Geophysical Research Abstracts
Vol. 18, EGU2016-9631, 2016
EGU General Assembly 2016

Physical mechanisms that lead to large-scale gas accumulation in a volcanic conduit

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The eruption of viscous magma at the Earth's surface often gives rise to abrupt regime changes. The transition from the gentle effusion of a lava dome to brief but powerful explosions is a common regime change. This transition is often preceded by the sealing of the shallow part of the volcanic conduit and the accumulation of volatile-rich magma underneath, a situation that collects the energy to be brutally released during the subsequent explosion. While conduit sealing is well-documented, volatile accumulation has proven harder to characterize. We use a 2D conduit flow model including gas loss within the magma and into the wallrock to find steady-state magma flow configurations in the effusive regime. Model outputs yield a strongly heterogeneous distribution of the gas volume fraction underneath a dense, impermeable magma cap. Gas accumulates in inclined structures hundredths of meters long and several meters thick. These structures probably constitute the gas pockets that accumulate explosive energy and that were intuited by previous studies. We tested the numerical robustness of our results by simulating the fragmented state of the magma contained within the pockets, by testing various fragmentation criteria, and by varying computational gird size. These gas pockets are robust features that occur regardless of wallrock permeability (from very permeable at 10-12 m2 to quasi impermeable at 10-16 m2) but that are sensitive to the volume to surface ratio of the volcanic conduit. One implication is that the formation of these large degassing structures probably plays an essential role in the triggering of violent explosions. Such large scale outgassing feature may also bring a partial answer to the long standing issue of the observed gas transfer across entire magmatic systems despite high magma viscosity and no obvious physical mechanism of transfer.