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Basal erosion and surface heat flux anomalies associated with plume-lithosphere interaction beneath continents

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Deep-seated upwellings within the Earth's mantle, also known as mantle plumes, affect the Earth's surface by inducing (large-scale) volcanism, initiating continental breakup and increasing surface heat flow. Plume-lithosphere interaction may also generate lithospheric erosion at the base of the tectonic plates. It is therefore important to understand the past positions and movements of mantle plumes relative to the surface plates. However, while hotspot tracks beneath thin oceanic lithosphere are visible as volcanic island chains, the plume-lithosphere interaction for thick continental or cratonic lithosphere often remains hidden due to the lack of volcanism.

To identify plume tracks with missing volcanism, we characterize the relationship and timing between plume-lithosphere interaction and associated surface heat flux anomalies by using numerical models of mantle convection. Our results indicate a relation between lithospheric thinning and surface heat flux anomaly, which is independent of geometry and can be approximated analytically. We have confirmed this close link between basal erosion of the lithosphere and surface heat flux anomaly using an analytical expression form the time-dependence of heat transmission through convectively thinned lithosphere. Anomaly amplitudes primarily depend on the viscosity structure of the lower lithosphere and the asthenosphere, with a minor dependence on plume temperature. Lithospheric thinning is strongest around the time the plate is above the plume conduit, while the maximum heat flux anomaly occurs about 40-140 Myr later. Therefore, continental and cratonic plume tracks can be identified by lithospheric thinning, even if they lack extrusive and intrusive magmatism, followed by elevated surface heat flux several 10s of Myr later. This has important implications, especially for arctic settings such as Greenland or Antarctica, as ice melting rates might be affected by elevated heat flow long after the plume passage.