Geophysical Research Abstracts, Vol. 9, 04891, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-04891

1 Transport and sedimentation of laboratory ash flows

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Pyroclastic flows are dense mass flows of hot particles and gas generated by volcanic eruptions. Their fluidal behaviour is widely attributed to high interstitial gas pore pressures and associated fluidization effects. We carried out experiments on the dynamics of laboratory-scale flows of fluidized volcanic ash in a 3.5-m-long lock-exchange flume at ∼170˚C, which is hot enough to render negligible effects of humidity-derived interparticle cohesion. The ash was the sub-250 μm fraction of a trachytic ignimbrite. The 1-D expansion and settling properties of the ash were first investigated in the flume reservoir with the gate shut. When fluidized, the ash expanded uniformly up to 45 vol% above loose packing prior to the onset of bubbling. Hindered settling velocities were determined by first expanding the material, then allowing it to re-sediment under gravity by abruptly cutting the gas flux (‘bed-collapse test’).

The flows were generated by first expanding the ash to a known amount (6-42 vol%) in the reservoir, then opening the lock gate. Each flow defluidized progressively as it travelled down the flume until motion ceased. Despite the polydisperse nature of the ash, no significant segregation took place during flow. Frontal velocity and runout both increased with increasing initial bed expansion, the most expanded flows being ∼5 cm thick with speeds of ∼2 m.s^{-1} and runouts of ∼2.8 m. Flow was laminar as revealed by tracer particles. Each flow exhibited three phases during transport: (1) a short initial phase of gravitational acceleration, (2) a dominant, approximately constant-velocity phase, and (3) a short stopping phase. High-speed (1000 frames/s) video footage showed that each flow thinned progressively by deposition until it simply ran out of mass. Within a given flow, the sediment aggradation rate was constant along most of the runout distance. Moreover, the rate of deposition in a flow of given expansion was identical to that in a (non-shearing) 1-D bed-collapse test at the same initial expansion. It appears that neither shear-dispersive stresses nor interparticle collisions within the flows were strong enough to affect particle-settling rates, despite the high rates of shear (up to 40 s^{-1}). Flow propagation and deposition were governed by two dimensionless parameters: (1) the initial aspect ratio of the expanded ash in the reservoir, and (2) the ratio of two times: t_{grav}, a characteristic time of gravitational acceleration, and t_{sed}, a characteristic time of sedimentation (determined independently from the 1-D collapse tests). Runout time t_{run} scales to a high degree of accuracy as $t_{run}/t_{grav} = (t_{sed}/t_{grav})^{0.55}$, reflecting the strong control of sedimentation on the flow dynamics.