Mass transfer across the Moho: Insights from deep lithospheric cumulates

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The Moho is not a simple geologic feature, but a complex zone of mass, heat and chemical transfer from the mantle into the crust. How heterogeneous is this transition, to what extent do mantle and crustal materials mix, and what are the implications for magmas? Deep lithospheric cumulates provide a high-fidelity record of Moho processes, as mafic cumulates are the earliest magma fractionation products and are therefore mostly free of crustal contamination. We first survey global cumulates across diverse tectonic settings and describe simple cumulate crystallization model trends (based on MORB) as a baseline framework for understanding more complex continental settings. We then present data on the two extremes of continental evolution, the Sierra Nevada, USA continental arc, where new continental crust was formed, and the East African continental rift, where continental crust is broken apart. In the Sierra Nevada, garnet quartzite xenoliths equilibrated at lower crust conditions show that orogenic thickening can transport upper crustal sediments into the deep crust. Cooling timescales of the deep lithosphere were constrained using coupled Lu-Hf and Sm-Nd geochronology of pyroxenite xenoliths ranging from mid-lower crustal to upper mantle depths. These results show that episodic arc growth may be modulated by cycles of thickening and slab-induced cooling of overriding lithosphere, rather than slab dip. In the East African rift, pyroxenite accumulation at the Moho may also be an important process, as evidenced by abundant clinopyroxene megacrysts and pyroxenite xenoliths. The E. African pyroxenites define a trend ranging from Fe-rich dunites to clinopyroxenites. In addition, they lie on a low-Al, HREE-depleted trend suggesting “ghost” garnet fractionation deeper in the lithosphere before equilibration at the Moho. The pyroxenites do not match modeled cumulate trends, and are better explained as mixtures between dunite and clinopyroxene. Although tectonically distinct, the arc and rift studies show that supracrustal input, thickening, and mixing between different cumulates all occur throughout a vertically extensive (10’s of km) Moho-mantle zone. The role of deeper mantle lithosphere processes must also be taken into account when interpreting the cumulate record.