ABSTRACT

Considerable debate exists on the nature of the early terrestrial crust, the timing and geodynamic regime of its formation, and how primordial crust extraction and recycling may have affected mantle depletion in the Hadean and the Archean. In this study, the U-Pb-Hf isotope and trace element chemistry of zircon from the Western Dharwar Craton (WDC) and the Singhbhum Craton (SC) is used to constrain Hadean and Archean crustal evolution, including the timing and geodynamic setting of granitoid crust formation, and the nature and age of their protoliths.

The granitoids of the WDC formed in four major pulses between ca. 3.43–2.65 Ga and were derived from shallow garnet-free plagioclase-bearing amphibolitic sources, with minor components derived from pre-existing tonalitic crust. The Paleoarchean granitoid suites have radiogenic $^{176}Hf/^{177}Hf$ and plot on a common Hf vs. time trend. Their Hf-isotopic compositions are consistent with repeated granitoid crust extraction from mafic sources that were separated from the depleted mantle between 3.55 Ga and 3.35 Ga. The Neoarchean granitoids have chondritic to slightly negative Hf isotopic composition and formed either by melting of the same 3.35 Ga mafic crust or by mixing between juvenile magmas and pre-existing granitoid crust. The detrital zircon in metasediments from the WDC preserve a continuous record of crust building from Eoarchean to Neoarchean. Major granitoid crust formation in the craton happened in distinct phases between ca. 3.68–2.65 Ga. The detrital zircon suites have both positive (mantle-like) and negative (crust-like) $\varepsilon Hf_{(t)}$. However, the majority have depleted-mantle like composition. Some of the Paleoarchean detrital zircon have strongly unradiogenic $\varepsilon Hf_{(t)}$ values, requiring protoliths that were extracted from the mantle in the Hadean.

The detrital zircon grains from the SC define major age populations at 3.95 ±0.10 Ga, 3.73 ±0.09 Ga, 3.55 ±0.06 Ga, 3.47 ±0.04 Ga, 3.36 ±0.03 Ga, 3.27 ±0.06 Ga, and 3.14 ±0.06 Ga. The Hf isotopic composition of the Eoarchean populations are unradiogenic and shows a transition towards chondritic values ($\varepsilon Hf_{(t)}$=-0.4 to -0.6) by ca. 3.7 Ga. Zircon younger than c. 3.63 Ga display a larger variation in $\varepsilon Hf_{(t)}$ (-9.2 to +3.17) but the majority have positive $\varepsilon Hf_{(t)}$ and crustal residence ages less than 3.6 Ga. Zircon chemistry records a transition in the Nb/Th and the Nb/U, coupled with the shift to more juvenile Hf-isotopic composition and younger protolith ages of the SC granitoids at ca. 3.7 Ga. This marks a significant change in the depth of melting of the granitoid protoliths and in the tectonic regime of continental crust formation. The Hf isotopic composition of Hadean to Eoarchean zircon generally reflect the signature of long-term storage of Hadean/Eoarchean crust and granitoid production in a geodynamic regime more akin to stagnant-lid like convective regime. In contrast, the appearance of juvenile $\varepsilon Hf_{(t)}$ in late Eoarchean to early Paleoarchean zircon with relatively short crustal incubation time for their protoliths require a tectonic regime characterized by rapid recycling of basalts at deeper levels and interaction with juvenile magma in arc-like environment. A distinct shift in the $\varepsilon Hf_{(t)}$ of the zircon from chondritic to positive value at Eoarchean to Paleoarchean transition may mark the emergence of a persistent depleted mantle reservoir.

Key Words (8): Western Dharwar Craton; Singhbhum Craton; zircon; U-Pb dating; zircon Hf-isotope; trace element; Depleted mantle; Archean