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Nonlinear dynamics of magma flows in conduits

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Dynamics of magma flows in volcanic conduits are strongly nonlinear because of some important processes, often neglected, such as viscosity changes due to variations of temperature, crystal fraction and water content or coupling with wall-rock deformation. Crystallization of microlites and gas loss through permeable flows are time-dependent processes that can introduce strong feedback mechanisms which greatly amplify the effect on extrusion rates of small changes of chamber pressure, conduit dimensions or magma viscosity. When timescales for magma ascent are comparable to timescales for crystallization, there can be multiple steady solutions. Such nonlinear dynamics can cause large changes in dome extrusion rate and pulsatory behaviour of dome growth. Time scales of this kind of ciclicity are also affected by wall-rock elasticity. Two distinct periods can be associated to the elastic deformation of both magma chamber and dyke walls. Thermal coupling play also a crucial role in the dynamics of magma rise because can lead to significant viscosity stratifications due to temperature gradients produced across and along the conduit. In order to capture these effects mass, momentum and energy equations for magma flow inside a cylindrical conduit need to be coupled with the heat conduction equation in the surrounding host rocks with far-field conditions for rocks temperature. Simulation results show that both viscous dissipation and heat loss to the conduit walls have a pivotal role on magma dynamics allowing to distinguish three regimes: i) a conductive-heat-loss-dominated regime, ii) an intermediate regime, and iii) a viscous-heating-dominated regime. Finally, explosive volcanic eruptions have hitherto been largely interpreted in terms of multiphase flows through rigid conduits of a fixed cross-section, ranging from cylinders to parallel-sided conduits to simulate dykes. More realistic situations in which the explosive flows occur along dykes, taking into account wall rock elasticity showed major differences to results for rigid conduits, implying new processes and phenomena that affect the evolution of explosive eruptions. Dyke flows show very large deformation due to under-pressures in respect to lithostatic at the vicinity of fragmentation level where conduit significantly narrows or even closes. The role of an extensional far-field stress is also discussed.