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Sinkhole Geohazard In Deformed Sulphates at Marina di Lesina (Gargano Promontory, Italy): a Combination of Anthropogenic, Lithologic, and Structural Causes

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Sinkhole development and collapse of underground caves within a gypsum substrate is focused in proximity to the beach resort of Marina di Lesina on the Adriatic coast of Southern Italy. This situation constitutes a serious geohazard for the local community and a threat to the development of the tourist activity. Fast sinkhole development has been reported in the last two decades both in terms of newly formed cavities and of widening of already existing ones. Morphologically, the apparent sinkholes are small (from a few meters to a few tens of meters) and restricted to the area of the harbour canal.

The substratum of the area consists of evaporite and carbonate platfom sediments of the Apulian margin, Triassic to Cretaceous in age, above which there is a thin layer (2 to 4 m) of Quaternary fine to medium sand deposits. Sheared marls, sub-volcanic igneous rocks, and bituminous limestone connected to a fault scarp, as well as small salt diapirs have been observed in proximity to the city. Below the urban area of Marina di Lesina, the platform sediments consist of fractured, sheared, and karstified sulfates (Burano Formation). Given solubility larger than that of carbonate rock, sulfates is a focus for the dissolution process. From a structural point of view, the Marina di Lesina area is probably in a push-up step between two secondary segments of East-West trending left lateral strike-slip faults with the same trend of the Mattinata fault system. The presence of a push-up structure is confirmed by the existing geological maps, the morphological, and the altimetry data available for the area that point out the presence of arcuate relief structures next to the Pietre Nere (Black Rocks) Head. These high relief areas are probable NW-SE oriented high angle reverse faults in the compressional quadrant of the southernmost strike-slip fault segment. The area within a push-up step is undergoing an intense compressive stress that results in strong pressure solution phenomena, uplift, fracturing, and shearing. This specific structural setting is likely to cause the intense deformation localization of the sulphates (mainly gypsum) observed in the boreholes drilled around the city. It is well known that the presence of structures, such as fault and fractures, focuses fluid flow and intensifies the dissolution and the karst evolution processes. An alignment of the sinkholes as well as their shape anisotropy, west of the harbour canal, suggests also a strong structural control.

Considering the combined effects of a gypsum lithology very sensitive to dissolution and the probable structural localization of faults and fractures in a fault step, it becomes apparent that Marina di Lesina is an area prone to strong karst development. Sinkhole formation and growth can be further enhanced by any anthropogenic activity especially those aimed to control the surface drainage, the infiltration of the water in the subsurface, the height of the watertable or the intrusion of seawater inland. The excavation of the harbour canal, in particular, seems to have enhanced the dissolution process as witnessed by the alignment of the sinkholes with the trend of the canal. The ongoing research of IGRG (Integrated Geosciences Research Group) at the University of Bologna is aimed to characterize the lithologic, structural, hydrologic, and anthropogenic drivers causing karst development, also for minimizing the risk on the urbanizated area and connected to sinkhole-related subsidence and collapse.