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Co-evolution of continental mantle and magmas, and some implications for carbon cycling

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Rocks preserved in the continental lithosphere represent our only direct archive of Earth's dynamic evolution. Both komatiites and kimberlites are strongly associated with cratonic lithosphere - albeit being prominent at different times - in sync with changing conditions in both the convecting and the lithospheric mantle. Notably, the different volumes, degrees of silica (under-)saturation and oxidation states of these magmas lead to profoundly different interaction mechanisms within the continental mantle and effects on the atmosphere after emplacement within the early crust.

The antiquity and chemical composition of harzburgitic diamonds require stabilization of thick, refractory and reduced lithospheric nuclei by Palaeo- to Mesoarchaean time and, therefore, deep onset of melting at high mantle potential temperatures. This accords with the emplacement of reduced, high-volume silicate melts like komatiites. Towards the Meso- to Neoarchaean, the convecting mantle had cooled enough to allow the rise of the continents and transition to plate tectonics. This welded together the earliest cratonic nuclei, as indicated by the eclogitic diamond record. Late Archaean komatiites attest to the persistence of deep, hot mantle domains, but their emergence and weathering now had profound effects on atmospheric CO_2 contents. By contrast, the asthenosphere was generally too reduced below thick cratonic rocks to stabilise kimberlites, except for anomalously oxidised deep regions.

The Palaeoproterozoic saw a waning of komatiite and waxing of kimberlite activity. Kimberlite interaction with the cold and reduced mantle lithosphere is witnessed by the first appearance of lherzolitic diamond, via reduction of CO_2 and concomitant oxidation of peridotite. Successful kimberlite eruptions were promoted by repeated interaction with oxidised melts and fluids, now derived both from the asthenosphere and subducted slabs, that increased oxygen fugacity enough to stabilise carbonated melts in the lithosphere, widening the “kimberlite window”.

Supercontinent breakup led to thinning of a significant fraction of cratonic lithosphere over time, with formation of volatile-rich small-volume magmas without the need for (strong) temperature anomalies. Their interaction with mid-continental lithospheres is witnessed by wehrlites and other strongly metasomatised mantle rocks typically associated with rifts and basins, and their emplacement led to release of amounts of CO_2 significant enough to affect atmosphere composition.