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Geoelectrical resistivity variations and lithological composition in coastal gypsum rocks: A case study from the Lesina Marina area (Apulia, southern Italy)

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A B S T R A C T

The Lesina Marina village (Apulia, southern Italy) lies on an exotic rocky body basically composed of Triassic gypsum surrounded and covered by thin Quaternary sandy deposits. During the last two decades instability phenomena connected to gypsum dissolution and cover suffusion sinkholes occurred mainly along the Acquarotta canal and in the urbanized area.

In this study, electrical resistivity tomographies, field and petrographic observations have been carried out just ca. 300 m to the South of the residential area. The East–West striking geoelectrical profile has a length of 1900 m, intercepts two boreholes and crosscuts the Acquarotta canal. Close to the boreholes, higher resolution geoelectrical profiles, both perpendicular and parallel to the former, were performed. The two boreholes highlight the presence, from the top to the bottom, of Quaternary sandy deposits, coarse grained gypsum and layered finer grained gypsum. In correspondence, electrical resistivities are very low for the wet sandy deposits (up to 5 Ω·m), increase for coarse grained gypsum (20–120 Ω·m) and reach the maximum values for the layered finer grained gypsum (greater than 300 Ω·m).

The relationship between the electrical resistivity and the lithological composition of the studied rocks is strongly controlled by their fracturing and water saturation degree. Thus considering, the main geological features here recovered are the impermeable bedrock and the above rocky body involved by mineral transformations and karstification phenomena. Additionally, the anhydrite/gypsum transformation and the gypsum dissolution are related to the groundwater circulation and localized within massive coarse grained gypsum rocks. Therefore, the hazard related to karst processes involves both an area and a depth greater than those considered up to now.

1. Introduction

Ancient gypsum rocky bodies often show different portions characterized by a variety of both lithological composition (e.g. Testa and Lugli, 2000; Gündogan et al., 2005; Schreiber et al., 2007) and/or texture (e.g. Gündogan et al., 2008; Hildyard et al., 2009). This complexity (e.g. alternating gypsum, limestone and clayey layers, as well as the presence or the absence of intergranular matrix) is due to either the primary chemical and physical conditions of the evaporitic environments of deposition, or to the subsequent mineral transformations resulting from a complexity of factors during diagenesis (e.g. tectonics, burial, exhumation and weathering processes).

The ability of electrical resistivity tomography (ERT) method to assess subsurface property, in an evaporitic setting, should be enhanced by the excellent electrical contrast between the near surface air-filled or water/clay filled cavities and the host material. Nevertheless, overlapping resistivity ranges exist for a single sulfate rocky mass since the electrical resistivity depend on a wide range of the petrophysical parameters (structure, texture, temperature, mineralogy, water content, concentration and chemical composition of the fluids, etc). In order to investigate these parameters in ancient sulfate rocky bodies, ERT has been successfully applied even though in few cases of study (e.g. Guinea et al., 2010, 2012, 2014; Manoutsoglou et al., 2010, and references therein). Particularly interesting are the results reached by Guinea et al. (2012), which demonstrated a direct relationship between the electrical resistivity values and the contents of gypsum and anhydrite in sulfate rocks, quantifying the decreasing of resistivity with the increasing of the lutitic matrix embedding sulfate particles.

Lesina Marina is a village lying a few meters above sea level on the Fortore River coastal plain that extends along the northern Apulia Adriatic coastline (southern Italy; Fig. 1a and b). In this area, exotic Triassic gypsum rocks crop out on a very gentle ridge (e.g. Carella, 1963), surrounded and covered on its sides by relatively thin Quaternary

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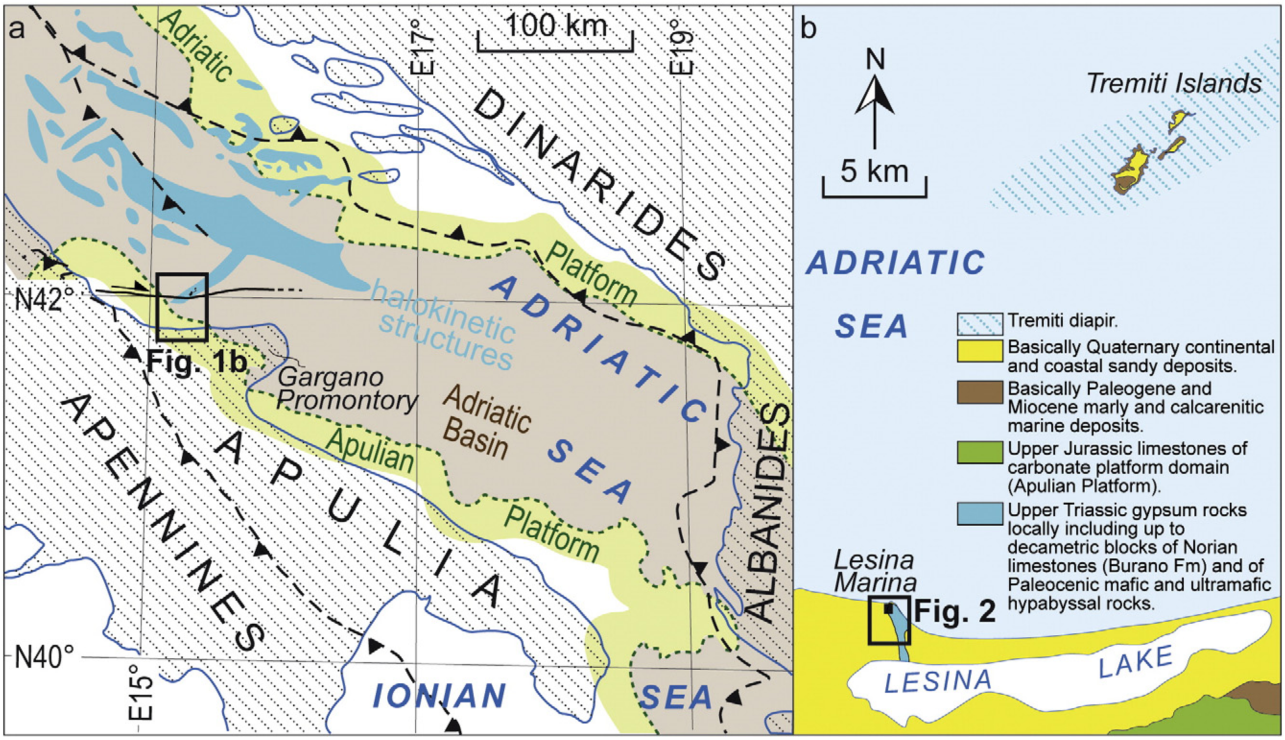

Fig. 1. (a) Schematic structural map of the Periadriatic region around the Adriatic Sea (after Zappaterra, 1990, 1994, modified). The Meso-Cenozoic paleogeographic position of the Adriatic Basin between the Apulian and Adriatic carbonate platforms is shown. The fronts of Apennines and Dinarides according to Scrocca (2006), and Fantoni and Franciosi (2010), respectively. The halokinetic structures are also indicated (after Geletti et al., 2008, modified). (b) Schematic geological map of northern Apulia, around the area of Lesina Marina village and of the Tremiti Islands (after Boni et al., 1969; Cremonini et al., 1971, modified); the location of the underlying halokinetic structure called Tremiti diapir is also indicated
After Festa et al. (2014), modified.

sandy deposits (Mastronuzzi and Sansò, 2012, and references therein; Figs. 1b and 2). Besides the uniqueness of these gypsum rocks in the surface geology of the southern Italy (e.g. Martinis and Pieri, 1964), their importance is also related to the large number of cover collapses and cover suffosion sinkholes that have been formed in the gypsum karst of the Lesina Marina area, thus impinging dangerously the residential area during the last two decades (e.g. Melidoro and Panaro, 2000; Fidelibus et al., 2011; Caggiano et al., 2012; Fig. 3a).

Melidoro and Panaro (2000) and Fidelibus et al. (2011) suggested that the changes in the hydrogeological functioning due to the Acquarotta canal (artificially excavated in 1930 in the gypsum rocky body, in order to connect the Lesina lagoon with the Adriatic Sea; Figs. 1b and 2) have favored both the erosion of the filling of cavities and the karstification processes, promoting the development of the sinkholes near the canal, especially along its western side. However, according to Campana and Fidelibus (2015), in the Lesina Marina area the evolution time of gypsum dissolution is much greater than human lifetime.

Previous studies were mainly focused within the urbanized area, and in the first 30 m in depth (Melidoro and Panaro, 2000; Selleri and Mastronuzzi, 2003; Fidelibus et al., 2011; Caggiano et al., 2012). Therefore, the extent of the karst system in depth and around the village is unknown.

The main objective of this study is to provide a wider and a deeper geological reconstruction. This reconstruction represents an essential tool to suggest a new framework of susceptibility to the possible occurrence of near-surface collapse phenomena, even outside the urbanized area. Indeed, sinkholes occurred not exclusively near and along the canal (e.g. Caggiano et al., 2012), and some clues for the happening of these phenomena, far from the canal, may be suggested by satellite images (Google Earth, 2013), consisting of sub-elliptical wetter soil compared to the surroundings (Fig. 3b). To this end, the electrical resistivity tomographies, field mapping and petrographic observations have been carried out. The results are discussed in relation to the outcomes of previous studies devoted to both the understanding of the collapse phenomena in the Lesina Marina area (e.g. Melidoro and Panaro, 2000; Fidelibus et al., 2011; Caggiano et al., 2012), and to ERT and petrophysical investigations on gypsum rocks (e.g. Guinea et al., 2010, 2012, 2014; Manoutsoglou et al., 2010).

2. Geological and hydrogeological setting

In the Adria Plate (sensu Channell et al., 1979), a narrow pelagic basin (the Adriatic Basin), flanked by carbonate platforms (the Apulian Platform, to the SW, and the Adriatic Platform, to the NE), developed during the Mesozoic, roughly occupying the same position of the present-day Adriatic Sea (Zappaterra, 1990, 1994; Bernoulli, 2001; Fig. 1a). The system made of these basinal and platform domains evolved as a consequence of early Jurassic rifting of an epeiric area dominated by the deposition of carbonates. It was rooted on Norian anhydrites and shallow-water limestones and dolostones, i.e., the Burano Fm, which overlie Permian continental deposits draping Hercynian basement (Ricchetti et al., 1988). Later, the basinal and platform domains were partially involved in the Tertiary shortening related to the Apennines and to the Dinarides–Albanides evolution. Near and along the front of these orogens, the evaporites belonging to the Burano Fm promoted diapirism, mostly during Neogene (e.g. Scrocca, 2006; Geletti et al., 2008; Festa et al., 2014, and references therein; Fig. 1a).

In the North of Apulia (Fig. 1a), in the Lesina Marina area, the cropping out of exotic Triassic gypsum rocks belonging to the Burano Fm (Fig. 1b), rose up from the deep anhydrite source (Cotecchia and Canitano, 1954; Bigazzi et al., 1996). According to Bigazzi et al. (1996), hydration of anhydrites, i.e., the formation of gypsum, possibly occurred after their uprise. Up to decametric blocks of Paleocenic mafic and ultramafic hypabyssal rocks (De Fino et al., 1983; Bigazzi et al., 1996), and Triassic limestones (e.g. Posenato et al., 1994), that locally crop out