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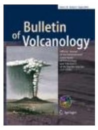

Pyroclastic flow erosion and bulking processes: comparing field-based vs. modeling results at Tungurahua volcano, Ecuador

Julien Bernard [1, 2, 3], Karim Kelfoun [1, 2, 3], Jean-Luc Le Pennec [1, 2, 3], Silvia Vallejo Vargas [4]

1. Clermont Université, Université Blaise Pascal, Laboratoire Magmas et Volcans, Clermont-Ferrand, France
2. CNRS, UMR 6524, LMV, Clermont-Ferrand, France
3. IRD, R 163, LMV, Clermont-Ferrand, France
4. Instituto Geofísico, Escuela Politécnica Nacional, Quito, Ecuador

Abstract

Pyroclastic density currents (PDCs) are high-temperature and high-velocity mixtures that threaten populations in the vicinity of many active volcanoes. Deciphering the cause of their remarkable mobility is essential for volcanic hazard analysis, but remains difficult because of the complex processes occurring within the flows. Here, we investigate the effect of bulking on dense PDC mobility by means of a double approach. First, we estimate the amount of material incorporated into scoria flows emplaced during the August 2006 eruption of Tungurahua volcano, Ecuador. For this, we carry out a detailed analysis of 3D-corrected digital images of well-exposed scoria flow deposits. Componentry analysis indicates that PDC bulking occurs principally on the steep (>25°) upper slope of the volcano, and the deposits typically comprise 40–50 wt% of non-juvenile (i.e., accessory and accidental) material. Secondly, we develop a simple stress-related grain-by-grain equation of erosion combined with two simple depth-averaged geophysical mass-flow models that compare the bulking mechanism to a non-fluidized and a fluidized flow. Two behaviors based on Coulomb and plastic rheologies are used to reproduce, on a first order basis, the 2006 Tungurahua PDCs. Cross-check comparisons between these modeled cases and the erosion pattern inferred from field-based data allow us to evaluate the accuracy of our modeling assumptions. Regardless of the rheological regime, the PDC-induced erosion pattern of the 2006 Tungurahua eruption can only be reproduced by fluctuations of the flow's basal shear stress during emplacement. Such variations are controlled by flow thinning-thickening processes, notably through the formation of a thick non-erosive flow body that pushes a thin frictional erosive front during PDC emplacement. The input volume of juvenile material, as well as the thickness of the erodible layer available prior to the eruption, are additional key parameters. Our work highlights complexities in PDC erosion and bulking processes that deserve further study. In terms of hazard assessment, our findings reveal that incorporation and bulking translate into increased flow mobility, i.e., the augmented flow mass enhances both flow velocity and runout distance (up to 20 %). These outcomes should be considered closely for hazard analysis at many other andesitic volcanoes worldwide where similar PDC events are common.

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