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The impact of the plumbing-system geometry on gas segregation and passive degassing in basaltic volcanoes

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Many basaltic volcanoes, such as Mount Etna and Stromboli volcano in Italy, emit substantial amounts of gas over long periods of time while erupting relatively little degassed lava, implying that gas segregation must have occurred in the magma feeding system. The geometry and degree of connectivity of this plumbing system control the movement of magma in that system and could therefore provide an important control on gas segregation in basaltic magmas.

Gas segregation has been investigated using analogue experiments and analytical modelling in a simple geometry consisting of a vertical conduit connected to a horizontal intrusion. Our investigation shows that non-vertical elements of the plumbing systems act as strong gas segregators. The presence of exsolved bubbles induces a buoyancy-driven exchange flow between the conduit and the intrusion that leads to gas segregation. Bubbles segregate from the fluid by rising and accumulating as foam at the top of the intrusion, coupled with the accumulation of denser degassed fluid at the base of the intrusion. Steady-state influx of bubbly fluid from the conduit into the intrusion is balanced by outward flux of lighter foam and denser degassed fluid. The length and time scales of this gas segregation are controlled by the rise of bubbles in the horizontal intrusion. These gas segregation processes are shown to be effective in bubbly fluid containing up to 40% gas bubbles by volume. Comparison of the gas segregation time scale with that of the cooling and solidification of the intrusion suggests that gas segregation is more efficient in sills than in horizontally-propagating dykes, and that this process could be efficient in intermediate as well as basaltic magmas.

Gas segregation also provides an important control on the generation of gas-rich and gas-poor magmas at persistently active basaltic volcanoes, and on their eruptive behaviour. For low magma supply rates, very efficient gas segregation is expected, which induces episodic degassing activity that erupts relatively gas-poor magmas. For higher magma supply rates, gas segregation is expected to be less effective, which leads to stronger explosions that erupt gas-rich as well as gas-poor magmas. These general physical principles can be applied to persistently-active basaltic volcanoes, and in the case of Stromboli volcano are shown to be consistent with independent field data. Observations of gas segregation at Stromboli can be explained by the presence of a shallow reservoir of sill-like geometry at 3.5 km depth with exsolved gas bubbles 0.1-1 mm in diameter. Transition between eruptions of gas-poor, high crystallinity magmas and violent explosions that erupt gas-rich, low crystallinity magmas are calculated to occur at a critical magma supply rate of 0.1-1 m^3 s^{-1}.