Fluidization by collapse of fine particles into ambient air: a possible mechanism for sustained low interparticle friction in pyroclastic flows

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Long runout distance of fines-rich pyroclastic flows is commonly attributed to their ability to generate and retain high pore pressure that reduces interparticle friction. This phenomenon, called fluidization, is caused by the relative vertical motion between a fluid (moving upward) and the particles (settling downward). Most of earlier works on fluidization have considered a constant vertical gas flux flowing through a static bed of particles. However, fluidization may also be caused by the collapse of particles into the (static) ambient air. Particle relative downward motion can occur during pyroclastic flow propagation, either when the flow bypasses a topographic break, propagates over a rough substrate (Chédeville and Roche 2014) or compacts itself. We carried out laboratory experiments which consisted of collapse of beds of particles (sub-spherical glass beads), in a static column of height of 1.4 m, triggered by rapid opening of a gate. Pressure sensors recorded the air pore pressure at different levels in the column. The collapse height was set at 20 or 90 cm, and bed properties such as bed thickness, particle size and bed temperature were systematically changed. The results showed three phases of pore pressure (Fig. 1): (1) An underpressure phase caused by the gate opening (t_1), rapidly followed by (2) a first overpressure phase in the reservoir (above the gate) when particles began to fall and forced the air to ascend through the bed (t_2), and (3) a second overpressure phase in the aggrading deposit at base of the column, during which pore pressure diffused slowly (t_4). Even at low collapse height of 20 cm, the maximum of the first overpressure phase showed that pore pressure compensated almost completely the bed lithostatic pressure, meaning that material was fluidized. This was true regardless the bed thickness and for particle sizes up to at least 400 µm. The second overpressure phase was strong when the particles were small enough (< 100-200 µm) but it was poorly developed or even absent when the particle size was increased. The duration of pressure diffusion in the deposit increased with the square of the bed thickness and decreased strongly with increasing particle size. Additional experiments with a natural ignimbritic material showed similar behavior but with a much longer diffusion duration (>30 s for a bed thickness of 28.5 cm), suggesting that such a fluidization mechanism can reduce internal friction for significant time in pyroclastic flows. At high temperature (up to 200 °C), overpressure during the first phase could overpass the bed lithostatic pressure. This suggested thermal pressurization of the cold air, which expanded rapidly when percolating through the hot material. We conclude that fluidization can be easily achieved for hot, fine-grained mixtures such as pyroclastic flows.

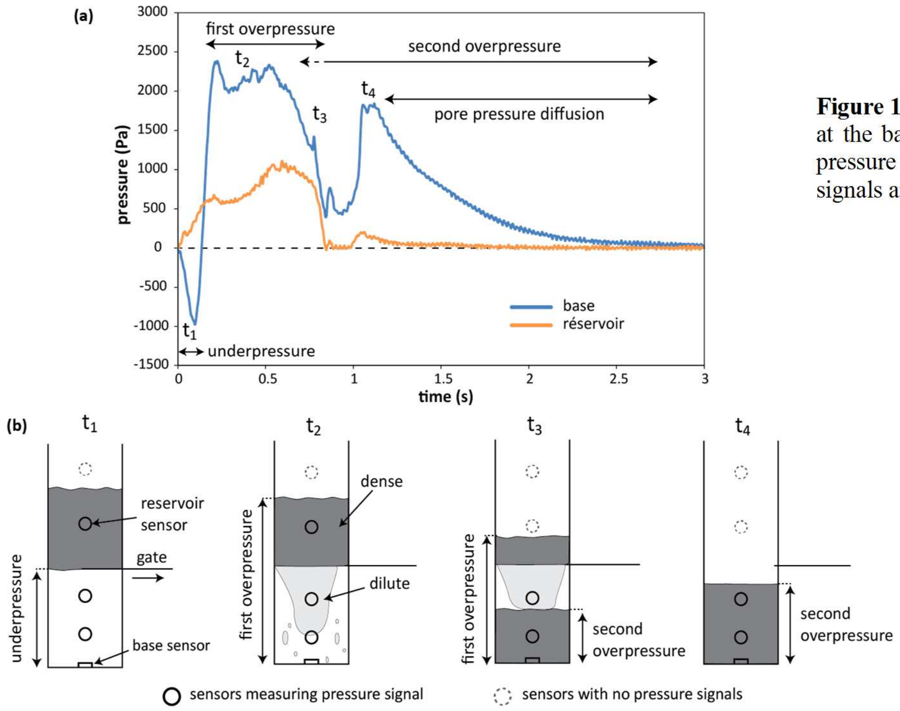

Figure 1. (a) Typical pressure signals measured at the base and in the reservoir, and principal pressure phases (b) Relation between pressure signals and position of particles in the column

Références

Chedeville, C., and O. Roche (2014), Autofluidization of pyroclastic flows propagating on rough substrates as shown by laboratory experiments, J. Geophys. Res. Solid Earth, 119, 1764–1776, doi:10.1002/2013JB010554