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Silicate melts derived from spinel harzburgite sources in the Earth's upper mantle: petrogenesis, volatiles and precious metals

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During the past ten years, petrological and geochemical data have been reported for sulfide-bearing orthopyroxenites cutting mantle-derived samples from the Kamchatka and West Bismarck arcs. In this presentation, I will compile these published data and present new geochemical analyses of volatiles (H_2O, F, Cl and S) and chalcophile and highly-siderophile metals (e.g. first-row transition metals, platinum-group elements, Ag, Re, Au).

All the orthopyroxenites contain abundant sulfides and some are characterised by the presence of interstitial glass and melt inclusions with Ti-poor and Mg-rich andesite compositions. Petrological data and models suggest that the parental melts were originally produced by low degrees of melting (≤5%) of spinel harzburgite at ≥1360°C and ≤1.5 GPa. Combining measurements in orthopyroxene-hosted melt inclusions and in the interstitial glass allows reconstructing volatile evolution through melt/rock reactions, which lead to sulfide and alloy formation. Elevated undercooling rates and S^{6+}-Fe^{2+} redox exchange with the host mantle constitute a key combination of conditions to trigger (H_2O, S, Cl)-rich hydrothermal fluid saturation, shortly after or concurrently with abundant sulfide formation. During such a process, up to 85% of the original melt S content (~2600 ppm) can be locally precipitated as magmatic and hydrothermal sulfides.

Monosulfide solid solution (MSS) in the orthopyroxenites crystallised from a parental sulfide liquid from ca. 1050-1100°C to ≤850°C, and under oxygen and sulfur fugacity conditions (fO_2 and fS_2) close to the fayalite-magnetite-quartz and Pt-PtS buffers, respectively. These MSS have fractionated, chondrite-normalised platinum-group element (PGE) patterns with elevated PPGE (Pt and Pd) relative to IPGE (Os, Ir and Ru) and Rh. Chondrite-normalised Pt/Pd>1 in some of the inferred, parental sulfide liquids is a signature inherited from their spinel harzburgite sources. Because it occurs at relatively low fS_2, the crystallisation sequence of these sulfide liquids is accompanied by the formation of abundant PGE alloys and other metallic phases, which are found in association with both sulfides and hydrothermal fluids.

Based on these data, I propose a model where oxidised silicate melts derived from spinel harzburgite sources can follow a sulfide-undersaturated evolution trend until they rapidly crystallise as orthopyroxenite dykes or sills, which host sulfides and alloys containing precious metals.