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Influence of dyke geometry on the dynamics of magma flow and associated ground displacement and seismic signals

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Detecting underground magma movement in dykes is of primary importance for the evaluation of the short term hazard at active volcanoes, especially those characterized by frequent eccentric eruptions like Mount Etna (Sicily), Kilauea and Mauna Loa (Hawaii), Nyamulagira and Nyiragongo (D.R.C.), Piton de la Fournaise (Reunion), and many others in the world. Fluid motion is often accompanied by distinctive low frequency seismic signals, the characteristics of which relate in complex ways to several characteristics of the volcanic system including the geometry of the crack through which fluid motion takes place, the viscosity and the flow regime of the fluid, the elastic properties and heterogeneities of the rock system, and so on. We have undertaken a numerical simulation study to investigate the control exerted by dyke geometry on the magma flow dynamics and associated ground displacement and seismic signals. Magma flow dynamics are simulated through the code GALES (Longo et al., 2006), which solves the 2D transient dynamics of multi-component fluids in compressible to incompressible regimes. The simulated system is represented by volcanic dykes having different geometries from vertical with smooth walls to inclined with protrusions and indentations. Fluid flow is allowed to occur by considering an initial gravitationally unstable condition with CO2-rich, lighter magma placed below a CO2-poor, denser magma. Both natural convection and forced convection (with prescribed overpressure applied at dyke base) are taken into account. The output of GALES in terms of time-space stress distribution at the fluid-rock interface is employed as the boundary condition for the simulation of elastic wave propagation in the surrounding rock system. This is done by employing a numerical code based on a discrete elastic lattice method (O'Brien and Bean, 2004) which accounts for complex topography and rock heterogeneities. The numerical results illustrate the complex time-space-dependent dynamics of magma convection and mixing in dykes and the important control on them exerted by dyke geometry, and show the basic characteristics, in terms of spectral amplitude, of the associated ground displacement signal expected at the surface. The present study and approach helps understand the relationships between seismicity and magma movement, and can be used as a tool for the evaluation of the short term hazard at active volcanoes.