frontiers | Frontiers in Earth Science

TYPE Editorial
PUBLISHED 29 August 2023
DOI 10.3389/feart.2023.1279960

Editorial: The fate of volatiles and metals in magmas: volcanic eruptions, plutons and ore deposits

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KEYWORDS

volatiles, ore deposits, arc magmas, volcanism, metals

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RECEIVED 19 August 2023
ACCEPTED 22 August 2023
PUBLISHED 29 August 2023

CITATION
Rezeau H, Forni F, Hsu Y-J, Troch J and Large S (2023), Editorial: The fate of volatiles and metals in magmas: volcanic eruptions, plutons and ore deposits.
Front. Earth Sci. 11:1279960.
doi: 10.3389/feart.2023.1279960

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Editorial on the Research Topic
The fate of volatiles and metals in magmas: volcanic eruptions, plutons and ore deposits

Introduction

Dissolved volatiles (e.g., H_2O, CO_2, S, Cl, F) and metals (e.g., Cu, Au, Mo, Ag, Sn, W, Pb, Zn) in magmas play a critical role in influencing physico-chemical properties of silicate melts and the eruptive behavior of volcanoes (Wilson, 1980; Dingwell, 1996), forming economically important mineral resources (Hedenquist and Lowenstern, 1994), and impacting Earth's climate through volcanic degassing (Graedel et al., 1985; Edmonds et al., 2018). Accurate characterization of the behavior of these elements during magmatic and hydrothermal processes generally requires challenging analyses of melt and fluid inclusions and volcanic gases (Rose-Koga et al., 2021; Wallace et al., 2021; Edmonds et al., 2022; Zhang and Audétat, 2023) or experimental and modelling approaches (Zajacz et al., 2008; Huber et al., 2012). It is not fully understood which are the main controlling factors dictating volatiles and metals transport and subsequent discharge during magmatic and hydrothermal processes, as well as which chemical and/or physical mechanisms dictate whether magmatic systems end up producing large eruptions, barren plutons or intrusions associated with large ore deposits.

This Research Topic aimed at widening our understanding of volatiles and metals transport, loss and deposition mechanisms in magmatic and hydrothermal systems emphasizing interdisciplinary contributions. This Research Topic includes five papers on the fate of volatiles and metals in magmatic and hydrothermal systems. All the contributions to this Research Topic focus on complementary research aspects from diverse fields across volcanology and magmatic petrology, hydrothermal geochemistry, and structural geology.

Volcanic volatile and metals emissions

In their new research paper, Mason et al. dig into the mysteries of volatile metals emitted by volcanoes. They explore Antarctic ice cores to understand the speciation, bioreactivity, and atmospheric transport of cadmium, lead, bismuth, and thallium emitted in multiple large eruptions (−17.7 ka) of Mt. Takahe in the West Antarctic Rift. Through correlation analysis and speciation modelling, they find that these chalcophile metals derived from magma degassing were transported as water-soluble chloride aerosols in the atmosphere, in contrast to lithophile elements transported as silicate ashes. These findings showcase ice cores as a vital record of distant trace metal emissions and regional continental volcanism.

The research paper by Kushner et al. introduces a novel methodology and approach that involves analyzing mercury (Hg) concentrations adsorbed onto volcanic ash across various downwind distances and eruptive events on three well-characterized volcanic eruptions in Alaska that occurred at Mount Spurr in 1992, Redoubt Volcano in 2009, and Augustine Volcano in 2006. The analysis of their own data and comparison with the literature suggests that the role of the volcano itself (e.g., tectonic setting, thickness, or composition of the crust where it sits) is the primary controlling factor for the reported range of Hg concentrations in ash. While this research offers the first estimate of Hg emission for explosive volcanic eruptions, it also concludes that global volcanogenic Hg emission have been underestimated and requires reassessment to refine Hg cycling.

Magmatic-hydrothermal transition in silicic intrusive systems

In their research paper, Fonseca Teixeira et al. focus on the Pikes Peak granite and the Wellington Lake pegmatite in Colorado, United States, to understand how the magmatic-hydrothermal transition is recorded in silicic magmatic systems. Mineral-based thermometry and fluid inclusion studies document a continuous temperature evolution from more than 850°C to below 400°C, with crystallization transitioning from silicate melt to solute-rich aqueous fluids and brines. Interestingly, pegmatitic conditions are also observed in the granite itself, as evident from plagioclase and quartz rims with crystallization temperatures below the haplogranite solidus. While previous works have inferred that up to 90% of quartz and feldspar in granites may crystallize below the traditionally inferred granite solidus, these authors estimate that subsolidus precipitation accounts for less than 20% of the granite volume.

Magma fertility path to ore deposit formation

In their new research paper, Piquer et al. takes a structural approach by investigating the role tectonic regime and stress orientiations for the transfer of magmatic products (volatiles and metals) through the crust and subsequent storage in the upper crust. The authors focused on the Principal Andean Cordillera of the Maule Region in southern Central Chile located between latitude 35°37′S and 35°45′S, in which active arc magmatism was produced over the last 18 Myr. The geological and petrological framework is constrained using new and compiled zircon U-Pb geochronology and whole rock geochemistry, while the stress regime is assessed using structural data on fault planes, magmatic foliation, intrusive contact, dikes, and hydrothermal veinlets. The key outcome is that fault systems orthogonal to the maximal horizontal compression favor slow magma ascent, magma storage in the middle to upper crust and melt differentiation, which ultimately promote the enrichment of volatiles and metals, and subsequent fluid release to form ore deposits. In contrast, fault systems subparallel to the maximum horizontal stress promote fast magma ascent to the surface and volcanism, thereby limiting the ore-forming potential of these magmas.

The research paper by Kouhestani et al. investigates the origin and the evolution of hydrothermal fluids in two epithermal base metal deposits formed along the Tarom-Hashtjin Metallogenic Belt in northwestern Iran. For these epithermal deposits, the authors present new detailed field and petrographic observations, zircon U-Pb ages of granitoids associated with the mineralization, oxygen and sulfur isotopes on gangue and ore minerals, and microthermometric analyses on quartz-hosted fluid inclusions from the mineralized veins. Oxygen and sulfur isotopes demonstrate that the mineralizing fluids was primarily sourced from a magma and subsequently mixed with meteoric waters and interactions with sedimentary rocks in shallow sub-surface environment. Complementary petrography and fluid inclusion data suggest that mineralogical features are typical of intermediate sulfidation epithermal deposits, and that fluid mixing and boiling are the main ore precipitation mechanisms. Based on the occurrences of Late Eocene granitoids dated at −38–41 Ma, it is proposed that the two epithermal deposits were genetically related to these intrusions, and therefore formed during the middle Eocene. Finally, this study proposes that the Tarom-Hashtjin Metallogenic Belt is highly prospective for precious and base metal epithermal mineralization, and hence offers new mineral exploration perspectives in the region.

Author contributions

HR: Conceptualization, Writing–original draft, Writing–review and editing. FF: Conceptualization, Writing–original draft, Writing–review and editing. Y-JH: Conceptualization, Writing–original draft, Writing–review and editing. JT: Writing–review and editing, Conceptualization, Writing–original draft. SL: Conceptualization, Writing–original draft, Writing–review and editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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