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Stability of unsaturated pyroclastic deposits at La Fossa flank (Vulcano Island, Italy): Do soil suction variations establish a link with crater degassing ?

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The stability of steep ($> 40^{\circ}$) slopes in loose or poorly cemented pyroclastic materials mantling some of the Italian mountain areas is guaranteed by the positive effects of matrix suction on shear strength until an increase in saturation (and hence a decrease in suction) occurs. Therefore, unsaturated cohesionless or slightly-bonded pyroclastic steep deposits are relatively stable. Slope instability, initiated by wetting, can occur through different processes, such as vapor condensation and, most typically, rainfall infiltration. The main effect is the decrease in suction up to possible development of positive pore pressures. Here, we examine the peculiar case of a landslide on the flank of the pyroclastic cone of La Fossa volcanic edifice in Vulcano Island (Aeolian Archipelago, Southern Italy). Its initiation is believed to have been influenced by a sharp increase in condensed vapor produced by the degassing of the active volcano. In active volcanoes hydraulic conditions are affected not only by infiltrating rainwater but also by volcanic activity, which produces complex changes in the state variables of pore fluids (i.e. pore fluid pressure). In particular, volcanic activity can modify pore fluid pressure as far as to induce slope instability.
At La Fossa crater the phenomenon was evidenced by in situ monitoring of soil suction and soil temperature. In situ observations and measurements indicate that seepage of condensed vapor is appreciable. Simple models based on the geotechnical characterization of pyroclastic materials suggest the hypothesis that variations in suction can be significant to stability of volcano slopes when these are very close to limit conditions and if material hydraulic anisotropy is considered. Noteworthy, at La Fossa at Vulcano Island steam condensation increased and variations of chemical ratios at fumaloles occurred while large slope movements developed on the NE flank of the cone during the most intense well documented volcanic unrest.
The validation of this hypothesis requires further monitoring data during periods of intense unrest and more comprehensive models that account for non-isothermal multiphase pore fluid pressure and groundwater circulation, influencing the state of stress and hence stability. Our in-progress approach points toward a correlation between degassing activity of the hydrothermal-magmatic system and slope movements, that may bear significant implications for the definition of the scenarios of joint volcanic-hydrogeological hazard and for the development of monitoring techniques in the frame of volcanic surveillance. However, much more efforts are needed to establish phenomenological relationships with the budgets of volcanic steam condensation. This should include extensive field measurement of CO_2 and thermal fluxes from the soil, as well as electrical measurements.