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It's cold in Siberia: Low crustal heat production in the Siberian Craton constrained by xenolith petrochronology

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Temperatures of the lower crust and Moho are key boundary conditions for models of heat transfer and production within Earth's lithosphere, information that also impacts models of the bulk composition of continental crust. U-Pb thermochronology applied to xenoliths can help decipher the long-term (100–1,000 Myrs) thermal evolution of the lower crust and Moho. Implicit to generating thermal histories from U-Pb thermochronology is the assumption that Pb in different thermochronometers—like rutile and apatite—undergoes thermally-mediated volume diffusion during slow cooling in the lower crust. Here, laser ablation split stream U-Pb and trace-element analyses of accessory phases in xenoliths from the Late Devonian Udachnaya kimberlite (Siberian Craton, Russia) show that the U-Pb system is sensitive to transient heating of the lower crust and not just slow cooling. Rutile and apatite in lower-crustal garnet granulite xenoliths record U-Pb dates that extend from 1.8 Ga to the timing of kimberlite eruption (360 Ma); this contrasts with shallower granitoid and amphibolite xenoliths that contain solely Paleoproterozoic apatite. Depth profiling of rutile from the lower crustal xenoliths reveals young U-Pb rim dates that increase gradually towards the core of the grains. Multi-element profiles vary across length scales similar to U-Pb profiles, incompatible with slow cooling as the primary mechanism for partial Pb loss in xenolithic rutile. These data instead require depth-dependent heating of the crust for <1 Myr prior to eruption; long-term, ambient lower-crustal temperatures before this thermal perturbation could have been substantially cooler than the Pb closure temperature of rutile (<550 °C). Permissible lower-crustal temperatures based on these data are in agreement with geothermal gradients suggested by the pressure-temperature arrays of Udachnaya peridotite xenoliths, signifying that the mantle xenoliths accurately capture the thermal state of the lithosphere prior to eruption. The inferred lower-crustal temperatures require low heat production for the Siberian Craton (0.2–0.7 $\mu W/m^3$ assuming average surface heat flow values for cratons), similar to other cratons.