The Role of an Excess Fluid Phase in Controlling Eruption Styles and Ascent Rates in Basaltic Andesite Magmas

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Abstract

Effusive and explosive eruptions often occur from the same volcano, yet the reasons behind such a wide ranging eruptive behaviour remain poorly understood. Here we explore the role of various physical parameters focusing on the explosive-effusive-explosive basaltic andesite eruptions of Kelud volcano, Indonesia in 1990, 2007, and 2014, respectively. Through phase equilibria experiments, we find the magma storage conditions feeding explosive and effusive eruptions are broadly similar at 975 +/- 39 Celsius, 175 +/- 25 MPa, and 4-6 wt. % water in the melt. We also estimated magma ascent rates from halogen diffusion profiles in zoned apatite, and found that ascent rates of the 2007 dome (0.003-0.05 m/s) are at least one order of magnitude slower than those recorded by apatite from 1990 and 2014 explosive eruptions (more than 0.1 m/s). Comparison of the atmospheric sulfur dioxide mass released during the explosive eruptions with that dissolved in the melt shows that explosive eruptions accumulated an excess fluid phase prior to eruption of up to 0.1 Mt sulfur dioxide, whereas such fluid accumulation was not associated with the 2007 effusive eruption, given that the system was much more open during its inter-eruptive repose. The calculated viscosity and magma ascent rates also overlap with independent constraints from magma discharge rates for these same eruptions. We propose that the presence of an excess fluid phase played a critical role in controlling the observed eruption style. Implications of our findings indicate that the presence of an excess fluid phase should be taken into account when modelling eruptive processes, and parameters associated with fluid accumulation and degassing could be monitored for signs of unrest before explosive events.

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Effusive and explosive eruptions often occur from the same volcano, yet the reasons behind such a wide ranging eruptive behaviour remain poorly understood. Here we explore the role of various physical parameters focusing on the explosive-effusive-explosive basaltic andesite eruptions of Kelud volcano, Indonesia in 1990, 2007, and 2014, respectively. Through phase equilibria experiments, we find the magma storage conditions feeding explosive and effusive eruptions are broadly similar at 975 ± 39°C, 175 ± 25 MPa, and 4-6 wt. % water in the melt. We also estimated magma ascent rates from halogen diffusion profiles in zoned apatite, and found that ascent rates of the 2007 dome (0.003-0.05 m/s) are at least one order of magnitude slower than those recorded by apatite from 1990 and 2014 explosive eruptions (> 0.1 m/s). Comparison of the atmospheric SO_2 mass released during the explosive eruptions with that dissolved in the melt shows that explosive eruptions accumulated an excess fluid phase prior to eruption of up to 0.1 Mt SO_2, whereas such fluid accumulation was not associated with the 2007 effusive eruption, given that the system was much more open during its inter-eruptive repose. The calculated viscosity and magma ascent rates also overlap with independent constraints from magma discharge rates for these same eruptions. We propose that the presence of an excess fluid phase played a critical role in controlling the observed eruption style. Implications of our findings indicate that the presence of an excess fluid phase should be taken into account when modelling eruptive processes, and parameters associated with fluid accumulation and degassing could be monitored for signs of unrest before explosive events.