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Peritectic crystal entrainment during partial melting in the mantle: Importance for the formation of layered ultramafic complexes & chromitite seams.

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This study presents a novel hypothesis for the formation of the silicate-chromitite layering in ultramafic complexes. Instead of focusing on melt saturation in the crystal phases that define the layering, we consider the implications of entrainment of peritectic minerals in the magma source on the resultant magma chemistry. Thermodynamically constrained phase-equilibrium modelling[1] was used to identify the pressure-temperature domains in a garnet peridotite source where peritectic orthopyroxene would be produced during partial melting (Figure 1a-b). Magma extraction routines removed melt once it reached 5 wt.% and, where peritectic crystals were produced, these were entrained to the melts. In all cases, peritectic orthopyroxene is the first orthopyroxene phase to be produced. Given the high propensity for orthopyroxene to nucleate[2] and the high rates of plume-driven melt production apparent in the formation of large igneous provinces[3], entrainment of the peritectic orthopyroxene upon magma extraction seems unavoidable. Modelling results demonstrate that the peritectic orthopyroxene contains significant Cr (Figure 1c), and during decompression, its entrainment changes the mineral makeup of the extracted magma fundamentally. The peritectic orthopyroxene is consumed by reaction with melt to produce peritectic olivine and chromite (Figure 1e). On high-temperature intrusion in the upper crust, sills of the resulting crystal slurry carry significant olivine, chromite, and, in some cases, pyroxene, allowing for immediate density segregation at emplacement and flow velocity decrease to form dunite and chromitite layers. Continued fractional crystallisation and density segregation within the sills, combined with melt drainage[4], can produce pyroxenite and anorthosite layers (Figure 1d). We thus demonstrate how magmas extracted from an upper-mantle source undergoing incongruent melting and carrying peritectic orthopyroxene can transport far more Cr from the mantle source to the crustal magma chamber than any liquid magma could.

[1] Holland, Green & Powell (2018), *J. Petrol.* 9, 881–900.

[2] Zellmer, Sakamoto, Matsuda, Iizuka, Moebis & Yurimoto (2016), *GCA* 185, 383–393.

[3] van Wijk, Huismans, ter Voorde & Cloetingh (2001), *Geophys. Res. Lett.* 28(20), 3995–3998.

[4] Connolly, Schmidt, Solferino & Bagdassarov (2022), *J. Geophys. Res. Solid Earth* 127(9).

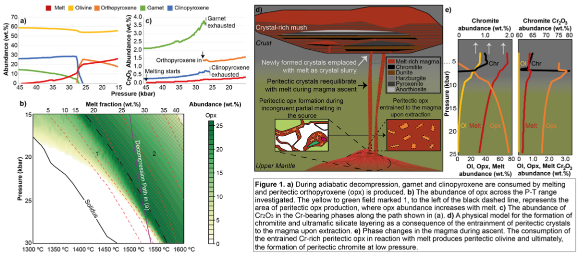

Figure 1. a) During adiabatic decompression, garnet and clinopyroxene are consumed by melting and peritectic orthopyroxene (opx) is produced. **b)** The abundance of opx across the P-T range investigated. The yellow to green field marked 1, to the left of the black dashed line, represents the area of peritectic opx production, where opx abundance increases with melt. **c)** The abundance of Cr_2O_3 in the Cr-bearing phases along the path shown in (a). **d)** A physical model for the formation of chromitite and ultramafic silicate layering as a consequence of the entrainment of peritectic crystals to the magma upon extraction. **e)** Phase changes in the magma during ascent. The consumption of the entrained Cr-rich peritectic opx in reaction with melt produces peritectic olivine and ultimately, the formation of peritectic chromite at low pressure.