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Granitic liquids derived by fractional crystallization: an experimental liquid line of decent from olivine-tholeiite to granite at 0.7 GPa

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Silicic plutonic rocks are common in arc-related igneous complexes. The origin of the corresponding liquids is still debated and several processes affecting Si-rich liquids are invoked (crystallization-differentiation, partial melting and assimilation).

This experimental study traces the process of crystallization-differentiation in detail. Previous equilibrium crystallization experiments generated only small amounts of derivative silicic melts at mid-to-deep crustal levels compared to required amounts of mafic cumulates to produce these liquids from basaltic parental magmas. This study investigates the isobaric fractional crystallization of primitive, hydrous olivine-tholeiite at intermediate crustal levels (0.7 GPa, 20-25km depth).

Experiments were conducted in an end-loaded piston cylinder apparatus. A synthetic equivalent of a natural olivine-tholeiitic dike composition from the Adamello batholith (Northern Italy) was used as an initial starting material. The starting composition contained 3 wt.% of water and was additionally doped with 32 trace elements at 40 ppm level. Recovered experimental charges were analyzed by EPMA, micro-Raman and LA-ICP-MS. Glass compositions representing the liquid composition in equilibrium with solid phases were subsequently synthesized from oxides, hydroxides and silicates and employed as starting material for the succeeding experiment conducted at 30°C lower temperature. Liquidus temperature of the initial starting composition was bracketed at 1165°C (±5°C) and the experimental series has been extended to 700°C. Micro-Raman analyses confirmed the targeted H_2O contents (±0.5 wt.%) in the derived liquids. The liquid line of decent follows a calc-alkaline fractionation trend generating intermediate to granitic compositions closely resembling plutonic and volcanic rocks that compose arc-related igneous and volcanic complexes.

The following crystallization sequence has been determined: olivine (ol) => clinopyroxene (cpx) => plagioclase (plg), spinel (sp) => orthopyroxene (opx), amphibole (amph), magnetite (mag) => apatite (ap) => quartz (qtz), biotite (bt). The liquid line of decent at 7 kbar evolves towards (slightly) peraluminous compositions. The reactions cpx + liq => amph marks amph saturation concomitantly crystallizing with opx, plag and mag. The liquid line of decent terminates close to the granite eutectic at 76 wt.% SiO_2. The final experiment saturated qtz as well as bt, potentially replacing amph by reaction (amph + liq=> bt). Amph crystallized over a wide temperature interval (300°C) allowing systematic assessment of trace element partitioning between melt and amph. Partition coefficients for Rare Earth element (REE) increase with decreasing temperature. Simultaneously, the Young's Modulus of the corresponding lattice site increases too. This is only partially a temperature effect as both liquid and amph compositions significantly change over this extended temperature interval.