

Growth of lithospheric mantle roots triggered by upwelling carbonated silicate melts in an extensional setting

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Thick lithospheric mantle roots maintain continent stability and modulate mantle dynamics, but the mechanisms that form these thick roots (>200 km) remain debated. Here, we present results from seismic tomography and Mg-Zn isotopic analyses of Cenozoic basalts in Northeast Asia. Full-waveform tomographic results reveal the presence of three thick (>200 km) lithospheric mantle roots with an inverted wedge structure located in the northern Great Xing'an Range, southern Songliao Basin, and Bohai Bay Basin, respectively. A thin low-velocity layer is observed between the lithosphere-asthenosphere boundary identified by seismology and newly growing roots. Rock physics models, together with seismic results, indicate that these newly growing roots are less dense and depleted in water, representing distinct features of the lithospheric mantle. The Cenozoic basalts (e.g., Wudalianchi-Nuomin, Shuangliao, and Dashan volcanoes) are widely distributed within regions corresponding to three lithospheric mantle roots. Geochemically, these basalts belong to the alkali series and exhibit lower $\delta^{26}\text{Mg}$ and higher $\delta^{66}\text{Zn}$ values than the mantle (Teng, 2017; Sossi et al., 2018), suggesting that recycled carbonates have contributed to their magma sources. Combined with the presence of carbonated peridotites as xenoliths in these Cenozoic basalts (Xu et al., 2024) and the close relationship between these Cenozoic volcanoes and low-velocity bodies originating from the mantle transition zone (Xu et al., 2021), we propose that carbonated silicate melts are generated through the interaction of silica-rich melt derived from partial melting of stagnant slabs with carbonated peridotites (<300 km). The upwelling carbonated silicate melts will extract water from ambient asthenosphere and transform asthenospheric mantle into lithospheric mantle, further resulting in the growth of lithospheric mantle roots. In Cenozoic, the NE Asian continental margin was characterized by an extensional setting. Consequently, the development of these continental lithospheric mantle roots occurred under extensional conditions, challenging traditional views on root development mechanisms such as mechanical compression (Pearson et al., 2021), gravity loading (Forsyth, 1985), and plume activity (Liu et al., 2021). Our findings indicate that the generation and subsequent upwelling of carbonated silicate melts represent a crucial mechanism for promoting lithospheric mantle root growth.

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