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Extensive Magmatic Heating of the Lithosphere Beneath the Hawaiian Islands Inferred From Salt Lake Crater Mantle Xenoliths

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An ongoing challenge in studies of the oceanic upper mantle is how intraplate hotspots impact the thermal structure of the lithosphere. To address this issue at the Hawaiian hotspot, we analyze mineral compositions for a petrographically diverse suite of garnet pyroxenite xenoliths from the Salt Lake Crater (SLC) rejuvenation stage, volcanic tuff ring in Honolulu. Garnet-clinopyroxene geobarometry and two-pyroxene geothermometry indicate equilibrium pressures of 13–18 kbar and temperatures of 1000°C–1100°C. These pressures place the xenoliths at mid-lithospheric depths of 45–55 km, with temperatures 200°C–300°C hotter than expected for normal 90-Myr-old oceanic lithosphere. Garnet and clinopyroxene occur as discrete primary grains, as well as exsolution blebs and lamellae, with lateral dimensions up to several hundred microns. Compositions within garnet and pyroxene grains are remarkably uniform and display no systematic variation with distance to grain boundaries. Together, these observations indicate that the calculated pressures and temperatures reflect the thermal state of the lithosphere under which the xenoliths last equilibrated. We attribute the elevated lithospheric temperatures under Honolulu primarily to the heating by magma as it penetrated the lithosphere during rejuvenation magmatism and the voluminous shield magmatic stage. We anticipate such magmatic heating to be common among all Hawaiian volcanoes, supporting conclusions of a recent study of earthquakes beneath Hawai'i Island. This local lithospheric thermal anomaly may also contribute to the enigmatically weak flexural response of the lithosphere due to volcano loading along the Hawaiian hotspot chain.