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Radiogenic heat production in the Earth's mantle: Implications for the structure and dynamics of continental cratons

The tectonic plates form the upper thermal boundary layer of Earth's mantle convection system. In the oldest continental regions (the cratons), the lithospheric plate thickness can exceed 200 km. The thickness and stability of the craton lithosphere is controlled by its thermal structure, which in turn depends on the vigour of the underlying mantle convection and the thermal properties of the lithosphere itself. One key uncertainty arises from the amount of heat generated by the decay of radioactive elements within the craton mantle lithosphere. Estimates based on xenolith measurements and geotherm modeling suggest heat production of 0.01–0.06 μW·m-3. However, these relatively high values may reflect samples biased toward regions of lithosphere that were modified by fluids or melts. A recent study by McIntyre et al. (2021) shows that unmodified mantle lithosphere may have negligible heat production (<0.0001 μW·m-3), whereas refertilized or metasomatized mantle may reach values of 0.006 μW·m-3. Xenoliths are small samples of Earth's lithosphere, proximal to melt transfer channels. Developing improved methods for integrating heat production over larger volumes of lithospheric mantle would yield new constraints on how representative xenolith heat production estimates are.

The magnitude of heat production has important consequences for lithospheric structure and evolution. Steady-state geotherm calculations show that for a given surface heat flow, a lower heat production results in higher temperatures in the craton mantle and thus a thinner lithosphere (by 10-80 km). Such differences influence the long-term stability of cratons and their capacity to host diamonds. Geodynamic models demonstrate that even modest increases in deep lithosphere temperature reduce the strength, making cratons susceptible to destabilization and thinning. Furthermore, localized areas of elevated heat production may create weak regions that promote intraplate deformation. Constraining the spatial distribution of heat-producing elements in craton mantle is therefore crucial for understanding craton longevity and the broader thermal evolution of Earth.

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