EXPERIMENTS ON ENTRAINMENT OF A GRANULAR SUBSTRATE BY PYROCLASTIC FLOWS AND IMPLICATIONS FOR THE PEACH SPRING TUFF SUPER-ERUPTION (USA)

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Pyroclastic flows are ground hugging gas-particle mixtures generated during volcanic eruptions. The most voluminous flows are produced by super-eruptions associated with caldera collapse. They are characterized by long run-out distances >100 km on relatively horizontal topographies and form deposits of volume typically >500-1000 km^3. Such pyroclastic flows often entrain large blocks of size of 0.5-1 m from the underlying substrate, which is likely to give insights into the flow dynamics. The entrainment mechanisms of these blocks are poorly understood. We studied the emplacement mechanisms of pyroclastic flows on a granular substrate through laboratory experiments of dense gas-particle flows generated by sudden (dam-break) release of a granular material fluidized in a reservoir and that propagated over a horizontal granular layer of particles in a channel (Fig. 1). The particles were fine glass beads of diameter d=80 µm, which conferred a hydraulic permeability of ~10^{-11} m^2 to the mixture. The low permeability permitted slow diffusion of the interstitial pore-fluid pressure during flow so that the dense mixture propagated in a fluid-like state. The granular substrate consisted of a horizontal layer of coarse steel beads of size d=1500-1590 µm. Experiments filmed at 500-1000 frames/s showed how the large beads were entrained from the granular substrate by the dense gas-particle flow (Fig. 1). Most of the uppermost substrate beads were first surrounded by the fine flow particles, extracted from the substrate, and then dragged slowly at flow base. Many of the dragged beads were uplifted into the flow at a critical velocity [1], to a height up to ~6-8 mm, and were transported downstream. These beads finally settled at flow base and stopped moving at the same time as the granular flow, at height up to ~4-5 mm above the original top of the substrate. We combined our experimental results with the model of [1] to investigate the mechanisms of the pyroclastic flows that formed the >1300 km^3 Peach Spring Tuff (western USA) during the ~18.8 Ma Silver Creek caldera super-eruption, which travelled as far as ~175 km from the eruptive center [2-3]. The Peach Spring Tuff contains substrate-derived blocks up to ~70-90 cm that were entrained along the flow paths by the pyroclastic flows over distances of tens to a several hundreds of meters. Application of the model of [1] suggests that the basal part of the pyroclastic flows had high particle concentrations and that entrainment of the largest substrate blocks required a relatively uniform and modest speed of ~5-20 m/s, which corresponds to a maximum discharge rate of ~10^7-10^8 m^3/s (or ~10^{10}-10^{11} kg/s) for a minimum of 2-8 hours. These rates are two to three orders of magnitude higher than those of the 1991 Mount Pinatubo and the AD 79 Vesuvius eruptions, but are similar to those of other caldera-forming eruptions such as Tambora (~75 ka) and Taupo (~1.8 ka). These results provide new insights into the emplacement dynamics of pyroclastic flows produced by super-eruptions.

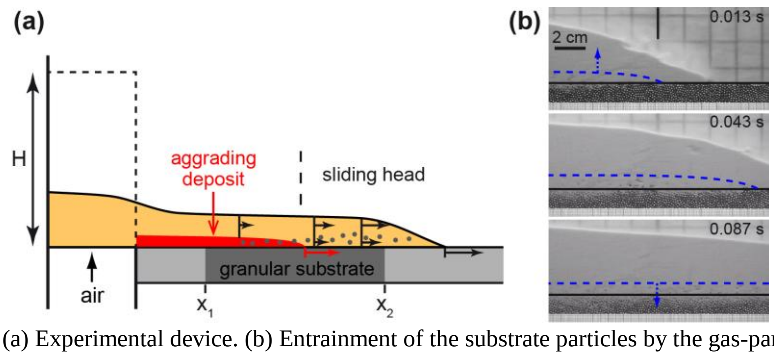

Figure 1. (a) Experimental device. (b) Entrainment of the substrate particles by the gas-particle flow.

References

[1] Roche O. , Y. Niño, A. Mangeney, B. Brand, N. Pollock, G. Valentine, *Dynamic pore pressure variations induce substrate erosion by pyroclastic flows*, Geology **41**, 1107-1110 (2013).
[2] G.A. Valentine, D.C. Buesch, R.V. Fisher, *Basal layered deposits of the Peach Springs Tuff, northwestern Arizona, USA*, Bull. Volcanol. **51**, 395-414 (1989).
[3] D.C. Buesch, *Incorporation and redistribution of locally derived lithic fragments within a pyroclastic flow*, Geol. Soc. Am. Bull. **104**, 1178-1193 (1992).