

On the hydrothermal concentration of chromite and sulfide in layered intrusions.

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A common feature of many chromitite seams in layered intrusion is the lack of other minerals that might reasonably be expected to co-precipitate with chromite. For example, the Dwars River chromitite-anorthosite association of the Bushveld Complex would require the magma to oscillate between crystallizing chromite alone or plagioclase alone. A chromatographic interpretation was presented by Marsh *et al.* (2021, doi: 10.1093/petrology/egaa109), who suggested that chromite precipitated at a reaction front as a Cr-bearing (gabbro)norite protolith reacts with a Cl-rich aqueous fluid that became progressively undersaturated in pyroxene, leaving an anorthositic residue, as it moved into the hotter parts of the crystal pile. Cr dissolved into the fluid re-precipitates as chromite at a moving reaction front between the anorthosite and the norite owing to liberation of Mg and Cr from pyroxene.

Two important secondary mechanisms accompany this process. First, other chromite components (MgO, FeO, Al₂O₃) at the chromite precipitation front are supplied, in part, by the local reaction with the existing solids. MELTS modelling shows that the isothermal addition of Cr₂O₃ alone to a nearly solid (gabbro)norite assemblage increases the amount of both chromite *and liquid* at the expense of other solid phases owing to the liberation of Ca, Na, and Si, the latter two acting as fluxing agents that enhance local remelting. Samples of this alkali-rich liquid are preserved as (now crystallized) amphibole- and mica-bearing polyphase inclusions in the chromite.

Second, PGE-bearing sulphides can be associated with chromitites (e.g., the Merensky Reef), suggesting a concurrent precipitation mechanism. Cr is dissolved largely as a divalent ion in the CrCl(OH)⁰ complex at expected temperatures and pressures (Huang *et al.* 2019 doi: 10.7185/geochemlet.1926), whereas chromite Cr is trivalent. Thus, precipitation of chromite would require an oxidation step in the precipitation reaction, which can involve S species. An example of the co-precipitation of pyrrhotite and chromite via redox reactions involving solution species including FeCl₂, SO₂, and H₂S:

