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Experimental investigation of silica enrichment in Archean cratonic lithosphere

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A distinguishing feature of Archean cratonic lithosphere is that it trends towards silica-rich compositions, with elevated SiO_2/MgO ratios and a high abundance of orthopyroxene. These compositions are too silica-rich to have been produced by partial melting of fertile peridotite. One plausible mechanism for silica enrichment is the reaction between peridotite and ascending komatiite melts, particularly Al-depleted komatiite (ADK). ADK melts have low Al and so do not stabilize additional garnet and are highly magnesian so maintain high Mg/(Mg+Fe) ratios in the reacted peridotite. Komatiites are generated by high-degree melting and were primarily erupted in the Archean, however their elemental and isotopic compositions exclude a direct residue-melt relationship with depleted peridotites of the cratonic lithosphere.

We conducted reaction couple experiments to investigate the effect of komatiite-peridotite reaction on peridotite modal mineralogy and komatiite melt composition. We used ADK powder (CaO/Al_2O_3=0.85, MgO=34.9wt%) beneath either fertile (Mg#=89.2) and depleted (Mg#=92.2) peridotite rods. Both peridotite starting materials are orthopyroxene free and contain olivine + garnet + clinopyroxene. Experiments were conducted at 5GPa and 1600–1650°C, at conditions just above the peridotite solidus in order to simulate interaction of the cratonic lithosphere with hot, infiltrating komatiite melt.

Our results show that the reacting peridotite evolves from an assemblage of olivine+garnet+clinopyroxene to one consisting of olivine+garnet+orthopyroxene, with clinopyroxene stabilizing at lower temperatures and orthopyroxene at higher temperature. Orthopyroxene (Mg#=92.3) reaches locally high modal abundances (>70%) in the peridotitic layer, where it coexists with olivine and garnet, large orthopyroxene crystals often poikiliticly enclosing resorbed olivine and garnet. These abundances and textures are similar to those seen in silica-rich peridotite xenoliths. The melt phase trends from Al-undepleted komatiite (AUK, CaO/Al_2O_3 ~0.75), the increase in Al_2O_3 relative to the starting ADK consistent with consumption of garnet; to picrite (MgO 12-18wt%, SiO_2 46-48wt%), similar to picritic lavas commonly associated with komatiite in Archaean greenstone belts.

These experiments provide new insights into Archaean mantle processes, demonstrating the potential for komatiite to react with the lithosphere during ascent and modify the compositions of both the residue and the melt. This process potentially provides the missing link between Archaean residue and melt compositions.