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Electromagnetic survey to detect a section of the Messapian city walls in Ugento (Lecce)

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***Abstract* – The Messapian city walls in Ugento (Puglia, in south Italy) are of great archaeological importance and some sections are still visible. In order to locate a stretch of the city walls, a non-destructive geophysical prospection was performed, applying the electromagnetic method. The survey was carried out in a peripheral area of Ugento, near a visible section of the city walls. The analysis and interpretation of the measured electromagnetic data (specifically in this work, the quadrature-phase component) revealed a clear anomaly that could be ascribed to the city walls; in fact, it is aligned with the adjacent section of the visible walls.**

I. INTRODUCTION

Ugento is one of the most important Messapian centers of the Salento peninsula (Fig. 1a). The best preserved archaeological evidence of Ugento is represented by the city walls of which some sections are still visible. Dated between the second half of the 4th and 3rd century BC, they were aimed at defending an area of about 145 hectares: Ugento was the largest urban center in Messapia. The modern city partially overlaps an ancient settlement, the most extensive of ancient Messapia [1]. Only some areas have not been reached by the building expansion of the last few decades, which has led to the destruction of much archaeological evidence. The present research aims to study a site in a peripheral area of Ugento.

Geophysical investigations are able to provide detailed geometric reconstructions of the buried structures (geological and/or of archaeological interest) and represent a fundamental tool in archaeological research, especially when there is no possibility of direct investigation. In order to identify structures of archaeological interest, in this study the geophysical survey was conducted with the electromagnetic (EM) method in the frequency domain (FDEM).

This method is mainly used for preliminary surveys of large areas, being one of the fastest geophysical methods.

The EM conductivity meters are composed of a transmitting coil and 3 or 4 receiving coils mounted at set distances. The transmitting coil generates a time-varying primary magnetic field, which propagates above and below ground, generating alternating currents (eddy currents) within the soil and the buried objects. The eddy currents create a secondary magnetic field, proportional to the rate of change of the primary magnetic field, and measured by receiving coils.

The received secondary magnetic field consists of an imaginary part (the quadrature component) which is proportional to the ground conductivity and of a real part (the in-phase component) which is influenced by magnetic properties.

The acquired data are processed and interpreted to characterize the subsurface EM properties. Subsurface EM energy is influenced by three electromagnetic properties of matter: electrical conductivity, dielectric permittivity, and magnetic susceptibility. Electrical conductivity and magnetic susceptibility govern the magnitude of the received EM signal and, therefore, are used to understand the electrical properties of subsurface materials [2].
In this work, we focus on the interpretation of the electrical conductivity distribution.

Figure 1b shows the site being studied: the investigated area is marked with a dashed black rectangle and it has dimensions of 57 m x 8 m. The specified area has been identified on the basis of previous extensive studies: in fact, the evidence of a section of walls is in an adjacent area.

II. ELECTROMAGNETIC SURVEY AND DATA PROCESSING

The EM survey was conducted using the CMD mini-explorer probe, a multi-depth electromagnetic conductivity meter by GF instruments (Fig. 2).

Fig. 1. Ugento is located in the southern part of Salento. The study site is located in a peripheral area of the city: the investigated area is marked by the black dashed rectangle; it is close to dry stone walls.

Fig. 2. The electromagnetometer CMD mini-explorer by GF instruments. It is composed by 3 receiving coils that allow to obtain information in n. 3 depth ranges. As the distance between the transmitting coil and the receiving coil increases, the depth of investigation increases.

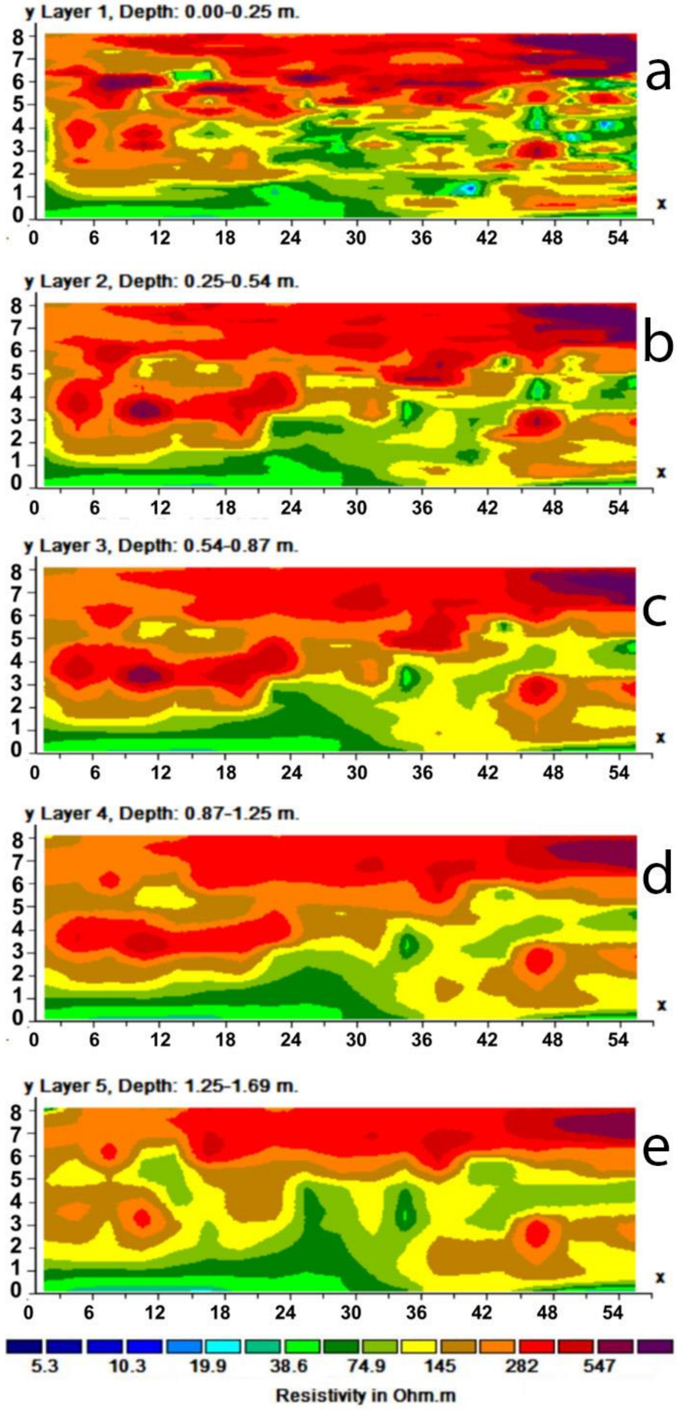

Fig. 3. Depth slices: layer with depth range z = 0:0.25 m (a); layer with depth range z = 0.25:0.54 m (b); layer with depth range z = 0.54:0.87 m (c); layer with depth range z = 0.87:1.25 m (d); layer with depth range z = 1.251.69 m (e).

It consists of n. 3 sensors that allow obtaining information in n. 3 depth ranges. As the distance between the transmitting coil and the receiving coil increases, one is able to explore greater depths. Setting the probe to HIGH mode allows measuring with maximum depth range. In fact, the vertical orientation of magnetic dipoles allows measuring in the full depth range. The survey, with this setting, allowed the exploration of the subsoil up to a depth of about z=2 m from the ground level.

The measurement was carried out in the continuous mode, setting the measuring period to 0.2 seconds and maintaining a constant speed of movement which not exceed 9 km/h. The out-of-phase and the in-phase components are measured as average values obtained during one measuring period. Longer measured time causes more accurate measurement under stable conditions, but it can also cause fuzzy edges of objects in conductivity map, due to too high a speed of movement.

Data were acquired in a grid with parallel profiles equally spaced at 3 m.

The acquired data were exported to Res3DInv. Considering the quadrature component, the negative values of conductivity were removed and then the inversion routine was applied, obtaining the distribution of the electrical resistivity values at several depth ranges, as shown in Figure 3.

III. RESULTS

EM results are shown in Figure 3. They provided the identification of several resistivity anomalies related to the presence of significant buried archaeological structures. In detail, the resistivity depth slices show high resistivity anomalies (greater than 400 Ohm m) potentially related to the presence of buried structures: the elongated shape of this anomaly probably proves the presence of the buried city walls (W). The presence of this trend is visible in all the layers obtained through the inversion process (Figure 3a to 3e), thus at shallow depth up to a depth of z = 2 m. It is visible at depths between 0 m and 1.69m. Other high resistivity anomalies (S) could be related to other structures probably related to the walls. In figure 4 the georeferenced data are shown. The high resistivity anomaly named W (Figure 4a) runs along the dry stone wall. It is evident that its orientation is aligned with the adjacent section of the visible walls (marked with the dashed black line) shown in figure 4b.

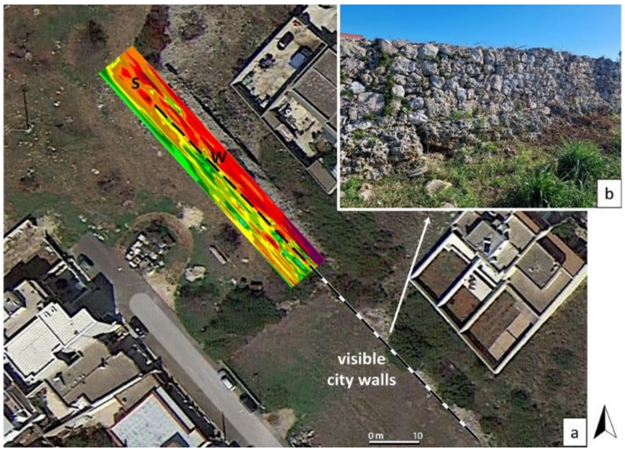

Fig. 4. Georeferenced depth slice (depth of 0:0.25 m) with indication of the anomaly referable to the buried Messapian city walls (named W) and of other anomalies which probably are referable to structures related to the buried walls (named S) (a). The elongated high resistivity anomaly (W), indicated by the black dashed line, aligns to a section of visible city walls (b) in the adjacent area.

IV. CONCLUSIONS

The EM survey performed in a peripheral area of Ugento, near a visible section of the city walls (Figure 4, a and b), allowed for the collection of important new data on the extension of the Messapian city walls.

The geophysical prospecting highlights a high resistivity anomaly whose shape probably traces the course of the walls. The identification of this new section was possible thanks to the georeferencing of the depth slices from EM investigations.

The revealed anomaly is ascribed to the city walls; in fact, as shown in Figure 4a (marked by the dashed black line) it is aligned with the adjacent section of the visible walls.

The presented study highlights the importance of the geophysical methods as a tool for planning excavation activities saving time and money.

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