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Thermo-mechanical modelling of gravity-induced deformations affecting the volcanic slopes of a resurgent caldera at Ischia Island (Italy)

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Volcanic islands commonly testify the strict relation between volcano-tectonic activity and slope instability as very recently testified by the flank collapse of the Anak Krakatau active volcano which induced the destructive tsunami on 23 December 2018. The island of Ischia (Italy), which is part of the Phlegrean Volcanic District, has experienced since the Holocene several slope scale instabilities (i.e. debris- and rock avalanches). The latter occurred as direct consequence or feedback of a rapid caldera resurgence and associated seismicity and/or renewal of hydrothermal and magmatic systems. An ongoing slope-scale gravitational deformation process still affects large volumes of a thick greenish alkali-trachytic tuff sequence (the Mt. Epomeo Green Tuff - MEGT -) cropping out on the western flank of Mt. Epomeo (Mt. Nuovo), that represents the remnant of the caldera's most uplifted sector. The rock mass affected by ongoing deformation mobilized along a structurally controlled biplanar compound shear zone.

In order to assess the relations and the possible interactions between the ongoing gravitational deformation and the hydrothermal system beneath the island, thermal and thermo-mechanical models of deep geothermal and slope systems were respectively reconstructed. Based on available geomechanical and petrophysical characterization under relevant temperature and pressure conditions, as well as on literature wells' geothermal profiles, a 2D thermo-mechanical model of the Mt. Nuovo slope was designed. A numerical model was computed along a section crossing the Mt. Nuovo slope, where ongoing deformation is testified by geomorphic evidence. The model was validated adopting an uncoupled thermal and mechanical numerical solution, back-analyzing the ongoing slope-scale gravitational process.

The outcomes highlight the main role of Mass Rock Creep (MRC) in the onset of the slope instability, suggesting the interactions with the geothermal field in modifying the stress-strain response of the slope, which is able to alter its short- and long-term gravitational equilibrium.

Thermo-baric field induced by hydrothermal rejuvenation can interact with the slope equilibrium causing the mechanical weakening of the compactant (i.e. ductile) MEGT tuff as consequence of transient exposure to high thermal perturbations, therefore increasing the rate of slope deformation. The thermo-mechanical numerical models, once constrained by geomorphic evidence and monitoring data, can be adopted for defining future scenarios (i.e. forward modelling) resulting by variation of physical conditions and/or mechanical parameters of the rock masses involved in the gravity-induced slope deformations. Through these forward analyses is possible to depict the worst physical conditions leading to ultimate paroxysmal events consisting in a generalised and catastrophic slope failure.