

DOUBLE, DOUBLE TOIL AND TROUBLE: THE MELT INCLUSION BUBBLE

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Melt inclusions provide a powerful means for probing the depth of magmatic processes and volatile budgets of magmas. Both objectives require that the inclusions accurately record the volatile content of the entrapped melt. However, post-entrapment cooling and diffusive loss of water lead to a decrease in internal pressure, resulting in volatile exsolution (importantly CO₂) and vapor bubble growth in inclusions. Several methods have been developed recently that attempt to reconstruct the entrapped CO₂ contents, but the methods yield inconsistent results. Here we report on new homogenization experiments and attempt to reconcile inconsistencies in CO₂ reconstruction methods.

Experiments were conducted on olivine-hosted melt inclusions from Seguam volcano using a piston cylinder apparatus at 500 MPa, 1150-1170 °C, hydrous conditions, and a run duration of 1-2 hours. FTIR analyses of the homogenized inclusions show some diffusive water gain (≤ 1 wt% excess) relative to unheated inclusions (most ~ 4 wt%). Inclusions from this same sample were previously reconstructed using Raman addition (RA; Moore et al., 2015), and we have constituted the CO₂ with two different computational approaches: the ideal gas law (IGL; Shaw et al., 2010) and a bubble growth model (BG; Riker, 2005). CO₂ and S contents of heated inclusions are correlated, defining a S-CO₂ degassing path. Relative to this empirical degassing path, IGL results are offset to higher CO₂ (100s-1000s of ppm) or lower S (100s of ppm), while RA and BG results overlap and are offset to lower CO₂ (≤ 100 s of ppm) or higher S (≤ 100 s of ppm). Because S contents of heated and unheated inclusions have similar ranges, we attribute the discrepancy to CO₂. High values of CO₂ from the IGL correction may be because CO₂ diffusion cannot keep pace with bubble growth during rapid cooling upon eruption. Mass balance calculations indicate that a minute amount of carbonate, which could escape detection by Raman, would affect CO₂ content, providing an explanation for low values of CO₂ determined by RA. The discrepancy in the BG results might relate to diffusive loss of H⁺ and uncertainties (e.g., temperature) involved with the calculation. Thus, homogenization via heating has advantages over other techniques in constituting the CO₂ of inclusions, and may lead to a more accurate computational method.

PLAIN WORD SUMMARY

Pinning down the depths at which magmas undergo physical and chemical evolution is of key importance to understanding events leading to volcanic eruption, cycles of gas influencing climate (e.g., H₂O, CO₂, SO₂), continent formation, and more. One of our best tools for investigating the depth of magmatic processes is the melt inclusion, which forms when a crystal growing from a magma at depth entraps a pocket of the magma. The dissolved gas content (importantly CO₂) of melt inclusions indicates the depth of formation. A major difficulty for this analysis is that melt inclusions typically lose some of their originally entrapped CO₂ by forming bubbles. CO₂ concentration of the melt inclusion is easily measured. However, methods (e.g., computational) for adding CO₂ in the bubble back into the melt inclusion yield inconsistent results. We attempt to reconcile the different methods of bubble addition by conducting experiments at high pressures and temperatures to dissolve the bubble (and CO₂) back into the melt inclusion. Our results indicate that the methods of bubble addition yield values of CO₂ typically offset to higher and lower values than those observed in heated melt inclusions, and we explore the causes to work towards a better computational approach.