The effect of pre-existing craters on the initial development of explosive volcanic eruptions: an experimental investigation

Jacopo Taddeucci[1], Greg A. Valentine[2], Ingo Sonder[2], James D.L. White[3], Pierre-Simon Ross[4], Piergiorgio Scarlato[1]

[1]HP-HT Lab, Istituto Nazionale di geofisica e Vulcanologia, Italy, [2]Department of Geology and Center for Geohazards Studies, University at Buffalo, USA, [3]Geology Department, University of Otago, New Zealand, [4]Institut national de la recherche scientifique (INRS), centre Eau Terre Environnement (ETE), Canada

E-mail: taddeucci@ingv.it

Most volcanic eruptions occur in craters formed by previous activity. The presence of a crater implies specific confinement geometries, variably filled by loose fragmental deposits, which are expected to exert a strong, yet poorly studied, control on the violent gas expansion that drives the eruption. Here we analyze patterns of ejection from buried explosions in analog experiments, in order to investigate how the presence of a crater and changes in explosion depth and intensity may affect the formation of eruptive ejecta jets. Different explosive charges were detonated at variable depth in prepared pads of granular material, resulting in variable scaled depth (charge burial depth divided by the cubic root of charge energy). Explosions were filmed at 600 frames per second, and video analysis provided information on: 1) jet morphology and evolution; 2) jet vertical speed; 3) jet spread angle. Results show that explosions with progressively smaller scaled depth produced exponentially faster-growing jets with linearly larger spread angles. Deeper scaled depth explosions are marked by more-complex jets, featuring a central, narrower, faster portion that pierces upward through a larger, slower annulus having a stronger component of lateral expansion. For a fixed scaled depth, the pattern of expansion of the jet seems to be largely controlled by the initial presence of a crater, which limits the development of a laterally expanding annulus.

The relationship between jet velocity and scaled depth holds true independently of the presence of a pre-existing crater infill, while jet spread angle shows, overprinted on a major control exerted by scaled depth, also an effect of the presence of a crater. Finally, the presence of a crater around the explosion site does exert a strong control on the expansion pattern of the jet. The complex development of explosions with both a vertically-expanding central core and a peripheral, lateral expanding annulus seems promising for characterizing the intra-crater evolution of an eruption. This distinction has also implications for both hazard assessments and for investigations of eruptive products. The vertical core and radial annulus could be associated with the formation of buoyant jets and ballistic showers, and dilute pyroclastic density currents, respectively. Since the radial annulus tends to be inhibited by the presence of a relatively deep crater, this could promote a decrease in the occurrence of coarse-grained pyroclastic surges (and their deposits) extending beyond a crater as an eruption and the respective crater evolve over time. Conversely, the fallback of a vertically-focused jet could trigger a fine-grained pyroclastic surge, potentially leaving fine-grained, bedded deposits.