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Magma decompression rate calculations with EMBER: A user-friendly software to model diffusion of H_2O, CO_2 and S in melt embayments

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The ascent rate of magmas during volcanic eruptions is a challenging parameter to decipher yet key in controlling eruption dynamics. One estimation method relies on fitting volatile elements diffusion profiles along a concentration gradient in crystal-hosted open melt pockets called embayments. We developed EMBER (EMBayment-Estimated Rates), a standalone versatile tool that models diffusion of volatile elements along melt embayments that relies on MATLAB scripts to calculate 1D diffusion profiles of H_2O, CO_2 and S, and seeks out the best fit among all grid search generated profiles to find a constant decompression rate, initial dissolved and exsolved volatile concentration while setting a fixed temperature and pressure at the beginning and the end of the ascent. This new software is able to compute the rate for basaltic, intermediate, and rhyolitic compositions and provide results in minutes to hours depending on the size of the user generated grid search. It can work with any existing solubility models, such as VolatileCalc, SolEx, and RhyoliteMELTS 1.2.0. We tested EMBER on existing studies' diffusion profiles. These profiles length range between 60 and 400 µm and the H_2O, CO_2 and S concentration go up to 5 wt%, 400 ppm and 2000 ppm, respectively. Most results fall within a factor of two range of reported decompression rates. Usually, the studies with the results close to our calculation, use modeling approach similar to EMBER. Notable differences originate from the choices of diffusion coefficient, weighting and scaling method for the least-square to determine the best fit, and boundary condition at the mouth of the embayment. EMBER-calculated literature data are useful for the comparison of ascent rates from different volcanoes and studies, as they are free of model-dependent biases. Results range from 0.02 to 2.7 MPa/s for relatively mafic magmas (<55wt% SiO_2) and from 0.005 to 0.6 MPa/s for differentiated compositions (>55wt% SiO_2).

We compared the newly recalculated decompression rates available to date to eruption magnitudes and find no statistically significant correlation. We hope our model will develop an increasing interest for the embayment method and will multiply the number of comparable data for future studies.