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Origins of carbonatites and links to REE-rich IOA/IOCG mineral systems

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Carbonatites are enjoying a renaissance due to increasing awareness that these rocks may host giant REE deposits. The dominant paradigm suggests that economic REE mineralization in carbonatites forms only after protracted magmatic differentiation and post-magmatic overprinting by carbo(hydro)thermal fluids in the crust. There are indications, however, that some mantle sources – especially in collision zone settings – are more conducive to the formation of economic carbonatites than others. In such environments, links between deep carbonatite magmatism and the formation of Kiruna-type IOA mineralization at surface may exist and present a new class of REE deposits.

We analyze a database of the isotopic compositions of carbonatites through the past 3 Gyr. In Sr-Nd-Hf isotope space, the carbonatite array develops between a well-defined moderately depleted endmember, reminiscent of prevalent mantle, and a range of enriched components. These are highly heterogeneous and may represent ancient metasomatized mantle lithosphere or various types of recycled crust including sediment. Carbonatites from collision zones contain uniquely enriched 'mantle' flavours. Importantly, several isotopic tracers – in particular the $d^{11}B$ and $d^{34}S$ compositions – show that recycled crustal components in the mantle sources of carbonatites became increasingly common after 1 Ga, linked to Earth's transition into a modern plate-tectonics regime.

To test this secularity, we present new isotope data for Archean carbonatites. Our Pb and Hf isotope data, as well as SIMS-determined $D^{33}S$ data for carbonatite-hosted sulphides, reveal a dominant mantle source signature without traceable inputs from Archean recycled crust. Initiation of colder subduction after 2.5 Ga promoted deeper levels of lithosphere transfer into the convecting mantle, including a more effective introduction of volatiles and sediment into the deep Earth. We suggest that it is no coincidence that the richest REE deposits occur in post-Archean carbonatite districts located in Proterozoic mobile belts and Phanerozoic collision zones, where their upper mantle sources received a larger contribution of fertile recycled crust. We suggest further that the deep magmatic plumbing systems to Proterozoic Kiruna-type IOA deposits (and to certain IOCG systems) had received contributions from enriched carbonatitic melts or fluids, critical for their recently identified economic REE potential.