Research programme on volcano-tectonics

Liquefaction hazard in the Campi Flegrei caldera

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Liquefaction is often interpreted as seismically-induced, during which saturated sands become fluid-like as a consequence of the abrupt increase of the pore-water pressure, thereby reducing the rigidity of loose sediments to zero. The loss of the ground strength can trigger landslides and, in inhabited areas, can cause buildings tilt and damage, and destroy roadways and pipelines. Generally, the most spectacular liquefaction effects are related to high-magnitude earthquakes (Ms>6.5; for example, the earthquakes of Nijgata, 1964, Kobe, 1995, Izmit, 1999 and Canterbury 2010-2011). However, evidence of soil liquefaction processes also occurs in association with moderate seismic magnitudes (Ms≥ 4.2). The liquefaction/fluidification process, typical at the mesoscale, causes the formation of (i) intrusions of fluidized sands in fractures crosscutting undeformed strata (clastic dikes) and (ii) sand volcanoes and blows along planar fissures. Other seismically induced soft-sediment deformations (SSDs) are load structures and slumps frequently hosting minor thrust and normal faults, mainly recorded in coastal, deltaic and turbidite settings, but also in flat-lying layers such as lacustrine sediments. Although seismically induced sand dikes and slumps are commonly observed within the geological record, examples of paleo-sand volcanoes are very limited. These features are useful for improving the paleoseismological record, especially in areas of low to moderate seismic activity. Recently Vitale et al. (2019) report, for the first time, evidence of seismically induced SSDs in the central area of the active Campi Flegrei caldera (southern Italy). These structures were observed within the marine-transitional and continental sequences located along the coastal La Starza cliffs and several stratigraphic logs exposed during the excavation of a 1 km long tunnel in the Pozzuoli area. The successions host several soft-sediment structures including sand dikes and sand volcanoes, which are largely dated within the 4.55 - 4.28 kyr BP interval.

Unrest episodes which occurred during the last 15 kyr at CF caldera, were characterized by seismic activity and ground deformation consistent with that presently observed at CF caldera. Moreover, the evidence of liquefaction processes in the past can provide further insights into the future volcano-seismic activity. As indicated by the ERT survey provided in Vitale et al. (2019), most of La Starza sands are presently water-saturated. Hence, they are potentially liquefiable during a seismic shaking, with significant effects being closest to the coast, where the piezometric surface is closest to the ground surface. Furthermore, the occurrence of liquefaction structures during the unrest episode preceding the AVS eruptions (4.28 kyr BP) suggests that moderate earthquakes occurred in the past, which implies that the hazard of liquefaction has to be considered for future volcanic unrest scenarios at CF caldera.

Proposal for a Ph.D. position

The aim of the Ph.D. research consists of two main parts. The first one focuses on the reconstruction of liquefaction processes occurred in the past, through the study of SSD structures hosted in the marine-continental succession of the CF caldera. The second goal concerns the reconstruction of maps of liquefaction susceptibility for the present.

For the first part, the PhD student has to reconstruct the deformation history of the volcano in the last 15 kyr by means of a structural survey of the CF caldera, paying particular attention to the occurrence of SSD structures such as clastic dikes, sand volcanoes, slumps in lacustrine sediments and sand injections associated to the faults. This part is necessary to understand the role of the liquefaction in the past and highlight the occurrence of earthquakes able to trigger liquefaction processes. For the second part, the Ph.D. student has to reconstruct the subsurface geology of the area with particular attention to the spatial distribution of La Starza sands. This will be done by studying the available well logs. From the collected data he has to extract the information useful for defining the susceptibility to liquefaction, such as the depth of the water table and the depth and the thickness of layers characterized by prevailing sandy texture (sand, silty sand, clayey sand, gravelly sand). The information on the water table will be obtained directly from the analyzed geognostic data and/or from the hydrogeologic map of the CF caldera. The reconstruction of the stratigraphy at depth will be integrated with electrical resistivity tomography surveys. Different maps of liquefaction susceptibility will be provided, taking into account for the future scenarios of the ground deformation phenomenon (bradyseism) within the caldera by using mathematical models of magmatic/hydrothermal fluid intrusions.

Chronoprogramme

First year: a structural survey in the CF caldera and data gathering of SSD structures including attitudes, displacements, kinematics, crosscutting, and abutting relationships between structures and well-dated tephra in the last 15 kyr. Reconstruction of the deformation evolution of the CF caldera in the last 15 kyr. Reconstruction of maps of SSDs and eventual localization of paleo-earthquakes.

Second year: Analysis of the depth of the water table and the depth and the thickness of the La Starza marine/transitional deposits, by geognostic data and/or from the hydrogeologic map of the CF caldera and electrical resistivity tomography surveys. Reconstruction of maps of the water table and the depth and the thickness of the La Starza succession. Six months for the experience abroad.

Third year: reconstruction of different maps of liquefaction susceptibility, taking into account for the ground deformation within the caldera by using mathematical models of magmatic/hydrothermal intrusions.