Termination of arc magmatism by lithospheric thickening: insights from Lu-Hf and Sm-Nd chronology and Al-diffusion kinetics

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Petrology and thermobarometry of Sierra Nevada peridotite xenoliths suggest that arc lithosphere cooled and thickened from 1 to 3 GPa, reaching depths that may have impinged against the top of a subducting slab. Thickening was caused by magmatic inflation during Mesozoic subduction, and resulted in depth-gradation in refertilization. Garnet (gt) peridotites record final P of 3–3.5 GPa and final T of 670–845 °C. High-Mg gt websterite is interleaved with peridotite and record similar final P and T. At shallower levels (1–2 GPa), low-Mg gt clinopyroxenites are interpreted to be evolved cumulates of high-Mg pyroxenites. Garnet peridotites contain Al-depletion halos associated with gt exsolution in opx, and opx in gt websterites are zoned from high-Al cores to low-Al rims, all features indicating cooling. Here, we estimate the time required to form Al-depletion halos using 1D Al diffusion and thermal models. To constrain when the root attained its final P and T, we obtained coupled Lu-Hf and Sm-Nd internal mineral isochron ages on gt websterite and lower crustal gt clinopyroxenite. Results show no age difference between chronometers for websterite (Lu-Hf: 92.6±1.6 Ma; Sm-Nd: 88.8±3.1 Ma). In contrast, clinopyroxenite shows a 24 Ma difference (Lu-Hf: 107.9±1.4 Ma; Sm-Nd: 84.0±4.1 Ma). Ages are consistent with pyroxenites originating as cumulates complementary to Cretaceous granitoids, and imply that a ~100 km thick root was already in place by that time. T-t paths from thermal modeling reveal rapid cooling from 1350 to 750°C within 10-20 My at 80-100 km, and Al-diffusion models suggest halo formation in 10-20 My. We propose that slab chilling was rapid enough at 100 km for both the Lu-Hf and Sm-Nd chronometers to have closed at the same time in the websterite. In contrast, cooling was slower in the lower crust away from the chilling slab, resulting in the age difference observed for the clinopyroxenite. Instead of shallowing of the Farallon plate, we suggest that the Sierran arc root thickened until it hit the slab, resulting in pinchout of the mantle wedge, rapid cooling, and termination of arc magmatism.