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Magma Evolution due to Degassing and Circulation in Persistently-Active Volcanic Systems

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Persistently-active basaltic volcanic systems are characterised by continuous degassing in the absence of any significant eruption of magma. This requires the recirculation of magma between the conduit and the magma chamber: volatile-rich magma releases its gas at the surface and returns to a deeper magma reservoir driven by the density contrast between volatile-rich and degassed magma. In addition, the reservoir may also be supplied by magma rising from the deeper magmatic system. In this study, we explore the range of possible circulation patterns for a convecting magma reservoir supplied by magma inputs of different density, and use this to model the evolution of magma composition within the reservoir.

Under conditions typical for persistently-active volcanic systems, magma supplied to a convecting reservoir generates circulation which takes the form of a turbulent buoyant plume propagating in a confined, convecting environment. We study this flow for the case of point source dense plumes entering the reservoir (representing the return of dense, degassed magma from the conduit) and line source light plumes entering the reservoir (representing the supply of volatile-rich magma from depth). By assuming that the convecting environment removes fluid from the plume at a rate proportional to a characteristic environmental velocity scale, we derive a model describing the fluid behaviour. For the example of pure buoyancy plumes, entrainment dominates near the source and the plume radius increases with distance, while further from the source removal, or extrainment, of plume material dominates, and the plume radius decreases to zero. For line source plumes, the mixing dynamics are strongly dependent on plume source width even far from the source, and we find that concentrated sources of buoyancy released from narrow sources and pure plumes are extrained into the environment more efficiently than dilute, wide-sourced plumes which also possess source momentum. The theoretical predictions are consistent with laboratory experiments, a major feature of which is the natural variability of the convection.

We extend the study to include the evolution of a finite confined environment, the end-member regimes of which are a well-mixed environment at all times (high convective velocities), and a 'filling-box' model consisting of layers of different density fluid whose density evolves with time (low convective velocities), similar to that of Baines & Turner (1969). The convecting environment can generate overturn of the stratified layers, leading to a cyclical structure to the magma reservoir. The dynamical model for the magma reservoir circulation is coupled to a parameterisation of the phase behaviour of basalt at Stromboli (Di Carlo et al., 2006) to describe the evolution of magma composition and volatile content within the magma reservoir at Stromboli.

References

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