Two-layer aerated granular flows and implications for pyroclastic density current structure

Pete Rowley1,2 & Olivier Roche1

1 Laboratoire Magmas et Volcans, Clermont-Ferrand, France
2 Department of Earth and Environmental Sciences, University of Portsmouth, UK

Introduction
Two-layer gas-particle currents are investigated using heated (~70°C) aerating powder (sub-45 micron diameter silica beads) in a flume with a porous base (Figure 1). These flows provide a unique method for observing the interface between a dense granular underflow and a turbulent dilute over-lying flow, as envisaged to exist within many pyroclastic density currents (PDCs), with the aeration effective in overcoming scaling issues related to rapid pore pressure diffusion in thin flows under laboratory conditions (Rowley et al. 2014). Sediment supply from a hopper enables sustained currents to form. High speed video at 1024 x 256 pixels is used to record the flow behaviour through a transparent perspex sidewall.

Observations
On reaching the channel base, the powder spontaneously partitioned into a two-layer current, with minimal coupling (Figure 2). At entry, some particles are lifted into the turbulent flow only by energetic impingement, some of which was sedimented back to the dense flow along the length of the flume. The morphology of the turbulent current is similar to that observed in earlier simulations of turbulent dilute PDCs (Figure 3). The interface between the two flow layers was sharp and distinct. This interface developed breaking waves, leading to sediment transfer from the lower flow into the upper flow, resulting in temporally and spatially variable mass flux in both currents.

Pixel brightness can be used as a proxy for sediment concentration in the turbulent suspension (e.g. Andrews & Manga 2012) to assess the degree to which sediment transfers between the lower and upper flows (Figure 4).

Breaking waves and sloshing in the dense current were only apparent between 2 and 4 seconds of the current entering the flume. These instabilities transferred material into the over-riding turbulent suspension, increasing the sediment load, and causing the mean grayscale values to peak.

Conclusions
Energetic impingement of powder materials causes spontaneous formation of two-layer gravity currents. These comprise a dense basal flow with high interstitial gas pore pressures, over-ridden by a dilute turbulent powder suspension. Sustained aerated conditions enable the investigation of more long-lived flow properties anticipated in larger natural flows with slower pore pressure diffusion.

High speed video reveals that the interface between these layers can feature breaking-waves and sloshing in the basal current. These actions provide a supply of material to the faster-moving over-riding turbulent cloud, which in turn sediments some material back to the basal flow. The relative flux of these two processes is inferred to be a controlling factor on the growth rate of each flow layer.

These results provide insight into the possible flow structure and mass-partitioning processes between the two discrete layers inferred to exist within some PDCs, which have to date proved impossible to observe or record in the field. Unsteady flow and interface conditions may result in complex inter-flow sediment transfer processes and bulking.

Acknowledgements
This work was conducted through a Université Blaise Pascal Postdoctoral Fellowship. Additional funding for experimental work was provided by the volcanology group of the Laboratoire Magmas et Volcans. Support in preparation of this presentation has been provided by the University of Portsmouth Geological and Environmental Laboratories, and Rock Mechanics Laboratory.

References