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What factors control the superficial lava dome explosivity?

Georges Boudon (1), Hélène Balcone-Boissard (2,3), Benoit Villemant (2,3), and Daniel J. Morgan (4)

(1) Institut de Physique du Globe de Paris, Sorbonne Paris Cité, Université Paris Diderot, UMR 7154 CNRS, 1, rue Jussieu, 75238 Paris, France , (2) Sorbonne Universités, UPMC Univ. Paris 06, UMR 7193, ISTEP, F-75005, Paris, France., (3) CNRS, UMR 7193, ISTEP, F- 75005, Paris, France, (4) Institute of Geophysics and Tectonics, School of Earth & Environment, University of Leeds, Leeds, LS2 9JT UK.

Dome-forming eruption is a frequent eruptive style; lava domes result from intermittent, slow extrusion of viscous lava. Most dome-forming eruptions produce highly microcrystallized and highly- to almost totally-degassed magmas which have a low explosive potential. During lava dome growth, recurrent collapses of unstable parts are the main destructive process of the lava dome, generating concentrated pyroclastic density currents (C-PDC) channelized in valleys. These C-PDC have a high, but localized, damage potential that largely depends on the collapsed volume. Sometimes, a dilute ash cloud surge develops at the top of the concentrated flow with an increased destructive effect because it may overflow ridges and affect larger areas. In some cases, large lava dome collapses can induce a depressurization of the magma within the conduit, leading to vulcanian explosions. By contrast, violent, laterally directed, explosions may occur at the base of a growing lava dome: this activity generates dilute and turbulent, highly-destructive, pyroclastic density currents (D-PDC), with a high velocity and propagation poorly dependent on the topography. Numerous studies on lava dome behaviors exist, but the triggering of lava dome explosions is poorly understood.

Here, seven dome-forming eruptions are investigated: in the Lesser Antilles arc: Montagne Pelée, Martinique (1902-1905, 1929-1932 and 650 y. BP eruptions), Soufrière Hills, Montserrat; in Guatemala, Santiaguito (1929 eruption); in La Chaîne des Puys, France (Puy de Dome and Puy Chopine eruptions).

We propose a new model of superficial lava-dome explosivity based upon a textural and geochemical study (vesicularity, microcrystallinity, cristobalite distribution, residual water contents, crystal transit times) of clasts produced by these key eruptions. Superficial explosion of a growing lava dome may be promoted through porosity reduction caused by both vesicle flattening due to gas escape and syn-eruptive cristobalite precipitation. Both processes generate an impermeable and rigid carapace allowing overpressurisation of the inner parts of the lava dome by the rapid input of vesiculated magma batches. The thickness of the cristobalite-rich carapace is an inverse function of the external lava dome surface area. Thus the probability of a superficial lava dome explosion inversely depends on its size; explosive activity more likely occurs at the onset of the lava dome extrusion in agreement with observations. We evidence a two-step process in magma ascent with edification of the lava dome that may be accompanied by a rapid ascent of an undegassed batch of magma some days prior the explosive activity. This new result is of interest for the whole volcanological community and for risk management.