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Simulation of the Etna 2001 flank eruption with a steady-state numerical model of magma ascent

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Volcanoes exhibit a wide range of eruption styles, from relatively slow effusive eruptions, generating lava flows and lava domes, to explosive eruptions, in which very large volumes of fragmented magma and volcanic gas are ejected high into the atmosphere. Magma ascent dynamics in a volcanic conduit play a key role in determining the eruptive style of a volcano. However, due to the lack of direct observations in the conduit itself, numerical models, constrained with observational data, provide invaluable tools for quantitative insights into the complex magma ascent processes.

We have developed a 1D steady-state multiphase multicomponent gas-magma-solid mathematical model, consisting of a set of non-linear partial differential and constitutive equations. The governing equations used in this work are designed to model multiphase fluid with disequilibrium processes, represented through the formalism of thermodynamically compatible hyperbolic systems as a system of conservative partial differential equations with relaxation terms.

This numerical model has been used to reproduce the 2001 flank eruption at mount Etna. During this eruption, seven fissures at different altitude were active, showing different eruptive styles: fire fountains, Strombolian activities and lava effusions. From a mineralogical point of view, two different lavas were erupted. The vent higher than 2600 m a.s.l. (hereafter Upper vents, UV) erupted plagioclase-rich magma with an high crystal content. On the other hand, the vents located at 2550 and 2100 m a.s.l. (hereafter Lower vents, LV) produced a plagioclase-poor magma with a lower crystal content than UV magmas. With our numerical model we have investigated both eruptive events at UV and LV. Using the estimation for volume flow rate and for crystal content we are able to constraint the conduit radius and the temperature of the magma chamber. Furthermore, our numerical results indicate that UV and LV magmas are originated from the same magma, but with a different time available for crystallization. Our data show that LV magma is erupted before the crystals reach an equilibrium profile, while for UV the equilibrium is achieved. These conclusion are consistent with the presence of a shallow sill below UV where magma can circulate and reach the equilibrium crystal content, while for LV activities, magma ascends vertically without having enough time to completely crystallize.