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Application of a new multiphase multicomponent volcanic conduit model with magma degassing and crystallization to Stromboli volcano.

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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. During an eruption, much information regarding the magma ascent dynamics can be gathered: melt and exsolved gas composition, crystal content, mass flow rate and ballistic velocities, to name just a few. Due to the lack of direct observations of the conduit itself, mathematical models for magma ascent provide invaluable tools for a better comprehension of the system. The complexity of the multiphase multicomponent gas-magma-solid system is reflected in the corresponding mathematical model; a set of non-linear hyperbolic partial differential and constitutive equations, which describe the physical system, has to be formulated and solved. The standard approach to derive governing equations for two-phase flow is based on averaging procedures, which leads to a system of governing equations in the form of mass, momentum and energy balance laws for each phase coupled with algebraic and differential source terms which represent phase interactions. For this work, we used the model presented by de' Michieli Vitturi et al. (EGU General Assembly Conference Abstracts, 2013), where a different approach based on the theory of thermodynamically compatible systems has been adopted to write the governing multiphase equations for two-phase compressible flow (with two velocities and two pressures) in the form of a conservative hyperbolic system of partial differential equations, coupled with non-differential source terms. Here, in order to better describe the multicomponent nature of the system, we extended the model adding several transport equations to the system for different crystal components and different gas species, and implementing appropriate equations of state. The constitutive equations of the model are chosen to reproduce both effusive and explosive eruptive activities at Stromboli volcano. Three different crystal components (olivine, pyroxene and feldspar) and two different gas species (water and carbon dioxide) are taken into account. The equilibrium profiles of crystallization as function of pressure, temperature and water content are modeled using the numerical codes AlphaMELTS and DAKOTA. The equilibrium of dissolved gas content, instead, is obtained using a non-linear fitting of data computed using VolatileCALC. With these data, we simulate numerically the lava effusion that occurred at Stromboli between 27 February and 2 April 2007, and find good agreement with the observed data (vesicularity, exsolved gas composition, crystal content and mass flow rate) at the vent. We find that the model is highly sensitive to input magma temperature, going from effusive to explosive eruption with temperature changes by just 20 °C. We thoroughly investigated through a sensitivity analysis the control of the temperature of magma chamber and of the radius of the conduit on the mass flow rate, obtaining also a set of admissible temperatures and conduit radii that produce results in agreement with the real observations.