Experimental determination of the liquid line of descent of primary, hydrous calc-alkaline magmas under high pressure conditions

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Calc-alkaline rocks typically occur in suprasubduction environments characterized by crustal thickness in the order of 30 km, corresponding to a pressure of approximately 10 kbar.

Primary magmas, generated in the mantle wedge overlying the subduction zone buoyantly rise to the base of the crust, where the positive density contrast to the lower (continental or island-arc) crust forces them to pond at or just above the MOHO. Further rise of the magmas into shallower crustal levels, where plutonic and/or volcanic complexes are formed, is probably driven by fractionation differentiation to more evolved, less dense liquids.

A series of H_2O-undersaturated supersolidus melting experiments starting from an H_2O-bearing picrobasaltic composition has been carried out in a piston cylinder apparatus. An approximation to pure fractional crystallization was achieved by a stepwise approach. The liquid compositions are determined from each experiment and the next experiment is performed at lower temperature starting with the liquid composition of the previous (higher temperature) experiment. The temperature difference between two experiments is 30°C. This procedure simulates in a stepwise manner the extraction (fractionation) of crystals formed at a given P and T. As starting composition a natural picritobasalt from the Adamello-Batholith (Italy) was used. All further starting materials were synthesized from oxides and hydroxides. The water content ranges from 2.6 up to more than 10 wt.%.

The resulting liquid composition closely approximate the true liquid line of descent for a calc-alkaline magmatic system derived by fractional crystallization. The difference between conventional crystallization (melting) experiments and this approach is that peritectic reaction, known to occur during the crystallization of primitive calc-alkaline compositions (e.g. ol + liq = opx) are suppressed, leading to a considerably different liquid line of descent than the one derived from closed system (equilibrium) crystallization.

At 1230°C olivine and spinel are the liquidus phases, producing dunitic cumulates. The fractionation of the Fo-rich olivine leads to a rapid decrease in the Mg- content of the residual liquid. At 1200°C cpx joins the crystallizing assemblage. This is reflected in a rapid decrease of the Ca-content in the residual melt. At 1170°C olivine ceases to crystallize leaving cpx alone on the liquidus. Cpx, Opx and Spl represent the crystallizing assemblage at 1140°C. Plg is first observed on the liquidus at 1110°C together with cpx. At 1080°C the differentiation trend is dictated by the extensive plg crystallization, which dominates over Opx, Cpx and Spl. This results in a tholeiitic differentiation trend characterized by Fe-enrichement at constant SiO_2. In contrast, a calc-alkaline differentiation trend requires suppression of the plg crystallization to lower temperatures and concomitantly a stabilization of amph and/or mgt to higher temperatures. The major factors controlling amph/mgt versus plg crystallization are (1) H_2O fugacity and (2) oxygen fugacity. The potential role of these two parameters controlling tholeiitic versus calc-alkaline differentiation trends is currently evaluated.