Simulating the Dynamics of Volcanic Columns: a New Challenge in Volcanology

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Since the middle of the 70s volcanologists have successfully tried to describe the origin of volcanic deposits and complexities of volcanic eruptions on the basis of physical transport laws. First, simple one-dimensional steady-state and homogeneous flow models were used to investigate the different eruptive mechanisms of explosive eruptions as well as the relationships between eruptive style and magmatic conditions. Similar models were developed to describe the fallout of pyroclastic particles from the umbrella region of a buoyant convective column and to study the emplacement and propagation of pyroclastic density currents produced by the collapse of the column. These models were able to capture the main processes controlling the explosive phenomena and still remain a useful tool for a first-order analysis of volcanic sequences.

Based on this fundamental understanding, about 10 years later, the development of the first numerical 2D two-phase flow models indeed started the age of numerical simulation of volcanic processes. New and fundamental features of magma chamber chemical evolution and withdrawal, country rock deformation, magma ascent dynamics, and pyroclastic dispersal into the atmosphere and along the volcano slopes were predicted and compared with direct observations. Despite a large number of limitations, it was shortly clear the added value of this new generation of models. Nowadays, at the beginning of the third millennium, the development of transient, 3D, multiphase flow models using state-of-the-art formulations of the underlying physics, new-generation experimental data, and high-performance numerical techniques, represents a new opportunity and challenge for modern volcanology. In the coming decades, these models will likely contribute to the solution of unresolved problems of the physics of explosive eruptions as well as to a more accurate assessment of their hazard. However, such an opportunity appears to be strictly tied to our capacity to validate the physico-mathematical models developed. In turn, this capacity will mostly depend on the production of reliable transport and constitutive equations of the magmatic mixture through ad hoc laboratory experiments as well as on the collection of accurate quantitative measurements of the ongoing eruptive phenomena.