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The origin of phoscorite: Evidence from a study of melt inclusions and experiments on synthetic analogues

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Phoscorites are rare plutonic rocks composed of magnetite, apatite and mafic silicates such as forsterite, diopside or phlogopite. They almost always occur in close association with carbonatites in intrusive complexes comprising alkaline rocks derived from nephelinite and melilitite parental magmas, or, alternatively, ultrapotassic rocks of kamafugite family. Formation of high-Mg ultramafic rocks from strongly evolved magmas simultaneously or right before crystallization of carbonatites is puzzling and the origin of phoscorites has been contentious. They have been interpreted as magmatic cumulates, or products of a separate phoscorite magma rich in Fe, Ca and phosphate, or as skarn-like metasomatic products.

The first objective of this study was to evaluate compositions of liquids parental to classical phoscorites of the Kovdor intrusive complex in Russia by LA-ICPMS analyses of melt inclusions trapped in forsterite crystals from the earliest to the latest phoscorite facies. Using the results of melt inclusion study, we then prepared synthetic mixtures analogous to the average composition of the least evolved forsterite-hosted melt inclusions from the earliest phoscorite facies and performed a series of experiments on them in rapid-quench cold-seal pressure vessels at 200 MPa and 700-900 °C. Melt inclusions in forsterite crystals from Kovdor phoscorite are carbonatitic containing 24-28 CaO, 20-25 Na_2O,3.5-4 K_2O, 5-7.5 MgO, 2.5-3 FeO and 2-5 P_2O_5 (all values are in weight percent). Synthetic liquids of similar compositions crystallized in experiments mineral assemblages typical for phoscorite (olivine, clinopyroxene, phlogopite, magnetite and apatite) and, after addition of aluminosilicate components to reactant mixtures, produced ijolite mineral association (nepheline and clinopyroxene), and also immiscible phonolitic-nephelinitic liquid. Calcite appeared in run products at 700 °C. Silica content in experimental liquids equilibrated with phoscorite varied in the range of 0.7-1.5 wt.%, whereas liquids equilibrated with ijolite and silicate immiscible liquid contained up to 7.5 wt.% SiO_2. The results of our study imply that phoscorites are likely to be formed by reaction of carbonatitic melts with earlier-formed silicate cumulates such as peridotites, pyroxenites and ijolites.