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Development of a 3D numerical model to evaluate the Stromboli NW flank instability in relation to magma intrusion

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A stress-strain analysis of the Stromboli volcano was performed using a three-dimensional explicit finite difference numerical code (FLAC 3D, ITASCA, 2005), to evaluate the effects associated to the presence of magma pressure in magmatic conduit and to foresee the evolution of the magmatic feeding complex. The simulations considered both the ordinary state for the Stromboli, characterized by a partial fill of the active dyke with regular emission of gas and lava fountains and the paroxysmal conditions observed during the March 2007's eruptive crisis, with the magma level in the active dyke reaching the topographic surface along the Sciara del Fuoco depression. The modeling contributes to identify the most probable directions of propagation of new dikes, and the effects of their propagation on the stability of the volcano edifice.

The numerical model extends 6 x 6 x 2.6 km3, with a mesh resolution of 100 m, adjusting the grid to fit the shape of the object to be modeled.

An elasto-plastic constitutive law was adopted and an homogeneous Mohr-Coulomb strength criterion was chosen for the volcanic cone, assuming one lithotechnical unit (alternation of lava and breccia layers "lava-breccia unit"- Apuani et al 2005). The dykes are represented as discontinuities of the grid, and are modeled by means of interfaces. The magmatic pressure is imposed to the model as normal pressure applied on both sides of the interfaces. The magmastatic pressure was calculated as Pm=d•h, where d is the magma unit weight assumed equal to 25 KN/m3, and h (m) is the height of the magma column. Values of overpressure between 0 and 1 MPa were added to simulate the paroxysmal eruption.

The simulation was implemented in successive stages, assuming the results of the previous stages as condition for the next one. A progressive propagation of the dike was simulated, in accordance with the stress conditions identified step by step, and in accordance with the evidences detected by in situ survey, and by means of the National Institute for Geophysics and Volcanology (INGV)-National Civil Protection Department (DPC), monitoring system.

The results are expressed in terms of deformations and shear strain increments. The much unstable portion of the Sciara depression is evidenced by the highest value of the shear strain increments and is located on its upper right portion. The strain distribution is coherent with the ground motion recorded by the GB-InSAR monitoring system installed by the University of Florence thanks to the INGV-DPC 2004-2006 research program. Superficial displacements of metric amount are developed in this sector and indicate local instability, but are not sufficient to expect deep seated collapse of the volcano's flanks.

A mechanism for sub horizontal sill intrusion starting from a vertical dike was proposed, and modelled, to explain the formation of the eruptive vent appeared on the Sciara slope at an altitude of about 400 meters a.s.l.. The results indicate an highly stressed and disturbed band extended transversally to the Sciara at the same elevation; furthermore the maximum value of the shear strain increments is located in correspondence with the actual position of the eruptive vents.

The obtained results are very coherent with the field evidences, and could represent one possible explanation of the observed 2007 events.