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# Where is all the missing komatiite implied by refractory Archaean cratonic harzburgite?

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We report coupled thermodynamic and dynamic incongruent melt trace element modelling to reconstruct pertinent petrological and geochemical features of erupted liquids, cratonic harzburgite and refractory olivine and garnet diamond inclusions. The model results show that heavy rare earth element-depleted (HREE) garnet harzburgites are residues after advanced stages of deep melt extraction (>1,700°C) between 3.5 and 6 GPa. Very high $Cr_2O_3$ garnets, such as often found as diamond inclusions, form within 30°C of the garnet-out reaction [1].

The refractory residues result after fractional melting whereby several batches of liquid are sequentially extracted from the source. The escaping liquids evolve in chemistry from Al-depleted, to undepleted, to Al-enriched and Ti-depleted komatiite (Figure 1, left panel). In addition, the observed Si-rich harzburgites and dominant Al-undepleted komatiites (Figure 1, right panel) can form via open-system melting, in which stationary resident harzburgite of the proto-lithosphere hybridises with incoming deeper ultramafic liquids [2]. Regardless of model, the mineralogy and chemistry of the bulk of the cratonic lithospheric mantle implies loss of dominantly komatiitic rather than basaltic liquids. For example, for a 100 km thick, highly depleted lithosphere, we require 15-25 km piles of corresponding komatiite. However, our global survey of Archaean greenstone belt stratigraphies demonstrates that komatiite (regardless of chemical type) is often only a subordinate component and within exposed middle Archaean crust, ultramafic intrusions are volumetrically also minor.

One solution to this mass imbalance is that on cratons with a dearth of komatiite (e.g., Slave), the crust and deep mantle lithosphere are not complementary and mechanical coupling of unrelated crust and mantle residues occurred during final cratonisation or later still. On other cratons (e.g., Kaapvaal) corresponding komatiite suggests whole coupled lithosphere formation. Ultramafic liquids lost from depths corresponding to 3.5 to 6 GPa would thus mainly have erupted into Archaean oceanic lithosphere with low preservation prospect. The potential former presence of dominantly very olivine-rich Archaean oceanic crust would have had major implications for the redox state of the early ocean and atmosphere due to its vast $O_2$-buffering capacity.

[1] Walsh, Kamber & Tomlinson (2023), *Nature* 614(7952).

[2] Tomlinson and Kamber (2021). *Nature Communications* 12(1), p.1082.

Figure 1