EGU25-18413, updated on 21 Apr 2026
https://doi.org/10.5194/egusphere-egu25-18413
EGU General Assembly 2025

Three-phase flow modelling of immiscible melt segregation in the genesis of magnetite-apatite deposits

Tong Chai and Tobias Keller
Department of Geographical and Earth Sciences, University of Glasgow, Glasgow, United Kingdom
(t.chai.2@research.gla.ac.uk)

Magnetite-apatite (MtAp) deposits, also known as iron-oxide-apatite or Kiruna-type deposits, are critical sources of high-grade iron ore and rare earth elements (REE), essential for industrial applications and the global transition to green energy. The formation of MtAp deposits is commonly attributed to the immiscibility between iron oxide phosphate liquids and silicate magma (FeP–Si). Recent studies have shown that light rare earth elements preferentially partition into the iron-phosphorus melt, explaining the enrichment of light rare earth elements in MtAp deposits. While there is good evidence of an origin involving sub-volcanic intrusion to volcanic extrusion of an Fe-enriched orthomagmatic melt, the exact formation mechanisms remain controversial.

This study focuses on the El Laco deposit in northern Chile, adopting the hypothesis that spontaneous magma unmixing has indeed occurred within an El Laco-type subvolcanic magma body. The research aims to explore the formation mechanisms of magnetite-apatite (MtAp) deposits by investigating the role of iron-rich magmatic melts. Using a one-dimensional (1D) three-phase mechanical model based on existing theoretical frameworks, we simulated the separation and accumulation of immiscible iron-rich melts within an increasingly crystalline parent magma. The model reproduces the previously proposed transition from droplet settling to porous drainage mode and quantifies the relative efficiency of both modes of phase separation. We also perform a scaling analysis to define porous, mush, and suspension flow regimes and construct a regime diagram for three-phase flow. The results show that the separation efficiency of immiscible iron-rich melts reaches its maximum under intermediate crystallinity conditions. Furthermore, the model-derived accumulation rate of iron-rich melts can be used to estimate the time required to accumulate immiscible melt sufficient to form magnetite deposits of a given scale. Our findings support the physical viability of the liquid immiscibility hypothesis in the genesis of MtAp deposits and provide new insights into the formation mechanisms of other valuable deposits associated with immiscible melts, such as the segregation of Ni-Cu-Co-enriched sulphide melts in orthomagmatic Cu-Ni-sulphide deposits and metal-enriched magmatic brines in porphyry copper systems.