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Niobium, glimmerite and fenite, an experimental view

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The major challenges in developing a model for the genesis of carbonatite-hosted niobium deposits are the high solubility of pyrochlore in carbonatitic magmas and the fact that pyrochlore is an early crystallising mineral. Given the close association of the niobium mineralisation with glimmerite (biotitite) in the three carbonatite-hosted deposits (Araxá, Catalão and St Honoré) that are responsible for 99% of global niobium production, we propose that pyrochlore saturates in the magma because of its prior consumption owing to its reaction with K-feldspar fenite to form glimmerite. We have tested this hypothesis by reacting a niobium- and fluorine-doped hydrous dolomitic liquid with a K-feldspar prism containing trace sodium at 800 ^{o}C and 200 MPa. This produced a rind of fine-grained phlogopite on the prism, and subordinate calcite that increased in proportion outwards to form a zone of fine-grained calcite via the metasomatic reaction:

$3CaMg(CO_3)_2 + KAlSi_3O_8 + H_2O = KAlMg_3Si_3O_{10}(OH)_2 + 3Ca(CO_3) + 3CO_2$.

An adjacent domain containing phlogopite books and coarse calcite represents the residual liquid. Pyrochlore crystallised at the edge of the rind and in the residual liquid. The starting liquid crystallised calcite, magnesite and minor dolomite beyond this domain. We propose that niobium ore genesis begins with partial melting of the mantle to form a carbonatitic magma, which ascends via episodic metasomatic alteration of the host rock, production of CO_2 and fluid overpressures that percussively fracture the overlying rock. In the continental crust, the pressure release induces exsolution of an aqueous Na-K-rich fluid that rises above the magma and fenitises (K-feldspar) the overlying rocks. The magma reacts with the fenite to form glimmerite. Repetition of these processes leads to the ascent of mixtures of new batches of magma with the reacted batches and the formation of a carbonatite complex at the final site of magma emplacement. As a result, the concentrations of Nb and F increase progressively in the evolving magma, saturating it in pyrochlore to form a carbonatite-hosted, glimmerite-associated Nb deposit. This model successfully explains the association of glimmerite with calcite carbonatite and the genesis of the carbonatite-hosted ores that supply most of the World's niobium.