Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.34405

Linking carbonatites, rare earth ores, and subduction-fertilised mantle lithosphere

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Continental intraplate magmatism through time has played a crucial role in ancient mass extinctions, landscape evolution, global climate and volcanism. These magmatic systems are also crucial sources of critical metals, including the rare earth elements (REE) and Nb. Nonetheless, the origins of alkaline intraplate magmas, such as carbonatites, remain enigmatic. Here, we use kinematic plate modelling (using Gplates) to identify the location of continental mantle lithosphere domains that have high potential to be metasomatically enriched via prolonged plate subduction (ie. stable continental arcs lasting > 100 m.y). ~35% of present-day subcontinental lithospheric mantle is proposed to have experienced substantial subduction-related fertilization in the last two billion years. Today, these fertilized mantle domains underlie ~67% of post 1.8 Ga carbonatites and ~72% of magma-related REE ore deposits (and ~92% of Precambrian REE deposits), substantiating a genetic link between ancient, enriched mantle lithosphere and alkaline intraplate magmatism and associated ore deposits. These results suggest that processes such as upwelling mantle plumes or fluxes from deep-mantle slab graveyards are not required to produce the source regions for alkaline intraplate magmatism, although it also does not exclude these mechanisms.

We find no correlation between the timing of mantle source fertilization and carbonatite formation, indicating that the evolution of these magmas is multistage, including an initial metasomatic ‘primer’ of the mantle lithosphere and a subsequent and disconnected melting ‘trigger’ event responsible for magma generation. This trigger event may include deformation of the lithosphere due to an impinging mantle plume or intracontinental extension, asthenospheric flow around a lithospheric step, or even mantle decompression due to deglaciation.

Recognition that fertile mantle lithosphere domains host a majority of REE deposits, including ~92% of Precambrian deposits, means that these zones can be used as a first order target for mineral exploration. More specific targeting may benefit from spatial correlation between fertile mantle domains, cratons and lithospheric structures or steps, which are also recognized to control the location of REE deposits.