

Silica metasomatism by reactive flow of komatiite through cratonic harzburgite

BALZ S. KAMBER¹, NATHAN R. DACZKO², ROBYN L.
GARDNER² AND SANDRA PIAZOLO³

¹Queensland University of Technology

²Macquarie University

³University of Leeds

Excess SiO₂ in cratonic peridotites is often attributed to metasomatism by cryptic silica-rich ‘liquids’. We present a combined microstructural and mineral chemical investigation of 15 coarse-grained, SiO₂-rich, spinel and garnet facies peridotites from the Kaapvaal craton. All samples exhibit microstructural evidence of former melt presence, including low apparent dihedral angles, irregular grain boundaries, and extremely elongate grains. Despite their SiO₂-excess, these peridotites are highly refractory, with whole-rock Mg# ranging from 91.8 to 93.3 and very low concentrations of incompatible elements (e.g., TiO₂ <0.02 wt% and Na₂O <0.1 wt%). This strongly challenges models attributing excess SiO₂ to evolved liquids or fluids.

Thermodynamic modelling of melt-solid interaction between deep (≥7 GPa) komatiite melt and harzburgite lithosphere reproduces the petrology of SiO₂-rich peridotites when treated as an open system. In this scenario, the incoming melt reacts with pre-existing olivine + orthopyroxene, modifying its chemistry, typically lowering MgO content, before exiting the system. This process removes incompatible elements from the melt-rock interaction system, explaining the highly refractory nature of the modified SiO₂-rich peridotites. The reactions also change the melt SiO₂/MgO ratios, which match natural komatiite compositions. Unlike melt impregnation, where the incoming melt reacts, crystallises, and elevates incompatible element concentrations, open-system behaviour preserves the refractory signature observed in the peridotites.

At the very high temperatures (ca. 1600–1700°C) implied by thermodynamic modelling and orthopyroxene exsolutions, melt-solid reaction favours the growth of coarse-grained peritectic crystals, preserving microstructures distinct from typical granular peridotites. The mineral modes observed in hand specimens and thin sections likely represent reaction zones where melt percolated through pre-existing lithosphere. Despite clear evidence of melt-solid interaction, these coarse-grained cratonic peridotites show no mineral chemical zonation or compositional differences between reacting and reactant minerals. This is unexpected from thermodynamic modelling and suggests that prolonged cooling onto the geotherm erased initial chemical variability via diffusional re-equilibration.

In summary, open-system komatiite-harzburgite reactions at varying melt/solid ratios and across temperature gradients can account for the surprisingly wide SiO₂/MgO range in peridotites and erupted komatiites. This process may also yield decoupled radiogenic isotope ratios while maintaining ordinary mantle O-isotope compositions.