Melt inclusion CO_2 contents, pressures of olivine crystallization, and the problem of shrinkage bubbles‡

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ABSTRACT

The H_2O and CO_2 contents of melt inclusions can potentially be used to infer pressures of crystallization and inclusion entrapment because the solubility of mixed H_2O-CO_2 vapor has been determined experimentally for a wide range of melt compositions. However, melt inclusions commonly develop a shrinkage bubble during post-entrapment cooling and crystallization because these processes cause a pressure drop in the inclusion. This pressure drop causes a vapor bubble to nucleate, leading to exsolution of low-solubility CO_2 from the trapped melt. To investigate the loss of CO_2 into such bubbles, we experimentally heated large, naturally glassy melt inclusions in olivine (Fo contents of 88.1 ± 0.2) from a Mauna Loa picrite to rehomogenize the inclusions. Rapid heating to 1420 °C using a high-temperature heating stage dissolved the shrinkage bubbles into the melt. CO_2 contents measured by FTIR spectroscopy and recalculated for melt in equilibrium with the olivine host are 224–505 ppm (n = 11) for heated inclusions, much higher than the CO_2 contents of naturally quenched inclusions from the same sample (38–158 ppm; n = 8). Pressures of inclusion entrapment calculated from the H_2O and CO_2 data for the heated inclusions range from 0.5 to 1.1 kbar, indicating that Mg-rich olivine crystallized at very shallow depths beneath the surface of Mauna Loa. Our results indicate that 40–90% (average 75%) of the original CO_2 dissolved in the melt at the time of inclusion entrapment can be lost to the shrinkage bubble during post-entrapment cooling. We show that the computational method of Riker (2005), which predicts the pre-eruption shrinkage bubble size as a function of the difference between trapping temperature and pre-eruption temperature, successfully reproduces our experimental results. Our results demonstrate that the mass of CO_2 contained in shrinkage bubbles must be considered to accurately infer original pressures of crystallization for melt inclusions. However, the effect is expected to be smaller for more H_2O-rich melt inclusions than those studied here because the vapor bubble in such inclusions will have lower mole fractions of CO_2 than the low-H_2O inclusions in our study.

Keywords: Melt inclusions, volatiles, carbon dioxide, shrinkage bubble