Evolution of bubble size distribution by buoyancy-driven coalescence

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The coalescence of ascending bubbles driven by buoyancy leads to the spatial heterogeneity of volatile in basaltic magma, to control the style and dynamics of basaltic eruptions. It is essential to quantitatively know what factors and how they control bubble size distribution (BSD), because the BSD controls the coalescence process through approaching velocity between two bubbles, and in turn, the coalescence process entirely changes the BSD. First, we derive the effective cross-section for bubble coalescence, including hydrodynamic interaction between bubbles. As a result, it is found that our newly-derived effective cross-section is proportional to the product of the radii, although the geometrical cross-section is proportional to the square of the sum of the radii. Next, using both cross-sections, we numerically calculate the evolution of BSD for the initial distribution with a narrow size range. For the geometrical cross-section, the BSD shows power-law with exponent -1.3 for larger bubbles. For our effective cross-section, the BSD shows power-law with exponent -2.2 for smaller bubbles. The exponent of -2.2 is close to the exponent of -2.0 for basaltic lava (Gaonach et al., 1996). Our calculation of BSD allows us to estimate the timescale of formation of power-law, as sometimes recorded in natural samples. For both cross-sections, the power-law region extends with time and covers all the sizes at a finite time, which can be interpreted as a rapid formation of large bubbles. This result may explain the formation of large bubbles observed in lava lakes and Strombolian eruptions.

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