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SPECIAL COLLECTION: GLASSES, MELTS, AND FLUIDS, AS TOOLS FOR UNDERSTANDING VOLCANIC PROCESSES AND HAZARDS

Bubbles matter: An assessment of the contribution of vapor bubbles to melt inclusion volatile budgets†

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Abstract

Melt inclusions (MI) are considered the best tool available for determining the pre-eruptive volatile contents of magmas. H_2O and CO_2 concentrations of the glass phase in MI are commonly used both as a barometer and to track magma degassing behavior during ascent due to the strong pressure dependence of H_2O and CO_2 solubilities in silicate melts. The often unstated and sometimes overlooked requirement for this method to be valid is that the glass phase in the MI must represent the composition of the melt that was trapped at depth in the volcanic plumbing system. However, melt inclusions commonly contain a vapor bubble that formed after trapping owing to differential shrinkage of the melt compared to the host crystal, and/or crystallization at the inclusion-host interface. Such bubbles may contain a substantial portion of volatiles, such as CO_2, that were originally dissolved in the melt. In this study, we determined the contribution of CO_2 in the vapor bubble to the overall CO_2 content of MI based on quantitative Raman analysis of the vapor bubbles in MI from the 1959 Kilauea Iki (Hawaii), 1960 Kapoho (Hawaii), 1974 Fuego volcano (Guatemala), and 1977 Seguam Island (Alaska) eruptions. We found that the bubbles typically contain 40 to 90% of the total CO_2 in the MI. Reconstructing the original CO_2 content by adding the CO_2 in the bubble back into the melt results in an increase in CO_2 concentration by as much as an order of magnitude (thousands of parts per million). Reconstructed CO_2 concentrations correspond to trapping pressures that are significantly greater than one would predict based on analysis of the volatiles in the glass alone. Trapping depths can be as much as 10 km deeper than estimates that ignore the CO_2 in the bubble. In addition to CO_2 in the vapor bubbles, many MI showed the presence of a carbonate mineral phase. Failure to recognize the carbonate during petrographic examination or analysis of the glass and to include its contained CO_2 when reconstructing the CO_2 content of the originally trapped melt will introduce additional errors into the calculated volatile budget. Our results emphasize that accurate determination of the pre-eruptive volatile content of melts based on analysis of melt inclusions must consider the volatiles contained in the bubble (and carbonates, if present). This can be accomplished either by analysis of the bubble and the glass followed by mass-balance reconstruction of the original volatile content of the melt, or by re-homogenization of the MI prior to conducting microanalysis of the quenched, glassy MI.

Keywords: Melt inclusion, degassing path, Raman spectroscopy, carbon dioxide, vapor bubble