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Controls on stability of volcanic jets from vent shape and particle-size distribution

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Explosive volcanic eruptions produce turbulent, particle-laden jets that can undergo gravitational collapse to produce ground-hugging pyroclastic density currents or loft material several tens of kilometres. The key to determining which of these two phenomena will occur is the turbulent entrainment of atmospheric air, which adds buoyancy to the jet. We demonstrate how two important factors, vent shape and particles critically coupled to the flow, affected turbulent entrainment, and hence jet stability.

Natural volcanic vents can have a variety of shapes including circular, flared (craters), elongated (fissures) and annular (calderas). Recent work using scaled analogue experiments, has tested the effect of these different vent geometries on the entrainment rates into jets laden with inertial particles (Jessop et al, GRL 2014; Jessop et al, EPSL 2016). This work shows that the smallest gap size sets the initial entrainment rate and that the aspect ratio (e.g. gap size/diameter for annular vents) of these more complex vent shapes has a strong influence on the stability of the jet, with more extreme aspect ratios causing the jets to collapse more readily. These findings make explicit predictions for deposit architectures which can be tested using field data.

The coupling of particles to a turbulent flow is determined by how rapidly it responds to fluid accelerations. This depends on the particles' size, density, the fluid's viscosity, and the speed and size of turbulent eddies. Critically-coupled particles have a response time approximately equal to the time scale for fluid accelerations. We use scaled analogue models and numerical simulations to show that the presence of critically-coupled particles, even in low concentrations, can dramatically alter the dynamics of turbulent entrainment by changing the size and intensity of the eddies that are responsible for entraining ambient fluid into the flow.