



## **Influence of stratigraphic factors on the failure mechanisms of sinkholes related to man-made underground caves at Cutrofiano (South-Eastern Italy)**

Piernicola Lollino (1), Stefano Margiotta (2), and Mario Parise (1)

(1) Institute of Research for Hydrogeological Protection, National Research Council, Bari, Italy (m.parise@ba.irpi.cnr.it, +39 080 592 9611), (2) University of Salento, Lecce, Italy

An increasing number of areas in southern Italy are being interested by sinkholes related to the presence of man-made cavities, with underground quarries representing the more problematic typology of anthropogenic caves in terms of instability. The case of Cutrofiano (Apulia, SE Italy) is here presented as a representative case study. This territory is well known for the underground quarrying activity of soft calcarenitic rocks that caused in the last decades widespread phenomena of subsidence at the surface, with extensive damage and problems to the main communication routes in the area. A very complex and intricate network of subterranean galleries is present underground, for a total development on the order of several tens of kilometres. The Gravina Calcarenite Formation, that is the object of the underground quarries, consists of whitish calcarenite with an upper greenish clayey-sandy interval rich in fossils. This formation is overlain by grey sandy clays (Subapennine Clays) grading upward to fossil-rich sands (Brindisi Sands). In recent years, clay mining has been resumed at the ground surface, following the opening of a cement factory, and resulting in the realization of wide open-pit quarries. The local sedimentary sequence is closed by terraced calcarenite deposits, that holds a phreatic groundwater body. The results of detailed geological, geomorphological and geomechanical surveys, supported by laboratory tests, show that in the Cutrofiano area the thickness of the stratigraphical succession, the depth of the underground galleries, the structural conditions of the rock mass, and the failure mechanisms observed within the quarries are variable.

The geological model reconstructed represents the base for the implementation of numerical simulations, which are aimed at defining the eventual mechanisms of rock failure, up to the formation of the sinkhole. Local changes in the stratigraphy are very common in the area, due to the overall slight attitude of the strata, dipping toward the SW, and to lateral variations in the geological succession. Thus, at least two different geological settings may be recognized: the first is typical of those areas closest to the town, where the calcarenite rock mass is at low depth, and appears to be covered by very thin deposits; in such a situation, the underground quarries develop at depths ranging from 7 to 10 meters below the ground surface. The second setting, which typically characterizes the sectors a few kilometres farther south, shows, on the other hand, the presence of thick cover of the clay-sandy intervals, and has the galleries of underground quarries located at depth variable from 15 to 45 m. Starting from these different situations, two-dimensional numerical analyses have been developed by using the finite element method to investigate the stress-strain evolution of the rock mass surrounding the galleries due to long-term degradation of the rock properties induced by weathering and water infiltration. The results obtained from the numerical simulations point out a quite different behaviour between the two geological settings, since the presence of the significant clay layer overlying the calcarenite substratum affects the geometry of the subsidence cone, and, consequently, the real extent of the likely sinkholes at the surface.

These outcomes are of great importance to highlight the need to use detailed, site-specific, data in order to perform numerical modelling, and warn about the common habit of extending a small number of borehole data, tens of hundreds of meters apart, over large areas. Especially when carried out to define vulnerability and/or risk of specific elements at risk, the researches should be performed having available on-site data, or, alternatively, the end users should be properly warned in the use of the outcomes from the study.