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Trace element fractionation within granitic magma chambers or rising diapirs

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Granitic intrusions commonly show chemical/petrological differentiation trends within a single body or among related bodies that are attributed to fractional crystallisation processes. Modelling of the differentiation trends is however much more complicated than in systems of basic to intermediate composition, because the physical separation of crystalline phases from highly viscous residual liquids must be a very slow and inefficient process. Hence, granitic samples represent compositions of crystal-rich mushes, and do not normally correspond to either the composition of a cumulate fraction or of a residual liquid. A second major problem in the modelling of differentiation trends in granites derives from the control of the accessory minerals, that are the main host phases (up to 95%) of many trace elements in granitic rocks. However, in order to control trace element fractionation, an accessory mineral must be a liquidus phase during the main stages of melt/crystal segregation. This is a reasonable assumption for zircon and apatite, but a contentious one for rarer accessory minerals (e.g., monazite, allanite) which often occur in clusters precipitated during the final closed-system solidification of patches of highly evolved trapped liquid. As such their control on trace element fractionation on a macro-scale must have been negligible.

A theoretical model for trace element fractionation in granitic crystal-rich mushes has been developed and will be illustrated with the modelling of differentiation trends of the Variscan Kagenfels and Natzwiller granites from the Northern Vosges, France. The granites show considerable variations in major and trace element concentrations (Rb, Sr, Ba, Zr, Hf, Th, REE), which make them very useful for modelling exercises. Of particular relevance is the large change of REE patterns in the course of differentiation of the Kagenfels leucogranite. REE overall decrease with increasing differentiation, but the depletion is much more pronounced for the middle REE (Nd to Dy) and especially for Eu. While it is obvious that apatite and zircon (and very minor allanite or monazite) largely controlled the Kagenfels trend, no truly acceptable model fit could be obtained by considering only minerals and residual silicate liquids. Improved trace element fractionation models attribute a significant role to an exsolved aqueous fluid phase in the evolution of the shallow Kagenfels leucogranite. It indicates that initial water content and final pressure can considerably influence trace element fractionation in the final differentiation stages of granitic mushes.

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Insights into andesites from Ruapehu Volcano, New Zealand and links to rhyolitic volcanism in the Taupo Volcanic Zone

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Andesites are complex mixtures between a melt component, that itself may have experienced multiple mixing and mingling events, and a cargo of crystals that represent various stages of equilibrium and disequilibrium crystallization, restitic accumulates from previous magmatic events and ingestion or partial assimilation of wall rock material. This complexity means that whole rock analyses are blurred images of the true magmatic processes and may lead to difficulties in applying conventional modeling approaches to magma evolution. Using a combined micro-analytical approach (electron microprobe, laser ablation and micro-drilling), it is possible to unravel these events and to cast new light on the anatomy of andesite.

For example, volcanian bombs from the 1995 and 1996 eruptions of Ruapehu Volcano in the North Island, New Zealand show a composition range that exceeds those of all eruptions from the previous 50 years and nearly the entire life span of the volcano (~ 300 ka). We have investigated selected samples from these eruptions using the micro-beam approach, concentrating on groundmass glasses and melt inclusions in phenocrysts. A result of this work is that we have analysed rhyolitic and dacitic glasses in andesites that are chemically indistinguishable from rhyolites of the large caldera centres of the Taupo Volcanic Zone to the north. This has important implications for the way in which large crustal magma chambers evolve in volcanic arcs.