Analogue modelling of fluidised pyroclastic density currents

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Aims

Following pilot work (Rowley et al 2014), this project was targeted at investigating the first-order controls on sustained continuously fluidised dense granular flows, as analogues for pyroclastic density currents. In particular the work was to establish a new and globally unique experimental facility, and begin to explore variables including slope, material heterogeneity, mass flux, flow unsteadiness, and variation in fluidisation.

Methods

A new flume was constructed (Figure 1), which comprises perspex sidewalls and a gas-permeable base through which compressed air can be fed in order to fluidise powder and granular materials. The design of the flume allows independent gas-fluidisation control in three 1 m long sections, as well as tile of the flume by up to 10 degrees.

Specific variables and conditions have been investigated using a range of techniques, including high speed video capture and particle tracking velocimetry.

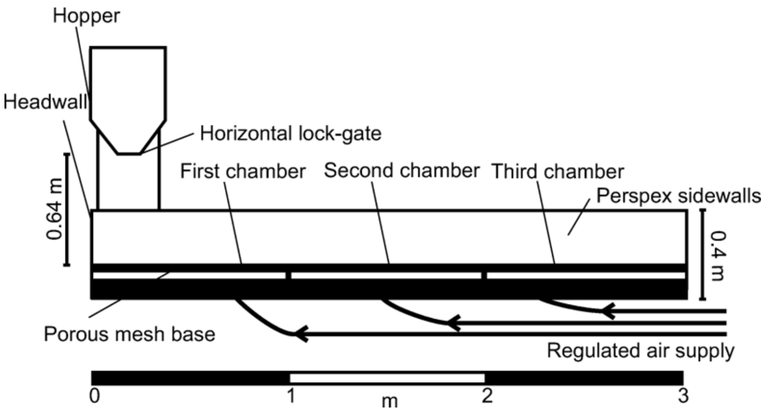

Figure 1 Flume design, from Smith et al 2018

Main Findings

The work based on this grant is still ongoing. However, a number of outputs have been achieved to date.

The work carried out under this grant has established controls on run out due to different levels of fluidisation at different points in the flows propagation, and the relative impact of slope on these conditions. It has also shown that rate of defluidisation is a strong control on bedform morphology. We have observed spontaneous unsteadyness in these currents, derived form sustained steady supply conditions.

These currents travel as a series of supercritical pulses (Fr = 7) which come to a relatively rapid halt. This is important, as it tallies with an emerging paradigm in pyroclastic density current sedimentology, where these currents are envisaged as exhibiting a pulsing stepwise aggradation. The results also link flow style to deposit morphology; thicker, longitudinally confined deposits aggrade rapidly, and correlate to rapid defluidisation. Such behaviour may be seen in natural PDCs subject to processes which result in de-aeration, such as temperature drops and/or loss of fines.

Upcoming publications explore the response of currents to obstacles, as well as the parameter space that controls the formation of different types of dune bedforms (Figures 2 and 3). This establishes the very first stability diagram for dense granular flow bedforms, and provides an entirely new tool for interpreting deposits in the field. In addition, we quantify the development of the lower flow boundary zone; the space between static deposit and the bod of the flow, which has poorly defined characteristics in the field, and whose physical characteristics appear strongly controlled by fluidisation and flow properties. The upcoming work represents the first attempt to tie flow boundary zone properties to bedform dynamics.

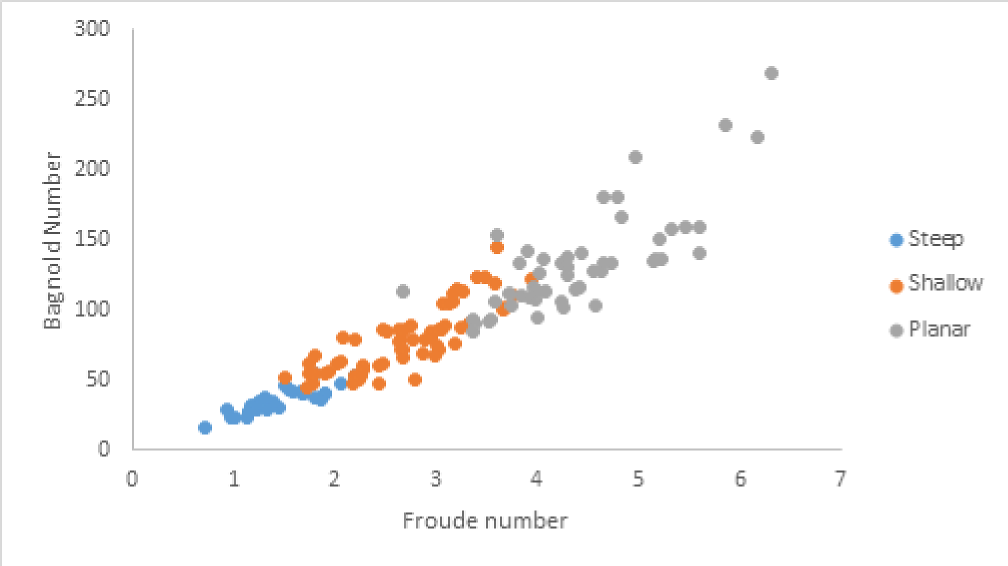

Figure 2 Preliminary dimensionless analysis of bedform growth conditions in experiments. Smith et al. (in prep).

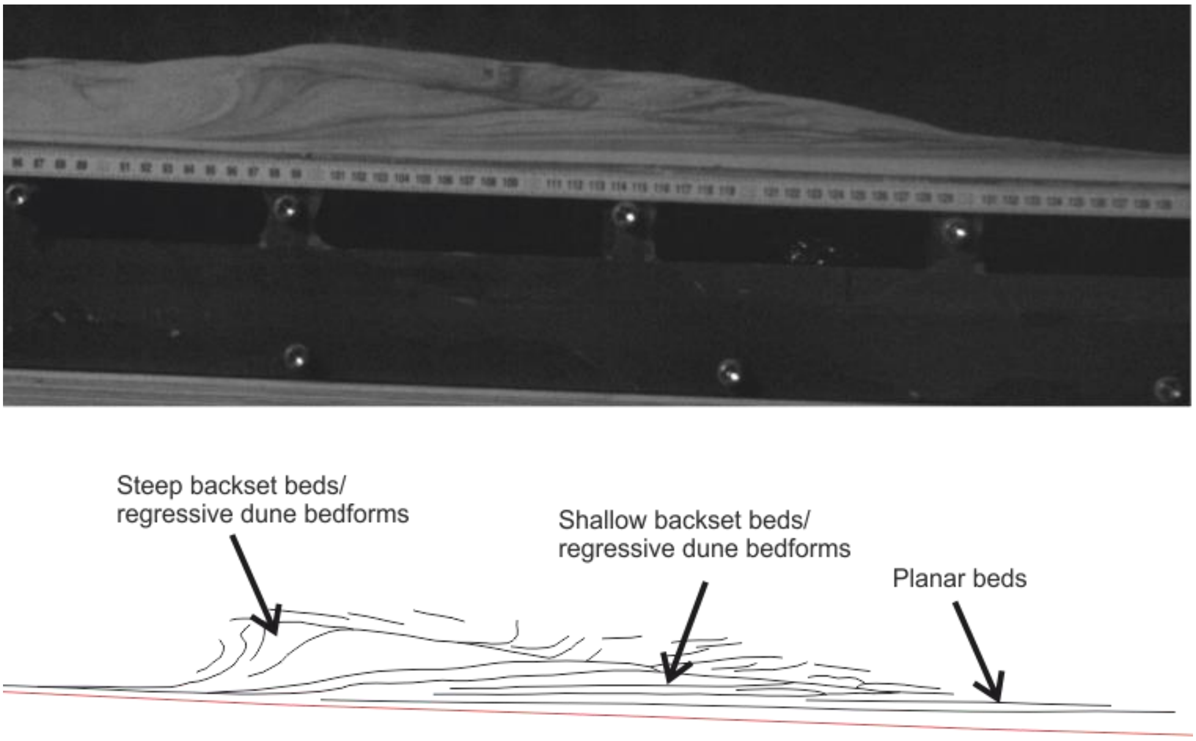

Figure 3 Interpretation of complex deposit architectures with varying bedform characteristics. Smith et al. (in prep).

Further outputs

The award of this grant led to the award of a PhD Scholarship through the University of Hull Catastrophic Flows research cluster. Greg Smith - the PhD student appointed to the scholarship - is now in his final year. In 2018 he published Smith et al (2018), has a second paper nearly ready for submission, and a third paper in preparation. These are all outputs directly reliant on the BSG ECR grant.

In addition to this 3 Masters projects have completed and another is in progress as a result of this grant;

- Frederico Barata (MRes, University of Portsmouth, publication in prep)
- Samuel Capon (MSc Geological and Environmental Hazards, University of Portsmouth, publication in prep)
- Nicola Brown (MSc Geological and Environmental Hazards, University of Portsmouth)

- Robert Walmsley (MSc Geological and Environmental Hazards, University of Portsmouth).

The grant and resulting outputs have been used to support several grant applications, a Royal Society Fellowship application, and are anticipated to be used for further applications in the following 18 months. Collaboration with Rebecca Williams enabled by this grant has resulted in further spin-off work, including a paper exploring the collapse of the Anak Krakatau volcanic edifice in December 2018 (Williams et al. 2019, in review).

Several conference presentations have been built on work conducted under this grant, including work taken to IAVCEI 2017, VMSG 2018, VMSG 2019, and EGU 2019.

References
Smith, G.M., Williams, R., Rowley, P.J. et al. 2018. "Investigation of variable aeration of monodisperse mixtures: implications for pyroclastic density currents". Bull Volcanol 80: 67. https://doi.org/10.1007/s00445-018-1241-1https://doi.org/10.1007/s00445-018-1241-1
Williams, R., Rowley, P. and Garthwaite, M.C. 2019. “Small Flank Failure of Anak Krakatau Volcano Caused Catastrophic December 2018 Indonesian Tsunami.” EarthArXiv. doi:10.31223/osf.io/u965c