition, in the granulite segment of the WDC, we speculate a Himalaya-like crustal thickness (50–70 km) beneath the middle Archean crust pointing toward a plate tectonic-like scenario at ~3.0 Ga.

1. Introduction

Zircon chronology on minerals suggests existence of continental crust as far back as 4.2 Ga (Compston and Pidgeon, 1986; Bowring et al., 1989). However, most of our knowledge of the crustal characteristics and its evolution mechanism is restricted to continental crust younger than ~3.3 Ga, due to large-scale thermal modifications prior to this age. Two prominent continental crust forming events, at ~3.3 Ga and 2.7 Ga, have been reported during the Archean (De Wit et al., 1992; Rudnick, 1995; Condie, 2005; Hawkesworth and Kemp, 2006; Van Kranendonk, 2011; Dhuime et al., 2012). Based on geochemical analysis of rocks and minerals, and supported by geophysical signatures, various geodynamic models have been proposed for the evolution of the Archean continental crust. These include the formation of crust in the late Archean (3.0–2.5 Ga) through accretion of volcanic arc (Lowe, 1994; Kusky and Polet, 1999), and interaction of mantle plume with the arcs (Choukroune et al., 1997). Estimates of the beginning of plate tectonics vary from about 800 Ma to close to 4.2 Ga (Stern, 2005; Hopkins et al., 2008), with a clear preference for the end of the Archean (Calvert et al., 1995; White et al., 2003; Arndt, 2013). More recent papers place the start even earlier, around or before 3.0 Ga (Bastow et al., 2011; Arndt, 2013). Middle Archean terrains (3.6–3.0 Ga), however, lack most of the features associated with convergent plate boundaries and could possibly have evolved through melting of thick mafic crust (De Wit, 1998; Zegers and van Keken, 2001; Nagel et al., 2012). Scientific opinion, however, remains divided on the processes responsible for the formation and evolution of the early and middle Archean continental crust. For better identification of the crust evolution process during Archean,

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