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Transport and sedimentation processes of small-volume pyroclastic flows

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Small-volume pyroclastic flows are some of the most hazardous phenomena at explosive volcanoes because they form frequently during explosive eruptions as well as by repeated lava-dome collapse, they occur suddenly, and they spread at high velocities. An improved physical understanding of their high mobility and their sedimentation processes is a prerequisite to assess their hazard potential.

Field observations of moving pyroclastic flows are rare and most of our current knowledge stems from interpretations made upon their resulting deposits. Most of these interpretations favour a granular flow type model to describe small-volume pyroclastic flows. The application of granular flow models to geophysical mass flow situations is complicated by the absence of general constitutive equations for flowing granular media. Current numerical models of granular flows mostly computed in a depth-averaged framework heavily depend on empirical bulk friction parameters. From the geological point of view such models are difficult to compare with and test against field data since they do not realistically describe internal flow deformation and sedimentation.

We will first summarise results from fundamental laboratory experiments on rapid granular flows to emphasize (a) that in contrast to current granular models internal and basal friction are largely irrelevant to describe the main flow processes; and (b) that instead internal deformation and sedimentation are crucial processes to describe the flow dynamics and resulting deposits. We will provide a functional description of sedimentation in terms of the position of the moving interface between already deposited and still flowing particles as a function of time.

Along with these results we present a unique data set for one of the world's best examples of low-energy, coarse-grained pyroclastic flow deposits – the 1975 scoria-and-ash flow deposits from Ngauruhoe. This data set includes (1) the very detailed spatial distribution of the individual flow units in a 2.5 m accurate DEM; (2) new insights into the internal structure of small-volume pyroclastic flows from completely excavated horizontal profiles; and (3) the first complete mechanical analysis of a flow unit from its most proximal to distal reaches. The apparent trends developing with flowing distance are interpreted in a qualitative model explaining transport and sedimentation as a function of distance and time.