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Instability assessment of “Grotta della Poesia” (Lecce, Italy).

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***Abstract* – The instability of the hypogean archaeological site named “Grotta della Poesia”, was studied by combing geological and geophysical methods. The inside geometry of fractures and the physical parameters of the surrounding and underground materials were the primary objectives of the geophysical survey. 2D seismic tomography and 2D electrical resistivity tomography (ERT) were combined to make a first diagnosis. First seismic data were acquired along one horizontal profile delimited by the line of the sources inside the cave and the receiver lying on the ground surface. ERT profile was overlapped with the seismic profile but the electrodes were placed on the ground surface. The interpretation of integrated geophysical data resulted in evaluating some of the rock mass parameters such as the rock quality designation, linear fracture density and fracture density.**

I. INTRODUCTION

A study on the instability assessment of the archaeological site “Grotta della Poesia”, located 20 kilometres east of Lecce near the Melendugno village (Lecce province, southern Italy), was performed by combing geological and geophysical methods. Two large dolinas (named respectively Large Poesia and Small Poesia) are the main surface landforms of a hypogean karst system developed inside a tabular coastal plain which is presently a few meters elevated above sea level. The system is furtherly made of intervening galleries, a large dome cave, some minor cavities and a gallery which connects the Small Poesia to the sea cliff (Fig. 1). In detail, is the Small Poesia which has a special importance by virtue of an impressive number of signs, symbols and inscriptions datable between the Second Millennium before Christ and the Republican Roman Age. The name derives from the Greek term “poesia”, which points out the rising of sweet water and, in fact, in the small cave a spring flowed until few years ago [1].

Archaeological and geological studies have shown that the Small Poesia has suffered some morphological changes, evolving from an underground cave to a large dolina through a series of collapses of the ceiling, caused by a composite karstic and sea erosion phenomena probably triggered by artificial mediaeval excavation [2]. The zone of “Roca” is carved in soft calcarenites referable to the Upper Pliocene and it is elevated about 10 m above mean sea level.

This bedrock is covered by recent and present beach and dune sands. Landward, the lansdcape grades down to a number of depression, placed at about 1 - 2 m above m.s.l., and filled by sandy-clayey deposits. In the northern part of the area, thick layers of calcarenites and calcirudites with abundant macrofossils crop out; they have been referred to the “Calcareniti del Salento” Pleistocene unit by [3].

Numerous karstic caves occur in the area, some of them recorded in the regional inventory of the “Federazione Speleologica Pugliese” [4] (such as “Grotta dello Spezzale”, “Grotta della Poesia Grande” and “Grotta della Poesia Piccola”).

The calcarenitic and calcilutitic layers are affected by four systems of fractures, clustering around the directions N-S and E-W [2]. These fractures, to a large extent sealed by carbonatic concretions, show varying spacing from some decimeters to some meters. Fractures constitutes the preferential surface of detachment of numerous rockfalls occurring along the coastline. Some karstic caves develop at the base of the cliff along the fractures. The analysis of the spatial distribution of the density of fracture point out a substantial uniformity of the degree of the fracture. In some small tracts of the coastline, the density of fractures increases to about 0.65 m/m2 [5]. Fractures are generally sealed by calcitic concretions; however, some fractures are widened by karstic dissolution. Fractures of this last type show at present openings of the order of some millimeter to some meters in the case of complete development of galleries. Some fractures are partially or totally filled by colluvial deposits.

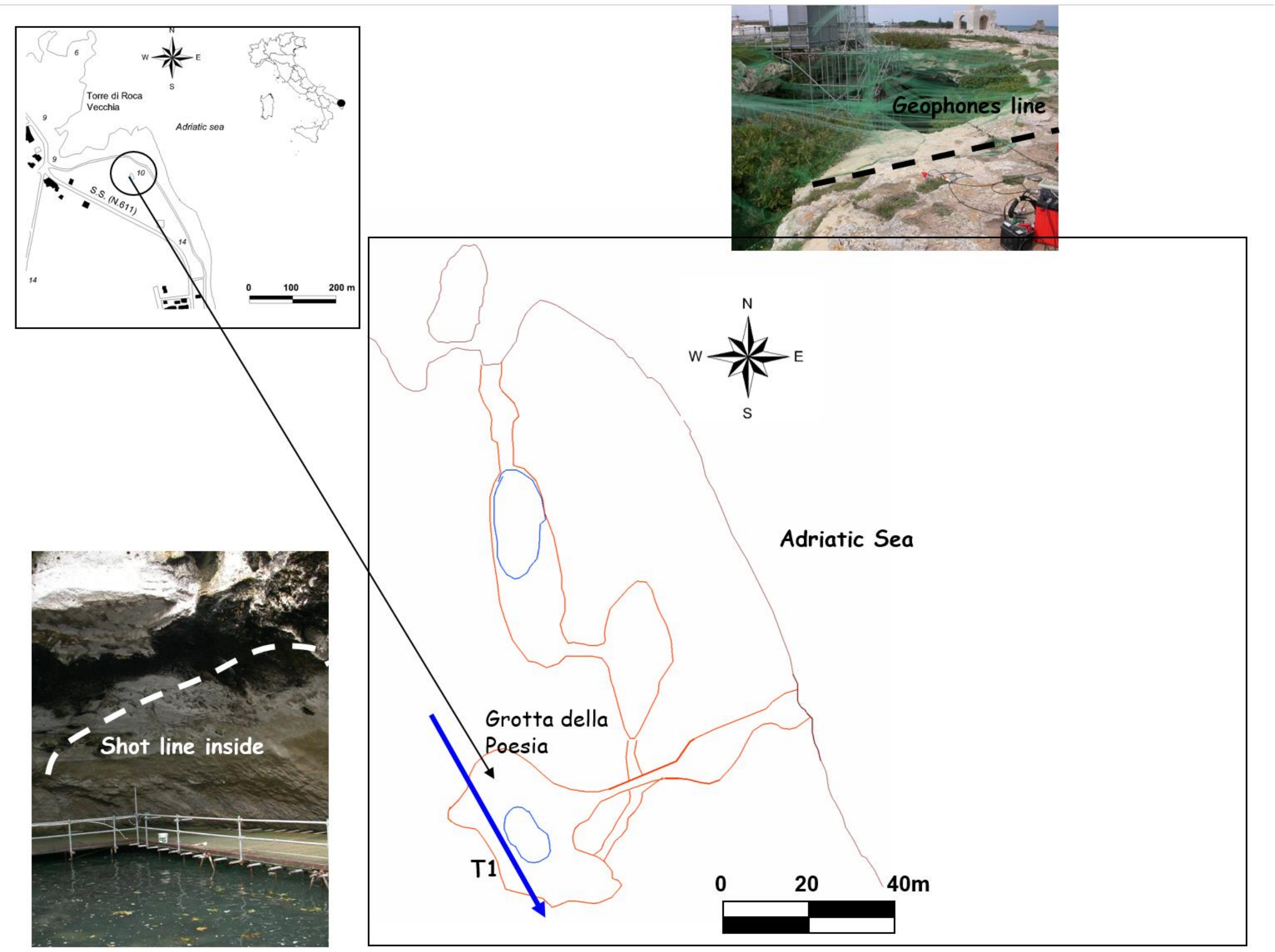

Fig. 1. The “Grotta della Poesia” with the location of seismic profile

II. II GEOPHYSICAL SURVEY

Geophysical survey consists of an integrated interpretation of two geophysical methods, electrical resistivity tomography (ERT) and seismic traveltime tomography.

The degree of fracturing can be estimated by evaluating the ratio between the seismic velocity in the fractured rock and the not-fractured one. The number of fractures per unit length defines the linear fracture density (Γ). Its value is obtained by counting the number of fractures intersecting a unit length of the scanline.The fracture density parameter C is defined as [5]:

$$C = \frac{\Gamma}{\langle \cos\theta_i \rangle \cdot (1 - \ln r_{\min})} \qquad (1)$$

where θi is the orientation of the i^{th} set of fractures (θi = 0° for vertical fractures assuming vertical flow), ⟨.⟩ denotes average, Γ is the linear fracture density and r_{min} is the smallest fracture length.

The rock quality designation (RQD) parameter, based on number and spacing between fractures, is simply defined as the sum of lengths of rock pieces (intact lengths) or fracture spacings greater than 10 cm expressed as a percentage of the total length of the scanline. Table 1 shows the rock quality classification based on RQD parameter.

Once the thickness of the rock that forms the roof of the cave had been estimated, a seismic traveltime tomography survey was undertaken. The seismic tomography was performed along one line (Figure 1) by distributing 48 geophones and 29 source locations (Figure 2). 48 vertical geophones (14 Hz) with 1 m spacing and 29 shot points were located along two parallel lines. The geode instrument was used. The elastic signal was generated by striking a rod with a hammer. The 48 receivers were placed at the measurement surface (z = 0) every 1 m, and 29 shot were placed inside the cave every 1 m. This source-receivers geometry (Figure 2) allows to obtain information about the seismic waves velocity in the roof of the cave.

RQD %	ROCK QUALITY
0-25	Very low
25-50	Low
50-75	Discrete
75-90	Good
90-100	Very good

Table 1. Rock quality classification based on RQD parameter.

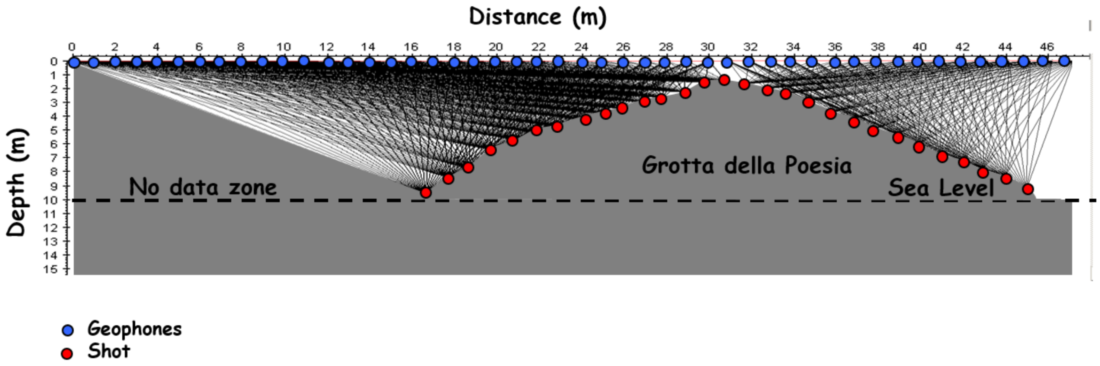

Fig. 2. The traveltime tomography acquisition geometry.

Figure 3 illustrates the seismic wave velocity variation model. A low seismic velocity area is noted, labelled L (300 < Vp < 600 m/s).

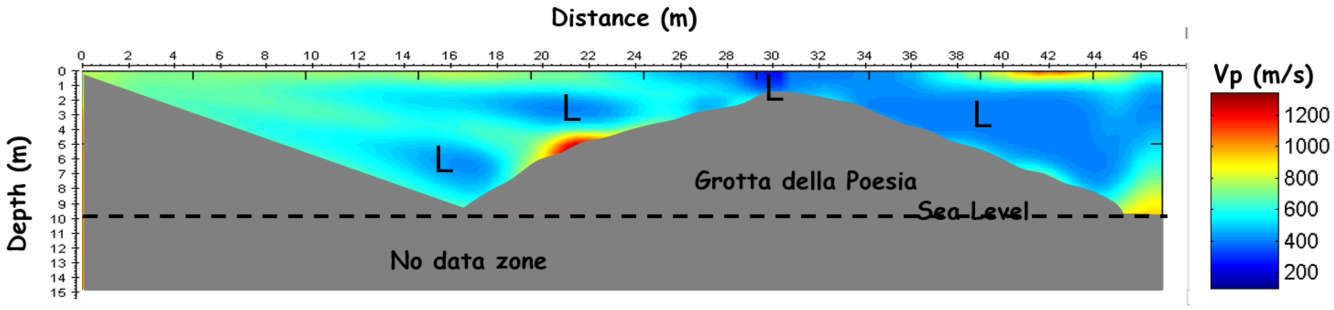

Fig. 3. The Seismic velocity Vp distribution

Using the relationship 1 is possible to obtain the parameter density of fracture C (Figure 4)

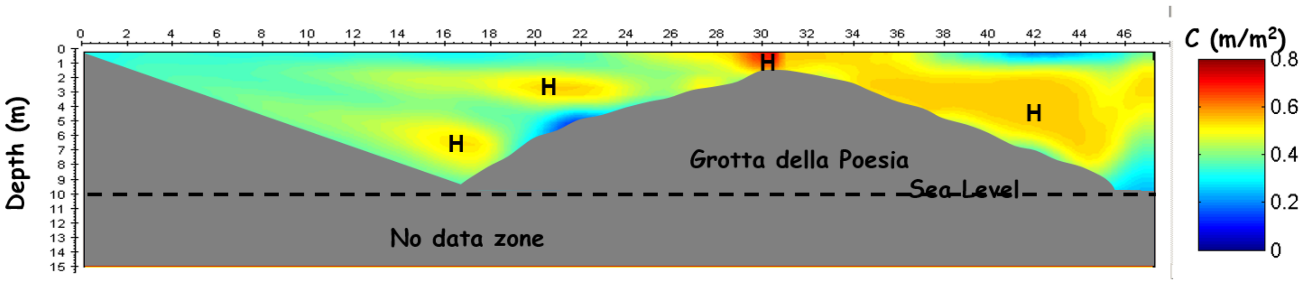

Fig. 4. The Seismic density of fracture C distribution

Figure 4 show an higher density of fractures (H) in corrispondence with the low (L) seismic velocity.

For the ERT survey a 48-channel Syscal-R1 Resistivitymeter (manufactured by the Iris Instruments), in multielectrode configuration was used. Resistivity field data were collected using 48 electrodes with 0.5m spacing. The selection for electrode arrays was dipole-dipole. The dipole-dipole array is very sensitive to horizontal changes in resistivity, but relatively insensitive to vertical changes in the resistivity.This means that it is good in mapping vertical structures, such as voids, but relatively poor in mapping horizontal structures [6].

The geological model established by means of a 2-D resistivity imaging profile (Figure 5), allows for two different zones to be detected. The first zone (upper 1–2 m):

– the high resistivity zone (about 400 ohm m), labelled H in Figure 5, clearly indicates a zone of poor quality rock. The resistivity values indicate that the zone consists of fractured carbonate rock;

– the low resistivity zone (about 30 to 40 ohm m), labelled (L) in Figure 5, corresponds to the fractured carbonate rock, although the resistivity values are low enough to indicate that the carbonate rock is fractured and the fractures could be filled with clay or "terra rossa".

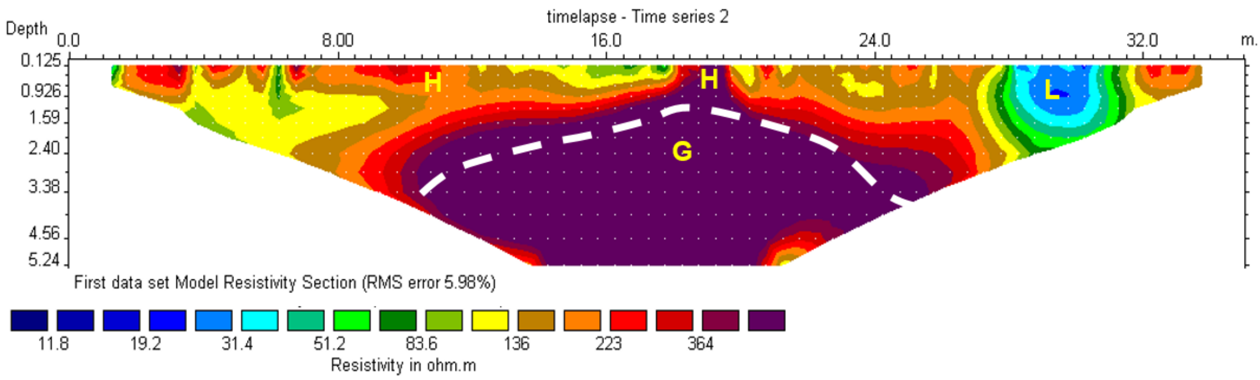

Fig. 5. 2D distribution of the resistivity.

III. CONCLUSIONS

In this research it was used an integrated interpretation of the results obtained from ERT and seismic tomography data sets to identify fractures in a calcarenite and therefore to assess its quality in order to perform a preliminary evaluation of the stability of the roof of the Grotta della Poesia. The ERT method provided estimates of the resistivity distribution in the shallow subsoil. By combining resistivity and P-wave velocity distributions in the subsoil ambiguities in the interpretation were minimised. The integration of the two geophysical methods is a useful tool in carrying out geognostic investigations at restricted sites, where invasive techniques such as drillings cannot be performed. The integrated geophysical analyses outlined, in the studied area, a highly unstable region in the zones labelled L in the seismic results that indicates very intense anomalies, most likely referable to open fractures.

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