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The solubility of pyrochlore in carbonatite melts at crustal conditions

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Niobium (Nb) is a critical metal with many high technology applications. Nb mineralization is widely associated with carbonatites, in which pyrochlore, a complex Nb oxide, is the dominant ore mineral. Previous studies suggest that pyrochlore is extremely soluble in carbonatite melts [1]. This study aims to experimentally investigate the effects of various conditions on pyrochlore solubility and determine which processes can trigger pyrochlore saturation in carbonatites.

Our starting materials were a mixture of sintered oxides with the composition of the ideal formula of pyrochlore and a model sodic-calcitic carbonatite melt. Piston-cylinder experiments were performed on homogenous mixtures of 50% pyrochlore and 50% carbonatite powder enclosed in Pt capsules, at 1000~1300°C and 1 GPa. Experimental products were saturated in pyrochlore crystals, which coexisted with quenched carbonate melt, enabling determination of the solubility of pyrochlore in the melt. The effect of melt composition on pyrochlore solubility was examined by systematically adjusting the Ca# and CaF_2 (up to 3.84 wt%) as well as introducing SiO_2 (up to 13.04 wt%).

Results indicate that (1) pyrochlore solubility increases with temperature (lnKsp = -20.82 ~ -16.20 from 1000-1300°C), (2) decreases with decreasing melt Si contents (lnKsp = -5.79 ~ -5.17 from 0 to 13 wt% SiO2), (3) is unaffected by melt F content over the limited range thus far investigated, and (4) is largely unaffected by melt Ca#, although, elevated melt Mg contents favor the crystallization of other Nb oxide phases over pyrochlore, such as fersmite ($CaNb_2O_6$) and/or oboniobite ($Mg_4Nb_2O_9$). These results suggest that the Si- and Mg-consuming processes such as phlogopite formation during crustal interactions for carbonatite intrusive rocks could facilitate pyrochlore crystallization, providing valuable insights into the mechanisms of Nb enrichment in carbonatites.

[1] Mitchell, R.H., Kjarsgaard, B.A., 2004. Solubility of niobium in the system $CaCO_3$-CaF_2 -$NaNbO_3$ at 0.1 GPa pressure: Implications for the crystallization of pyrochlore from carbonatite magma. Contrib. Mineral. Petrol. 148, 281–287.