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Simulation of eruption styles based on advanced studies of magma degassing

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For comprehensive understanding and successful simulation of volcanic explosions it is necessary to integrate various research outcomes obtained from theoretical and experimental studies as well as field observations. Among related problems the mechanism of magma degassing involves the greatest uncertainty even if it plays a key role in describing eruption styles over explosive to effusive eruptions. On this subject recent extensive experimental studies using some natural and artificial materials of magma-like compositions are suggesting that percolation of volatile gasses can be one of the most likely mechanisms that transfer gasses in magma. These studies also have clarified nature of the permeability, particularly its dependence on the gas volume fraction. Taking this trend into account, I have formulated the degassing rate due to permeable gas flow in ascending magma and made a computer simulation of magma ascent processes with degassing.

In formulating the degassing rate, we consider the bubble pressure that is enhanced due to viscous resistance of magma to gas expansion in ascending and decompressed magma. The enhanced bubble pressure is proportional to the decompression rate and so the magma ascent velocity. Because the ascent velocity laterally changes from its peak at the center of the magma flow to zero at the interface with the country rock, it produces a lateral gradient of gas pressure that may drive permeable gas flow in magma. The degassing rate associated with this permeable flow is proportional to the permeability and the mean ascent velocity of magma and the degassing intensity is represented by the ’degassing factor’ that is defined by the proportionality coefficient in the expression of the degassing rate. This formulation of degassing rate is used in the simulation of a one-dimensional non-stationary magma flow in which the volatile component has the same ascent velocity as the liquid magma and deposits on bubbles when its amount exceeds the solubility.

The simulation reveals that the gas volume fraction in erupting magma sharply drops from high values near unity to vanishing low values as the degassing factor increases. This relation is not seriously affected by variations of material properties as well as physical and geometrical conditions if the degassing factor is suitably scaled and made dimensionless. Namely, an eruption should be explosive and effusive if the dimensionless degassing factor is greater and smaller, respectively, than a critical value that can be fixed almost uniquely. This criterion is displayed concisely on a simple diagram in which explosive and effusive eruptions occupy their own areas on the viscosity-permeability plane separated by a boundary line that may more or less shift following the size and geometry of the conduit. The result can be a useful working hypothesis for further studies on related subjects because of its great simplicity.