Geophysical Research Abstracts
Vol. 15, EGU2013-8081, 2013
EGU General Assembly 2013

3D numerical modeling of an anthropogenic sinkhole in the Marsala area of western Sicily

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The Marsala area (western Sicily) is characterized by the presence of a Lower Pleistocene (Calabrian) calcarenite succession (Marsala Calcarenite Fm). It can be divided into three lithofacies that show the regressive evolution of the depositional system: a) coarse to fine yellow bio- and lithoclastic calcarenites, b) sands, and c) gray sandy clays. At least 80 m-thick, this succession gently dips (5-10°) towards the south and the south-west. Locally, the Marsala Calcarenite may be covered by Middle and Upper Pleistocene marine terraced deposits.
The town of Marsala presents several historical quarries for the extraction of this building material. Many of them were excavated underground, at depth ranging from a few meters to about 25 m, and are arranged in one or two levels, following the galleries and pillars excavation technique. With time, the underground quarries have been progressively abandoned due to the high costs of extraction, as well as to the dangers and difficulties encountered in working underground.
Since the 1960's the quarries, as a matter of fact, have been affected by several instability processes for the decay of the physical and mechanical properties of the calcarenite rock mass and the interaction with the groundwater. Such instability processes are represented by collapses and deformations of vaults and pillars. These phenomena often propagate upward reaching the topographic surface and forming sinkholes which may likely affect and severely damage the built-up areas above.
In particular, two case studies of sinkholes related to different underground quarries have been already described by the Authors in a previous contribution at EGU 2012, also integrated by a two-dimensional numerical study. The aim of the present work is to develop a three-dimensional numerical analysis aimed at describing the most significant processes and factors responsible of the instability processes, as well as to investigate the three-dimensional features of the same processes, based on rock laboratory testing data and a detailed reconstruction of the underground cave geometry. At this goal, we took advantage of detailed topographic surveys of the underground quarry, carried out before (year 2000) and after occurrence of one the sinkholes, that opened in July 2011 at the eastern sector of the town of Marsala, causing significant damage to a school. In the implementation of the 3D-model, the geomechanical survey of the calcarenite rock mass was also taken into account, as a required input layer depicting the main discontinuity systems, and their main features (pervasiveness, joint opening and spacing, etc.).
Relevant differences between the results from 2-D and 3-D analyses are pointed out in the paper, highlighting the need to perform 3D-modeling in order to define the real instability conditions of the rock mass, and to evaluate the possibility of sinkhole occurrence at the surface.