Phoscorite – the 'Secret Weapon' of Carbonatite Niobium-Enrichment

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Over 98 % of the World's niobium is supplied by carbonatites, one of which is at St.-Honoré (Canada) with reserves of 74.7 Mt grading 0.54 wt.% Nb_2O_5. The process of Nb-enrichment to mineable levels in these rocks, however, is poorly understood. Here, we present a model, which provides a plausible explanation for this enrichment at St.-Honoré.

The St.-Honoré carbonatite is finely laminated with alternating carbonate-rich and -poor layers. The latter are composed mostly of fluorapatite, magnetite and phlogopite, an assemblage that defines phoscorites. They are the main host of Nb (as pyrochlore in fresh and Fe-columbite in altered layers). Pyrochlore crystallised early, followed by fluorapatite, phlogopite and magnetite. A striking feature of the St.-Honoré carbonatite is the abundance of halite.

The alternation of carbonate-rich and -poor layers could have been a product of the early crystallisation of pyrochlore and associated minerals, and their redistribution by flow-segregation. Experimental studies, however, have shown that the solubility of pyrochlore in carbonate magmas is too high for it to be an early liquidus mineral, given the low concentration of Nb (<1 wt.%) even in well-mineralised carbonatites. Indeed, Mitchell and Kjarsgaard (2004) have shown that the solubility of Nb_2O_5, as pyrochlore, can reach ~14 wt.% in F-rich systems. Thus, the occurrence of pyrochlore as an early crystallising mineral is precluded in F-rich carbonate magmas, such as those, which produced the St.-Honoré carbonatite, and consequently, its association with apatite, phlogopite and magnetite cannot be explained by flow-segregation. We propose instead, that the carbonate-poor layers originated by the exsolution of a phosphate-silicate magma (P^{5+} substitutes easily for Si^{4+} provided that it is charge-balanced by OH^-, Cl^- or F^-) from the carbonate magma, and these layers are phoscorites. Owing to its high charge and preference for low coordination, niobium would have partitioned strongly into the phosphate-silicate magma, which would have increased the probability of pyrochlore being an early liquidus phase. The high concentration of NaCl and its later crystallisation as halite would have played a pivotal role in Nb concentration by inducing exsolution of the phosphate-silicate magma and promoting the crystallisation of pyrochlore, respectively.