

Effect of F and P on the magmatic enrichment of Nb, Ta and REE in carbonatic melts

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Rare earths (REE) and high-field strength elements (HFSE) are considered as critical metals for the development of modern green technologies. A main source of REE, but especially Nb and Ta in carbonatite and phoscorite economic mineralizations is found in pyrochlores (ideal formula $\text{Ca}_2\text{Nb}_2\text{O}_7$). Depending on the petrological setting, other HFSE- and REE-rich minerals may include perovskite, titanate, baddeleyite, apatite or monazite [1,2].

While fractional crystallization has long been suggested to account for the extreme enrichment of Nb, Ta or REE in alkaline magmas, the stability of HFSE- and REE-bearing phases in carbonate melts remains understudied. For instance, though early experimental work demonstrated that pyrochlore could be a liquidus phase in the $\text{CaCO}_3\text{-NaNbO}_3\text{-Ca(OH)}_2\text{/CaF}_2$ analog system [3,4], it remains unclear if such conditions can pertain to more realistic compositions, involving Ca, Na, H_2O , CO_2 and F, but also Mg, P and various trace elements (Mn, Ti, Zr, REE). Few other studies are available on zircon, baddeleyite or apatite but are mostly limited to F- and P-free compositions [5]. Finally mineral-melt partitioning of HFSE and REE is only available for baddeleyite and apatite [6,7].

Here, we thus present piston-cylinder experiments conducted at 900-1200 °C and 1 GPa to 1) investigate the effect of P and F on the stability of pyrochlore and other potential HFSE- and REE-bearing phases and 2) determine the mineral/melt partitioning coefficients for HFSE and REE for the different phases formed upon crystallization of carbonate melts. The experimental results will be used to discuss crystallization sequence and the interplay between magmatic and hydrothermal controls on the development of economic Nb, Ta and REE enrichments in carbonatite systems.

[1] Mitchell, 2015. *Ore Geol. Rev.* 64, 626-64. [2] Chakhmouradian et al., 2015. *Ore. Geol. Rev.* 64, 642-666. [3] Mitchell and Kjarsgaard, 2002. *Contrib. Mineral. Petrol.* 144, 93-97. [4] Mitchell and Kjarsgaard, 2004. *Contrib. Mineral. Petrol.* 148, 281-287. [5] Gervasoni et al., 2017. *Am. Mineral.* 860-866. [6] Klemme and Meyer, 2003. *Chem. Geol.* 199, 233-242. [7] Klemme and Dalpe, 2003. *Am. Mineral.* 88, 639-646.