2020 IMEKO TC-4 International Conference on
Metrology for Archaeology and Cultural Heritage
Trento, Italy, October 22-24, 2020

A NEW METHODOLOGICAL APPROACH ON THE EVALUATION OF STABILITY OF CAVITIES IN “SOFT” CARBONATE ROCKS.

Lara De Giorgi[1], Giovanni Leucci[1]

[1] *Institute of Cultural Heritage Sciences (ISPC-CNR),prov.le Lecce-Monteroni, 73100 Lecce (Italy), giovanni.leucci@cnr.it*

***Abstract* – Seismic tomography, seismic refraction tomography and electrical resistivity tomography (ERT) imaging was employed to make diagnosis for an very important archaeological cave named “Grotta della Poesia”. Rock fracturing and destructive force of sea waves causes structural instability in the roof of the cave that has partially collapsed. The inside geometry of fractures and the physical parameters of the surrounding and underground materials were the primary objectives of the geophysical survey. Seismic and ERT data were acquired along one horizontal profile on the roof of the cave. The interpretation of integrated geophysical data resulted in an evaluation of the conservation degree of the Cave.**

I. INTRODUCTION

This paper focus on the instability assessment of archaeological site “Grotta della Poesia”, located 20 kilometres east from Lecce near the Melendugno village (Lecce province, southern Italy) (fig. 1), performed combing geological, geophysical and mine engineering complementary 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 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. 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 “posia”, that points out rising of sweet water and, in fact, in the small cave a spring flowed until few years ago (Fig. 2).

Archaeological and geological studies have shoved that the Small Poesia has suffered some morphological changes, evolving from underground cave to large dolina through a series of collapses of the ceiling, caused by a composite karstic and sea erosion phenomena [1, 2] probably triggered by artificial mediaeval excavation.

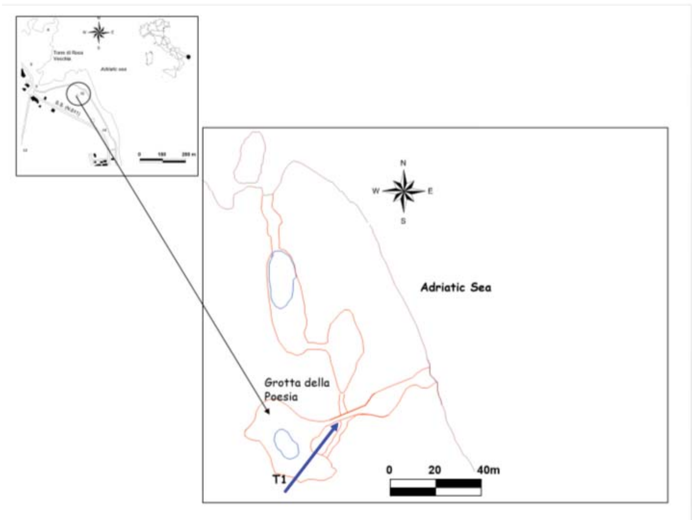

Fig. 1. The “Grotta della Poesia”location.

Fig. 2. The “Grotta della Poesia”

II. GEOPHYSICAL DATA ACQUISITION AND ANALYSIS

The seismic tomography was performed along one line (Fig. 3) by distributing 48 geophones and 48 source locations. 48 vertical geophones (14 Hz) with 1 m spacing and 48 shot points (one for each geophone position) were located inside the cave. The elastic signal was generated by striking a rod with a hammer.

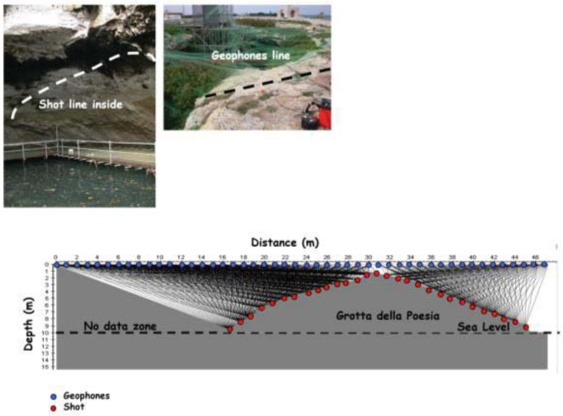

Fig. 3. The acquisition geometry of the seismic travel time tomography profile

Figure 4 illustrates the 2D seismic wave velocity variation model. A low seismic velocity area is noted, labelled L (400 < Vp < 700 m/s).

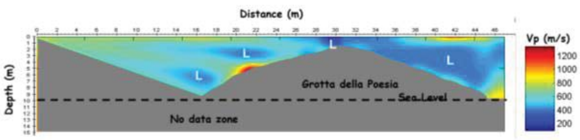

Fig. 4. Seismic travel time tomography: Vp distribution

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 [3]. The above described electrodes array allows one to investigate, with a good resolution, the shallow 3m of subsoil [4, 5]. The measured data were processed by means of 2-D inverse modelling software, applying Loke and Barker inversion methods. The software employs a quasi- Newton technique to reduce the numerical calculations [6]. It produces a 2-D resistivity model satisfying measured data in the form of a pseudosection. The goodness of the fit is expressed in terms of the relative RMS error. This method is more suitable where both strong lateral resistivity variations and depth changes occur and in complex geological models such as in a karstic area [4, 5].

A typical image from the ERT survey is shown in Fig. 5: it shows a layered resistivity profile in the top 5.5 m, a zone of low resistivity (about 20 to 100 ohm m) from the surface to about 2.3m depth, underlined by an high resistivity zone labelled (_>1000 ohm m).

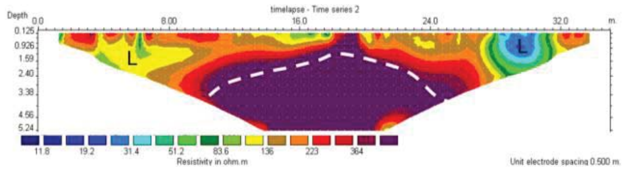

Fig. 5. Two-dimensional electrical resistivity model

The high resistivity area represent the cave.

III. DISCUSSION AND CONCLUSION

The seismic and ERT profiles were overlapped to compare and integrate the results (Fig. 6), in order to eliminate the ambiguity inherent in each method.

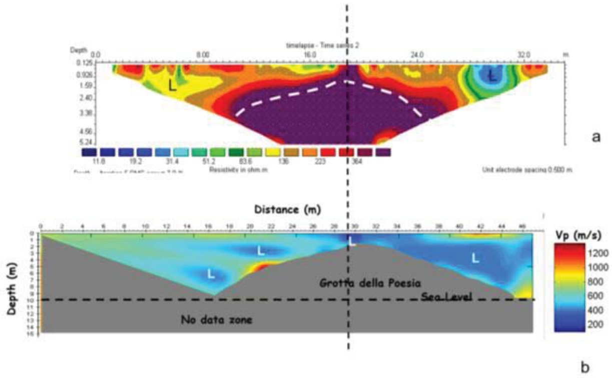

Fig. 6. Survey results: (a) 2-D electrical resistivity model;(b) 2-D Vp model

Resistivity values in a good quality carbonate rock ranges between 500 and 1500 ohm m [4], then a resistivity of about 100 ohm m suggests that the carbonate rock is highly fractured and filled with other materials, such as terra rossa. This was confirmed by seismic tomography results. The low Vp velocities are related to low resistivity values confirming the high degree of fracture inside the rock. Furthermore high resistivity zone and very low Vp (dashed dark line) suggest an area with high degree of degradadation (fractures air filled).

IV. CONCLUSIONS

The “Grotta della Poesia” is one of the most important archaeological site of the Salento peninsula. The safeguard of the “Grotta della Poesia” and, therefore, its conservation can be performed by precise location of fractured zones. In this research an integrated interpretation of the results obtained from 2-D electrical resistivity tomography and seismic tomography data sets was used to identify fractures in a carbonate rock formation, in order to perform a preliminary evaluation of the stability of a karstic cave. Plotting the two data sets on the same scale produces reasonable data correlation and interpretation.

By combining the two methodologies 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. The seismic wave velocity analysis, together with the ERT model analysis, allowed one to hypothesize if the fractures are void or filled with other materials (such as “terra rossa”). This approach, if extended to the whole area of the cave, can be used to produce a 3-D map of the cave itself, to provide more effective suggestions in order to obtain suitable conditions for the its conservation and safeguard.

REFERENCES

[1]Leucci G., 2007. geophysical investigations to study the physical – mechanical characteristics of the rock in coastal environment: the cliff of roca (lecce, italy). Journal of Geophysics and Engineering, 4, 462-475; doi:10.1088/1742-2132/4/4/012

[2]Leucci G., De Giorgi L., 2006. experimental studies on the effects of fracture on the p and s wave velocity propagation in sedimentary rock (“calcarenite del salento”). Engineering Geology, 84, 130–142; doi:10.1016/j.enggeo.2005.12.004

[3] Loke, M. H.: Electrical imaging surveys for environmental and engineering studies, A practical guide to 2-D and 3-D surveys: RES2DINV Manual, IRIS Instruments, www.iris-instruments.com, 2001.

[4]Leucci G., 2019, Nondestructive Testing for Archaeology and Cultural Heritage: A practical guide and new perspective. Springer editore pp 217, ISBN 978-3-030-01898-6

[5]Leucci G., 2020, Advances in Geophysical Methods Applied to Forensic Investigations: New Developments in Acquisition and Data Analysis Methodologies. Springer editore, pp 200, ISBN 978-3-030-46241-3

[6]Loke, M. H. and Barker R. D.: Rapid least-squares inversion of apparent resistivity pseudosections using a quasi-Newton method,