Geophysical Research Abstracts
Vol. 21, EGU2019-16040, 2019
EGU General Assembly 2019

Polybaric fractional crystallisation of arc magmas - an experimental study

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Despite a still ongoing debate, differentiation of primary, mantle-derived, hydrous calc-alkaline magmas by fractional crystallisation is now generally accepted as one of the main driving mechanism controlling the compositional evolution of arc magmas. However, previous experimental studies failed to reproduce the predominantly metaluminous natural rock record by lower crustal crystal fractionation. At high pressures, experimental liquids rather evolve towards peraluminous differentiates. The absence of abundant cumulates in the upper crust does not support the alternative scenario of major differentiation at low pressure conditions. Therefore, we propose an alternative process, namely polybaric fractional crystallisation, inferring that arc magmas differentiate progressively by crystal fractionation and interaction with crystal mushes/cumulates upon ascent through the crust. This hypothesis is tested through a series of experiments along several pressure - temperature ascent trajectories with continuously decreasing temperatures and pressures. Phase equilibria data, chemical compositions of stable mineral phases, liquid lines of descent as well as the evolution of crystal/melt ratios provide crucial information to improve our understanding of the evolution of the calc-alkaline magmatic series and clarify if fractional crystallisation can be considered as a major process in the differentiation of mantle derived magmas at convergent plate boundaries. First experimental results support theoretical considerations on the effect of decreasing crystallisation pressure on mineral phase equilibria: the olivine-clinopyroxene cotectic curve is shifted towards more Cpx-rich compositions (equivalent to a destabilisation of clinopyroxene) rendering residual melts more metaluminous and, therefore, circumventing a rapid evolution of liquid lines of descent towards and into the peraluminous compositional field. The polybaric evolution of the experimental liquids more closely approaches the prevalent compositions of intermediate to SiO_2-rich plutonic and volcanic rocks observed at convergent plate margins.