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Combining Geological and Geophysical Surveys with Cave Explorations for the Assessment of the Sinkhole Susceptibility in Coastal Areas

Stefano Margiotta (1), Sergio Negri (1), Antonio Pagliara (2), Mario Parise (3), and Tatiana A.M. Quarta (1)
(1) University of Salento, Di.S.Te.B.A., Lecce, Italy (sergio.negri@unisalento.it), (2) geologist, (3) CNR-IRPI, Bari, Italy

Evaluating the susceptibility related to occurrence of sinkholes is of particular relevance in coastal settings, due to the likely high frequency of sinkholes, that are especially favored by the interaction between fresh and brackish water, with the consequent strong aggressivity on the soluble rock masses. Long stretches of the Ionian coastline (southern Apulia, SE Italy) are affected by sinkholes, that in more than one occasion have caused significant damage and problems to the human infrastructures, and in particular to the main communication routes in the area. In this study, we combine the outcomes of different methodologies to reach a good understanding of the sinkhole susceptibility in the area of Torre Castiglione, in the proximity of Porto Cesareo (Lecce province): starting from geological analysis, and the building up of a detailed database on the sinkholes in the study area, the obtained data were used to plan the following research, consisting of geophysical surveys, that were carried out with different techniques.
At the same time, cave explorations (including scuba-diving) were performed in one of the most important sinkhole at Torre Castiglione: this phase of the activity allowed to get remarkable insights into the features of the submerged karst systems in the area. Flooded passages, 4 to 9 mt-wide and 5,5 mt-high, were explored for several tens of meters. A chaotic jumble of breakdown deposits constitute the cave pavement, and the vault and walls of the passages are heavily fractured, pointing out to the possibility of further detachments, which likely will result in opening additional sinkholes at the surface. The underground systems appear to be quite complex and extensive, but the difficulty in the explorations (mostly due to narrowing of the passages and to the rock mass instability) suggested to stop the scuba-diving activity for safety reasons.
Sinkholes detection and imaging is a challenging task for geophysical methods, not only because of the required resolution and depth of penetration, but also because major pitfalls may arise in such geologically complex areas, from the speculative interpretation of geophysical anomalies as geological features. Data integration from different geophysical methods is essential to remove these interpretation ambiguities, caused by large near-surface gradients and heterogeneities in the soil properties, as well as by water table.
In the case of Torre Castiglione, we illustrate here an investigation procedure consisting in the sequential application and integrated interpretation of several geophysical methods (Electrical Resistivity Tomography and Seismic Reflection measurements) for locating sinkholes and for the characterization of the subsoil. Geophysical surveys allowed us to obtain a detailed geological model in the study area, cross-checked by the outcomes of several boreholes, and to detect the presence of underground voids, that are characterized by low resistivity values (<100 ohm*m) and a seismic velocity of about 1500 m/s.