FLUID DYNAMICS OF EXPLOSIVE VOLCANIC ERUPTIONS

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Explosive volcanic eruptions involve the high velocity discharge of hot gas and tephra into the atmosphere. The fluid dynamics of explosive eruptions are complex, often involving compressible flow and interactions between solid particles, gas and air. There is only a rudimentary understanding of the full complexity of dynamical phenomena in explosive eruptions. However, significant insights into their dynamics have resulted from simplified numerical modelling and laboratory experiments on analogue systems. Gas and tephra always emerge from the vent with a bulk density greater than the atmosphere. In some cases turbulent entrainment and heating of cold air by the high velocity flow reduces the density sufficiently for the flow to develop into a buoyant thermal plume rising to a few tens of kilometres into the atmosphere. Such columns form air-fall tephra and can be successfully modelled using simple plume theory despite the complications of entrained particles. In other cases the flow does not mix with enough air and column collapse occurs in the form of a fountain to form pyroclastic flows. Recent experimental studies and observations, however, indicate that the mechanisms of collapse are more diverse and complex than implied by the simplified models of Sparks and Wilson. S.W. Kieffer and B. Sturdevant have shown that the processes of entrainment and mixing in high pressure jets can be very different to those in a simple pressure adjusted jet. In addition, the assumption that ejecta emerges as an homogeneous particle-gas mixture to which single values of density and temperature can be assigned at a given pressure must be questioned. Fluidised bed studies imply that expanding particle-gas systems are often highly inhomogeneous with regions of very high and very low particle concentration.

S. Carey, H. Sigurdsson and I have carried out experiments on the fluid dynamics of two-phase plumes and fountains. These experiments involve the discharge of mixtures of fresh water and solid particles into a tank of salty water. The behaviour of the flows depends on particle concentration and grain size. For plumes with high particle concentration several kinds of convective instability were observed generating dilute gravity currents and rapid sedimentation at rates much faster than Stokes Law. These flows were generated at the margins of the plume by re-entrainment of surrounding sedimentary particles which had fallen out from higher in the plume. When the density of the flow exceeded the density of the tank fluid collapse fountains formed which generated radial gravity currents. These currents reached a fixed distance at which buoyant plumes formed. The experiments give new insights into the mechanisms of particle fall-out from plinian columns and indicate that there are several different mechanisms of generating pyroclastic flows and surges from eruption columns.