Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Geophysical survey in the area of aguglia d'agosta (Priolo Gargallo, Sicily)

To cite this article: L. De Giorgi *et al* 2022 *J. Phys.: Conf. Ser.* **2204** 012001

Geophysical survey in the area of aguglia d'agosta (Priolo Gargallo, Sicily)

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Abstract. Syracuse and its countryside played a crucial role in the economy of ancient Sicily. Despite its historical and economic importance in the Roman and Medieval periods, our knowledge about the organization of its agricultural production, and economic circuit between the rural settlements and the city are limited. From 2009 the researches of the "Institute of Heritage Sciences – CNR" attempt to remedy this omission by outlining a preliminary picture of the rich historical and archaeological heritage of Priolo Gargallo, which will be analysed using a multidisciplinary approach (archaeological survey, geophysical investigations, aerial photography analysis, etc.).

1. Introduction

The site of Specchia-Aguglia is a most important roman rural settlement localized km. 2 southeast of Priolo Gargallo [1, 2]. It lies in a rich plane (fig. 1) between the lagoon of Saline di Priolo and the Bigeni feudum, along the roman Via Pompeia and medieval via puplica [3]. A large scattered ceramic fragments on a surface of about ha 7 limits the area of settlement and defines the site chronology from the 5th Century BC to the 4th/5th Century AD. Inside, a Late Hellenistic funerary monument (3th-1th Century BC) named Aguglia d'Agosta or Guglia di Marcello (fig. 2) emphasizes the presence of roman élites in the settlement [4, 5, 6]. Little now remains of this and it is therefore difficult to determine its architecture and location of the grave. In order to understand this question and the development of Roman and Medieval settlements in the area an integrated researches were undertaken. A combined archaeological, geological, geophysical surveys were performed.
The results have established new parameters to dating Roman and Medieval settlements. Integrated data evidenced an essential continuity of settlement from the Late Hellenistic period to the Republican Period; furthermore the field surveys revealed a diversity of rural sites during the Republican Period and the Early Imperial Age. During the Middle Imperial Period and the onset of Late Antiquity the number and size of settlements in the territory increased dramatically. But by the first half of the 5th Century, the numerous medium-scale settlements spread out over the area seem to have contracted significantly in size, and some of them were abandoned. After the middle 5th Century AD archaeological evidence is again indicative of a growth of settlements in the territory of Priolo, where previously uninhabited areas began to flourish. This is most evident from research into the area of Manomozza, where a wide settlement prospered until the 9th century AD. Moreover, the church of Santa Foca was built during the same period and was also a focal point for trade and commerce.

Figure 1. The location of surveyed area

2. 3D Geological model of the study area

Using the software Groundwater Modeling System (GMS) a 3D geological model, containing lithological information was performed. The scope of building a model is to simplify the field problem and organize the field data so that the system can be analyzed more readily. The conceptualization of the model includes synthesis and framing up of data pertaining to geology, hydrogeology, hydrology, and meteorology.

The lithologic data were collected from 12 lithologs of drinking-water, and irrigation wells shown in Figure 2.

Figure 2. The location of wells used for the 3D geological model

Depth of the lithologs ranges from 25 to 30 m below the ground level. Based on the acquired lithologs, a lithologic model was developed with Groundwater Modeling System (GMS). The lithologic solid model was created using a block-centric finite-difference grid. The gridding was performed through the eight nearest-neighbor methodology with 3-D interpolation by average minimum distance. The solid model was developed to a depth of about 30 m below the ground level. The sensitivity of the model was tested by varying the horizontal and vertical spacing of the nodes, and an optimized final model, least sensitive to changes in spatial resolution (i.e., smaller grid sizes), was built. The resolution of the final model was 100m×100m×2m. The resulting discretization consisted of 250nodes×250nodes×100nodes, obtaining 6,250,000 solid model nodes, each with a voxel volume of 20,000 m^3. It should be noticed that the results of the modeling are not free from uncertainties, which could be reduced by increasing datapoints, but they illustrate one of the most probable scenarios. The smallest scale of variation that the model is able to depict is equal to the resolution of one voxel.

The model was vertically discretized in 4 layers. The layers had variable thickness as a result of wells stratigraphy. The 4^{th} layer was defined as the basal no-flow boundary, consistent with the extensive clay layer at about 10 m below MSL. The layers were allowed to have seepage from the top and leakage through the base, making them hydraulically connected. The top-most layer and the second layer were defined as unconfined.
The lithologic modeling suggests the presence of a very complex 3-D hydrostratigraphic framework in the subsurface of the studied area. A detailed description of the study area at the block scale is provided here to illustrate the general spatial trends in aquifer thickness and spatial variability. The 3D lithologic model (Fig. 3a) with the cross-sections in Fig. 3b provide detailed depictions of the geology of the studied area.

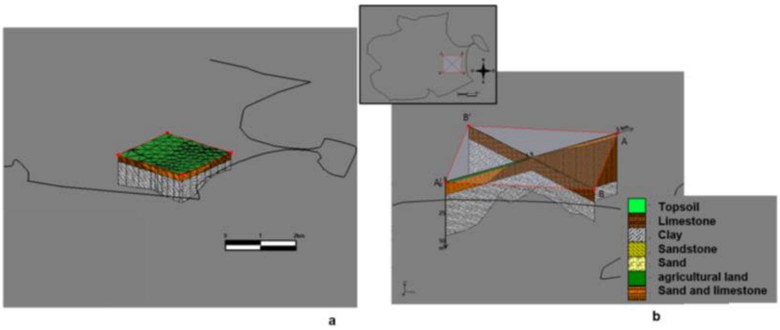

Figure 3. The 3D geological model of the surveyed area

3. Geophysical Survey

Geophysical surveys were carried out on two zones (Fig. 4) where archaeologists think that might be archaeological features.
A 3D ground penetrating radar (GPR) measurements were performed. GPR data were collected using a georadar Ris Hi Mod with a 200 and 600 MHz (centre frequency) antennae manufactured by “Ingegneria dei Sistemi” (IDS).

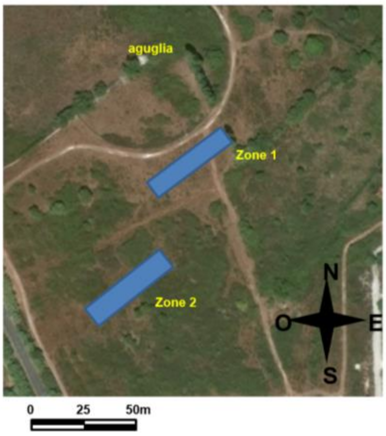

Figure 4. The zones surveyed with GPR

A reconnaissance survey was conducted in a continuous mode, in two zones labelled zone 1 and zone 2 in Fig 4. Zone 1 was 10×55 m^2, while zone 2 was 7×55 m^2 . Data were acquired along parallel profiles, 0.5 m spaced.

The quality of the raw data did not require advanced processing techniques. However, appropriate processing was performed for easier interpretation.
The GPR data were processed using standard two-dimensional processing techniques by means of the GPR-Slice 7.0 software [7]. The processing flow-chart consists of the following steps: i) header editing for inserting the geometrical information; ii) frequency filtering; iii) manual gain, to adjust the acquisition gain function and enhance the visibility of deeper anomalies; iv) customized background removal to attenuate the horizontal banding in the deeper part of the sections (ringing), performed by subtracting in different time ranges a 'local' average noise trace estimated from suitably selected time-distance windows with low signal content (this local subtraction procedure was necessary to avoid artefacts created by the classic subtraction of a 'global' average trace estimated from the entire section, due to the presence of zones with a very strong signal); v) estimation of the average electromagnetic wave velocity by hyperbola fitting; vi) Kirchhoff migration, using a constant average velocity value of 0.12 m/ns. The migrated data were subsequently merged together into three-dimensional volumes and visualized in various ways in order to enhance the spatial correlations of anomalies of interest.
For 2D velocity migration the EM wave velocity must be estimated along the radar section. The EM-wave velocity can be more quickly and easily determined from the reflection profiles acquired in continuous mode, using the characteristic hyperbolic shape of reflection from a point source [8]. This is a very common method of velocity estimation and it is based on the phenomenon that a small object reflects EM-waves in almost every direction. In the data set, several hyperbolic reflections caused by stones and objects of small dimensions (Fig 5) are present, enabling EM wave velocity analysis to be performed.

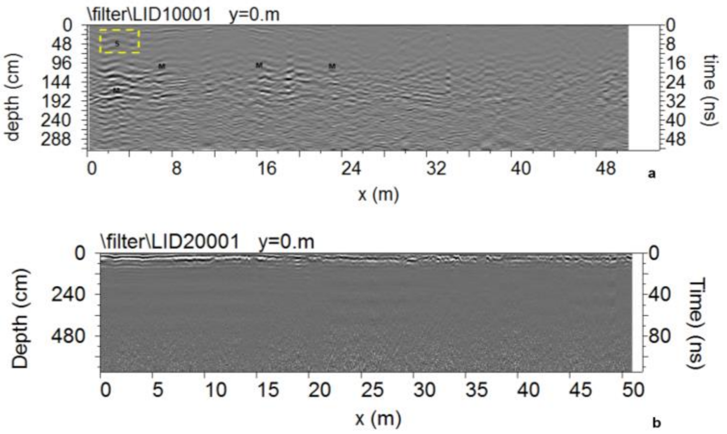

Figure 5. The processed radar sections: a) 600MHz antenna; b) 200MHz antenna

A general characteristic of the surveyed area seems to not allow a good penetration of electromagnetic (EM) energy,about 50 ns for 600MHz and 200MHz antenna corresponding respectively to a depth of about 3.0m if the mean electromagnetic wave velocity value of 0.12 m/ns is used, (Figs 5a and b). This is essentially due to the physical characteristics of the subsurface, made up of material which highly dissipates EM energy. This is also the case in all the other profiles acquired in the area.
In the processed radar sections, several reflection events are clearly identifiable. At times ranging from about 4 ns to about 8ns (0.24 m to 0.48 m in depth) it is possible to identify a reflection event (dashed yellow box). This event, labelled "S", was interpreted as being due to the presence of a roman road visible also on the ground surface near the surveyed areas (Fig. 6). Other reflection events (labelled "M") at times ranging from about 16 ns to about 40 ns (0.8 m to 2.4 m in depth) in Fig. 5a and from about 20 ns to about 110 ns (0.96 m to 2.4 m in depth) in Fig. 5a, due to its shape (hyperbolic) and dimension (about 0.6m), have been interpreted as being due to walls. This interpretation is related to the presence of some walls in an excavated trench near the surveyed areas.

Figure 6. The roman road

Since GPR data were acquired in a grid of closely spaced profiles, reflection amplitude can be accurately placed in three dimensions. A way to obtain visually useful maps for understanding the plan distribution of reflection amplitudes within specific time intervals is the creation of horizontal time slices. There are maps on which the reflection amplitudes have been projected at specified time (or depth), whit a selected time interval [9]. In a graphic method developed by [10], named "overlay analysis", the strongest and weakest reflectors at the depth of each slice are assigned specific colors. This technique allows the linkage of structures buried at different depths. This represents an improvement in imaging because subtle features that are indistinguishable on radargrams can be seeing and interpreted in an easier manner. In the present work the time slice technique has been used to display the amplitude variations within consecutive time windows of width Δt = 5 ns. The time slices (Figs. 7 a and b) show the normalized amplitude using a range that define the blue color as the zero level and red color as 1 level. Figs. 7 and 8 shows the most significant slices in the zones 1 and 2 respectively. In the slices ranging from 0.0m to 2.4m depth, relatively high amplitude anomalies are clearly visible (dashed dark lines). These correspond to archaeological features.

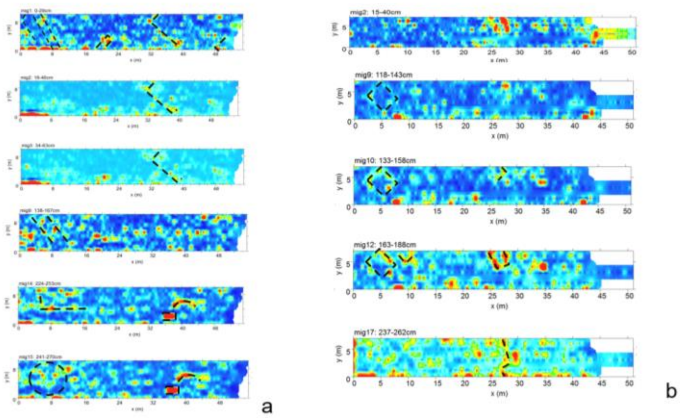

Figure 7. a) Zone 1 Time slices; b) Zone 2 Time slices

4. Conclusions

This work emphasize the importance of integrating several methods of investigation in an attempt to locate the sites in their environment and their mutual spatial relations, which are essential to understanding the activities and organization of past societies. Here assumes critical importance the research on the ground that allow the identification of archaeological traces. This type of survey conducted in a systematic manner over a defined area represents, together with the examination of the

sources, the preliminary work in the analysis of the past.
The surface survey carried out by the archaeologists, as numerous research experiences have shown is a strategy essential to understanding the history of ancient societies. The topographic data, chronological obtained by observation of the surface is a first level of knowledge necessary for the formulation of historical hypotheses and to plan for further more detailed research. Research is an integral part of surface geological and geophysical and geological prospecting.
Therefore paper describes an approach to the idea of archaeological research of a particular site that begins with a detailed description of the geology and geophysics.
In the Aguglia of Agosta were therefore conducted detailed geological and geophysical surveys. The Geological Survey of detail thanks to the use of the stratigraphy of 12 wells in the area led to the creation of a 3D geological model. In this model it was possible to define the morphology and some physical characteristics of the main geological bodies in the area. Therefore, it has provided a better definition and a further contribution to the understanding of the structural geology of the area and has improved the overall geological interpretation of the subsurface, through the instruments of control and interactive modification to the scale of detail desired. The resulting 3D model is a permanent record that can be amended on the basis of new information that may come as a result of new studies.
The geophysical survey has highlighted the presence of archaeological structures on three levels with depths between 0.5 and 0.7m (the first level), 1.6 and 1.8m (the second level) and 1.9 and 2.0m (the third level). Since it is not clear correlation between the three levels is likely that they are related to a situation of collapse and subsequent reconstruction. This demonstrated the probable connection between seismic events occurred at different times which eventually led to the final abandonment of the area. The study of the current situation of the Aguglia of Agosta shows how this structure has undergone the influence of several earthquakes over the centuries in the area and they have changed the layout of the structure.

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