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Sinkhole susceptibility in carbonate rocks of the Apulian karst (southern Italy)

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Apulia region, the foreland of the southern Italian Apennines, is made up of a 6-7 km-thick succession of Mesozoic shallow-water limestones and dolostones, locally covered by thin and discontinuous Tertiary and Quaternary carbonate and clastic deposits. Due to their long subaerial exposure, the Mesozoic carbonate bedrock recorded the development in the subsurface of a dense network of karst cavities, mostly controlled by tectonic discontinuities. As a result, a strong susceptibility to natural sinkholes has to be recorded in Apulia. In addition, the possibility of occurrence of other problems related to the high number of man-made cavities has to be added in the region. A great variety of different typologies of artificial cavities (mostly excavated in the Plio-Pleistocene soft calcarenites) is actually present, including underground quarries, worship sites, oil mills, civilian settlements, etc. Overall, 2200 natural and 1200 artificial cavities, respectively, have been so far surveyed in Apulia.
Following the urban development in the last century in Apulia, many of these cavities lie nowadays below densely populated neighborhoods, roads or communication routes. These conditions are at the origin of the main geomorphological hazard for the human society in Apulia, which requires a careful evaluation, aimed at protecting and safeguarding the human life, and at providing the necessary information for a correct land use planning and management. The importance of the sinkhole hazard is further testified by the worrying increase in the number of events during the last 5-6 years.
In response to these situations, joint research activities were started by the Institute of Research for Hydrological Protection of the National Research Council (CNR-IRPI) and the Basin Authority of Apulia, aimed at several goals, that include (but are not limited to) the collection of information on natural and anthropogenic sinkholes in Apulia, the implementation of numerical analyses for modelling the instability processes, and the development of charts for a preliminary evaluation of the stability of underground caves.
Two distinct approaches were established to take into account the different petrographic, structural and geotechnical features of both the hard and soft carbonate rocks. The approach dealing with hard carbonate rocks (where natural karst caves develop) is based on speleological and geometrical surveys of the caves and on an integrated geological and geomechanical characterization of the carbonate rock mass, aimed at individuating the main critical aspects of the karst caves in terms of likely effects on the society.
On the other hand, the approach to verify the stability of soft rocks where artificial cavities have been excavated is mostly dependent upon the peculiar petrographic and geomechanical characteristics of the calcarenite rock mass, typically massive and unaffected by tectonic discontinuities. As a consequence, the traditional analytical methods of rock mass classification fail in these materials, since the rock strength of soft calcarenites is mostly dependent upon sediment texture, porosity type and distribution and degree of cementation. The fluid circulation into the rock mass is also important because the removal of the rock matrix may induce a rapid deterioration of the mechanical behaviour of the rock mass. The approach to the calcarenite is mostly based on the characterization of petrographic and geotechnical parameters by means of direct sampling from the rock walls and in situ surveys (wells, trenches, etc.).
Through implementation of the two approaches, our goal is to reconstruct accurate geometrical, geological and geotechnical models for both natural caves and artificial cavities. These models will be useful also to plan specific monitoring activities in order to understand the development of underground instability, and the related evolution through the rock mass, possibly threatening the urban areas and infrastructures above.