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Phase relations in extremely iron- and halogen-rich peralkaline compositions

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The peralkaline Ilímaussaq intrusion (South Greenland) is a plutonic complex that mainly consists of cumulates and formed through fractional crystallization processes. The phase relations of an iron-rich, extremely evolved, halogen-bearing peralkaline composition (FeO* = 11.6 wt. %; #Mg = 3; Cl = 0.1 wt. %; F = 0.3 wt. %; alkalinity index = 1.45), which is suggested to represent the parental magma of Ilímaussaq (Marks & Markl 2003), were investigated experimentally in hydrothermal rapid quench vessels at 100 MPa and T = 950 – 750 ˚C.

Oxygen fugacity (fO_2) and water activity (aH_2O) were found to have a strong influence on phase relations and liquid lines of descent. Nominally dry and reducing conditions (fO_2 = Δ log FMQ $\sim$ -1.5) adjusted in graphite-lined Au capsules at T = 850 – 800 ˚C were found to stabilize titano magnetite (Mag), hedenbergite-rich clinopyroxene (Cpx), alkali feldspar (Afs), fayalitic olivine (Ol), and nepheline (Nph) with a coexisting alkali- and iron-enriched but silica-depleted residual melt. In contrast, H_2O-bearing and oxidizing (fO_2 = Δ log FMQ $\sim$ +1) experiments in Au capsules stabilize only Mag and Cpx coexisting with a silica-enriched, iron-depleted residual melt. Low fO_2, particularly in graphite capsules, changes the dominating Fe-bearing crystal phase from Mag in Au capsules to Ol in graphite capsules, explaining the dramatic compositional differences of the coexisting residual melt. The concentrations of Cl (up to 0.3 wt. %) and F (up to 0.8 wt. %) increase with decreasing amount of residual melt, but no halogen-bearing crystal phases were observed.

The comparison of fractional crystallization (FC) and equilibrium crystallization (EQ) experiments on mineral-melt equilibria shows large differences concerning mineral stabilities and liquid lines of descent (e. g. Villiger et al. 2004). To simulate fractional crystallization, we synthesized a starting glass matching the residual melt composition of a nominally dry graphite capsule experiment at 800 ˚C (FeO* = 14.8 wt. %; #Mg = 1; Cl = 0.4 wt. %; F = 0.8 wt. %; A. I. = 2.67). The phase relations of this composition were investigated experimentally at 100 MPa and $T \leq$ 800 ˚C. Similar to the preceding experiments, fO_2 and aH_2O exhibit major changes in phase relations and liquid lines of descent. Nominally dry and reducing conditions were found to stabilize Cpx, Afs, Nph, aenigmatite (Ae) in addition to Cl-rich phases like sodalite (Sdl) and eudialyte (Eud) at 750 ˚C, whereas H_2O-bearing and oxidizing conditions only stabilize Mag. The phase assemblages present in nominally dry FC experiments differ substantially from those observed in EQ experiments at the same T. In FC experiments Mag is absent, whereas Ae, Sdl and Eud are additionally stabilized. Our results support the model of fractional crystallization processes for phase relations and liquid lines of descent relevant for the Ilímaussaq intrusion.

References: Marks & Markl (2003) Mineralogical Magazine 67: 893-919. Villiger et al. (2004) Journal of Petrology 45: 2369-2388.