

Do melt inclusions record the pre-eruptive volatile content of magmas?

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In the last several decades the number of publications describing the use of melt inclusions (MI) to determine the pre-eruptive volatile contents of magmas has significantly increased. However, in most MI studies, the volatile contents of the MI vary widely within phenocrysts from the same volcanic sample. It is common for MI hosted in the same phenocryst to show significant variations in volatile concentrations, especially for CO₂. In fluid inclusion (FI) studies, workers have developed a protocol to test that the inclusions in a sample record the original trapping conditions by studying groups of FI trapped at the same time (Fluid Inclusion Assemblage, FIA), and which obey Roedder's (Sorby's) Rules. Specifically, (i) the FI must have trapped a single homogeneous phase, (ii) the volume of the FI must remain constant after trapping, and (iii) nothing can be added or lost from the FI after trapping. While this approach has worked successfully in FI studies and should be successful in MI studies, there are two main reasons why MI studies rarely apply this methodology. The first is related to the lower probability, relative to fluid inclusions (FI), of finding Melt Inclusion Assemblages (MIA) in a phenocryst. The second is related to the necessity of exposing MI at the crystal surface in order to obtain chemical analyses, and this is particularly true for volatile analyses. In this study, the MIA approach has been used to assess if MI provide reliable information of pre-eruptive volatile contents. Groups of MI within well-defined MIAs hosted in phenocrysts from White Island (New Zealand) and from Solchiaro (Italy) were analyzed by Secondary Ion Mass Spectrometry (SIMS). We have studied 39 MIA and 144 MI were analyzed for CO₂, H₂O, F, S, and Cl.

In most MIA, H₂O, F, and Cl abundances are consistent, indicating that MI in these MIA represent the pre-eruptive abundance of these three volatile species. CO₂ and S abundances were consistent in some MIA, but especially CO₂ showed a wide variation in others. The wide range in CO₂ content could reflect the presence of a CO₂-rich boundary layer at the MI/host interface controlled by post-entrapment crystallization of the MI, and may also be a function of the MI morphology. Thus, MI may appear to be highly heterogeneous in volatiles such as CO₂ and S that are the less soluble in melts of this composition. The wide range in S is restricted to MIA hosted in Fe-bearing phenocrysts, suggesting that the variability may be due to post-entrapment processes. Although working with MIAs is time consuming and tedious, we recommend the MIA approach to study pre-eruptive volatile contents in order to recognize MI whose volatile abundances do not accurately reflect pre-eruptive volatile concentrations in the magma.

Bulk and Micro Mineralogical Characterization of As in Uranium Mine Tailings

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Introduction

In northern Saskatchewan, Canada, high-grade uranium ores and the resulting processed tailings can contain high levels of arsenic (As). The potential mobilization of As from the tailings management facilities (TMFs) to contaminate regional groundwater systems is an environmental concern in the uranium mining industry.

Knowledge regarding the speciation of As in natural systems is critical for determining its long-term environmental fate. Specifically, characterization of As-bearing mineral phases and complexes within the processed U tailings is required to evaluate their potential transformation, solubility, and long-term stability within the tailings mass. Synchrotron-based bulk X-ray absorption spectroscopy (XAS) was used to study the redox and molecular speciation of As in tailings samples obtained from the Deilmann TMF at Key Lake, Saskatchewan. Electron microprobe analysis (EMPA) and synchrotron-based micro-focussing X-ray fluorescence mapping and absorption spectroscopy (μ XRF; μ XAS) were employed to study the spatial distribution and speciation of As at the micron scale.

Results and Conclusion

Comparisons of K-edge XAS spectra of tailings samples and reference compounds indicate As in the tailings samples primarily exists in the +5 oxidation state; this reflects the generation of the tailings in a highly oxidic mill process, their deposition in an oxidized environment, and complexation within stable oxidic phases. Extended X-ray absorption fine structure (EXAFS) analysis of As K-edge spectra indicates that As⁺⁵ (arsenate) present in the tailings samples is adsorbed to ferrihydrite through an inner-sphere bidentate linkage. Backscattered electron (BSE) images of the tailings from the electron microprobe show the presence of nodule-like features with bright rims. Data from elemental mapping indicate the nodules are largely composed of Ca and S (i.e., gypsum), with the surrounding rims mainly consisting of As and Fe. μ XRF elemental mapping confirms the EPMA results. μ XAS data collected at various points on the rims surrounding the gypsum nodules suggest that Fe is present as ferrihydrite with adsorbed As.

These findings will facilitate the accurate characterization and quantification of the potential for long-term migration of As from TMF porewaters to adjacent groundwater systems.