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An assessment of the reliability of melt inclusions as recorders of the pre-eruptive volatile content of magmas

ROSARIO ESPOSITO[1,2,*], JERRY HUNTER[3], JAMES D. SCHIFFBAUER[4], NOBUMICHI SHIMIZU[5] AND ROBERT J. BODNAR[2]

[1]DiSTAR, Università di Napoli Federico II, Napoli 80138, Italy
[2]Department of Geosciences, Virginia Tech, Blacksburg, Virginia 24061, U.S.A.
[3]Nanoscale Characterization and Fabrication Laboratory, Virginia Tech, Blacksburg, Virginia 24061, U.S.A.
[4]Department of Geological Sciences, University of Missouri, Columbia, Missouri 65211, U.S.A.
[5]Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543-1050, U.S.A.

ABSTRACT

Many studies have used melt inclusions (MI) to track the pre-eruptive volatile history of magmas. Often, the volatile contents of the MI show wide variability, even for MI hosted in the same phenocryst. This variability is usually interpreted to represent trapping of a volatile-saturated melt over some range of pressures (depths) and these data are in turn used to define a magma degassing path. In this study, groups of MI that were all trapped at the same time (referred to as a melt inclusion assemblage or MIA) based on petrographic evidence, were analyzed to test the consistency of the volatile contents of MI that were all trapped simultaneously from the same melt.

MIA hosted in phenocrysts from White Island (New Zealand) and from the Solchiaro eruption on the Island of Procida (Italy) were analyzed by secondary ion mass spectrometry (SIMS). In most MIA, H_2O, F, and Cl abundances for all MI within the MIA are consistent (relative standard errors <27%, with the exception of two MIA), indicating that the MI all trapped a melt with the same H_2O, F, and Cl concentrations and that the composition was maintained during storage in the magma as well as during and following eruption. In several MIA, S abundances are consistent (relative standard errors <33%, with the exception of five out of 28 MIA). Conversely, CO_2 (White Island and Solchiaro MIA) showed wide variability in several MIA. The result is that some MIA display a wide range in CO_2 content at approximately constant H_2O. Similar trends have previously been interpreted to represent degassing paths, produced as volatile-saturated melts are trapped over some significant pressure (depth) range in an ascending (or convecting) magma body. However, the CO_2 vs. H_2O trends obtained in this study cannot represent degassing paths because the MI were all trapped at the same time (same MIA). This requires that all of the MI within the MIA trapped a melt of the same composition (including volatile content) and at the same temperature and pressure (depth). The cause of the variable concentration of CO_2 within some MIA is unknown, but may reflect micrometer-scale heterogeneities within the melt during trapping, heterogeneities within individual MI, post-entrapment crystallization within the MI, or C-contamination during sample preparation. These results suggest that trends showing variable CO_2 and relatively uniform H_2O obtained from MI may not represent trapping of volatile-saturated melts over a range of pressure, and care must be taken when interpreting volatile contents of MI to infer magma degassing paths.

Results of this study have been used to estimate the uncertainties in volatile concentrations of MI determined by SIMS analysis. The H_2O, F, and Cl contents have an average estimated uncertainty of 11, 9, and 12%, respectively, which is consistent with the SIMS analytical error. In contrast, the S and CO_2 contents have an average estimated uncertainty of 24 and 69%, respectively, which is considerably larger than the SIMS analytical error.

Keywords: Melt inclusions, melt inclusion assemblage (MIA), pre-eruptive volatile contents, magma degassing path, secondary ion mass spectrometry