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Anthropogenic sinkholes in the Marsala area (western Sicily) linked to underground quarries

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Marsala territory (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. At some locations the Marsala Calcarenite is covered by Middle and Upper Pleistocene marine terraced deposits.
Since the Roman period, due to the great abundance of calcarenite rocks, and to the facility of extraction, the Marsala area has been characterized by a high number of quarries for the extraction of this building materials. Many of them were excavated underground, at depth varying 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 for the decay of the physical and mechanical properties of the calcarenite rock mass, the interaction with the groundwater, the high costs of extraction, and the dangers and difficulties encountered in working underground.
Since the 1960's the quarries have been affected by instability processes, visible through collapses and deformations of vaults and pillars. These phenomena often propagate upward reaching the topographic surface and forming sinkholes which affect and severely damage the built-up area.
In particular, two case studies of sinkholes related to different underground quarries will be analyzed in this paper. The aim is to provide a description of the most significant processes and factors responsible of the instability processes based on field surveys, as well as to understand the generation mechanisms of these anthropogenic sinkholes by means of numerical modeling, based on rock laboratory testing data, that represents in these cases a remarkable tool for the investigation of the cause-effect relationships, as already performed in other areas of Italy.