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Stability of volcanic conduits: insights from magma ascent modelling and possible consequences on eruptive dynamics

Alvaro Aravena (1), Mattia de' Michieli Vitturi (2), Raffaello Cioni (1), and Augusto Neri (2)

(1) Dipartimento di Scienze della Terra, Università di Firenze, Florence, Italy, (2) Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy

Geological evidences of changes in volcanic conduit geometry (i.e. erosive processes) are common in the volcanic record, as revealed by the occurrence of lithic fragments in most pyroclastic deposits. However, the controlling factors of conduit enlargement mechanisms are still partially unclear, as well as the influence of conduit geometry in the eruptive dynamics. Despite physical models have been systematically used for studying volcanic conduits, their mechanical stability has been poorly addressed.

In order to study the mechanical stability of volcanic conduits during explosive eruptions, we present a 1D steady-state model which considers the main processes experimented by ascending magmas, such as crystallization, drag forces, fragmentation, outgassing and degassing; and the application of the Mogi-Coulomb collapse criterion, using a set of constitutive equations for studying typical cases of rhyolitic and trachytic explosive volcanism.

From our results emerge that conduit stability is mainly controlled by magma rheology and conduit dimensions. Indeed, in order to be stable, feeding conduits of rhyolitic eruptions need larger radii respect to their trachytic counterparts, which is manifested in the higher eruption rates usually observed in rhyolitic explosive eruptions, as confirmed by a small compilation of global data. Additionally, for both magma compositions, we estimated a minimum magma flux for developing stable conduits ($\sim 3 \cdot 10^6$ kg/s for trachytic magmas and $\sim 8 \cdot 10^7$ kg/s for rhyolitic magmas), which is consistent with the unsteady character commonly observed in low-mass flux events (e.g. sub-Plinian eruptions), which would be produced by episodic collapse events of the volcanic conduit, opposite to the mainly stationary high-mass flux events (e.g. Plinian eruptions), characterized by stable conduits.

For a given magma composition, a minimum radius for reaching stable conditions can be computed, as a function of inlet overpressure and water content. Under the assumption that magma chamber conditions during a typical volcanic eruption follow a depressurizing trend, a continuous conduit widening process is expected. This process could explain the pervasive and continuous presence of lithic fragments in most pyroclastic deposits, even with stationary properties and conditions of the magma source (e.g. water content, temperature, composition).