Goldschmidt 2021 Abstract
https://doi.org/10.7185/gold2021.5321

The fate of ore metals with progressive magma evolution

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Evolved magmas in the upper crust are recognised as major source of ore-forming metal-bearing fluids associated with magmatic-hydrothermal ore deposits. They make up a significant proportion of current global metal resources. Under favourable conditions, elements of economic interest are efficiently transferred from residual melt into ore-forming fluids that transport elements to potential mineralisation sites. Understanding the pre-enrichment of economic metals during igneous evolution of a crystallising melt and the evolutionary stage at which the magma saturates in a magmatic-hydrothermal fluid is therefore significant for understanding magmatic-hydrothermal ore deposit formation.

This study aims at investigating the geochemical evolution of the shallow, arc-related Torres del Paine igneous complex (TPIC), starting with the extraction and ascent of magmas from lower crustal mush reservoirs to their emplacement at shallow crustal depth. With progressive fractional crystallisation of dominantly anhydrous minerals, the TPIC magmas reach fluid saturation by second boiling. Based on initial melt water contents of 1.5 wt.% H_2O, residual melt attains saturation of an aqueous fluid phase at 50–75% solidification, in agreement with maximum H_2O solubilities in granitic melts at pressures between 90–120 MPa. The most prominent fluid exsolution features documenting this process are quite abundant, but isolated miarolitic cavities. Cavities and surrounding host rocks thus record the magmatic history leading up to the point of fluid exsolution.

Bulk rock compositions of evolved granites (73.1–76.8 wt.% SiO_2) together with literature data for less evolved rocks constrain the geochemical evolution of TPIC magmas. Rock types in the transitional alkaline TPIC range from hornblende gabbros to biotite granites and are characterised – especially at the late stages – by a distinct increase in incompatible Th, Nd, Rb, and Pb, and decrease in compatible Ti, Sr, Ba, and Zn.

Employing petrological models linking these geochemical datasets, we can examine the effects of progressive fractional crystallisation upon cooling, felsic cumulate formation and melt extraction, as well as magma replenishment. We focus on improving our understanding on the behaviour of trace elements including ore metals during these petrological processes up to the timing of fluid exsolution, to identify favourable conditions for the economic enrichment of ore metals.