2019 IMEKO TC-4 International Conference on
Metrology for Archaeology and Cultural Heritage
Florence, Italy, December 4-6, 2019

THE PIETRAGALLA PROJECT: FIRST RESULTS OF THE GEOPHYSICAL ACTIVITIES ON THE MONTE TORRETTA ARCHAEOLOGICAL SITE

L. Capozzoli [1], V. Capozzoli[2], G. De Martino[3], A. Duplouy[4], A. Henning[5], E. Rizzo [6]

[1]CNR - IMAA, Laboratorio Hydrogeosite, Tito – Marsico Nuovo (PZ), luigi.capozzoli@imaa.cnr.it
[2] Université Paris, 1 Panthéon-Sorbonne, vincenzo.capozzoli@univ-paris1.fr
[3]CNR - IMAA, Laboratorio Hydrogeosite, Tito – Marsico Nuovo (PZ), gregory.dematino@imaa.cnr.it
[4] Université Paris, 1 Panthéon-Sorbonne, Alain.Duplouy@univ-paris1.fr
[5]Humboldt Universität zu Berlin, Agnes.Henning@hu-berlin.de
[6]CNR - IMAA, Laboratorio Hydrogeosite, Tito – Marsico Nuovo (PZ), enzo.rizzo@imaa.cnr.it

***Abstract* – This paper presents the preliminary results obtained through a geophysical survey realized in 2017-2018 in investigating the archaeological site of Monte Torretta (Pietragalla, PZ), one of the most interesting and less known settlements of modern Basilicata. The geophysical survey is part of the Pietragalla Project, an international research program led by the Université Paris 1 Panthéon-Sorbonne and the Humboldt-Universität zu Berlin aiming at the study and the valorisation of the site. Through the comparison and integration of different geophysical methodologies, including Ground Penetrating Radar, Electrical Resistivity Tomographies and Magnetometric measurements, it was attempted to enhance the knowledge of the site and help the archaeologists in their investigation. The main targets were the understanding of the settlement pattern within the fortification walls, especially near the two gates known up to now on the site, as well as the geological characterization of the first meters of the subsoil.**

I. THE ARCHAEOLOGICAL CONTEXT OF MONTE TORRETTA

The Pietragalla Project is an international research program established by the Université Paris 1 Panthéon-Sorbonne and the Humboldt-Universität zu Berlin with the collaboration of the Soprintendenza Archeologia Belle Arti e Paesaggio della Basilicata, the IMAA and IBAM of the Italian CNR, as well the Department of Agriculture and Forestry of the Università degli Studi della Basilicata (SAFE). The first objective of the project is the study and promotion of the archaeological and cultural heritage of the archaeological site of Monte Torretta di Pietragalla (Italy). The site, located in the northern part of modern Basilicata, reaches an altitude of 1,070 m and belongs to the high basin of the river Bradano, one of the two most important rivers of the region.

The hilltop settlement of Monte Torretta has already been the subject of many excavations since the mid-1950s. In 1956, Francesco Ranaldi, director of the Museo Archeologico Provinciale di Potenza, obtained the hilltop to be archaeologically constrained and launched the first official archaeological investigation of Monte Torretta di Pietragalla. His field investigations, continued until the end of the 1960s, brought to the light an impressive fortification system consisting of an outer wall that include the whole settlement, and an inner wall around the so-called Acropolis. Both walls are characterized by the presence of two gates, respectively a courtyard gate (now called Porta Marie) and a simple gateway (now called Porta Livia). After Ranaldi, the Soprintendenza Archeologica della Basilicata launched a first restauration program of the walls until the end of the 1980s, which simultaneously tried to elucidate the chronology of the settlement and of the fortification (generically dated to the 4th century BC.) through some excavation trenches.

Unfortunately, there is almost no documentation on these activities. Hence the resumption of the investigations in August 2017 by our international team, highlighting the still unexpressed potential that lies

buried on the summit of Monte Torretta. Before starting a systematic excavation, our main objectives are, first, to understand through a topographic survey the visible structures and, second, to intercept and record the older excavations. Up to now, despite such embryonic state of research, it is already clear that the Monte Torretta's fortification system is about to become one of the main sources of information of pre-roman military architecture in the region. Unfortunately, if the fortification system is known – despite many doubts on the west and north side of the Acropolis – we know nothing about the area within the walls.

Beyond the specific issues of Monte Torretta, the main goal of the Pietragalla Project is to re-examine the complex question of the so-called 'Lucanization' of the area, a the term through which historians and archaeologists encapsulate a series of transformations that characterize the Lucanian region from the middle of the 5th c. BC. Various interpretations have been produced: some interpret them as the result of the invasion by Samnite populations coming from the north, and others as the result of an internal evolution of the indigenous populations. A crucial point concerns the fortified hilltop settlements that appeared in the whole Lucanian region during the 4th c. BC. Accordingly, the archaeological site of Monte Torretta di Pietragalla offers a privileged observatory for dealing with these issues. A fortified hilltop site on the northern edge of Lucania, it is also an important regional crossroads that lasted for centuries: unlike many other sites of the region that arose almost suddenly during the 4th c. BC., Monte Torretta di Pietragalla offers a more or less continuous occupation from the end of the Geometric period (with already some faint traces of the Neolithic and Bronze period) until the 2nd c. BC, that is after the Roman conquest. Through an interdisciplinary approach that crosses new data recovered during fieldwork with the study of early excavations' material culture, the scientific program of the Pietragalla Project aims at giving a precise answer to such age-old questions in Lucanian studies, following a cultural anthropology perspective.

II. GEOPHYSICAL APPROACH TO THE ARCHEOLOGY

The use of geophysical methods is an inevitable step in the archaeological context and the Monte Torretta archaeological site is a good expression of their applications. The information obtainable by the geophysical approach provides to contribute to the localization of the excavation activities. This aspect is fundamental in this historical context where a smart approach for investigating archaeological context is strongly required. For this reason, the integration of archaeological knowledge and technical competences coming from other scientific field represents a key crucial for improving the comprehension of the acquired data. This necessity has led to the creation of a recent geophysical sub-discipline called Archaeogeophysics. Archaeogeophysics, that is also part of the more general discipline of the geoarchaeology, is based on the integrated use of different geophysical techniques, able to detect contrasts of physical properties of the subsoil associated to archaeological buried structures, and archaeological data [1]. The use of different geophysical techniques clearly provides a fundamental support to reduce the uncertainties related to the interpretation of the acquired data. In the case here presented Ground Penetrating Radar (GPR), Magnetometric measurements (MAG) and Electrical Resistivity tomographies (ERT) are realized in order to localized buried structures and identify the ancient settlement. These activities are performed for analysing the site of Torretta di Pietragalla that hosted an ancient Lucanian settlement. In the last two decades, the Lucania territory has been widely and successfully studied with geophysical methods to discover buried archaeological structures. The presence of masonry walls of notable size, typical of local architecture, generate a good geophysical contrast between anthropic constructions and geological contexts providing optimal information for reconstructing the ancient settlements in areas generally wooded and mountainous difficult to human access [2-3].

III. METHODS

As defined before, three different methods were applied: MAG, GPR and ERTs. The theoretical notes of the methods are here briefly described.

MAG investigates a physical property called magnetic susceptibility that is characteristic for each magnetisable material and depends mainly on the volume per cent content of magnetite. The induced magnetization in a rock due to the Earth's field, F is directly proportional to magnetic susceptibility. Further, a remnant magnetization phenomenon should be considered added to the one caused by Earth's field due to the thermoremanent magnetization acquired by magnetic grains during cooling from the Curie temperature to normal atmospheric temperature in the presence of an external field. This methodology is able to measure the variation of the magnetic field of the Earth and the effects caused by anthropogenic artefacts located in it. The methods is applied with success in many archaeological scenarios and allows to quickly investigate large areas ensuring a good resolution for discovering archaeological targets [4-5-6-7].

GPR method is based on the introduction of electromagnetic (e-m) pulses at different frequencies, generally included in the range of 0.01 to 2 GHz. The scattering phenomena occurring in the subsoil produce some reflections due to the e-m impedance variations characterizing the medium encountered by the e-m waves

generated by the GPR antennas. GPR is widely applied in the archaeological field thanks the highest resolution provided by the method if compared with the other non-invasive methodology [8-9-11-12]. The most suitable geophysical methods in the archaeological field, are the geo-magnetometric and ground penetrating methods, where MAG is used to give a large-scale reconstruction of the anomalies related to archaeological features, while GPR is often applied to obtain details of the most interesting anomalies. In this way, geophysicists and archaeologists try to combine the advantages of the MAG methods, its speed and low cost, with those of the GPR, which allows for higher resolutions at known depths [13].

The resistivity method is based on the introduction of electrical current into the ground and analysis of the electrical behaviour of the subsoil. The method is carried out by the introduction of current (I) into the ground by using a couple of electrodes and the measurements of the drop of potential (DV) by a second couple of electrodes. The data acquired are expressed in form of apparent resistivity. The apparent resistivity values are then elaborated in terms of real resistivity and depth by means of inversion software that compute the 'best' set of resistivity values, which satisfies both the measured dataset and some a priori constraints, in order to stabilize the inversion and constrain the final result. Resistivity methods are less adopted for archaeological issues for its low ratio archaeological-results/acquisition-time. However, ERTs can effectively support archaeological studies for understanding the area context in order to give strong information on the geomorphological and geological aspects of the territory included its historical evolution. [14-15-16-17-18].

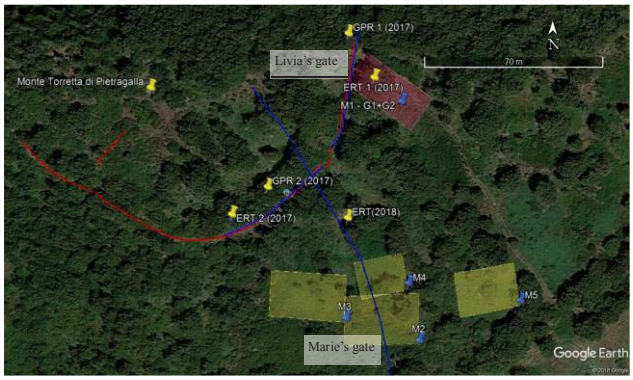

Fig. 1. Acquisition scheme adopted for the geophysical campaigns carried out between the years 2017 and 2018; in blue the geoelectrical profiles, in red the GPR lines, in yellow the area investigated only with MAG and in pink the area investigated with GPR and MAG (G1-G2 and M1)

IV. THE GEOPHYSICAL ACQUISITION

The presence of dense vegetation and anthropic obstacles have restricted the accessibility of the site. Only a limited part of the site was analysed as showed in figure 1. Thanks to the efforts of the archaeologists, some areas near the two monumental gates (Maria and Livia's gates), where the excavation activities are actually focused, have been made available for GPR and MAG acquisitions. As regard GPR, the two maps G1 and G2 with a total size of 15 x 30 meters, are investigated at the frequency of 400 MHz. GPR data are acquired with the SIR-3000 GPR System (GSSI Instruments) and processed with the software Reflex-W (see figure 2c). Further, some GPR radargrams are collected in parallel to the ancient walls of the site at the frequencies of 200 and 400 MHz. MAG acquisitions have provided to investigate the map M1 (that overlaps the GPR maps G1 and G2) and the maps M2, M3, M4 and M5 with sizes of 20x30m, 18x30m, 15x20 m and 18x25m, respectively. MAG acquisitions are carried out with the optical pumping magnetometer G-858 (by Geometrics) in a gradiometric configuration, with two magnetic probes set vertically at a distance of about 1 m from each other (see Figure 2a). CSAZ software (by Geometrics) was used to correctly direct the sensor axes so as to take complete account of the Earth's field, inclination, and declination at the site being investigated. The data were acquired along parallel paths 1 m apart, with a sampling rate of 10 Hz, using a snake configuration to achieve a mean spatial resolution of 1.0 m × 0.125 m. The MAG acquired data were processed in a first phase with MagMap software (Geometrics) in order to improve the acquired geomagnetic image from the zig-zag errors, due to operator walking. The second step the geomagnetic data were elaborated by TerraSurveyor software that provides a wide range of processes, allowing the data to be manipulated to produce the best possible interpretation.

The ERT 1 and 2 were acquired near the walls according the Dipole-Dipole and Wenner-Schlumberger arrays. The electrode spacing was one meter and 48 channels are used. ERT 3 was acquired in correspondence of the acropolis and the Livia Gate and crosses the initial part of the ERT2 (see figure 1). In this case the electrode distance was fixed equal to two meters to enhance the depth of investigation. The total length of the acquisition was 138 meters. Data are collected with the georesistivimeter Syscal-Pro (Iris-Instruments) and inverted with the software Zondres2D (see figure 2b). Then, all the geophysical data, after the necessary processing, are imported in a GIS environment to better identify the presence of significant alignments for the archaeological issues.

V. PRELIMINARY RESULTS

As showed in figure 3, the magnetic maps M2-M3-M4 have identified some slight magnetic anomalies related to the presence of some walls, actually buried, linked to the near structures belonging to the Marie's Gate.

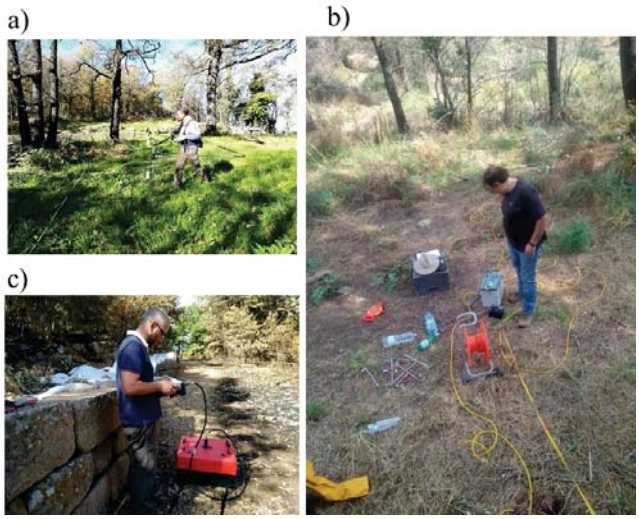

Fig. 2. Acquisition phases of MAG (a), ERT (b) and GPR (c).

Instead, a great number of magnetic anomalies, often distributed chaotically on the investigated area, characterizes the map M5, where some alignments are identifiable and associable to archaeological structures.

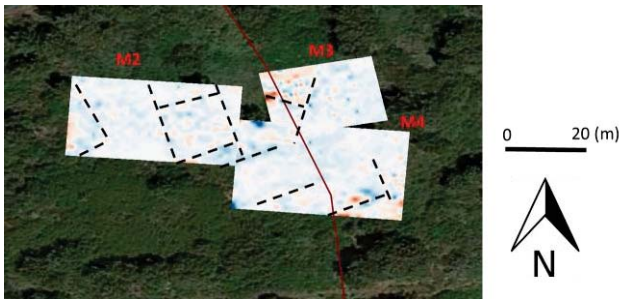

Fig. 3. MAG results obtained near the Marie's gate; the maps M2-M3-M4 provides to identify some alignments likely due to the presence of walls linked to the Livia's gate (black dashed lines).

The GPR maps G1 and G2, showed in figure 4, have provided to localize some reflective areas, placed at depths greater than 0.50 m near the Livia's gate. Some magnetic anomalies are recorded in the map M1, just in correspondence to these reflective events. As concerns the GPR profiles acquired along the monumental walls of the site, it was possible identify some reflections that are supposedly associable to archaeological features.

ERTs 1 and 2, acquired near the walls of the site, have identified the presence of an alternation between conductive and resistive values as showed in figure 5.

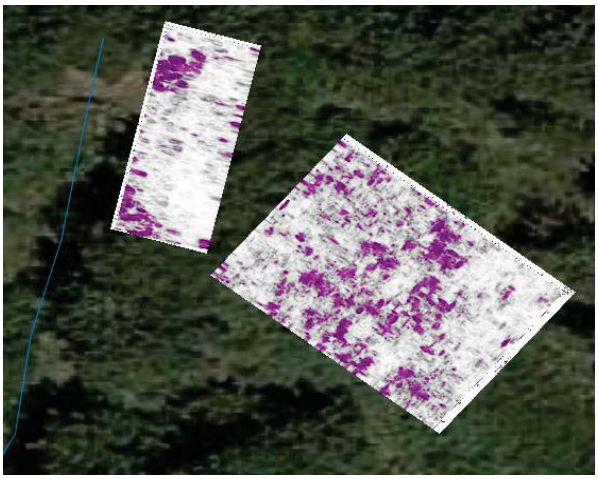

Fig. 3. GPR results obtained at the depth of 0.50 meters in the maps G1 and G2; the violet areas correspond to the higher reflections maybe due to the presence of archaeological features.

This interesting anomaly (between the letters C1 and C2 of the figure) could be associated to the presence of a paleochannel or an area where, for geological reason, the concentration of water is greater than the nearest areas. The GPR data, recorded at the frequency of 200 MHz, have identified some isolated reflectors imputable to the presence of walls or other archaeological features (A1, A2 and A3) and some horizontal reflective layers (D1, D2 and D3) supposedly associable to the ancient walkway floor.

VI. CONCLUSIONS AND FUTURE PERSPECTIVES

On the archaeological site of Monte Torretta, the integration of different geophysical methods, including GPR, MAG and ERT, has provided to identify some geophysical anomalies for supporting the archaeological activities carried out for the Pietragalla Project. The difficulties related to the presence of dense vegetation and loose materials over the entire site have limited the geophysical investigations. However, some remarkable results are obtained that are here briefly presented.

In particular, ERTs have demonstrated their usefulness in the archaeological context discovering some anomalies likely associated to geological variations of the subsoil. Further, it is probable that some resistive nuclei, recorded by the ERTs, are due to presence of previous excavations activities as well as the ancient walkway floor.

GPR maps have allowed to identify some reflective areas that could hide ancient structures placed in front of the main entrance of the so-called Acropolis (Porta Livia). These anomalies are also confirmed by the MAG data, in particular for the map M1. The MAG maps M2, M3 and M4 have identified some aligned anomalies that are most likely imputable to the presence of ancient walls linked to the south-western gate of the site (Porta Marie). In the absence of sufficient archaeological data and excavations, the interpretation of the data is very difficult, but the integration of the geophysical data is supporting efficiently the archaeologists in studying the settlement of Pietragalla. The necessary scrub operations on the archaeological site will soon enable the extension of the investigation on the acropolis and on the ancient walls.

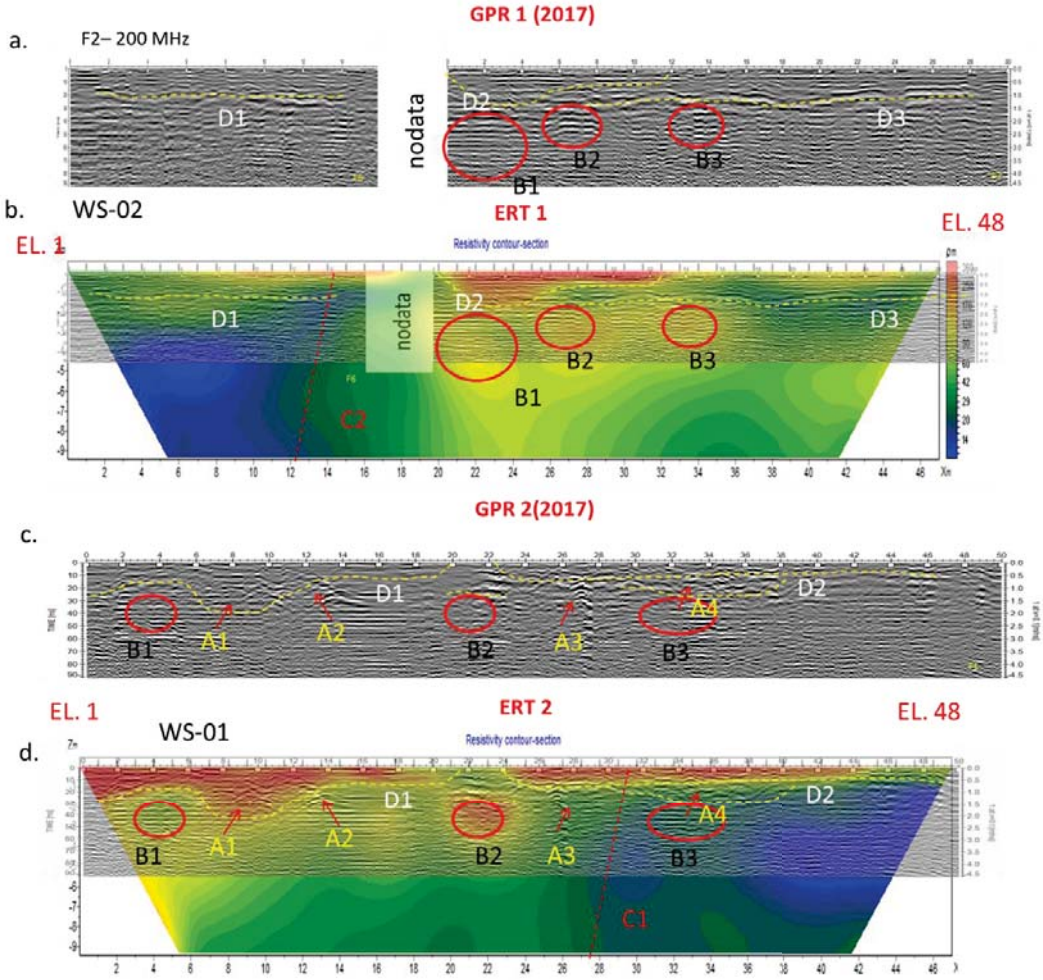

Fig.5. GPR and ERT processed data obtained by the geophysical measurements carried out in front of the monumental wall of the site. The resistivity data are expressed in Ωm. (a) and (c) show the two radargrams while in (b) and (d) are showed the co-rendered images

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