Dynamic pore-pressure variations induce substrate erosion by pyroclastic flows

O. Roche [1], Y. Niño [2], A. Mangeney [3], B. Brand [4], N. Pollock [5] and G.A. Valentine [6]

[1] Laboratoire Magmas et Volcans, Université Blaise Pascal, CNRS UMR6524, IRD R163, 5 rue Kessler, F-63038 Clermont-Ferrand, France, [2] Department of Civil Engineering and Advanced Mining Technology Center, University of Chile, Av. Blanco Encalada 2002, Casilla 228-3, Santiago, Chile, [3] Institut de Physique du Globe de Paris, Sorbonne Paris Cité, Université Paris Diderot, UMR 7154, 1 rue Jussieu, 75238 Paris cedex 05, France, [4] Department of Geosciences, Boise State University, 1910 University Drive, Boise, Idaho 83725-1535, USA, [5] Department of Earth and Space Sciences, University of Washington, 4000 15th Avenue NE, Seattle, Washington 98195-1310, USA, [6] Department of Geology and Center for Geohazards Studies, University at Buffalo, 411 Cooke Hall, Buffalo, New York 14260-1350, USA

Abstract

Field evidence shows that pyroclastic flows can entrain blocks from underlying substrates formed by earlier geological events, yet, counterintuitively, they are less likely to erode unconsolidated layers of fine particles. Here we report laboratory experiments that reproduce these seemingly contradictory observations and also offer a means to infer pyroclastic flow velocity. Experiments demonstrate that the sliding head of a granular flow generates a dynamic upward pore-pressure gradient at the flow-substrate interface. Associated upward air flux is enough to fluidize a substrate of fines, so that particles are not entrained individually but the substrate instead is subject to small shear instabilities. In contrast, coarse particles forming a non-fluidized substrate are lifted at a critical upward force due to the pore-pressure gradient, according to their individual masses, which provides a basis for a model to calculate the flow velocity. Application to the 18 May 1980 pyroclastic flow deposits at Mount St. Helens (Washington State, USA) gives velocities of $\sim$9–13 m s^{-1} at $\sim$6–7 km from the vent on gentle slopes (<4°–6°), in agreement with field observations at this volcano and at others.

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