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A review of the dynamics of slumping granular materials and implications for pyroclastic flow propagation

J.C. Phillips
Centre for Environmental and Geophysical Flows, Department of Earth Sciences, University of Bristol, BS8 1RJ, U.K.

In this presentation we review recent new results on the dynamics of gravitationally-slumping granular materials that have been obtained in a number of European laboratories. Taken together, these experimental results and scaling laws provide new insights into the motion of unsteady geophysical granular flows, and we focus on the application of these new insights to the motion of volcanic pyroclastic flows. Field observations suggest a spectrum of pyroclastic flow states, from dense, granular flows to gas-fluidized flows, and laboratory studies have investigated granular collapse in analogous regimes.

Substantial progress has been made in examining how granular materials with a narrow size range (*mono-sized particles*) avalanche. These studies have used laboratory experiments to investigate the dynamics of the collapse of axisymmetric and two-dimensional granular columns onto a horizontal surface and the subsequent granular flow propagation. The results from these studies challenge the traditional view that the maximum extent of the flow (the *run out distance*) depends only on the volume of material involved in the flow and instead have emphasized the importance of the initial shape or aspect ratio of the material, finding clear power law dependence of the flow run out on the initial aspect ratio of the granular column only.

Experimental studies of the collapse of binary mixtures of fine and coarse granular materials has thrown up further surprises in which the run out can be substantially increased (by factors of up to 4) by appropriate mixtures of the two different sizes of material compared to either in pure form. The dependence of flow run out on initial aspect ratio is different compared to flows of mono-sized particles, suggesting that controls on the extent of flows containing more than one particle size are fundamentally different from those for mono-sized particle flows. The clear implication is that interaction of different particle sizes exerts a fundamental control on the operation of frictional forces during the flow.

Initial fluidization of the granular column disrupts the interparticle contact network, which controls the internal friction of the static bed. Laboratory experiments show that slightly expanded, fluidized flows are more mobile than non-fluidized flows of equivalent volume and material composition, and their mobility depends only weakly on their initial degree of fluidization. However, particle size provides a strong control on the flow dynamics. Initially fluidized flows of coarse particles behave as their non-fluidized counterparts, whereas initially-fluidized flows of fine particles propagate for most of their duration as slumping buoyancy-driven gravity currents of Newtonian fluids.

These experimental studies and scaling laws suggest that the dynamics of fluidized, ash-rich pyroclastic flows may be only weakly dependent on the internal particle friction, which may only become important in a short final stopping phase. These flows may propagate as inviscid fluids for most of their emplacement. In contrast, the dynamics of high concentration pyroclastic flows containing a wide range of particle sizes may be strongly dependent on particle interactions and segregation.